LA Sustainable Water Project: Los Angeles City-Wide Overview

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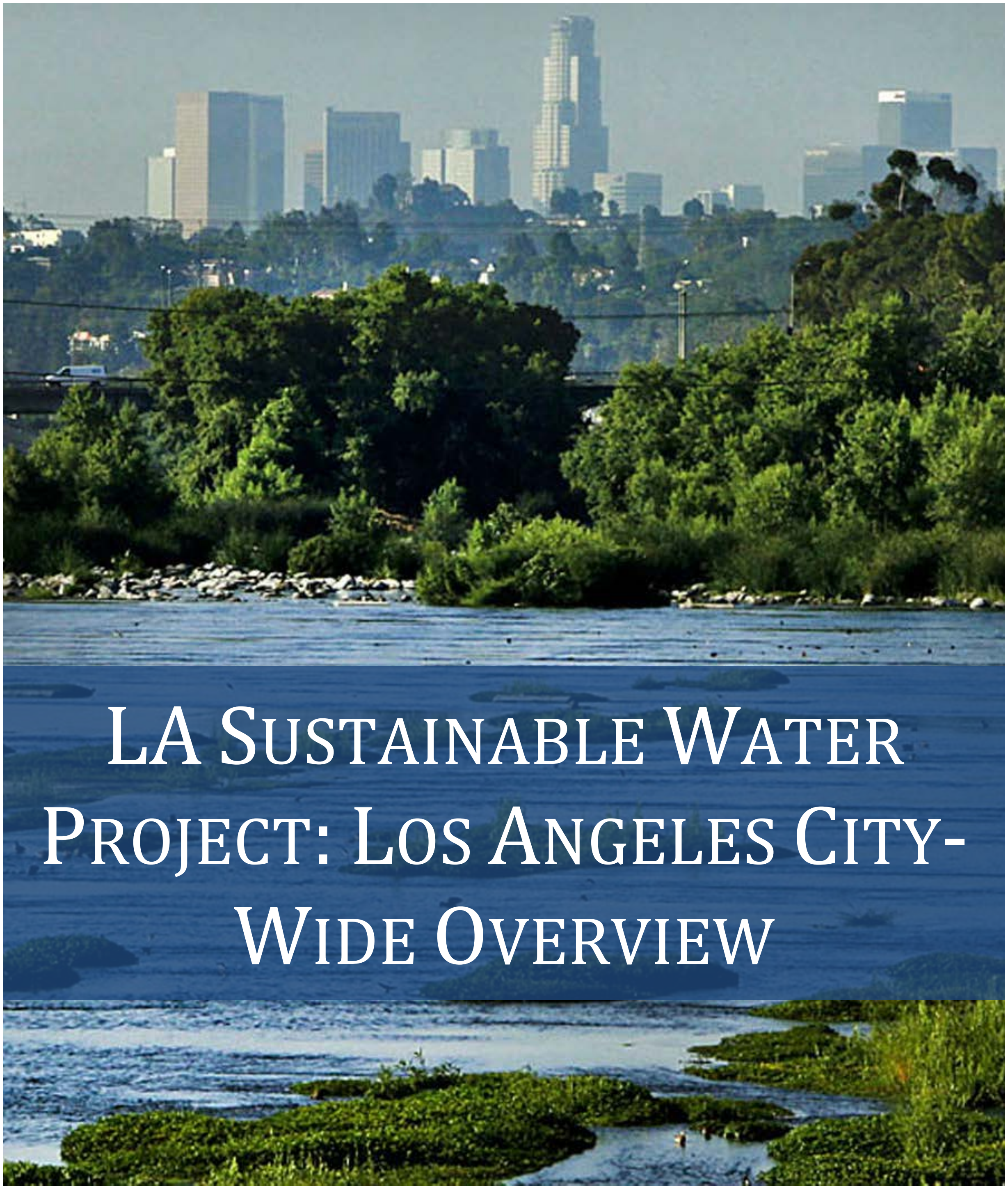

LA SUSTAINABLE WATER PROJECT: LOS ANGELES CITY-WIDE OVERVIEW

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This report is a product of the UCLA Institute of the Environment and Sustainability, UCLA Sustainable LA Grand Challenge, and Colorado School of Mines.

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Executive Summary

Background and Study Area – To achieve water supply sustainability, the City of Los Angeles (the City) must implement integrated water management (IWM) systems that incorporate all components of the urban water cycle (e.g., imported water, local groundwater, captured stormwater, greywater, treated wastewater, and water conservation). The City has researched, written, and begun implementing recommendations from IWM plans and reports that also helped define the current capacity of the system. While work on IWM has been ongoing for years, the impacts of the recent extreme drought on water supplies throughout California has created a new urgency to increase the City's ability to provide a secure, resilient water supply through local sources.

In addition to statewide efforts to reduce urban water consumption, many policies and plans have been created within the City that address urban water management, integrated resource planning, stormwater capture, and groundwater management. The Mayor's Office set aggressive goals to increase the sustainability of the City's water supply in coming decades. The goals included completing a comprehensive sustainability plan containing objectives for water supply and conservation in the City. The pLAn was released in April 2015 (Sustainable City pLAn). In an emergency drought directive released in October 2014, the Mayor identified additional accelerated water goals including reducing per capita potable water use by 20% by 2017 [from 2014 base-line of 130 gallons per capita per day (GPCD) to 104 GPCD], cutting the City's reliance on MWD water in half by 2025, and increasing local water supplies (not including the LA Aqueduct) to 50% of the City's water portfolio by 2035. Shortly thereafter, in April 2015, Governor Brown issued the first ever statewide mandatory cut of 25% urban water use due to continuing drought conditions.

This LA Sustainable Water Project built upon regional research and reports that analyzed components of water supply portfolio primarily comprised of local sources (e.g., groundwater, recycled water, and stormwater). Through data collection, integration, and analysis of flows of water and wastewater throughout the City systems and environment, project researchers identified and refined opportunities to implement IWM. As water quality regulation in the Los Angeles area currently drives much of the current water management practices, we examined greater water self-reliance through this lens. As a result, we used the geographic scope of watersheds to assess Total Maximum Daily Load (TMDL) compliance alongside IWM opportunities and challenges that exist and must be addressed to improve water quality and maximize local water supply.

The three previous reports released through this project (available at https://grandchallenges.ucla.edu/happenings/2015/11/13/100-local-water-for-la-county) focused on improving water quality and increasing local water supply in LA. The first report focused on the Ballona Creek Watershed (BC Watershed), Hyperion Water Reclamation Plant, and underlying groundwater basins (West Coast Basin, Central Basin, Hollywood Basin, and Santa Monica Basin). The second report focused on the Dominguez Channel and Machado Lake (DC and ML) watersheds, Terminal Island Water Reclamation Plant, and West Coast and Central Basin. The third report focused on the LA River (LAR) watershed, Donald C. Tillman and LA-Glendale Water Reclamation Plants, and the Upper LA Area Groundwater basins. This final report provides an overview of results from previous analyses, presents opportunities for and challenges to implementing IWM and increasing local water supply in the LA region, provides an analysis of GHG emissions and the costs and benefits of different water supply portfolios, poses a variety of potential mechanisms to fund these projects, and includes numerous policy and research recommendations.

Stormwater – Water quality and beneficial uses in the LA region have been impaired by pollutants from urban runoff including metals, fecal indicator bacteria, trash, and nutrients. Both dry and wet weather runoff carry pollutants to many water bodies in Los Angeles County. Implementing suites of Best Management Practices (BMPs) is one mechanism to capture and infiltrate, or treat and release, this runoff before it reaches downstream water bodies. In this study, a modified version of the US EPA's System for Urban Stormwater Treatment and Analysis (SUSTAIN) model was used to model water quality impacts of implementing various suites of BMPs (including vegetated swales, bioretention, dry ponds, infiltration trenches, and porous pavement) in the BC, DC, and LAR watersheds. Modeled scenarios that included combinations of treat-and-release BMPs and/or infiltration BMPs (installed on 'public land' uses) were designed to capture the 85th percentile storm (approximately ¾ of an inch of rain in a 24 hour period). Model simulations focused on the impairing metal pollutants copper, lead, and zinc because they are conservative pollutants for which sufficient water quality data was available.

While multiple modeled BMP scenarios were able to manage the 85th percentile storm in these watersheds, tradeoffs were present among the scenarios – some were cheaper, some were more effective at reducing water quality exceedances or peak flows, and others provided greater water supply benefits. Modeling BMP scenarios with a greater emphasis on treat-and-release BMPs, such as vegetated swales and dry ponds, resulted in fewer exceedances of the metals TMDLs as more treated "clean" flows were returned to the channel. However, this emphasis on treat-and-release approaches provided less potential recharge than those BMP scenarios with a greater emphasis on infiltration BMPs. A combination of treat and release BMPs and infiltration BMPs (vegetated swales and infiltration trenches) was low cost, provided groundwater recharge benefits, and greatly improved water quality for metals.

For example, infiltration based BMPs demonstrated the greatest potential groundwater recharge in the BC watershed (up to 77% of the runoff and up to 60,000 AFY with 15 inches of annual precipitation) and achieved considerable peak flow reduction in large storms (up to 47% peak reduction for storms with less than 2" of rain). Though infiltration-based BMPs significantly reduced TMDL exceedances compared to no BMPs, they are not as good as treat and release BMPs at reducing metals concentration exceedances because infiltration BMPs remove water from the channel, lowering the TMDL target at the point of compliance. However, infiltration BMPs remove more pollutant load than treat and release BMPs, so they improve the quality of the receiving waters as well as offer other potential IWM benefits such as groundwater recharge.

Implementing these watershed scale BMP programs can offer significant potential to increase local water supply. The range of stormwater volume estimated for potential groundwater recharge in the various BMP implementation scenarios in BC was 20,000 to 60,000 AFY, in DC was approximately 1,000 to 14,000 AFY, and in LAR was 130,000 to 170,000 AFY. It is, however, important to note that the volume of recharged stormwater water available to augment potable supply is less than the theoretical maximum infiltrated by BMPs. Additional research is needed to better understand the connectivity between surface and groundwater in these basins and quantify the water supply contribution of these stormwater recharge projects.

In addition to implementing watershed-scale BMP programs, source control and source tracking efforts to eliminate pollutant loads coming in from the watershed are critical to eliminating exceedances in these watersheds. For example, wet weather exceedances for copper were not eliminated even in modeling scenarios in which, for example, the event mean concentrations for industrial land uses in the DC watershed were set to the Waste Load Allocations in the TMDL. Thus, identifying and remediating sources of metals throughout the DC watershed is absolutely critical to resolving chronic water quality issues in DC.

A lack of data on the existing flows and runoff water quality, as well as on the performance of BMPs over time, was a limiting factor in some of this research, particularly in the DC and ML watersheds. Increasing monitoring efforts to include more sampling in DC and ML as well as at more of the industrial facilities in the watershed that are potential sources of pollutants, will facilitate attaining water quality standards in the DC watershed. The City's monitoring efforts, planned through the Coordinated Integrated Monitoring Programs (CIMP) in these watersheds will also provide additional data that can inform future efforts. Monitoring and/or data collection efforts matched to specific land use types will enable better characterization of loads in the watershed.

This type of analysis with modeling provides invaluable information on the potential tradeoffs among various BMP programs that all improve water quality. With this information, decision-makers can tailor programs, either through design of their own projects or programs to incentivize or require the construction of certain BMP types on private or public lands, to create desired outcomes in each part of the watershed. For example, infiltration-type BMPs could be preferentially selected where the connection of recharged stormwater to a groundwater basin used for water supply is readily quantifiable. Elsewhere, treat-and-release BMPs could be preferentially selected where the link to groundwater is not readily available or the released stormwater could be diverted to a local treatment plant for reuse or to a spreading basin for groundwater recharge. Yet, this approach still provides flexibility for implementing managers to devise BMP suites that can actually be achieved as part of municipal capital investment programs.

It is also important to consider the impacts of implementing these types of watershed-scale water quality-focused BMP programs to manage the 85th percentile storm, particularly those with a greater focus on the infiltration-based BMPs that increase the volumes of stormwater recharged into the groundwater basins, on other aspects of water management in the City. This is especially relevant for the LAR watershed as these programs could impact the volumes of water flowing through the LAR. For example, modeled average annual flows at Wardlow Gage dropped from 237,000 AF to between 63,000 and 111,000 AF (a reduction of 53 to 71%) with the implementation of various watershed-wide BMP scenarios.

It is important to note that these modeling analyses only included the water quality impacts (for metals) of watershed-scale BMP installation on public lands by stormwater permittees such as the City of LA. The transformation of private land use to more stormwater-friendly development will be important to improving water quality for a variety of reasons, including that the land area needed for regional BMPs may not be available where it would be most effective (e.g., further downstream in the watershed where runoff from larger drainage areas can be captured and treated). Watershed-scale BMP programs provide valuable water quality (and potential water supply) benefits that complement the many additional programs and plans happening concurrently in the LAR watershed. One example is the City's Low Impact Development (LID) ordinance, which reduces runoff from new development and redevelopment on privately owned land. Through a post-modeling analysis, we assessed the water quality and volume impacts of this LID ordinance as if it applied to the entirety of each watershed, instead of just the city of Los Angeles.

The LID ordinance in LA applies to parcels that create, add, or replace 500 ft.² or more of impervious area. For the presented analysis, we assumed a constant rate of redevelopment (ranging from 15% to 34% for different land uses as in other City of LA reports). With these assumptions, redevelopment under the LID ordinance will reduce the MS4 permit required volume of storm water (85th percentile storm) that has to be captured by LA City, LA County, and other cities in each watershed by between 19% and 28% by 2035. This would also result in a reduction in annual average loads of zinc and copper by 19% to 28% and 9% to 17%, respectively. Although required LID implementation will not result in water quality compliance on its own, the ordinance should result in the construction of thousands of BMPs over decades on private property; this green infrastructure, if properly operated and maintained, will improve water quality at minimal cost to the City as it will not be implemented by the City, but by private parties.

These benefits could be greatly magnified by extending the reach of an LID ordinance. For example, a LID retrofit upon sale ordinance that requires stormwater capture or infiltration for all parcels should be developed. The proliferation of LID projects can also be accelerated through the use of non-governmental organizations and other partners working with the City. Non-governmental organizations in particular can help on community engagement, implementing LID projects on private property, schools, parks, alleys, and in parkways, and LID BMP maintenance. The combination of watershed-scale BMP programs in concert with multiple efforts to reduce sources to the watershed and ramp up BMP implementation on private properties will result in greatly improved water quality as well as provide additional local water supply potential. These programs, however, must also include training for installers and property owners to ensure BMPs achieve the expected water quality benefits.

Recycled Water – To maximize the potential to source water locally, the final goal for recycled water in the City should be the reuse of the total volume of wastewater treated within the City (except for the brine and residuals generated through the process). Challenges to maximizing reuse within the City are linked to issues of both spatial distribution and available flows. In the current framework of City wastewater distribution and WRPs, there is potentially more demand for recycled water than current supply at certain facilities (e.g., at DCTWRP and at TIWRP) and more potential recycled water supply than demand at others (e.g., at HWRP). For example, TIWRP is designed to treat an average daily flow of 30 MGD and currently treats approximately 15 MGD; potential future local demands for TIWRP advanced treated recycled water of up to 24.5 MGD have been identified. Increasing volumes of wastewater recycled at HWRP is further complicated by its location downhill from much of the City-based demand. Future studies to identify the most effective strategies to maximize reuse of HWRP water should include assessments to increase indirect potable reuse to capitalize on the additional storage space in West Coast and Central Basins. In addition, the potential to integrate HWRP flows into the Regional Recycled Water Program that MWD and the LA Sanitation Districts are currently exploring should be considered.

The City is currently investigating opportunities to move flows around within its infrastructure to maximize the reuse of recycled water based on the current misalignments of local supply and demand for recycled water. As part of the One Water LA efforts, the City is exploring options such as augmenting sewer flows with runoff to increase the volumes available for recycling, reconfiguring sewer alignments to channel wastewater flows to WRPs closest to the most local demand, and building City-owned satellite WRPs to create new recycled water supply where sufficient local demand is present.

It is critical to quantify flows within and among systems to the greatest extent possible to assess foreseeable challenges and opportunities. For example, diverting dry and potentially even some wet weather runoff to WRPs would increase the volume of water that could be treated to reusable standards, going through these facilities. However, it is likely that continued gains in outdoor conservation will reduce available dry weather runoff, while indoor conservation will further decrease WRP flows. Increased implementation of on-site greywater technologies also would reduce flow volumes going to WRPs and could increase pollutant concentrations in wastewater effluent by removing one of the cleanest wastewater streams from the system, as well as most likely locking the use of that water into the potential use at that property.

These questions are especially important in the LAR, where recycled water is currently being discharged from WRPs into the LAR. Some of this flow also goes to support existing habitat and recreational features (e.g., Balboa Lake and the Japanese Gardens) before being discharged into the LAR. Non-potable reuses (e.g., irrigation and industrial) also currently provide local demand for treated effluent from these WRPs. The potential combined impacts of both watershed-scale BMP implementation and increased reuse of the treated effluent discharged into the LAR could significantly impact annual minimum flows. At Wardlow Gage, for example, modelled baseline annual minimum flows were 82-118 cfs, with flows dropping to 22-32 cfs after watershed-wide BMP implementation and reusing 50% of the discharged reclaimed water.

Groundwater – Recharge of both recycled water and captured stormwater can increase the volumes of groundwater in storage in local groundwater basins. Groundwater basins in Los Angeles provide significant opportunities to store advanced treated recycled water as well as captured stormwater that can be used later in times of need. However, contamination by legacy pollutants and complex political, legal, and regulatory environments present challenges that need to be addressed to take full advantage of this local water supply opportunity. This report examines these issues in detail, pointing to delicate policy needs and tradeoffs. There are multiple groundwater basins that partially underlie the City: the ULARA basins, West Coast Basin, Central Basin, Santa Monica Basin, and Hollywood Basin.

The City has water rights in ULARA, West Coast Basin, and Central Basin, which are all adjudicated basins. Two other local groundwater basins, Santa Monica Basin and Hollywood Basin, are unadjudicated. The ULARA groundwater basins include the San Fernando Basin, Sylmar Basin, Verdugo Basin, and Eagle Rock Basin; the City holds water rights only in San Fernando, Sylmar, and Eagle Rock Basins. The majority of the City's groundwater comes from San Fernando Basin. To more fully utilize these groundwater basins, the City has extensive plans to increase groundwater recharge into and remediate historical contamination in the San Fernando Basin.

Available dewatered space in West Coast (120,000 AF) and Central Basins (330,000 AF) provides potential opportunities to store and extract both recycled water and newly managed stormwater to increase local water supplies. The City has 1,503 AF of pumping rights in West Coast Basin and an allowed pumping allocation of 17,236 AF in Central Basin. The first opportunity for the City to more fully utilize these groundwater basins is to increase pumping capacity to allow full extraction of pumping rights in both basins. The City is currently undergoing efforts to expand their pumping capacity in Central Basin to allow the extraction of their total adjudicated rights volume; the City currently has no pumping capacity in West Coast Basin. Recent amendments to the adjudications in West Coast and Central basins also greatly expanded the potential for rights holders to increase the conjunctive use of the basin. For example, water augmentation projects offer additional opportunities beyond the existing pumping and storage rights for rights holders in the basin to store and extract water in these basins in each year. ULARA also has substantial space for storing additional water.

Multiple plans and projects have identified the potential to greatly increase the volumes of stormwater recharged into these groundwater basins. For example, LADWP's Stormwater Capture Master Plan (SCMP) identified goals to capture between 132,000 and 178,000 AFY of stormwater by 2035. Plans to increase stormwater recharge include both large-scale centralized and smaller-scale distributed projects. Large-scale projects that will increase surface water recharge through enhancing the capability of centralized infiltration sites include the Tujunga Spreading Grounds, the Lopez Spreading Grounds, the Big Tujunga Dam, Pacoima Dam, and the Pacoima Spreading Grounds (to store and/or infiltrate greater volumes of water).

Smaller-scale projects to capture stormwater across a wide variety of land use types will also increase the recharge of stormwater to groundwater basins. The Broadway Neighborhood Stormwater Greenway Project is an excellent example of a collaboration between the City of LA Bureau of Sanitation and Department of Water and Power, the Water Replenishment District, and others, which covers a 32 acre tributary area and is expected to capture 30 to 40 AFY. This is an example of a project that is not only helping to improve water quality, but also the project is monitored to quantify the potential water supply benefits of infiltrating runoff. In addition to increasing the volumes of stormwater recharged, the City is planning a large groundwater recharge project that will result in up to 30,000 AFY of advanced treated recycled water from DCTWRP being recharged into the San Fernando Basin through the Hansen and Pacoima Spreading Grounds.

Remediation is another important component to increasing the conjunctive use of these groundwater basins. Remediation efforts in ULARA are currently occurring in the North Hollywood, Burbank, and Glendale operating units, which pump and treat groundwater for use in local water supply. Additional treatment facilities are expected to be located in North Hollywood, Rinaldi-Toluca, and Tujunga wellfields to remediate additional groundwater in the San Fernando basin. Together, these facilities are expected to treat approximately 112 MGD (123,000 AFY) when they become operational in 2021. Design and construction costs are estimated to be around $600 million dollars.

There are many other options to increase the recharge and extraction of water into these basins. Additional opportunities for the City to increase their pumping in West Coast and Central basins includes purchasing and leasing additional pumping rights, perhaps through offering recycled water to industrial users in exchange for a lease on their pumping rights. The brackish plume in West Coast Basin, a result of historical seawater intrusion, currently takes up 600,000 AF of space and offers another opportunity to increase the extraction and remediation of groundwater, as well as create additional space for storing, for example, recharged stormwater. Additional research into opportunities to more fully utilize the capacity of the San Fernando Basin west of Interstate 405 or the potential to increase stormwater capture through Sepulveda Basin could also provide additional capacity for storage, recharge, and extraction.

Local Water Supplies - We also assessed three water supply portfolios with increasing volumes of locally sourced water from our baseline scenario, LADWP's water supply in FY 2013-2014 (WS 2013). Our second portfolio, WS City 2035, included goals that built off of City documents such as the pLAn [e.g., sourcing 50% of LA's water locally by 2035 and reducing consumption to 98.25 gallons per capita per day (gpcd)] and the SCMP. For WS City 2035, LAA was 139,400 AFY, MWD was 100,000 AFY, recycled water was 88,500 AFY, groundwater was 114,100, and stormwater was 37,000 AFY. We defined our WS Max 2035 portfolio to maximize local water supply even further. Our goal for LAA was 91,000 AFY, stormwater was 58,000 AFY, MWD was 35,000 AFY, recycled water was 161,400 AFY, and groundwater remained at 114,100. It is important to note that much of the increased local water supply coming from stormwater and recycled water would stem from recharge into and extraction from groundwater basins. The WS Max 2035 goals are extremely aggressive as they would result in sourcing approximately 73% of the City's 2035 water supply locally and reducing the imported water to only 27% of total supply.

The aforementioned supply and demand scenarios raise the possibility of achieving 100% local self-sufficiency in Los Angeles, without the addition of coastal desalination plants. The City can come very close to full self-sufficiency if conservation performance mirrors per capita consumption in other parts of the globe, including Australia and numerous European countries. The WS Max 2035 scenario provides a total supply of 459,500 AFY, but 126,000 AFY comes from imported water (91,000 AFY from LAA and 35,000 AFY of purchased water from MWD). Subtracting the imported water supplies leaves a total of 333,500 AFY from local supplies. Reducing per capita demand from the current 104 gpcd to 75 gpcd would decrease the City's total demand to 365,000 AFY, only 31,500 AFY more than local supplies. Local source volumes for stormwater and groundwater could be higher than those in our portfolios. For example, the LADWP SCMP goals are 132,000 AFY (conservative) and 178,000 AFY (aggressive), which are both greater than the subset we used to generate our 58,000 AFY assumption. These volumes could be far more than the shortfall of 31,500 AFY of local water between our WS Max 2035 portfolio and the WS Max 2035 (supply) / 75 gpcd consumption (demand) scenario.

Therefore, if the City continues to implement and accelerate the current goals, programs, and projects such as those outlined in the EWMPs, SCMP, the Mayor's Executive Directive, and the Recycled Water Master Planning documents, there is a wide array of potential local water supply sources that can be expanded. However, the City also must work very closely with regional partners such as the groundwater watermasters and the Regional Water Quality Control Board to address the challenges that are currently in place to moving forward with maximizing the use of recycled wastewater and captured stormwater in these watersheds to increase the sustainability of the City's water supplies.

We also assessed the GHG emissions of these three water supply portfolios (WS 2013, WS City 2035, WS Max 2035) to determine the impacts on the emissions of increasing the volumes of water that are sourced locally. Imported water generally has high carbon embeddedness due to the energy required to pump water long distances and over hills and mountains; the lowest carbon emissions come from the LA Aqueduct, stormwater, and groundwater supplies. Briefly, the combination of moving towards a more local water supply and decreasing the volume of water required through conservation resulted in a significant decrease in emissions in both WS 2035 portfolios compared to WS 2013. The total supply volume for WS Max 2035 decreased to 459,500 AF, a 4% decrease from WS City 2035 and a 22% decrease from WS 2013. Total emissions for WS Max 2035 were 187,571 MT of CO2e, which is approximately a 17% decrease from WS City 2035 and a 70% decrease from WS 2013.

Changing the power mix to include higher percentages of lower GHG energy sources such as renewable energy resulted in a decrease in emissions even with no change in the water supply mix. Absolute emissions decreased for all three water portfolios when the energy was generated by PP 2035 rather than PP 2014 due to the presence of an increased percentage of renewables in PP 2035 (based on California Senate Bill 350 goal to generate 50% of the state's electricity from renewable sources by 2030) relative to PP 2014. For example, total emissions decreased by 73% to 50,401 MT of CO2e for WS Max 2035 (compared to PP 2014) using PP 2035, which reflects a lower GHG power mix for all water supplies. Increasing the amount of locally sourced water to 50% from WS 2013 to WS City 2035 resulted in a decrease in total emissions by approximately 63% under PP 2014 and 58% under PP 2035.

Governance, Funding, and Economics – Multiple potential mechanisms to increase sustainable funding sources for implementing these water-focused projects are also described in this study; funding for operations and maintenance of existing and planned projects is an especially critical gap that must be filled to successfully implement integrated water projects to improve water quality and increase local water supply. Large bonds have become an important funding source for water projects in California, and may continue to be so, but agencies are limited in using these funds only for constructing capital improvement projects. Bond funds typically cannot be used for operations and maintenance of projects. Creating organizations and arrangements with sustainable lines of revenue, including Joint Powers Authority agreements, enhanced infrastructure financing districts, and public-private partnerships, are all potential governance solutions to be explored. Additionally, generating environmental impact bonds can offer innovative revenue sources.

One of the most critical measures to increase the funding available to implement these projects is approving a stormwater funding measure for Los Angeles County or the City, if the County measure fails. The proposed 2018 measure must establish a source of funding for new capital stormwater BMP projects, BMP monitoring efficacy, stormwater education and community engagement efforts, and operations and maintenance. If the 2012 approach was followed, then this measure would generate a minimum of $100 million per year for the City, and ideally $150 million. The division of funds was 50% for watersheds, 40% for municipalities and 10% for administration, education, and monitoring. Municipality funding should include a community grants program for nongovernmental organizations to work with the City to develop and/or maintain smaller scale distributed BMPs. Where feasible, projects should be LID in nature and provide multiple benefits to the community and the City. Quantitative eligibility criteria should be developed for projects funded under the watershed allocations (water quality compliance and water supply are the most critical benefits, followed by flood control, open space, habitat and recreation benefits, greenhouse gas emissions reductions, and reduced heat island impacts), as well as separate criteria for the community grants program. Funding should be allocated in an equitable manner countywide with a particular focus on projects in disadvantaged communities. In light of the substantial MS4 permit and TMDL requirements, the watershed projects must provide substantial water quality benefits to be eligible for funding.

In addition, a dedicated grant writing team should be created to develop and generate support for grant proposals to fund City water, water quality, and multi-benefit projects to take better advantage of available funding opportunities (e.g., the state revolving fund or water bonds). The office should not develop grants that compete with each other for the same funding source and could help ensure there is no overlap in departments applying to the same funding source. The grant developer also should be aware of City opportunities to provide match for grant proposals.

The process of building a more collaborative approach that enables diverse groups of stakeholders to identify and build the multi-benefit projects needed to transform the City's infrastructure to a local water system should be jumpstarted by creating a temporary, 5-year executive position, ideally located in the Mayor's Office. This Local Water Director position would lead on local water / one water projects to ensure timelines and budgets are met and would report to an executive council led by the Mayor. This council would also include the Deputy Mayor and the heads of agencies such as LADWP, LASAN, and BoE to ensure sufficient oversight. This group would jointly hire this position to be in charge of designing and building local water infrastructure. This position would entail working with hired consultants and designated staff from critical departments and bureaus and reporting back to the group on a monthly basis to describe successes and elevate challenges to implementation that need resolving.

A cost-benefit analysis of the three potential LADWP water supply portfolios described earlier, WS 2013, WS City 2035, and WS Max 2035, was also conducted. The most critical factors in determining long-term cost-effectiveness of policy options are planning time frames and assessed values for monetized benefits from local water supply options. Assessed benefits in this analysis included the avoided cost of imported water, reduced GHG emissions, enhanced recreational opportunities, and reduced stormwater-related damage.

For example, the net benefit of WS City 2035 is $4.3 to $5.8 billion, and the net benefit of WS Max 2035 is $7.4 to $10.1 billion. It is important to note that while these values are based on the best available data, there is a pressing need for additional high quality and local data on the costs and benefits of, in particular, the environmental benefits of putting in additional stormwater capture. Therefore, the exact numbers of these analyses may change as additional data is gathered, but the overall message that increasing the volumes of local water supply will provide both environmental and economic benefits to the region is clear.

Conclusion - The research undertaken in this project demonstrates the complex interrelationships within urban water management. The research also highlights potential pathways to a transformation of the City's historical reliance on imported water to an integrated, green infrastructure, water management approach that provides water quality, supply, flood control, habitat, open space and other benefits. Projects that are geared towards managing stormwater to improve water quality can also increase local water supply potential. Groundwater basins provide an opportunity to store water, whether that water comes from advanced treated recycled water, captured stormwater, or imported water in times of excess. Additional research, however, is required to quantify the water supply benefits of recharged stormwater in local groundwater basins (e.g., if 1 AF of stormwater is recharged, how much becomes available for extraction and use as water supply?). In addition, opportunities to expand the conjunctive use of these groundwater basins should be pursued.

The City and the LA region have made great strides towards developing and implementing IWM approaches, but much more remains to be done to transform local water infrastructure to meet or exceed the Mayor’s local water goals. Several pressing research needs remain to guide the implementation of these projects. For example, developing a coupled surface to groundwater model that will enable water managers to determine how much infiltrated water becomes accessible as water supply is critical. A comprehensive economic study that better defines the ancillary benefits (public health, property values, ecological, etc.) of water treatment strategies and projects and facilitates cost-sharing among agencies would provide a better understanding of the benefits of these programs. A study to identify the optimum / minimum flows on the LA River is critical to plan IWM in the LAR watershed that provides local water supply potential and improves water quality without harming the beneficial uses (e.g., habitat and recreation) in the LAR.

The regulatory and political environment surrounding water in the LA region provides both opportunities and challenges to implementing integrated water management programs that can truly address the multiple needs of urban water landscapes. Water quality BMPs should be considered within the context of other urban water management needs such as flood control, water supply, recreation, and habitat to identify multi-benefit and cost-effective projects. As more projects are designed with multiple goals in mind, partnerships will become established, methods of quantifying stormwater through the lens of water supply will become better defined, and regulations and policies can be adapted to reflect the equally important goals of cleaning up our surface water and increasing our local water supply resiliency in a semiarid region. Overall, our findings are very encouraging. A One Water approach overcomes many of the institutional barriers to water self-reliance that will enable a more effective use of the significant water resources in Los Angeles.

Background

Over the last decade, the City of Los Angeles (City) has worked closely with local communities and stakeholders to develop an integrated approach to managing water. The City understood that a siloed approach to wastewater, water supply, stormwater, and flood control management was inefficient and that integration of its water management programs would result in improved water quality, increased local water supplies, and better flood control. The City developed an integrated water approach with a series of plans including the Integrated Resources Plan, the Water Quality Compliance Master Plan and associated watershed compliance plans [Total Maximum Daily Load (TMDL) Implementation Plans, Enhanced Watershed Management Programs (EWMPs), and Coordinated Integrated Water Monitoring Programs (CIMPs), and a Water Supply Plan].

However, there is still a need for the assessment of integrated water management approaches that identify feasible opportunities for City-wide implementation to provide the City with the information necessary to develop integrated water infrastructure priorities and management frameworks, as well as garner broader support for implementation and funding. This report examines the opportunities and challenges to implementing integrated water management across the City of Los Angeles and incorporates the results of the three watershed studies (Ballona Creek Watershed, Dominguez Channel Watershed, and LAR Watershed) completed prior to this summary assessment. In addition to the water quality focus of the three prior reports, the potential for greater water self-reliance that can be achieved through implementing integrated water management programs will also be discussed.

I. Introduction

In the face of the recent record drought in California, it is critical to begin implementing integrated water management systems that incorporate all components of the urban water cycle and address both improved water quality and reliable water supply. These components include imported water, local groundwater, captured stormwater, conservation, and treated wastewater. Understanding the regulatory and management framework that underpins these systems is critical to creating a sustainable water supply for the City. The City has researched, written, and begun implementing recommendations from many reports critical to defining the current capacity of the system and creating and implementing an integrated water management plan for the City.

While the City has been working on this issue for many years, the impacts of the recent extreme drought on water supplies throughout California created a new urgency to increase water supply through local sources and to develop integrated water programs. The very wet weather in early 2017 immediately following a prolonged period of drought demonstrated that flood control is still critically important and that both infrastructure and planning capacity must be able to meet increasingly variable weather conditions. A concerted transformation towards greater local water self-sufficiency is critical for climate adaptation as well as system resiliency in the face of emergencies. Integrated water management plans offer the opportunity to improve water quality, maximize local water supply, and even to create, restore, or support habitat or recreational uses while still maintaining or even enhancing flood control capacity.

While the language of drought still is common currency, this report is part of a rethinking of California's precipitation regime that is resulting from climate change. Extreme drought periods – characterized by multiple years with below "average" rainfall – have always occurred periodically, but are predicted to grow more frequent in future decades. Rethinking how this new normal is characterized will be an important component of developing greater water system resiliency. Looking at past precipitation patterns to determine appropriate infrastructure sizing may have been appropriate for the 20th century, but increasing climate variability has demonstrated that a more prudent approach for determining infrastructure needs would be to utilize climate modeling in sizing decision making.

Regulations and policies covering a broad range of topics, from protecting surface water quality for human and environmental uses to complying with water rights laws and ensuring the appropriate level of treatment of recycled water for different uses, come into play when undertaking integrated water management. While water quality standards attainment (permits, receiving water quality standards, TMDLs, etc.) were the driving objective for the alternatives assessed in the previous watershed reports issued through this Sustainable LA water project (Ballona Creek, Dominguez Channel and Machado Lake, and LAR), many other laws and regulations affect the implementation of an integrated water management system.

This final overview report builds on our previous work and characterizes opportunities for implementing integrated water management (IWM) in the City to enhance local water supply capacity and improve water quality. It draws on and critically assesses available research outlining potential sources of local supply enhancement sources, including groundwater, recycled water, and stormwater capture. The focus of this report is on opportunities and challenges that exist to implementing integrated water management across the City, including comparison and discussion of results in previous watershed studies, regulatory and policy challenges throughout the study area, and economic and ancillary benefits associated with various integrated water management approaches. Further, we will describe potential scenarios to achieve water quality compliance and potential opportunities to increase local water supply and resilience through implementing an IWM approach in the assessed watersheds and across the City.

II. Los Angeles Water Supplies

LADWP receives its water from multiple sources. LADWP's water supply portfolio includes imported water from the Western and Eastern Sierras in Northern California through the State Water Project (SWP), from Owens Valley through the Los Angeles Aqueduct (LAA), and from Lake Havasu in Arizona through the Colorado River Aqueduct (CRA). The City also sources potable and non-potable water from groundwater, recycled water, and stormwater supplies. Due to the decrease in availability and reliability of imported water, the City is working toward water supply portfolios that increase its resilience.

In this section, we describe the landscape of current and potential water supplies in the Los Angeles region. Specifically, we identify three potential LADWP water supply portfolios with varying percentages of local water: a drought year, WS 2013, using the FY 2013-2014 LADWP water supply portfolio; a City-goal based portfolio for 2035, WS City 2035, which builds on goals in City documents such as the LADWP Urban Water Management Plan (UWMP) and the LA

Sustainable City Plan (pLAn); and a maximum local water supply portfolio for 2035, WS Max 2035, which maximizes locally sourced water to the greatest extent possible. A costs and benefits analysis and an energy use and greenhouse gas (GHG) emissions analysis were also conducted using these water portfolios and will be discussed in later sections.

A. LADWP Water Supply Background

a. Imported Water

LADWP imports water from three main sources, the SWP, the CRA, and the LAA. LADWP purchases imported water, which is a mix of SWP water and CRA water, from MWD. SWP water is stored at two different locations at the terminus of its East and West Branches.[1] The West Branch conveys water to Castaic Lake in Los Angeles County and the East branch conveys water to Lake Perris in Riverside County. Between 2010 and 2015, the West Branch provided an average of 241,671 acre-feet per year (AFY) and the East Branch provided an average of 14,249 AFY for LADWPs water supply.[2]

SWP water is treated at four different treatment plants: Los Angeles Aqueduct Filtration Plant (LAAFP) and Jensen Treatment Plant (Jensen) for the West Branch and Weymouth Treatment Plant (Weymouth) and Diemer Treatment Plant (Diemer) for the East Branch. The second source of imported water for MWD is from the Colorado River, conveyed via the CRA. CRA water from Lake Havasu in Arizona comprised an average of 49,199 AFY of LADWP's water supply between 2010 and 2015.[3] The water is then stored in Lake Mathews in Riverside. Water sourced from both branches of the SWP and the CRA comprise all the water imported through MWD. The final source of imported water is LAA water, which is treated at the LAAFP. LADWP imported an average of 167,008 AFY through the LAA between 2010 and 2015.[4]

A common thread among these imported water sources is that water has historically been stored in snowpack and can then be captured as the snow melts through spring and early summer; LADWP and others in the region have studied the impacts of a changing climate that could reduce this snowpack on the region's water supply, especially in the dry months. Briefly, although total precipitation in the region may stay at a similar volume, it is most likely that more precipitation will fall as rain then snow. Storms will also be flashier; modeling results described in the UWMP found high flows and also identified a number of locations along the LAA where flow could be

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[1] Draft 2015 Urban Water Management Plan (UWMP). February 16, 2014. Chapter 12 P. 12-18
[2] LADWP UWMP 2015 p. 12-25 Exhibit 12P
[3] LADWP UWMP 2015 p. 12-25 Exhibit 12P
[4] LADWP UWMP 2015 p. 12-25, Exhibit 12P

zero in dry months.[5] Climate change also has the potential to decrease SWP flows to areas south of the Bay-Delta as well as flows through the CRA.[6]

Recent climate modeling work at UCLA found that in the Sierra Nevada, warming and snow cover loss create a positive feedback that results in greater warming than previously projected at certain elevations. In 2081–2100 under a "business as usual" scenario of increasing GHG concentrations, warming averaged across the Sierra Nevada ranged from 7 to 10 degrees Fahrenheit, depending on the month, compared with 1981–2000. In the typical projected 2081–2100 April, snow-covered area decreased by 48%, compared with the typical 1981–2000 April.[7]

In another UCLA study, anthropogenic warming was found to have reduced snowpack levels during the 2011-2015 California drought by an average of 25% (26-43% at mid-to-low elevations).[8] End-century anthropogenic warming could lead to even greater snowpack reduction during drought, 60-85%, depending on GHG emissions levels.[9] These smaller snow packs would in turn lead to snow melt drying up earlier in the year and, thus, to lower volumes of water coming down for use during the summer. By the end of the century under "business as usual" emissions, peak flows are likely to arrive 2 to 3 months earlier than at the end of the 20th century.[10] The shifts in hydrologic regime could have ramifications on seasonal flooding patterns, the scope of flood events, and water temperatures and flows during critical end of summer/early fall time periods for aquatic life, including salmon. From global climate model results, researchers suspect that flows will be more variable, and that there will be more frequent and prolonged droughts punctuated by extremely wet years. But to date it is unclear how this will play out at the regional scale in the Sierra Nevada. This is the subject of current research at UCLA.

b. Groundwater

LADWP relies on groundwater basins for about 12% of its water supply.[11] On average from FY11 to FY15, ULARA supplied the City with 89% (59,621 AFY) of its local groundwater, extracting 58,741 AFY from SFB and 880 AFY from SB (Table 4.1).[12] Groundwater remediation

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[5] LADWP UWMP Chapter 12. P.12-11

[6] LADWP UWMP Chapter 12. P.12-13

[7] Walton DB, A Hall, N Berg, M Schwartz, and F Sun, 2017: Incorporating snow albedo feedback into downscaled temperature and snow cover projections for California's Sierra Nevada. Journal of Climate, 30(4): 1417-1438. DOI: 10.1175/JCLI-D-16-0168.1; https://www.ioes.ucla.edu/wp-content/uploads/Summary_Walton_Temperature.pdf

[8] Berg N and A Hall, 2017: Anthropogenic warming impacts on California snowpack during drought. Geophysical Research Letters, 44(5), 2511–2518. DOI: 10.1002/2016GL072104; http://research.atmos.ucla.edu/csrl/publications/Hall/Berg_snowpack_drought_2016.pdf

[9] Berg N and A Hall, 2017: Anthropogenic warming impacts on California snowpack during drought. Geophysical Research Letters, 44(5), 2511–2518. DOI: 10.1002/2016GL072104

[10] Schwartz M, A Hall, F Sun, DB Walton, and N Berg, 2017: Significant and inevitable end-of-21st-century advances in surface runoff timing in California's Sierra Nevada. Journal of Hydrometeorology, submitted.; Ongoing research by Alex Hall's group and UCLA Grand Challenges

[11] LADWP UWMP. Chapter 6. P. 6-1

[12] LADWP UWMP 2015 p. 6-4, Exhibit 6B

facilities remove organic and inorganic chemicals (TCE, PCE, DCE, TCP, NDMA; Perchlorate, nitrate). The largest wellfields are in the SFB, where Tujunga, Rinaldi-Toluca, and North Hollywood wellfields provide about 88% of the total groundwater from the SFB.[13] Erwin/Whitnall, Pollock, and Verdugo provide the rest of the supply from the SFB.[14] Wells in the 99th Street and Manhattan wellfields extract water from the Central Basin and wells in Mission extract from the Sylmar Basin. There are no established facilities in the Eagle Rock Basin.

c. Recycled Water

There are four city-owned or co-owned water reclamation plants (WRPs) that provide recycled water in the City: Hyperion Water Reclamation Plant (HWRP), Los Angeles Glendale Water Reclamation Plant (LAGWRP), Donald C. Tillman Water Reclamation Plant (DCTWRP), and Terminal Island Water Reclamation Plant (TIWRP). HWRP treats to secondary levels, LAGWRP and DCTWRP treat water to tertiary levels with nitrification/denitrification, and TIWRP produces advanced treated recycled water. Average flows to the four City-owned WRPs in 2015 were as follows: 240 MGD at HWRP (capacity 450 MGD), 32 MGD at DCTWRP (capacity 80 MGD), 19 MGD at LAGWRP (capacity 20 MGD), and 14 MGD at TIWRP (capacity 30 MGD).[15]

d. Stormwater

There are two types of stormwater capture systems: centralized systems and distributed projects. Centralized systems include regional flood control measures such as spreading grounds, flood control basins, and debris basins, as well as dams, reservoirs, and channel networks.[16] In the 2015 LADWP Stormwater Capture Master Plan (SCMP), centralized projects are described as those located and engineered to capture large flows and in general, able to capture and infiltrate more than 100 AFY.[17] Opportunities for large-scale stormwater conservation projects are limited due to their large space requirements and are not ideal for highly developed areas. While many centralized systems (e.g., spreading grounds) are gravity fed and thus require no additional energy to capture stormwater, there are some scenarios in which stormwater could be captured and stored at a lower elevation. In these cases, some pumping energy could be required to route the captured stormwater back up to the spreading grounds as space becomes available.

Distributed capture is comprised of individual projects located throughout the urban landscape of a city. These projects are characterized by their smaller per project contribution to aquifer recharge and limited capture capacity per project.[18] Distributed projects can be composed of a

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[13] LADWP UWMP. Chapter 6. P-6-5. The text says that those three account for 268 cfs and that the first two account for 70% of the water. If North Hollywood is included, the 268 cfs winds up being about 88% of the total groundwater.

[14] LADWP UWMP. Chapter 6. P 6-5.

[15] OWLA presentation, February 16, 2017

[16] LADWP SCMP 2015 p. 11, Table 2

[17] LADWP SCMP 2015 p. 10

[18] LADWP SCMP 2015 p. 12

variety of BMPs that utilize the natural processes of vegetation and soil to manage runoff close to the source. BMPs can be installed in parks, on public and private developments, and on public infrastructure. Further, BMPs can provide ancillary benefits such as wildlife habitat, water quality, flood protection, improved air and water quality, and recreation. Distributed projects are considered a solution to stormwater capture in heavily urbanized areas that are running out of space for larger projects.[19]

e. Brackish Groundwater and Seawater Desalination

In addition to the water supplies described above that are part of LADWP's current or future water supply portfolios, desalination is an additional potential source of water in the region. There are two desalination alternatives potentially applicable in the Los Angeles area: brackish groundwater desalination and seawater desalination. LADWP does not currently operate any brackish or seawater desalination facilities. While seawater desalination is not in LADWP's current water resource strategy due to environmental concerns, treating brackish water is a more viable alternative that is being considered (in the concept phase).[20] Brackish water TDS levels range between 1,000 and 15,000 mg/L; seawater TDS can range between 30,000 and 40,000 mg/L.[21] Any desalination process must result in water that meets the range for Secondary Maximum Contaminant Level (SMCL) for TDS of 500 mg/L to 1,000 mg/L as established by the SWRCB.[22]

There are a few examples of brackish water desalting that are already active in the Los Angeles area. The Robert W. Goldsworthy Desalter (Goldsworthy) and C. Marvin Brewer Desalter (Brewer) operate to remediate historical seawater intrusion in WCB; TDS levels at Brewer and Goldsworthy are 4,700 mg/L and 1,900 mg/L, respectively.[23] The Water Replenishment District (WRD) operates Goldsworthy, which has the capacity to extract and treat approximately 2.5 MGD (about 2,800 AFY) through reverse osmosis (RO). After the water passes through the RO process, it is re-blended with extracted groundwater that bypassed the main RO process to produce a final blended, treated water that is channeled into the Torrance water distribution system for potable use.[24] The waste stream that does not pass through the RO process into the potable water system is discharged to the regional wastewater collection and treatment system operated by the Sanitation Districts of LA County.[25] WBMWD operates Brewer, which extracts and treats approximately

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[19] LADWP SCMP 2015 p. 12

[20] UWMP. Chapter 9 P. 9-5,6

[21] Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination*. 2014. P. 243

[22] Todd Groundwater. Salt and Nutrient Management Plan – Central Basin and West Coast Basin Southern Los Angeles County, California. 2015. P 32

[23] Todd Groundwater. Salt and Nutrient Management Plan – Central Basin and West Coast Basin Southern Los Angeles County, California. 2015. P 49

[24] CH2MHILL. Initial Study: Robert W. Goldsworthy Desalter Expansion Project. 2013. P. 1-1, 1-2

[25] CH2MHILL. Initial Study: Robert W. Goldsworthy Desalter Expansion Project. 2013. P. 3-17

1,600 to 2,400 AFY from the West Coast groundwater basin.[26] Brewer treatment processes include cartridge filters and reverse osmosis. The treated water is blended with other potable water then stored on-site in a 5-million gallon storage reservoir.[27]

Additional reverse osmosis desalting facilities being planned in the region include the North Pleasant Valley Desalter in Camarillo (operated by the City of Camarillo), and the Moorpark desalter in Ventura County. The North Pleasant Valley Desalter would treat about 9,000 AFY of groundwater and produce about 7,500 AFY, yielding an 83% recovery rate.[28] The Moorpark desalter is in preliminary phases, but it would treat about 6,000 AFY and produce 5,000 AFY of potable water, with the same recovery rate of the North Pleasant Valley Desalter of 83%.[29] A typical recovery rate for seawater desalination is 50%.[30] A local example of this recovery rate is exhibited at the Carlsbad Seawater Desalination Plant: 104 MGD of seawater inflow would produce 50 MGD of desalinated water, which yields a 48% recovery rate.[31] These seawater desalination recovery rates are much lower than the 80%-plus recovery rates described above for local brackish groundwater desalters. This results in a larger volume of concentrated brine as a waste product that will require disposal.

B. LADWP Water Supply Portfolios

a. Potential Water Portfolios

Defining the potential local water supply in the Los Angeles of 2035 first requires defining what local water supplies in the City looks like. The City imports water in two different ways, through purchasing water imported by the Metropolitan Water District (MWD) via the SWP and CRA and through importing its own water from the Eastern Sierra Nevada Mountains through the City-owned LAA. The Mayor's pLAn and Executive Directive 5 set two distinct goals to increase local water supply in LA over the next two decades. The first is reducing the amount of purchased imported water (MWD water) by half from 2013-2014 levels by 2025 and the second is sourcing 50% of the City's water locally by 2035. The pLAn defines locally sourced water as "all local groundwater production, historical and future hardware-based conservation savings, centralized and distributed stormwater capture and recharge, and all recycled water produced in the City." For the purposes of defining local water supply in our scenarios, we do not include conservation as a component of supply, but rather apply it to create various demand scenarios to demonstrate the huge impact conservation can have on the supply that will be needed in the future.

It is important to note that water demand has greatly decreased since the 2013-2014 water year, so the City has already made significant progress towards some of the future demand scenarios

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[26] West Basin Urban Water Management Plan. 2010. Chapter 6. P. 6-4
[27] West Basin Urban Water Management Plan. 2010. Chapter 10. P. 10-5
[28] Padre Associates Inc. Draft Environmental Impact Report: Environmental Assessment for the North Pleasant Valley Groundwater Treatment Facility. 2014. P .5.7-17
[29] Sasek, David. Moorpark Desalter Project Update. 2015. P. 7
[30] Semiat, Raphael. Energy in Desalination Processes. *Environmental Science and Technology*. Vol. 42, No. 22. 2008.
[31] *City of Carlsbad. Precise Development Plan and Desalination Plant Project. Section 3. P. 3-1; 3-18*

outlined here (e.g., through implementing water conservation programs). It is also important to note that our approach to defining gpcd differs from that of DWP, the pLAn, and the SWRCB requirements for reporting gpcd. For example, per capita water use targets are established for potable water demand (e.g., not including NPR use). In the UWMP, LADWP's planned recycled water supply and water conservation are included in the gpcd targets. LADWP's approach and gpcd targets are consistent with the pLAn's goals and the SWRCB's reporting requirements.

Our pLAn-based targets vary from those in the UWMP as we took a more one-water approach to defining supply and demand in this study. As mentioned above, rather than including conservation as part of the supply, we used it to inform the supply of water that would be needed in the future. We considered the pLAn goal of 2035 to be a total gpcd (including both potable and non-potable uses) and counted imported water, recycled water, stormwater, and groundwater as parts of the supply.

Setting accurate goals for local water supply in the future also requires identifying potential overlap between components of the future supply (e.g., not double counting stormwater that is recharged into the ground as additional local water supply for both stormwater and groundwater). Setting goals for the City's imported water sources, LAA and MWD, is relatively straightforward as either less water can be purchased from MWD or less water can be imported through the LAA annually to meet these targets. We kept annual volumes of LAA water greater than those of MWD as LAA water requires no energy for transport, has negligible GHG emissions, and is closer to LA and under the jurisdiction of LADWP. In addition, LAA provides two benefits on energy and GHG emissions: any water sourced through LAA that replaces MWD water provides a substantial energy savings from importing less water as well as provides power as LAA itself generates power that is a clean source of energy for the City.[32]

Groundwater as a local water supply is mainly comprised of existing groundwater resources (water rights, native safe yields, etc.), stormwater recharge, and recycled water recharge. For example, the LADWP UWMP describes the potential to extract around 150,000 AFY of groundwater through a variety of mechanisms. These include pumping (on a safe yield basis) between 106,670 AFY and 114,670 AFY in average conditions in FY 2039/2040, 30,000 AFY of recycled water from DCTWRP recharged through Hansen Spreading Grounds, 15,000 AFY of additional extraction capacity through credits for recharged stormwater in SFB, and 5,000 AFY of stored water credits starting in 2019/2020.[33]

To avoid double counting storm water or recycled water recharge, we used the 2035 LADWP UWMP groundwater goal for an average water year, 114,070 AFY (rounded up to 114,100 AFY), for both WS City 2035 and WS Max 2035 as this number does not include additional groundwater pumping due to increased volumes of stormwater and recycled water recharge. Therefore, in thinking about the scenarios presented in this study, it is important to note that some portion of the

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[32] LADWP UWMP 2015 p 12-21.

[33] LADWP UWMP p. 11-4; p ES-19; p ES-18; p. ES-22

targets for stormwater and recycled water in the WS 2035 scenarios would become part of the water supply through increased groundwater pumping of recharged water volumes.

The SCMP identifies conservative and aggressive goals by which the City can increase stormwater capture by 2035. These SCMP goals are 132,000 AFY (conservative) and 178,000 AFY (aggressive); both goals include 64,000 AFY of existing baseline stormwater capture. Stormwater capture potential identified in the SCMP for 2099 is even higher, at 258,000 AFY.[34] This potential stormwater capture volume is further characterized within the SCMP into centralized capture, distributed capture, and distributed direct use. Under the SCMP's conservative 2035 scenario, centralized facilities could capture an additional 35,000 AFY, distributed facilities could capture 31,000 AFY, and distributed direct use facilities could capture 2,000 AFY.[35] Under the SCMP's aggressive scenario, centralized facilities could capture an additional 51,000 AFY, distributed facilities could capture 56,000 AFY, and direct use facilities could capture 7,000 AFY.[36]

Stormwater can play a role in increasing local water supplies through increasing the volumes recharged into groundwater basins for future use, but more work is needed to better quantify the water supply benefits of recharged stormwater. For example, the UWMP projects a potential to increase groundwater extraction by only 15,000 AFY as a result of the 132,000 to 178,000 AFY per year of increased stormwater recharge identified in the SCMP. This results in part from the fact that many factors come into play when determining the relationship between the volumes of stormwater infiltrated and the resultant increase in water supply. These variables include groundwater rights, connectivity between surface water and supply aquifers, infrastructure, existing or potential contamination, and others (e.g., adjudication).

More than 15,000 AFY of captured stormwater needs to be quantified as water supply to fully utilize our local potential to recharge and extract groundwater. Therefore, our WS 2035 stormwater goals are larger than 15,000 AFY to demonstrate the importance of overcoming the challenges that make it difficult to quantify stormwater from the supply side because stormwater can play an important role in increasing our local water supply sources. One challenge is that stormwater recharge is less certain than recycled water recharge, and therefore it is not currently a 1:1 ratio of recharge and extraction.[37] While aggressive, our 2035 goals only include SCMP volumes associated with direct use volumes and centralized capture. These larger projects are more likely to be able to be metered to accurately assess the volumes of storm water being captured and infiltrated into the groundwater basins, which makes these volumes more achievable potential goals from the supply side. Further, there is potential to establish partnerships to recharge and extract additional stormwater in West Coast and Central Basins under the amended adjudications.

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[34] LADWP SCMP p. 19, centralized facilities are defined as facilities which could capture greater than 100 AFY on an annual average basis, distributed facilities are defined as groundwater recharge projects capturing less than 100 AFY, and distributed direct use facilities are defined as direct stormwater capture systems under 10 AFY.

[35] LADWP SCMP P. 31

[36] LADWP SCMP P. 31

[37] P. 18 SFB Judgement "In calculating stored Water credit, by reason of direct spreading of imported or reclaimed water, Watermaster shall assume that 100% of such spread water reached the ground water in the year spread." Stormwater is not included. It also needs to be determined how much, if any of the additional recharged stormwater would be considered 'new' water.

For our baseline scenario, the LADWP water supply from FY 2013-2014 was used (WS 2013). WS 2013 consisted of 441,871 AF of MWD water, 61,024 AFY of LAA water, 79,403 AFY of groundwater, and 10,054 AFY or recycled water (Table 2.1). The two potential 2035 water supply portfolios are described in detail in the following paragraphs. It is important to re-emphasize that a portion of the recycled water and the majority of the stormwater volume in these portfolios will be an indirect source, where supply is generated via recharge of groundwater. So, for example, the percent of direct supply coming from groundwater in WS City 2035 is 41% (114,100 AFY of groundwater, 37,000 AFY of stormwater, and 43,100 AFY of GWR).

Water Source	WS 2013 [AFY]	% WS	WS City 2035 [AFY]	% WS	WS Max 2035 [AFY]	% WS
MWD	441,871	75	100,000	21	35,000	7.5
LA Aqueduct	61,024	10	139,400	29	91,000	20
Groundwater (net)*	79,403	13	114,100	24	114,100	25
Recycled Water (irrigation, industrial)	10,054	2	45,400	9	161,400	35
Recycled Water (GWR)			43,100	9		
Stormwater	N/A		37,000	8	58,000	12.5
Total	592,352	100	479,000	100	459,500	100

Table 2.1. 3 potential water supply mixes for LA: WS 2013, WS City 2035, WS Max 2035

WS CITY 2035

We adjusted City LAA and MWD goals to create WS City 2035 goals that comply with the Mayor's pLAn goal of sourcing 50% of LA's water locally by 2035 and also generate sufficient supply to meet the water demand 479,000 AFY generated by the pLAn goal of 98.25 gallons per capita per day (gpcd). For WS City 2035, we set LAA to 139,400 AFY, which is between the annual average from 2011/12 to 2014/15 (123,653 AFY) and the annual average from 2010/11 to 2014/15 (160,461 AFY). We set MWD to 100,000 AFY for WS City 2035 to keep the imported water supply (MWD + LAA water) below 50% of the required supply (479,000 AFY). We based our 2035 stormwater supply goals on the SCMP volumes that were potentially captured through centralized facilities and distributed direct use facilities, 37,000 AFY.

Finally, for our WS City 2035 recycled water supply goal, we used the 2040 UWMP values of 45,400 AFY for irrigation and industrial use of recycled water and added 13,100 AFY to the UWMP goal of 30,000 AFY for groundwater replenishment with recycled water.[38] This increased volume was necessary to create a portfolio that met the demand generated by the approximately 4.35 million people here in 2035 using 98.25 gpcd. Further, there are additional opportunities,

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[38] UWMP, p. ES-22

such as increasing the volume of stormwater captured through diversion to WRPs for treatment and infiltration into groundwater basins, to increase flows through WRPs.

WS MAX 2035

To maximize local water supply even further in WS Max 2035, we set the goal for LAA at 91,000 AFY (Table 2.1, adapted from the UWMP 2035 LAA goal of 51,000 AFY for a single dry year plus 40,000 AFY to keep LAA higher than MWD).[39] As described above, we kept annual volumes of LAA water greater than those of MWD as LAA water requires no energy for transport, has negligible GHG emissions, and is closer to LA and under the jurisdiction of LADWP. We based our WS Max 2035 stormwater supply goals on the SCMP volumes that were potentially captured through centralized facilities and distributed direct use facilities, 58,000 AFY (Table 2.1).

Our WS Max 2035 MWD goal was set to 35,000 AFY (adapted from UWMP 2040 MWD goal of 74,930 AFY for an average year minus 40,000 AFY so MWD supply would be lower than LAA and then rounded up from 34,490 AFY, Table 2.1).[40] This is an extremely aggressive goal, which would result in sourcing approximately 73% of the City's 2035 water supply locally and reduce the imported water to only 27% of total supply. It is also important to note that with the current infrastructure, there are certain areas within the City that can only be served by MWD water and the current estimates for the minimum MWD water supply is 66,000 AFY.[41] However, opportunities to reduce these volumes further when conditions are appropriate should be explored. For example, would 35,000 AFY or lower be feasible if additional infrastructure to maximize the use of the underlying groundwater basins was installed?

For the WS Max 2035 recycled water goal, we assumed the maximum reuse of the entire available volume of treated wastewater for the pLAn baseline year, FY 2013-2014: 385,280 AFY. Of this volume, 75,400 AFY is expected to be sent to West Basin Municipal Water District (WBMWD) for treatment and reuse mainly outside of the LADWP service area. An additional approximately 6,720 AFY is expected to go to the Dominguez Gap Barrier; neither of these volumes are thus available for reuse within the City. We further assumed a 20% reduction in wastewater flows by 2035 due to increased water conservation and a worst-case recovery rate after membrane microfiltration and reverse osmosis (MFRO) treatment of 71%.

It is important to note that only TIWRP currently has MFRO and that current City plans for the future only include installing MFRO at DCTWRP. However, we explored a future scenario where all recycled water was treated with MFRO because this level of treatment allows the reclaimed water to be used under the widest variety of circumstances (thereby making reusing the entire volume more feasible) including, potentially, direct potable reuse. Further, there is the potential for MFRO capacity to be placed at other WRPs if future planning efforts determine that is the best use for this water source. Based on these assumptions, the WS Max 2035 recycled water goal is approximately 161,400 AFY (Table 2.1).

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[39] LADWP UWMP ES-23
[40] LADWP UWMP ES-23
[41] LADWP, personal communication

In addition, several demand scenarios were assessed. UWMP demand projections for 2035 are approximately 550,000 AFY (after removing conservation as a part of the supply, Table 2.2), and pLAn goals of 98.25 gpcd would result in a demand (for the 4.35 million people projected to be in LADWP's service area by 2035) of 479,000 AFY (Table 2.3). However, more conservation would be required under WS Max 2035 as the total supply generated would be 459,500 AFY. Decreasing demand to meet this supply portfolio would only require additional conservation of a few gpcd beyond the pLAn goals (to between 94 and 95 gpcd).[42] Further conservation to levels commonly seen in Europe and Australia (75 gpcd), could result in a total demand of less than 400,000 AFY. Additional conservation, especially indoor conservation, could also reduce flows going through WRPs and those interactions must be taken into consideration throughout the planning process.

LADWP UWMP 2035 Demand Scenarios	AFY	AFY[43]
Dry year (including 143,500 AFY of post-FY14/15 conservation and 300 AFY of stormwater harvesting/direct use)	694,900	551,100
Average year (including 109,100 AFY of post-FY14-15 conservation and 1,600 AFY of stormwater harvesting/direct use)	661,800	551,100

Table 2.2. Projected City of LA water demand in UWMP.

Potential 2035 Demand Scenarios	AFY	AFY
City-based goal 98.25 gpcd, 4.35 million ppl[44]	479,000	n/a
90 gpcd, 4.35 million ppl	440,000	n/a
75 gpcd, 4.35 million ppl	365,000	n/a

Table 2.3. Potential future gpcds.

b. Getting LA to 100% Local Water

The aforementioned supply and demand scenarios raise the possibility of achieving 100% local self-sufficiency in Los Angeles, without the addition of coastal desalination plants. As one can see, the WS Max 2035 scenario provides a total supply of 459,500 AFY, but 126,000 AFY comes from imported water from the LAA (91,000 AFY) and purchased water from MWD (35,000 AFY). Subtracting the imported water supplies leaves a total of 333,500 AFY from local supplies. If per capita water demand is reduced from the current 104 gpcd to 75 gpcd, then the City's total demand decreases to 365,000 AFY; only 31,500 AFY more than local supplies.

The City can come very close to full self-sufficiency if their conservation performance mirrors per capita consumption in Australia and numerous European countries. The reduced consumption rate may have an impact on available recycled water because decreased demands often lead to reduced sewer flows. The 2035 pLAn goals call for a 25% reduction, but not all of this reduction

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[42] 94 gpcd for 4.35 million ppl would generate a demand of 458,000 AFY. 95 gpcd for 4.35 million ppl would generate a demand of 465,000 AFY.

[43] AFY in this column reflects UWMP demand scenarios after subtracting out the conservation and stormwater harvesting/direct use included in the UWMP demand portfolios. LADWP UWMP 2015 p. 11-11 & 11-13.

[44] City of LA pLAn, p. 20. 25% reduction from 131 gpcd by 2025=98.25 gpcd.

will be indoor uses; decreases in outdoor uses would not affect wastewater flows. Thus, we expect a smaller percent reduction in wastewater flows than the overall conservation goal and assumed a 20% reduction in wastewater flows. As much of the conservation benefit that remains to be gained is from the reduction of outdoor irrigation, we don't expect recycled water supplies to be reduced by more than this 20%. As described above, we also assumed that the majority of this volume would undergo MFRO treatment and applied a very conservative recovery rate of 71%.

The local source volumes for stormwater and groundwater used in the presented scenarios were not maximized in the same way as recycled water. As stated previously, the LADWP SCMP goals are 132,000 AFY (conservative) and 178,000 AFY (aggressive); both goals include 64,000 AFY of existing baseline stormwater capture. In addition, the stormwater capture potential identified in the SCMP for 2099 is even higher, at 258,000 AFY. These goals are far greater than the subset we used from these conservative and aggressive SCMP goals. Further, there are additional volumes of potential stormwater capture identified in the LA Basin Study, which is described in later sections. Therefore, assuming that a larger percentage of the 258,000 AFY of stormwater captured will be available for water supply than our 58,000 AFY assumption, stormwater volumes could contribute a great deal more to the City's water supplies. These volumes could be far more than the projected shortfall of 31,500 AFY in the WS Max 2035 / 75 gpcd consumption scenario. Further research (e.g., a new basin safe yield study that quantifies the safe yield restored through these recharged stormwater volumes) quantifying the percentage of infiltrated stormwater that truly augments groundwater supplies will provide greater certainty on the stormwater supply estimates.

The case for increasing groundwater supply through a more aggressive, adaptive management approach is equally strong. Currently, ULARA is being conservatively managed. The ULARA governance has not established a procedure for determining what percentage of stormwater infiltrated is actually new water that can be subsequently pumped from the basin for use in a sustainable manner. There may be potential to increase sustainable yields of ULARA, as well as an opportunity to expand stormwater recharge and extraction in West Coast and Central Basins. Also, the implementation of the Sustainable Groundwater Management Act (SGMA) in the Santa Monica and adjacent basins could provide additional opportunities to increase conjunctive use in those areas.

One potential additional moderate source of local water could be brackish groundwater desalination. The West Coast Basin currently has 600,000 AF of capacity impacted by historic sea water intrusion. Desalination of the brackish plume could provide additional water supply as well as greatly increased storage capacity in the West Coast Basin. As with all potential groundwater projects, any impacts on existing plumes (e.g., plume migration or spreading) must be considered before implementing any projects. If the City of LA partners with WRD and others on the brackish groundwater desalination effort, the City could receive an additional 5,000 AFY or more of local water supply. Thus, with more efficient treatment technologies, more effective stormwater capture, an improved, adaptive management approach to local groundwater basins that increases their conjunctive use, and greatly improved water conservation efforts, the City of LA could become 100% local water self-sufficient by 2050, if not earlier.

III. Stormwater Management

A. Introduction

In Los Angeles, pollutant loads carried by both dry weather runoff (from irrigation and other uses) and wet weather runoff from rainfall significantly contribute to water quality impairments in regional water bodies. Installing stormwater Best Management Practices (BMPs) that treat and release or capture stormwater is one mechanism to reduce the concentrations and loads of pollutants entering watersheds, which improves water quality. Stormwater capture and/or infiltration can provide multiple additional benefits in addition to water quality, including flood control, habitat, and recreational open space benefits.

In addition, capturing runoff further offers a potential source of local water to supplement imported water supplies, which can be affected by disasters, climate change, upstream environmental needs, or rapid increases in the price of imported water. Recent studies from UCLA have shown that while the timing and intensity of precipitation may change, the total amount of precipitation in Los Angeles is projected to be roughly the same through the end of the 21st century.[45] Captured stormwater can also be used to recharge local groundwater basins for use in drier times. In this section, we analyze results from our prior detailed modeling efforts to assess the feasibility of various scenarios to achieve compliance with water quality standards in the Ballona Creek (BC), Dominguez Channel (DC) and Machado Lake (ML), and Los Angeles River (LAR) watersheds. Further, we assess additional benefits, such as the potential to increase water supply through increased stormwater capture, that can result from implementing BMPs improve water quality.[46]

B. Watershed Characteristics

Each watershed has unique economic, socio-demographic, physical, and hydrologic characteristics, which results in varied costs, pathways to improving water quality, and ancillary benefits for each watershed. Each watershed was delineated using the storm-drain networks linked to the outfalls of BC, DC, Wilmington Channel, and the LAR (Figure 3.1).[47] The 123 mi^2 (78,720 ac) BC Watershed includes the Cities of Beverly Hills and West Hollywood, portions of the cities of Culver City, Inglewood, Santa Monica, Los Angeles, and unincorporated areas of Los Angeles County.[48] The City of LA accounts for 85% [105 mi^2 (67,200 ac)] of the BC Watershed, which drains into the Santa Monica Bay. BC's recent hydrologic regime is well-documented, with daily flow records starting as early as 1987 and water quality data starting in 1999.[49]

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[45] http://newsroom.ucla.edu/releases/ucla-researchers-project-southern-california-rainfall-levels-through-end-of-century

[46] Sustainable LA Water project reports on BC, DC, LAR; available at https://grandchallenges.ucla.edu/happenings/2015/11/13/100-local-water-for-la-county/

[47] Los Angeles County Storm Drain System Data. Available at http://egis3.lacounty.gov/dataportal/2013/08/08/los-angeles-county-storm-drain-system/ Accessed on 1/1/2016

[48] Ballona Creek EWMP workplan P. 1-3

[49] LARWQCB Ballona Creek Metal and Toxics TMDL Reconsideration Staff Report (2013), p.7

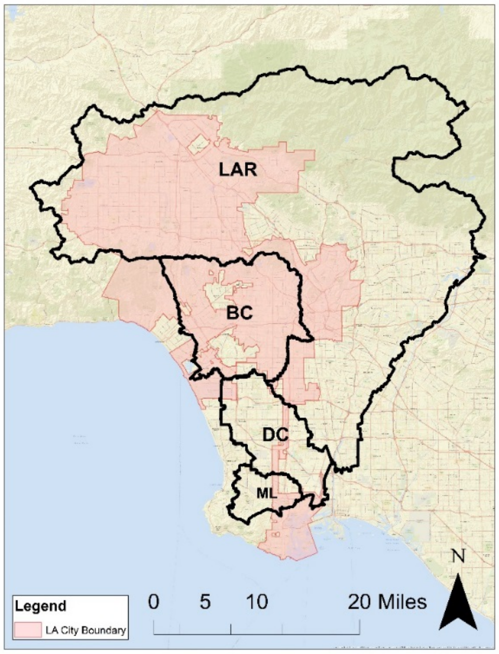

Figure 3.1: All watersheds delineated with respect to their outfalls.

The 71 mi^2 (45,400 ac) DC Watershed and the 23 mi^2 (14,720 ac) ML Watershed are comprised of DC Watershed Management Area (DC WMA) members [the Cities of Carson, El Segundo, Hawthorne, Inglewood, Lawndale, Lomita, and Los Angeles, Los Angeles County, and the Los Angeles County Flood Control District (LACFCD)] as well as other MS4 permittees that work independently from the DC WMA. Only 13.5% [9.59 mi² (6,138 ac)] of land area in the DC watershed and approximately 20% [5.05 mi² (3,232 ac)] in the ML watershed are located in the City of LA.[50] There is a lack of water quantity and quality data for the DC and ML Watersheds both temporally and spatially, which is discussed in greater detail in the DC report.[51] CIMP monitoring efforts will begin to address some of these gaps as they are implemented.

The 830 mi^2 (531,200 ac) LAR Watershed begins near the confluence of Bell Creek and Arroyo Calabasas in the southwest corner of the San Fernando Valley. The LAR Watershed spans from its headwaters in the Santa Monica and San Gabriel Mountains through the Glendale Narrows and extends to Long Beach, where the LAR flows into the San Pedro Bay. The LAR watershed was segmented into six reaches for modeling purposes based on the locations of flow gages and WRPs. The City of LA, with 289 mi^2 (184,960 ac), accounts for 35% of the LAR Watershed.

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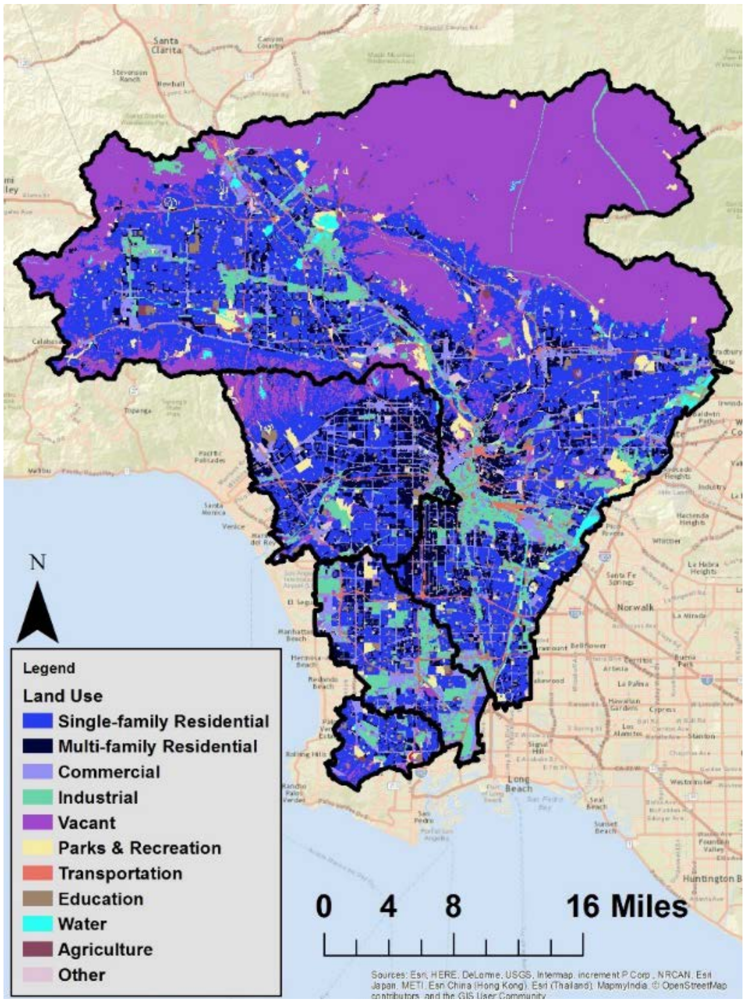
[50] Mika et al., Sustainable LA DC &ML report pg 8 available at: https://escholarship.org/uc/item/2w1916p4

[51] Mika et al., Sustainable LA DC & ML watershed pg 51 available at: https://escholarship.org/uc/item/2w1916p4

Land use distributions were also examined for the four watersheds. The area and percent imperviousness for each of the land use types were determined using a 2-acre resolution land cover raster from the Southern California Association of Governments (SCAG).[52] Single-family residential (SFR, 43.7%), multi-family residential (MFR, 13.6%), commercial (13.4%), and industrial (9.5%) land uses make up 80% of the total watershed area for the four watersheds (Table 3.1, Figure 3.2). This breakdown is important to gain a better understanding of the characteristics of the individual watersheds and provide insight on water quality variations.



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 3.2: SCAG land use distribution; legend in order of highest % of watersheds area to lowest. Forested areas in the northern LAR Watershed are color coded as vacant but not included in the ordering of the % area.

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[52] Southern California Association of Governments Land Use Data. (data set used from 2005) Available at http://gis-data.scag.ca.gov/Pages/GIS-Library.aspx

	Ballona	Dominguez	Machado	LAR w/ Forested	LAR w/o Forested
Total Area (mi^2)	123	71	23	830	512
Total Population	1,665,714	714,964	302,414	4,623,724	4,618,299
Percent Impervious (%)	60.9	71.1	52.1	38.2	57.6
Average Annual Flow (AF)	63,490	36,154	6,362	236,455	150,814
Land Cover Type	**% Watershed**				
Agriculture	0.1%	1.1%	2.3%	0.7%	1.1%
Commercial	14.2%	19.9%	22.3%	7.3%	11.8%
Education	3.0%	3.9%	5.6%	2.0%	3.3%
Forested	0.0%	0.0%	0.0%	38.3%	0.0%
Industrial	4.0%	20.9%	13.9%	6.0%	9.6%
Multi-Family Residential	21.7%	11.5%	15.8%	6.9%	11.1%
Other	1.3%	0.7%	0.0%	0.3%	0.5%
Parks & Recreation	3.1%	4.1%	7.5%	2.7%	4.3%
Single-Family Residential	37.4%	30.1%	20.2%	30.1%	48.8%
Transportation	2.1%	5.1%	1.3%	2.4%	4.0%
Vacant	13.3%	2.3%	10.6%	2.1%	3.4%
Water	0.0%	0.6%	0.4%	1.3%	2.1%

Table 3.1: Size, population, percent impervious, and land use area percentage for each watershed.[53]

For example, modeling efforts demonstrated that it is more difficult to eliminate metals exceedances in the DC Watershed than in the BC or LAR Watershed; one contributing factor is the high percentage of industrial area in the DC watershed. Industrial land use is only 9.5% of all four watersheds combined, but accounts for 20.9% of the DC Watershed (compared to 4% in the BC watershed and 9.6% in the LAR watershed, Table 3.1). Industrial land uses are highly impervious with elevated heavy metal pollutant washoff EMCs. More vacant land also improves water quality in modeling results as it is highly pervious, with low heavy metal pollutant washoff EMCs (and thus, lower pollutant loadings). The BC Watershed has both a higher percentage of vacant land (13.3%) and lower percentage of industrial land uses (4%) than the DC Watershed (2.3% and 20.9%, respectively).

The total area of each watershed varies widely; LAR is the largest, followed by BC, then DC, and then ML (Table 3.1). Population density also varies but is generally high throughout the study area. The BC Watershed has the highest population density with 13,542 people per mi^2, followed by ML with 13,148 people per mi^2 and DC with 10,070 people per mi^2. The LAR Watershed, without the forested area, has the lowest with 9,020 people per mi^2 (Figure 3.3); this drops even lower, to 5,571 people per mi^2, when including the forested area. Areas with the highest population density in some cases overlap with high percentages of MFR land uses (Figures 3.2, 3.3). The lower half of the DC watershed has a generally lower population density, as well as higher percentages of industrial and/or commercial land uses.

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[53] The LAR Watershed has been broken up into area including the northern forested mountain region and the area without this region. The area without the forested region better compares the urbanized regions of each watershed.

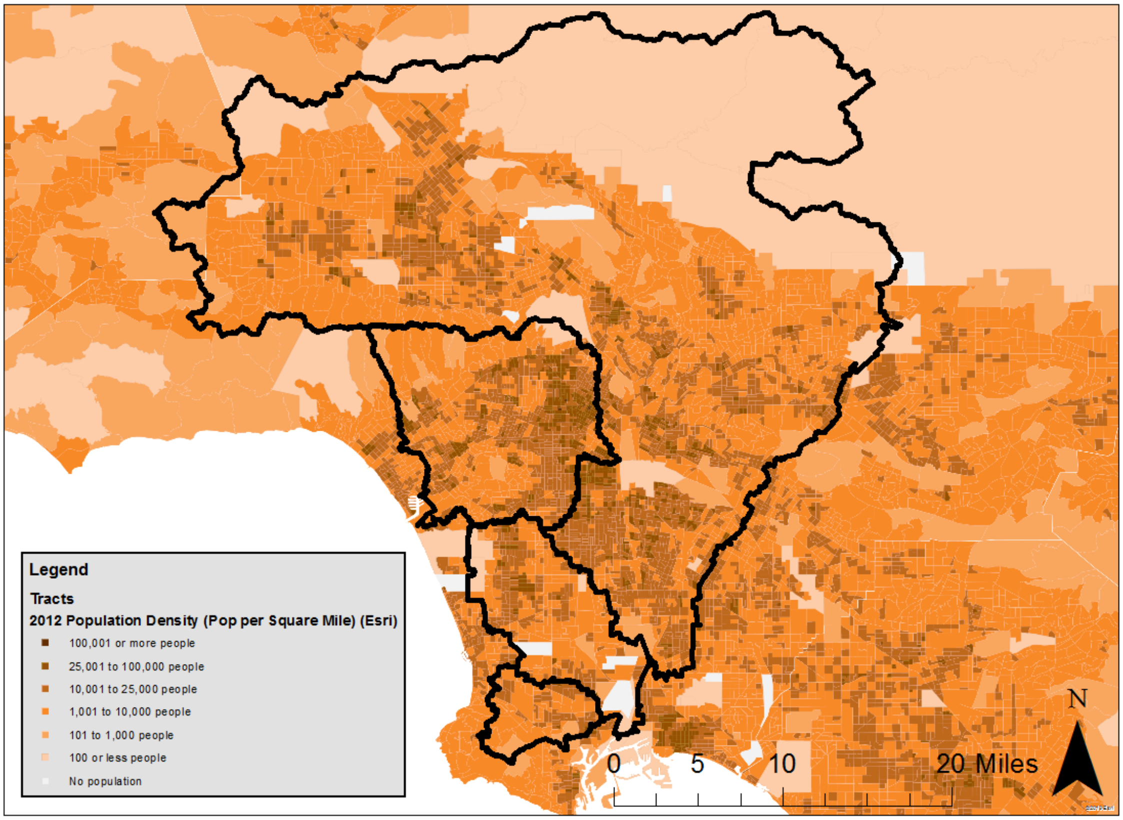

Figure 3.3: Population density throughout the LA region based on the 2012 Census.[54] The four watersheds are delineated with a black outline.

The industrial land uses also correlate with the areas of the lowest normalized difference vegetation index (NDVI) (Figure 3.4). NDVI is defined as the measure of greenness from vegetation where 1 is the highest and 0 is the lowest. Areas with a low NDVI either have less vegetation or the vegetation is more water stressed. Thus, the industrial land uses exhibit little to no greenness. The DC Watershed has a much lower average NDVI (0.188) than the BC (0.288), LAR (0.352), and ML (0.293) Watersheds. This is likely attributed to the lack of vacant or forested areas throughout the DC Watershed. Additionally, SFR land uses in the DC watershed tend to have lower NDVI than the other watersheds. The lower half of the LAR Watershed also has a lower average NDVI than the upper half due to the increase in urbanization and industrial land use area in the lower portions of the watershed (Figure 3.4).

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[54] https://www.census.gov/geo/maps-data/data/tiger-data.html

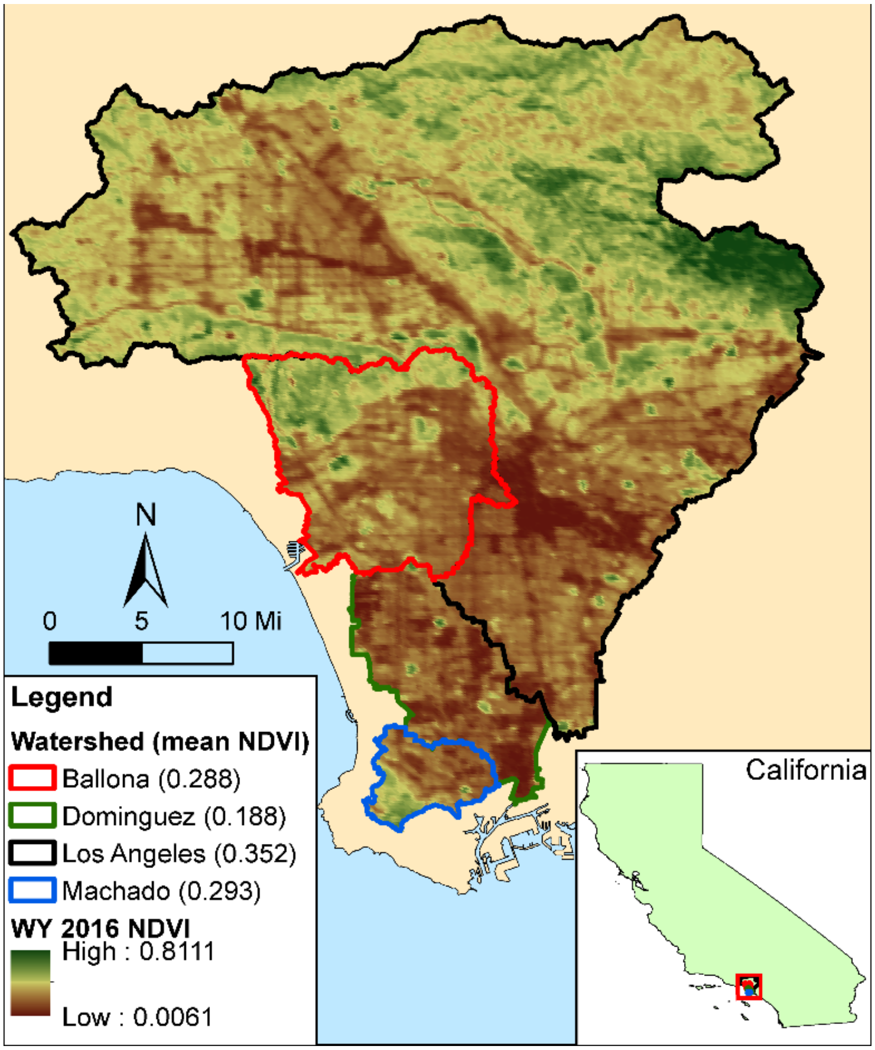

Figure 3.4: Measured NDVI from water year 2016 for all four watersheds. Colors range from dark green (higher NDVI) to dark brown (lower NDVI). Average NDVI for each watershed is listed in the legend. Flow regimes

The distribution of the 85th percentile storm depths throughout the four watersheds was used to determine the 85th percentile storm volumes for each watershed (Figure 3.5, Table 3.2). The DC and ML watersheds have the lowest weighted mean 85th percentile storm depth (0.86 in/24 hr). The weighted mean 85th percentile storm depth was 1.04 in/24 hr in both the LAR (including the forested area) and BC watersheds. The runoff coefficient was calculated by comparing the total volume of water falling within the watershed area to the actual volume of water observed at the outlet of the river channels. The ML watershed runoff coefficient was assumed to be the same as the DC Watershed due to the lack of observed data within the ML Watershed.[55]

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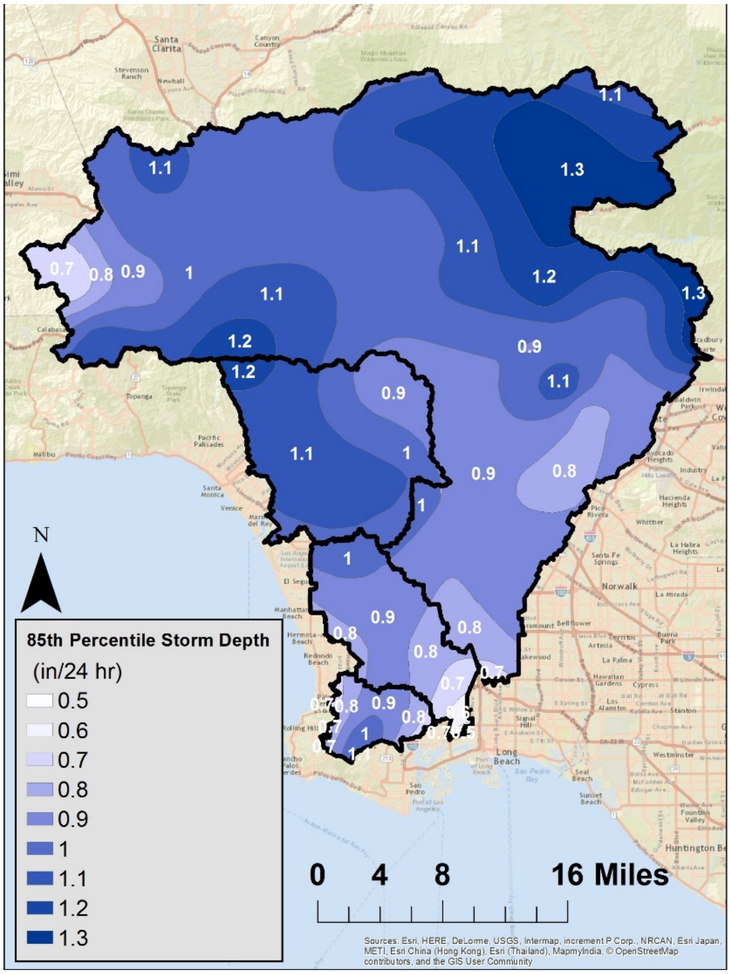
[55] See Mika et al., Sustainable LA DC & MLwatershed report, Machado Lake section. Available at: https://escholarship.org/uc/item/2w1916p4



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 3.5: 85th percentile storm depths in inches per 24 hour time period. The area of each storm depth was used to determine the 85th percentile storm volume for each watershed.

Watershed	85th Storm Depth (in) Weighted Mean	Runoff Coefficient	85th Storm Volume (AF)
Ballona Creek	1.04	0.51	3,621
Dominguez Channel	0.86	0.72	2,353
Machado Lake	0.86	0.72	755
Los Angeles River	1.04	0.36	16,342
Los Angeles River w/o Forested	0.96	0.58	10,396

Table 3.2: Flow regime comparisons between watersheds. Stats for the area not including the northern forested area of the watershed is also included.

A comparison of modeling results among the four watersheds was conducted to further analyze the flow regimes and pollutant loading (Table 3.3). This includes the average annual flow volume (AAFV) as well as the average annual load (AAL) of copper, lead, and zinc at the outlet for the BC, DC, and LAR Watersheds. While Water Effects Ratios (WERs) for copper have not been developed in the BC or DC Watersheds, wet and dry weather copper WERs have been assessed and approved for reaches and tributaries in the LAR watershed. Approved LAR copper WERs range from 1.32 to 9.69.[56]

	BC	DC	LAR
AAFV (AF)	63,490	36,154	236,455
Cu AAL (lbs)	4,088	2,885	36,180
Pb AAL (lbs)	2,584	1,208	35,541
Zn AAL (lbs)	23,824	14,021	127,593
Cu TMDL (ug/L)	13.7	9.7	17.0
Pb TMDL (ug/L)	76.7	42.7	94.0
Zn TMDL (ug/L)	104.7	69.7	159.0
WER	No	No	Yes for Cu

Table 3.3: Comparison of water quantity, quality, and TMDLs between the BC, DC, and LAR Watersheds.

C. Modeling Set-Up across Watersheds

To simulate metal loads and flows and the effect of BMP implementation in these watersheds, this study utilized the US Environmental Protection Agency (EPA)'s System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) Model. SUSTAIN contains multi-objective optimization algorithms and the ability to vary BMP dimensions and performance. In addition, SUSTAIN generates cost curves from output; taken in concert these features allow the user to identify optimal BMP suites and ultimately generate BMP scenarios.[57] SUSTAIN was selected over other stormwater management models due to its ability to model metal load reductions with cost, its optimization package, and its interface with ArcGIS.[58]

Watershed modeling efforts included an assessment of a variety of BMP scenarios to identify opportunities to achieve MS4 permit and TMDL compliance and other ancillary benefits. Optimization modeling results conducted on each watershed are further discussed in Appendix A. This section of the report concentrates on specific BMP scenarios that were developed and modeled for each watershed. In general, scenarios were compared by the number of days without exceedances for wet and dry weather metals TMDLs, average annual pollutant load reduction for each metal, storm peak flow reduction, and potential groundwater recharge volumes. However, variations existed between watersheds. For example, in the BC Watershed, the area of transportation land uses was determined differently than in the DC and LAR Watersheds. The BC Watershed utilized a transportation area from only the SCAG land use raster, which only allowed the identification of major highways due to the resolution of the SCAG land use raster. In order to more fully represent the entire area in the subsequent DC and LAR Watershed analyses, a road map that included all

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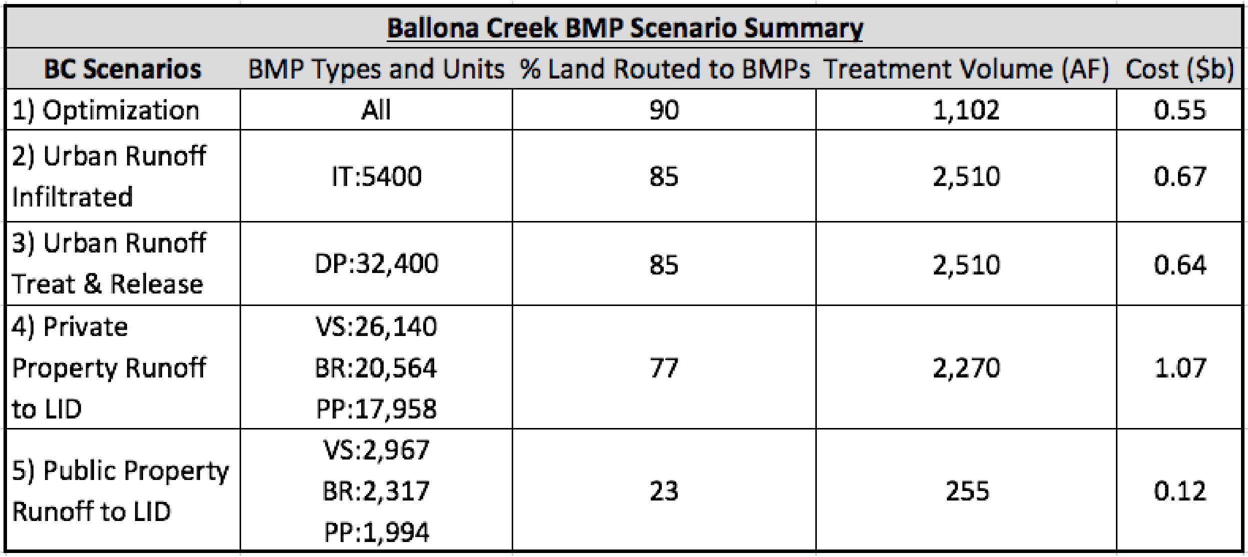
[56] Los Angeles River Copper WER Final Report, April 2014, p. ES-4

[57] Shoemaker, L.; Riverson, J.; Alvi, K.; Zhen, J.; Paul, S.; Rafi, T. (2009) SUSTAIN - A Framework for Placement of Best Management Practices in Urban Watersheds to Protect Water Quality. User's Manual, United States Environmental Protection Agency.

[58] See the Gold et al., Los Angeles Sustainable Water Project: Ballona Creek Watershed Report for more detail on the modeling selection. Available at: https://escholarship.org/uc/item/8s37c04z

primary, secondary, and minor roads was analyzed using GIS. In addition, a variety of BMP scenarios with a unique suite of BMPs to capture and treat runoff from different land-use types and drainage areas were explored in the BC watershed (Table 3.4). Scenario 1 applied the NSGA-II optimization algorithm to optimize the number of BMPs when runoff was routed to all 5 BMP types. Scenarios 2 and 3 routed water from 85% of the urban watershed to only infiltration BMPs (Scenario 2) or treat-and-release BMPs (Scenario 3). Low impact development (LID) BMPs to capture runoff from private or public land uses were utilized in Scenarios 4 and 5, respectively.



Ballona Creek BMP Scenario Summary				
BC Scenarios	BMP Types and Units	% Land Routed to BMPs	Treatment Volume (AF)	Cost ($b)
1) Optimization	All	90	1,102	0.55
2) Urban Runoff Infiltrated	IT:5400	85	2,510	0.67
3) Urban Runoff Treat & Release	DP:32,400	85	2,510	0.64
4) Private Property Runoff to LID	VS:26,140 BR:20,564 PP:17,958	77	2,270	1.07
5) Public Property Runoff to LID	VS:2,967 BR:2,317 PP:1,994	23	255	0.12

Table 3.4: Ballona Creek modeled scenarios and summary stats including the % of watershed routed to BMPs, the treatment volume based on BMP units and types, and capital cost. This is only one potential cost within a range.

It is important to note that the costs for each scenario shown in Table 3.4-3.6 only represent one example within a potential range of costs. The ranges in unit cost varied widely, which is further discussed in the Ballona Creek report[59]; tables 3.4-3.6 reflect the median capital cost of BMPs found in Southern California. For example, while a set cost of $10.07 was used for Vegetated Swales in this table, the minimum and maximum cost found in the SUSTAIN BMP cost database is $5.37 and $18.53, respectively. Therefore, the costs in Tables 3.4-3.6 are an example of a potential program cost within each scenario rather than an absolute cost of each scenario.

BC Watershed modeling results demonstrated that routing runoff from 90% of all urban area to BMPs, in addition to a pollutant reduction target of at least 60%, is optimal for modeling scenarios.[60] The pollutant target reduction of 60% was originally chosen for the BC watershed study based on the results of a BMP optimization study.[61] The LAR and DC watersheds were also set

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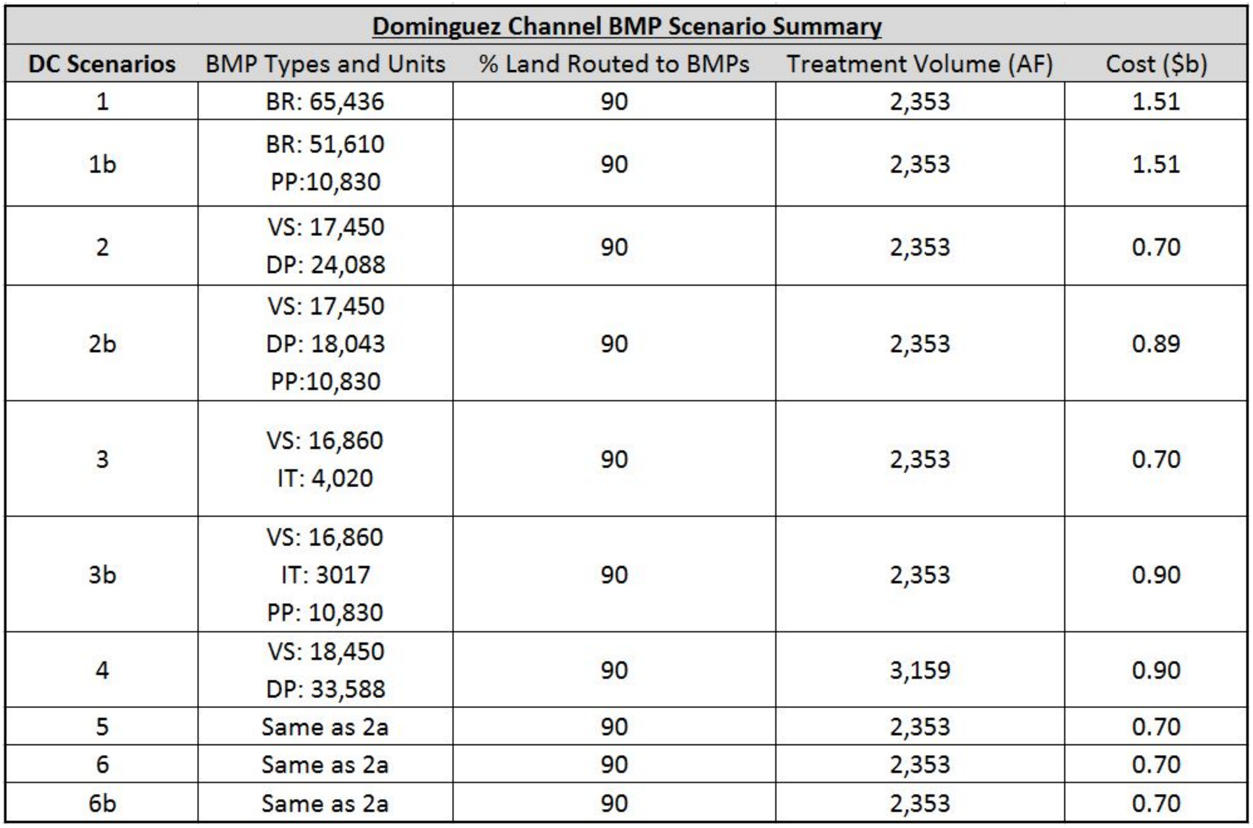
[59] Gold et al., Sustainable LA Water Project Ballona Creek Report, page 48. Available at: https://escholarship.org/uc/item/8s37c04z

[60] Gold et al., Sustainable LA Water Project Ballona Creek Report, page 42 42 Available at: https://escholarship.org/uc/item/8s37c04z

[61] Beck, Drew J., Evaluating Best Management Practice Scenarios in Ballona Creek Watershed Using EPA's SUSTAIN Model (2014), Colorado School of Mines, Master's Thesis.

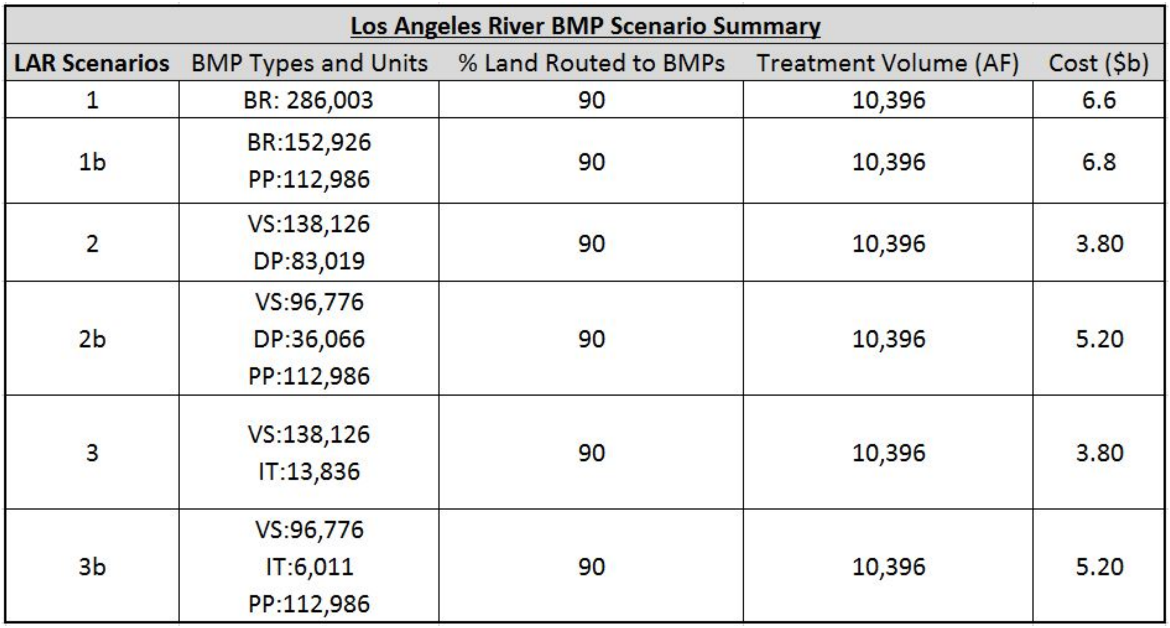
up so that every scenario routed water from 90% of the watershed to BMPs, but optimizations were designed around managing the 85th percentile storm rather than a specific pollutant load reduction (Appendix A). Six scenarios (1, 1b, 2, 2b, 3, and 3b) with different suites of BMPs were developed and modeled to assess pathways to improving water quality in both the DC and LAR watersheds (Table 3.5, 3.6). Scenario 1 utilizes bioretention (BR), Scenario 2 utilizes vegetated swales (VS) and dry ponds (DP), and Scenario 3 utilizes VS and infiltration trenches (IT). Scenario 1 was largely infiltration-focused (BR is designed to retain water up to 6 inches and allow infiltration or evapotranspiration over several days but overflows of stormwater during larger storms may occur). Scenario 2 was focused on treat-and-release (composed of 2 treat-and-release BMPs, DP and VS) and Scenario 3 emphasized infiltration (mix of VS and IT, with an emphasis on the infiltration-based IT). Scenarios 1b, 2b, and 3b add porous pavement (PP), which added additional infiltration capacity to each of the first three scenarios.



Dominguez Channel BMP Scenario Summary

DC Scenarios	BMP Types and Units	% Land Routed to BMPs	Treatment Volume (AF)	Cost ($b)
1	BR: 65,436	90	2,353	1.51
1b	BR: 51,610 PP:10,830	90	2,353	1.51
2	VS: 17,450 DP: 24,088	90	2,353	0.70
2b	VS: 17,450 DP: 18,043 PP:10,830	90	2,353	0.89
3	VS: 16,860 IT: 4,020	90	2,353	0.70
3b	VS: 16,860 IT: 3017 PP: 10,830	90	2,353	0.90
4	VS: 18,450 DP: 33,588	90	3,159	0.90
5	Same as 2a	90	2,353	0.70
6	Same as 2a	90	2,353	0.70
6b	Same as 2a	90	2,353	0.70

Table 3.5: Dominguez Channel modeled scenarios and summary stats including the % of watershed routed to BMPs, the treatment volume based on BMP units and types, and capital cost.



Los Angeles River BMP Scenario Summary

LAR Scenarios	BMP Types and Units	% Land Routed to BMPs	Treatment Volume (AF)	Cost ($b)
1	BR: 286,003	90	10,396	6.6
1b	BR:152,926 PP:112,986	90	10,396	6.8
2	VS:138,126 DP:83,019	90	10,396	3.80
2b	VS:96,776 DP:36,066 PP:112,986	90	10,396	5.20
3	VS:138,126 IT:13,836	90	10,396	3.80
3b	VS:96,776 IT:6,011 PP:112,986	90	10,396	5.20

Table 3.6: LAR modeled scenarios and summary stats including the % of watershed routed to BMPs, the treatment volume based on BMP units and types, and capital cost.

The modeling approach used in the DC and LAR watersheds took a more detailed look at what watershed-wide BMP approaches were needed to get as close to water quality standard attainment as possible in receiving waters. After initial modeling efforts (scenarios 1-3b) showed that load-based exceedances were not eliminated after managing the 85th percentile storm, three additional modeling scenarios were run in DC to assess further potential to improve water quality. These three scenarios included increasing the volume captured beyond the 85th percentile storm alternative[62] in the MS4 permit (Scenario 4), implementing higher efficiency BMPs (Scenario 5), and implementing a copper WER in DC (Scenario 6). Scenarios 4 to 6b were all built on Scenario 2 (VS + DP) as it had the fewest remaining load-based exceedances after BMP simulation. More specifically, in Scenario 4, the number of BMPs simulated was increased to evaluate the capture of a storm volume around the 95th percentile.

In Scenario 5, the impact of increasing the decay rates of the two modeled BMPs, VS and DP, was evaluated. Treatment efficiency was tested by increasing the 1st order decay rates for each BMP in the SUSTAIN simulations (i.e. improved pollutant removal). Each BMP type takes into account inflow time series, concentration time series for each pollutant, and the 1st order decay factor/rate (1/hr) for each pollutant to predict the outflow and concentration time series for each pollutant.[63] The decay factor simulates an exponential decay over time. The goal was to determine the theoretical decay rates needed for zero days of wet weather exceedances. However, the percent

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[62] Stronger storms can be more expensive to build for, e.g., section 6.1.1 Capture Curves in the SCMP Appendices. SCMP technical memo 3, p. 212 of pdf. Available at www.ladwp.com/scmp.

[63] Lai, Dennis, T. Dai, J. Zhen, J. Riverson, K. Alvi, AND L. Shoemaker. SUSTAIN - An EPA BMP Process and Placement Tool for Urban Watersheds. In Proceedings, WEF 2007 TMDL Specialty Conference, Belle-vue, WA, June 24 - 27, 2007. Water Environment Federation, Alexandria, VA, (2007).

pollutant reduction reached a maximum, even when simulating decay rates that were 100 times greater than the original rates. This is most likely due to factors relating to both the BMP design and external factors such as the volume of water routed to the BMPs. Pollutant decay rates modeled were those at which pollutant reduction reached its maximum.

Aggregated BMP placement in the LAR, DC, and ML Watershed modeling scenarios were based on the amount of total land potentially available without substantial land acquisition costs for BMP construction (e.g., ‘urban public’ land). [64] The eleven SCAG land uses were grouped into ‘urban private,’ which included agriculture, commercial, industrial, MFR, and SFR; ‘urban public,’ which included education, recreation, and transportation lands; and ‘water’ (Figure 3.6).

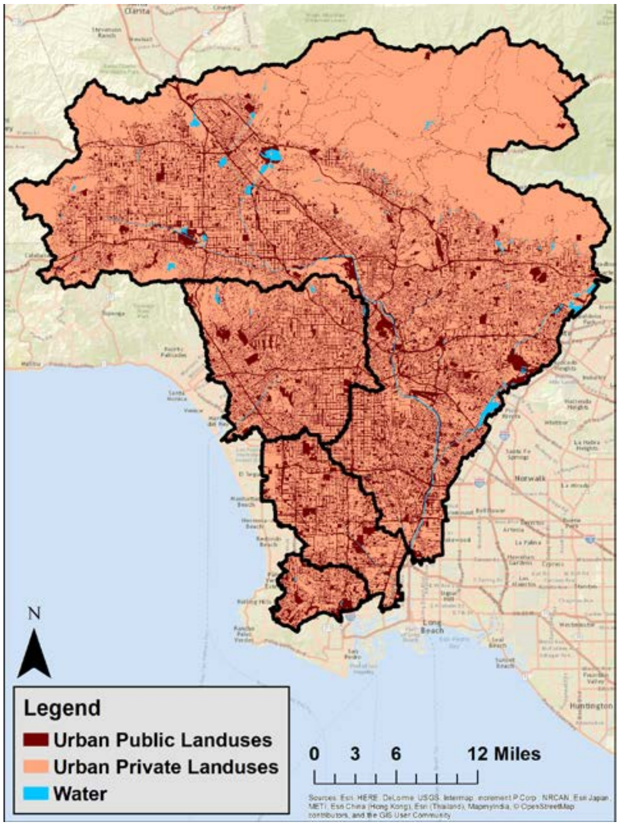

Figure 3.6: Land use distribution in the four watersheds broken up by ‘urban public’, ‘urban private,’ and water-bodies. Watersheds are delineated as previously discussed.

In our modeling efforts, BMP placement was not allowed on ‘water’ uses as there are many

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[64] The ML watershed is unique from the other three watersheds in that nutrients were analyzed rather than metals and the watershed also includes a lake. Thus, scenarios involved modeling BMPs throughout the watershed and within Machado Lake. We analyzed the impact of nutrient TMDLs for total nitrogen and total phosphorous as these pollutants pose compliance challenges and are of greatest concern in ML. As the modeling set-up was very different in the ML watershed, the results are not discussed in great detail in this report but the DC and ML watershed report contains a full description of these efforts. Where parallels and similarities exist, however, ML results are pulled into the discussion. Please see the Sustainable LA Water Project – DC/ML Report for full details on ML modeling. Available at: http://escholarship.org/uc/item/2w1916p4

regulatory hurdles that must be overcome to place a BMP in a water body. Further, BMPs were only placed on 'urban public' land uses in these modeling efforts as public lands usually do not come with land acquisition costs and are more readily available for BMP placement by the City and other public agencies. For example, placing BMPs on private land would require purchasing land or rights of way from private landowners or initiating large programs to encourage or require private landowners to install and maintain BMPs on site. However, even though they were not included in these modeling analyses, the conversion of private land uses to more stormwater-friendly spaces is an important piece of improving surface water quality and increasing potential local water supply (e.g., offsetting potable use or providing additional groundwater recharge). Therefore, to assess the potential impacts of LID development on private land, we conducted a post-modeling analyses that will be discussed later (III.E.a).

The land use types in 'urban public' (education, recreation, transportation, and public parking lots) were also chosen for modeling efforts as they were well-distributed throughout all four watersheds, and thus provided opportunities to model BMPs at many locations throughout the watersheds. Approximately 6.5-8% of the watersheds were covered by 'urban public' land uses that were considered available for BMP placement. The area available for BMP implementation on transportation land uses for this analysis includes major highways (from SCAG) as well as primary, secondary, and minor roads (from additional road maps utilized in GIS). Of the four watersheds, BC (7.1%) and ML (7.7%) watersheds had the highest available public land area percentage (Table 3.7). Educational land uses represented the largest available area for BMPs in DC, ML, and LAR; transportation represented the largest available area in the BC Watershed (Table 3.7). The opportunities for and challenges to increasing stormwater capture on school properties in LA is an area of active research as schools offer a large amount of land area that would be able to provide significant stormwater capture benefits with BMP implementation.[65]

	Area available for BMP Implementation (mi^2)					
Watershed	**Education**	**Recreation**	**Transportation**	**Parking Lots**	**Total**	**% of Watershed**
Ballona Creek	2.86	0.75	3.68	1.45	8.74	7.10%
Dominguez Channel	2.08	0.55	1.03	1.05	4.71	6.64%
Machado Lake	1.00	0.31	0.35	0.27	1.93	7.70%
LAR (w/o Forested)	14.00	4.87	7.52	8.00	34.39	6.72%

Table 3.7: 'Urban public' land use breakdown for the four watersheds.

D. Modeling Results

a. BMP Scenarios

Modeled scenarios in the BC watershed were designed to assess the impacts of managing stormwater from different land areas as well as with different BMP types. Thus, each modeled scenario captured a unique storm volume. It is important to note that in the BC watershed, unlike

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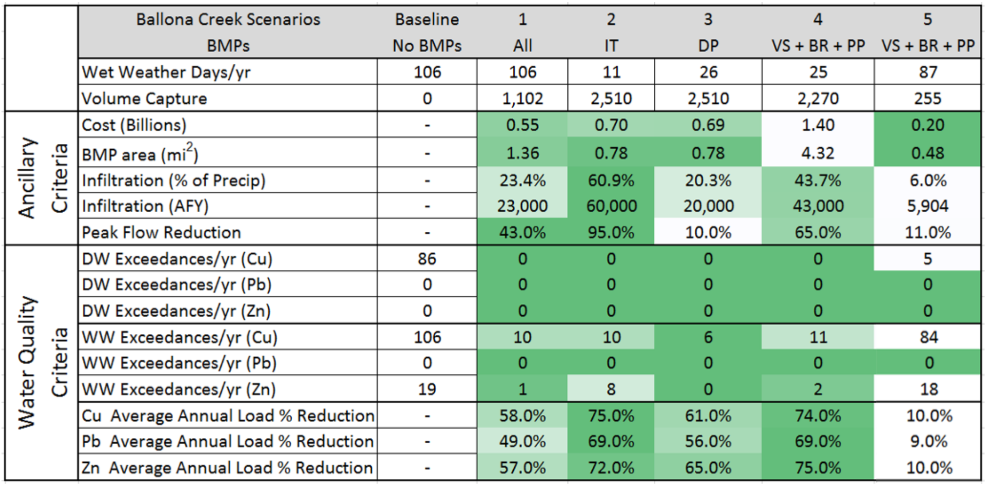
[65] Treepeople (2015) Unlocking Collaborative Solutions to Water Challenges in the Los Angeles Region: The Power of Schools. https://www.treepeople.org/sites/default/files/pdf/publications/TreePeople%20-%20The%20Power%20of%20Schools.pdf;

other modeled watersheds, these storm volumes were significantly less than the 85th percentile storm volume in BC (3,621 AF, Table 3.8). Ancillary benefits and water quality criteria generally varied with storm volumes managed through BMPs; smaller captured volumes required fewer BMPs and thus provided fewer benefits. For example, BC Scenario 5 (VS+BR+PP), which captured a significantly lower volume than other scenarios (255 AF from only 'urban public' land uses), also had a significantly lower cost and BMP area (Table 3.8). However, BC Scenario 5 also resulted in the smallest reduction in both the number of wet and dry weather exceedances and the average annual load as a lower volume of stormwater was managed.



	Ballona Creek Scenarios	Baseline	1	2	3	4	5
	BMPs	No BMPs	All	IT	DP	VS + BR + PP	VS + BR + PP
	Wet Weather Days/yr	106	106	11	26	25	87
	Volume Capture	0	1,102	2,510	2,510	2,270	255
Ancillary Criteria	Cost (Billions)	-	0.55	0.70	0.69	1.40	0.20
	BMP area (mi^2)	-	1.36	0.78	0.78	4.32	0.48
	Infiltration (% of Precip)	-	23.4%	60.9%	20.3%	43.7%	6.0%
	Infiltration (AFY)	-	23,000	60,000	20,000	43,000	5,904
	Peak Flow Reduction	-	43.0%	95.0%	10.0%	65.0%	11.0%
Water Quality Criteria	DW Exceedances/yr (Cu)	86	0	0	0	0	5
	DW Exceedances/yr (Pb)	0	0	0	0	0	0
	DW Exceedances/yr (Zn)	0	0	0	0	0	0
	WW Exceedances/yr (Cu)	106	10	10	6	11	84
	WW Exceedances/yr (Pb)	0	0	0	0	0	0
	WW Exceedances/yr (Zn)	19	1	8	0	2	18
	Cu Average Annual Load % Reduction	-	58.0%	75.0%	61.0%	74.0%	10.0%
	Pb Average Annual Load % Reduction	-	49.0%	69.0%	56.0%	69.0%	9.0%
	Zn Average Annual Load % Reduction	-	57.0%	72.0%	65.0%	75.0%	10.0%

Table 3.8: BC decision matrix to evaluate tradeoffs between BMP scenarios. Color scale created in Microsoft Excel with Conditional Formatting tool. Dark green to white color for each criteria row; darker is better.

In general, the number of exceedances per year was lowest in the BC scenarios in which treat-and-release BMPs were utilized and water was routed from the majority of the watershed to BMPs. With the exception of Scenario 5, all modeled scenarios resulted in zero dry weather exceedances for copper (lead and zinc were at zero dry weather exceedances in the baseline and remained there in the modeled scenarios). Although these approaches did not enable meeting water quality standards for copper and zinc all of the time, other factors in the BC watershed (beyond BMPs) will also contribute to meeting compliance with copper requirements. For example, subsequent modeling demonstrated that copper water quality standards could be met if the BC watershed is eligible for a copper water effects ratio (WER) of 2.[66] In other words, a Cu WER greater than 2 resulted in zero wet weather Cu exceedances per year in the modeled baseline scenario. In addition, the

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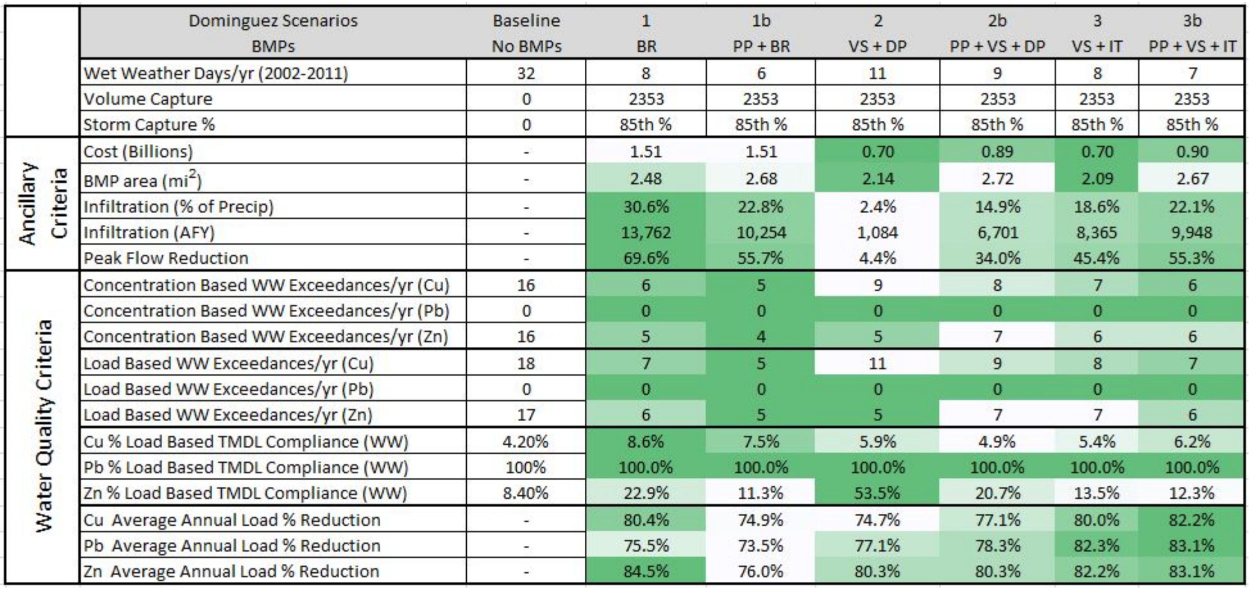
[66] Sustainable LA Water BC Report, Water Effects Ratio Analysis p. 60. Available at: https://escholarship.org/uc/item/8s37c04z

implementation of CA SB346, which requires a reduction of copper in brake pads, will decrease copper levels in runoff; one study estimates a potential reduction in copper levels by up to 61%[67]

The DC and LAR watershed BMP scenarios were designed to manage the 85th percentile storm volume to reflect the LA County MS4 permit. DC BMP scenarios were only run for wet weather (metals TMDL only in place for wet weather); LAR BMP scenarios were run for both wet and dry weather (metals TMDLs in place for both wet and dry weather). In addition, as described above, BMP scenarios in LAR were modeled with the copper WERs and lead site-specific objectives in place but neither DC nor BC have copper WERs in place.[68] None of the DC BMP scenarios resulted in eliminating load-based exceedances for copper or zinc; 5 to 11 copper exceedances remained and 5 to 7 lead exceedances remained after BMP implementation. The treat-and-release Scenario 2 (VS+DP) resulted in the fewest wet weather zinc exceedances per year (Table 3.9). However, Scenario 2 did not have the fewest wet weather copper exceedances; exceedances occurred on 100% of wet weather days in Scenario 2 (which also occurred in Scenario 2b, 3, and 3b).



	Dominguez Scenarios	Baseline	1	1b	2	2b	3	3b
	BMPs	No BMPs	BR	PP + BR	VS + DP	PP + VS + DP	VS + IT	PP + VS + IT
	Wet Weather Days/yr (2002-2011)	32	8	6	11	9	8	7
	Volume Capture	0	2353	2353	2353	2353	2353	2353
	Storm Capture %	0	85th %	85th %	85th %	85th %	85th %	85th %
Ancillary Criteria	Cost (Billions)	-	1.51	1.51	0.70	0.89	0.70	0.90
	BMP area (mi^2)	-	2.48	2.68	2.14	2.72	2.09	2.67
	Infiltration (% of Precip)	-	30.6%	22.8%	2.4%	14.9%	18.6%	22.1%
	Infiltration (AFY)	-	13,762	10,254	1,084	6,701	8,365	9,948
	Peak Flow Reduction	-	69.6%	55.7%	4.4%	34.0%	45.4%	55.3%
Water Quality Criteria	Concentration Based WW Exceedances/yr (Cu)	16	6	5	9	8	7	6
	Concentration Based WW Exceedances/yr (Pb)	0	0	0	0	0	0	0
	Concentration Based WW Exceedances/yr (Zn)	16	5	4	5	7	6	6
	Load Based WW Exceedances/yr (Cu)	18	7	5	11	9	8	7
	Load Based WW Exceedances/yr (Pb)	0	0	0	0	0	0	0
	Load Based WW Exceedances/yr (Zn)	17	6	5	5	7	7	6
	Cu % Load Based TMDL Compliance (WW)	4.20%	8.6%	7.5%	5.9%	4.9%	5.4%	6.2%
	Pb % Load Based TMDL Compliance (WW)	100%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Zn % Load Based TMDL Compliance (WW)	8.40%	22.9%	11.3%	53.5%	20.7%	13.5%	12.3%
	Cu Average Annual Load % Reduction	-	80.4%	74.9%	74.7%	77.1%	80.0%	82.2%
	Pb Average Annual Load % Reduction	-	75.5%	73.5%	77.1%	78.3%	82.3%	83.1%
	Zn Average Annual Load % Reduction	-	84.5%	76.0%	80.3%	80.3%	82.2%	83.1%

Table 3.9: Dominguez Channel decision matrix for evaluating tradeoffs between BMP scenarios.[69]

All modeled BMP scenarios in the LAR watershed resulted in significant improvements in water quality but none resulted in eliminating all dry weather metals exceedances. Scenario 2 (VS + DP) resulted in the lowest exceedances per year for dry weather TMDLs (Table 3.10) in LAR. While Scenario 2 was also very good in wet weather, with zero exceedances for copper or

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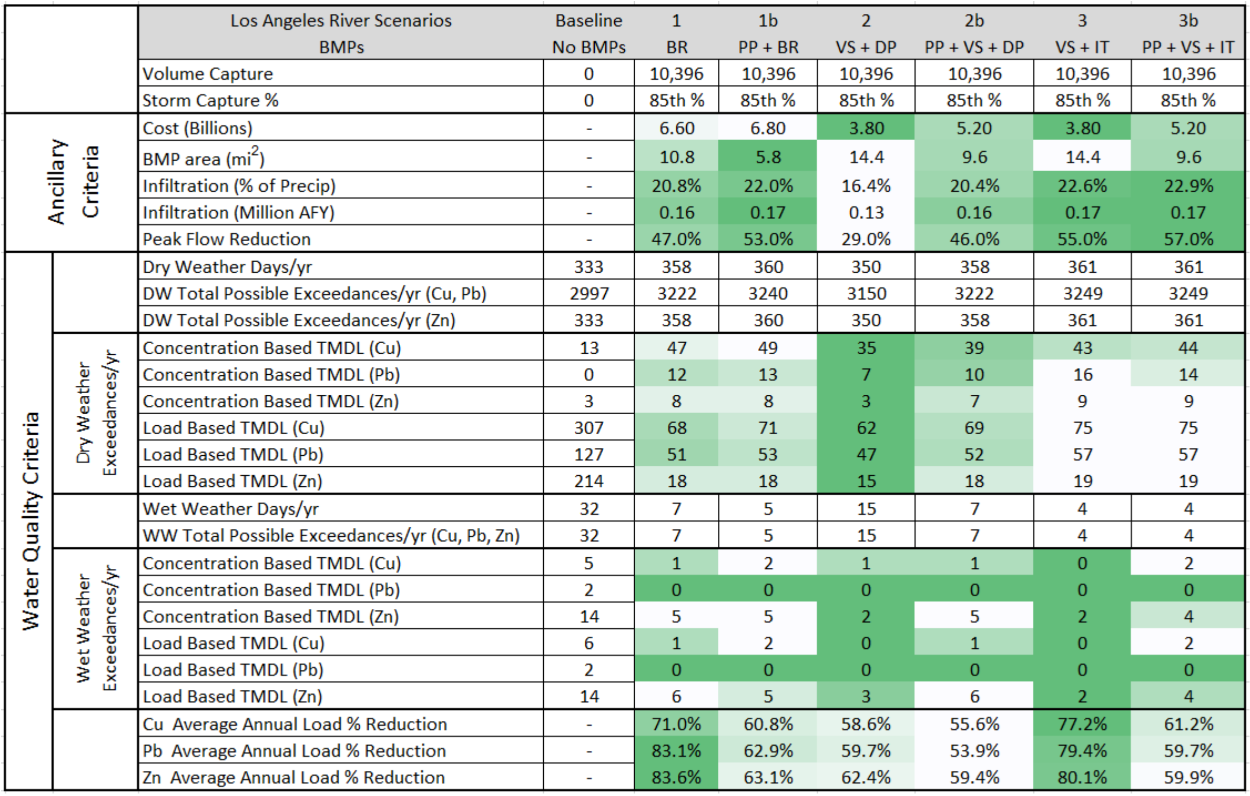
[67] Estimated Urban Runoff Copper Reductions Resulting from Brake Pad Copper Use Restrictions https://www.casqa.org/sites/default/files/library/technical-reports/estimated_urban_runoff_copper_reductions_resulting_from_brake_pad_copper_use_restrictions_casqa_4-13.pdf

[68] Mika et al., Sustainable LA Water Los Angeles River Watershed Report. Stormwater modeling section. Available at: https://escholarship.org/uc/item/42m433ps

[69] The color scale was created in Microsoft Excel by using the Conditional Formatting tool and displays a range from dark green to white for each criteria row. Darker colors indicate a better result for that row.

lead, Scenario 3 (VS + IT) is slightly better for zinc with two exceedances (compared to three exceedances for Scenario 2). In general, for all watersheds analyzed, scenarios with a focus on treat-and-release BMPs achieved a lower number of exceedances than scenarios with a focus on infiltration BMPs. Infiltration BMPs, however, often performed better in terms of overall pollutant load reduction. For example, the average annual load of metals was reduced by 58 to 62% in LAR Scenario 2 with treat-and-release BMPs, while the load was reduced by 77 to 80% in LAR Scenario 3, which included the infiltration BMP, ITs (Table 3.10). Different suites of BMPs offer different ancillary benefits; infiltration BMPs, for example, can offer greater potential for recharging local groundwater basins.



		Los Angeles River Scenarios BMPs	Baseline No BMPs	1 BR	1b PP + BR	2 VS + DP	2b PP + VS + DP	3 VS + IT	3b PP + VS + IT
		Volume Capture	0	10,396	10,396	10,396	10,396	10,396	10,396
		Storm Capture %	0	85th %	85th %	85th %	85th %	85th %	85th %
Ancillary Criteria		Cost (Billions)	-	6.60	6.80	3.80	5.20	3.80	5.20
		BMP area (mi^2)	-	10.8	5.8	14.4	9.6	14.4	9.6
		Infiltration (% of Precip)	-	20.8%	22.0%	16.4%	20.4%	22.6%	22.9%
		Infiltration (Million AFY)	-	0.16	0.17	0.13	0.16	0.17	0.17
		Peak Flow Reduction	-	47.0%	53.0%	29.0%	46.0%	55.0%	57.0%
Water Quality Criteria		Dry Weather Days/yr	333	358	360	350	358	361	361
		DW Total Possible Exceedances/yr (Cu, Pb)	2997	3222	3240	3150	3222	3249	3249
		DW Total Possible Exceedances/yr (Zn)	333	358	360	350	358	361	361
	Dry Weather Exceedances/yr	Concentration Based TMDL (Cu)	13	47	49	35	39	43	44
		Concentration Based TMDL (Pb)	0	12	13	7	10	16	14
		Concentration Based TMDL (Zn)	3	8	8	3	7	9	9
		Load Based TMDL (Cu)	307	68	71	62	69	75	75
		Load Based TMDL (Pb)	127	51	53	47	52	57	57
		Load Based TMDL (Zn)	214	18	18	15	18	19	19
		Wet Weather Days/yr	32	7	5	15	7	4	4
		WW Total Possible Exceedances/yr (Cu, Pb, Zn)	32	7	5	15	7	4	4
	Wet Weather Exceedances/yr	Concentration Based TMDL (Cu)	5	1	2	1	1	0	2
		Concentration Based TMDL (Pb)	2	0	0	0	0	0	0
		Concentration Based TMDL (Zn)	14	5	5	2	5	2	4
		Load Based TMDL (Cu)	6	1	2	0	1	0	2
		Load Based TMDL (Pb)	2	0	0	0	0	0	0
		Load Based TMDL (Zn)	14	6	5	3	6	2	4
		Cu Average Annual Load % Reduction	-	71.0%	60.8%	58.6%	55.6%	77.2%	61.2%
		Pb Average Annual Load % Reduction	-	83.1%	62.9%	59.7%	53.9%	79.4%	59.7%
		Zn Average Annual Load % Reduction	-	83.6%	63.1%	62.4%	59.4%	80.1%	59.9%

Table 3.10: Los Angeles River decision matrix for evaluating tradeoffs between BMP scenarios.[70]

These modeling results confirm that making decisions about the best BMP(s) to implement in an integrated water management framework requires the consideration of multiple criteria. Considering the impacts of the implementation of porous pavement throughout the LAR watershed provides a good example of this complexity. In general, water quality for scenarios including

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[70] TMDLs are in effect in several tributaries within the LAR Watershed as well as the main stem. The number of exceedances per year (rows), split by dry/wet weather and by metal, represent the number of exceedances over the entire LAR basin in one year. This value takes into account the fact that each tributary of the LAR is capable of exceeding its TMDL once per day, e.g. for eight tributaries with TMDLs, the total number of opportunities to exceed is 9*365 = 3650 exceedances per year. The color scale was created in Microsoft Excel by using the Conditional Formatting tool and displays a range from dark green to white for each criteria row. Darker colors indicate a better result for that row.

porous pavement as a BMP is poorer (i.e. more exceedances, Table 3.10). Although water quality is relatively worse in these "b" scenarios, the volume of water infiltrated is higher and the BMP spatial footprint is lower. Both of these are important ancillary benefits to consider in a semi-arid region that is highly developed and dependent on imported water.

However, the "b" scenarios that contain porous pavement are also much more expensive, and so may not be a feasible option for municipalities that are budget-limited in their decisions to satisfy water quality, cost [both capital costs and operations and maintenance (O&M) over time], BMP footprint, and infiltration criteria. However, porous pavement is also an opportunity to decrease imperviousness of a developed surface and continue to use the land (e.g. parking lot) as is, rather than needing to transform the area both structurally and for use. The relative intensity and cost of O&M needs (and O&M funding sources) of BMPs is another important consideration in selecting BMP suites. It is important to highlight here that there is a dearth of existing BMP O&M data that must be filled to better inform future modeling efforts. All BMP scenarios aided in reducing the peak flow from the 10 simulated water years, with values ranging from a 29% reduction (VS+DP) to up to a 57% reduction (PP+VS+IT); the highest flow reduction resulted from a scenario that included porous pavement (Table 3.10).

The highest performing options in terms of volume of stormwater infiltrated for the LAR watershed were 3 and 3b (VS+IT and VS+IT+PP, respectively). These scenarios were expected to do well in this regard because infiltration trenches have a large capacity to infiltrate stormwater, as does porous pavement. However, the relative difference in volume infiltrated between 3 and 3b is fairly insignificant and the cost difference is $1.4 billion (Table 3.10). Therefore, 3 offers a more cost-effective means to infiltrate relatively large volumes of stormwater. It should be noted that the volume of infiltrated stormwater does not necessarily equate to the volume of water that will actually reach groundwater aquifers or become available for local supply, a topic that needs further research in the LA region.

Each modeled BMP scenario for the LAR watershed managed the 85th percentile volume of stormwater (10,396 AF) and thus all equally complied with the 85th percentile stipulation in the MS4 permit. As previously mentioned, each scenario also routed 90% of the runoff from the entire watershed to BMPs that are sited on "public land." Thus, runoff from both 'urban private' and 'urban public' land uses was being treated in the BMP modeling scenarios. However, the various scenarios had significant differences in costs and in benefits such as water quality, potential infiltration, and flood control. This analysis can enable a decision maker to prioritize their criteria for implementation. For example, if ancillary benefits (e.g., infiltration, BMP footprint, peak flow reduction) are valued higher than exceedances, then Scenarios 3 and 3b might be optimal. If, however, the opposite were true, Scenario 2 may be more appropriate. It is important to emphasize, however, that this is a relative ranking between the modeled BMP scenarios and thus the magnitude of the differences among scenarios should also be considered when prioritizing. For example, the range of dry weather exceedances per year for copper only ranges between 0-2.

The wet weather TMDLs were applied to the average annual flow volume (AAFV) listed in Table 3.3 to calculate an estimate of the average annual TMDL (AA-TMDL). An estimate of the total allowable loads of pollutants per year based on the AAFV, average annual load (AAL), and TMDL numeric targets were calculated. For example, the DC AAFV of 36,154 AF is multiplied by the copper TMDL of 9.7 ug/L, using the appropriate conversions to get units in pounds, to get an AA-TMDL of 956 pounds. Comparing this number to the modeled baseline AAL of 2,885 pounds of copper, it is determined that a pollutant load reduction of 67% is required to reach the estimated AA-TMDL of 956 pounds (Figure 3.7). This is a rough estimate to allow comparison of pollutant reduction needed to meet TMDL requirements across the three watersheds. The DC Watershed has a higher predicted required pollutant reduction (Figure 3.7).

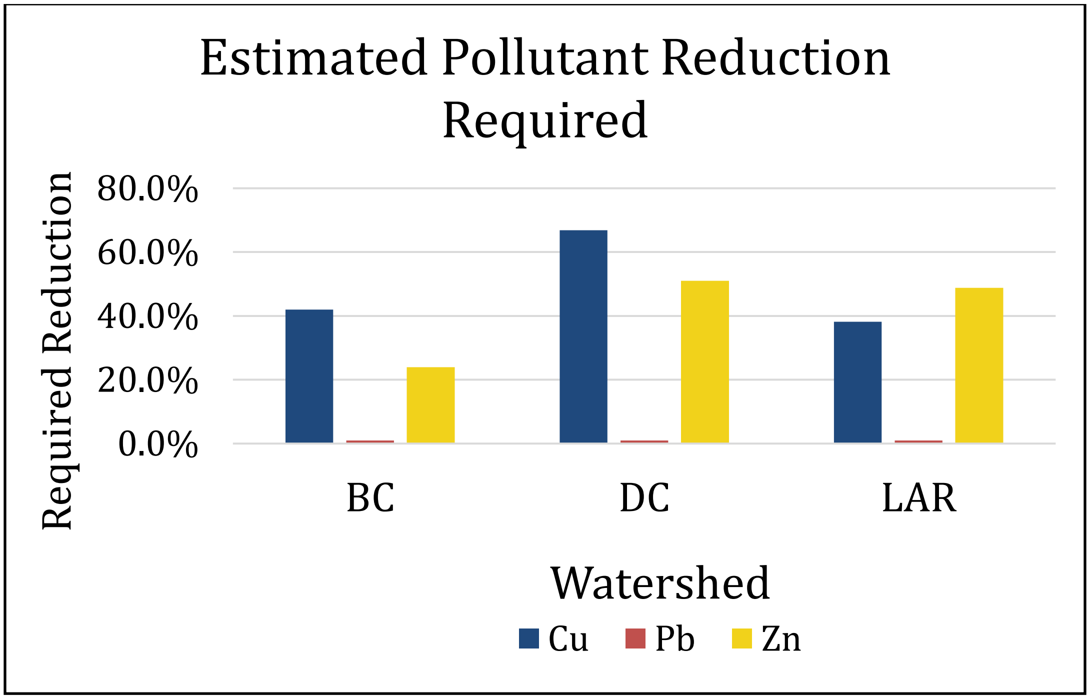

Figure 3.7: Estimated reduction in average annual loads to meet TMDL. DC requires a larger reduction than BC or LAR as TMDL is lower.

It should be noted that the LAR Watershed approved WER of 3.2 for the copper TMDL is applied to the LAR estimate. Without the WER, the LAR watershed would require a copper reduction of 81%, which is higher than the reduction of copper required for the DC Watershed. It should also be noted that the DC analysis utilizes the AAFV and AAL modeled for the full watershed rather than the volume and loads modeled at mass emission station, MS28, which monitors stormwater from the Upper DC Watershed.

Modeling results show that eliminating water quality standard exceedances will be difficult for some of the watersheds. For example, eliminating wet weather exceedances for copper and zinc in the DC watershed will be very challenging. In the LAR Watershed, dry weather exceedances for all metals are still present after implementing BMPs (a combination of treat-and-release and / or infiltration BMPs) that can manage the 85th percentile storm volume. Further modeling conducted on the DC Watershed showed that neither increasing the volume of stormwater captured to the 95th percentile storm (Scenario 4) nor increasing the decay rates of the pollutants in the BMPs (Scenario 5) was sufficient to eliminate all exceedances.[71] However, these watershed-scale BMP

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[71] Mika et al., Sustainable LA Water Project DC and ML Report. https://escholarship.org/uc/item/2w1916p4

programs do greatly improve water quality; exceedances are greatly reduced in all watersheds as a result of implementing these BMPs. It is also important to note, as described in greater detail below, that these modeling results do not include the other water quality improvement efforts that are concurrently occurring in this region.

Source control and source tracking efforts to eliminate pollutant loads coming in from the watershed will also be important to achieve compliance with water quality standards in all four watersheds. Source reduction is an additional mechanism that will assist in achieving compliance with copper water quality standards throughout these watersheds. For example, California state legislation (SB 346) requires copper be reduced to less than 0.5 percent copper by weight in new brake pads in cars by 2025 (currently, brake pads contain up to 20% copper with an average of 8% by weight).[72] This brake pad replacement is expected to greatly reduce copper concentrations in urban and stormwater runoff; a recent study found potential reductions in copper in urban runoff of as much as 61% if brake pads in essentially all on-road vehicles are at less than 0.5% copper.[73]

In addition, as is discussed later in the report, compliance with LID requirements for new and redevelopment provides substantial benefits in pollutant load reduction and stormwater infiltration. Over the next one to two decades, LID implementation may help lead to water quality standards attainment in receiving waters if watershed-scale BMP programs successfully manage the 85th percentile storm volumes. Increasing the quality and quantity of water quality data collected and available for all four watersheds is necessary to appropriately plan pathways to meeting compliance; monitoring efforts planned through the CIMPs will begin to address some of these gaps. Obtaining water quality data that is broad enough to capture the impacts of all potential land uses in a watershed and frequent enough to provide both seasonal information and a well-populated dataset for analysis is critical to assessing waterbody health and understanding the best approaches to attaining water quality standards for impaired water bodies.

It is important to note again here that the quantitative modeling component only considered the implementation of watershed-scale BMPs, not any of the additional measures that will be or are being implemented such as management control measures, source control, or BMP implementation on private land. In addition, these analyses only included metals impacts and the best scenarios for metals may not be the best scenarios for addressing other pollutants in the watershed such as trash or bacteria. The implementation of this type of watershed-scale BMP program does provide significant water quality benefits as well as offer the potential to augment local water supply and is thus a critical component of eliminating water quality exceedances. Robust modeling such as that outlined here provides the information necessary to address these trade-offs in planning efforts. The concurrent implementation of a wide variety of BMP programs of variable sizes on multiple land uses, as well as ongoing and planned source reduction mechanisms, will also help

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[72] Senators Kehoe and Simitian. February 25, 2009, amended on June 21, 2010. CA State Bill Number 346. http://www.leginfo.ca.gov/pub/09-10/bill/sen/sb_0301-0350/sb_346_bill_20100621_amended_asm_v92.html; https://calpsc.org/mobius/cpsc-content/uploads/2015/01/casqa_SB-346_brake_pad_Fact_Sheet.pdf;

[73] Estimated Urban Runoff Copper Reductions Resulting from Brake Pad Copper Use Restrictions https://www.casqa.org/sites/default/files/library/technical-reports/estimated_urban_runoff_copper_reductions_resulting_from_brake_pad_copper_use_restrictions_casqa_4-13.pdf

attain compliance with water quality standards in the studied watersheds. These BMP programs offer far greater water quality and ancillary benefit potential then, for example, a WER.

b. Potential Impacts on LA River Flows

In addition to improving water quality and providing additional stormwater recharge potential, implementing BMPs to meet water quality standards can also impact flow regimes in the downstream waterbodies such as the LAR. It is important to understand these flow impacts to ensure adequate year-round low flows in the LAR to support its designated uses. In the LAR, a large component of dry weather flow is WRP effluent. As a result, flows in these channels would also be affected if treated effluent being discharged by WRPs into the channel is reduced as the volume of reused treated effluent increases. To explore this, we assessed the impacts of implementing watershed-scale BMP programs to manage the 85th percentile storm and removing additional WRP flow from the LAR for reuse in the watershed. Three percentages (0%, 50%, 100%) of annual WRP flow (2004-2013) contribution reductions were assessed to understand how the annual minimum flow would respond if some portion (or all) of WRP flow was stored or diverted for supply at Wardlow Gage and Glendale Narrows. Results from this analysis are summarized here, please see our previous report on the LAR for additional detail on methodology and analyses.[74]

Flows in the LAR have changed greatly over time, and have been influenced by the discharge of effluent from three WRPs, wet and dry weather runoff from its urbanized watershed, and upwelling of groundwater. Effluent discharge into the LAR increased in-channel flows every time a new WRP came online. For example, 7Q10 flows in the LAR (using annual minimum flows) increased from 42 cfs for the period of record from 1956 to 1985 to 157 cfs for the time period between 1986 (when DCTWRP came online) and 2014. WRP effluent is now the largest component of the current volumes; flows in WY 2012-2013 from DCTWRP, LAGWRP, and Burbank Water Reclamation Plant (BWRP) combined were approximately 53 MGD. Historical records indicate rising groundwater has contributed 1 to 7 MGD in flows since 1928 and was approximately 1.6 MGD in WY 2012-2013 (Table 3.11).[75] The final flow component is composed of dry weather runoff and other urban sources; this volume has ranged from 1 to 11 MGD and was estimated to be approximately 10 MGD in WY 2012-2013.[76]

Source	Date	Flow[77]		
		CFS	MGD	AFY
WRPs	WY 2012-2013	82	53	56,300
Urban Runoff Etc.	WY 2012-2013	15	10	11,000
Rising Groundwater	WY 2012-2013	2.3	1.6	1,700

Table 3.11. Snapshot of flows into LAR from water year 2012-2013

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[74] Mika, K. et al., LA Sustainable Water Project: LA River Watershed (2017). Available at: http://escholarship.org/uc/item/42m433ps

[75] TNC LA River Study 2016 p. 3-30

[76] TNC LA River Study 2016 p. 3-30

[77] TNC LA River Study 2016 p. 3-30, 3-31

Multiple drivers, however, are changing or have the potential to change these patterns of flow in the LAR. Complying with water quality requirements will result in watershed scale implementation of BMPs to manage stormwater. These BMPs will likely include a combination of infiltration-based and treat-and-release systems, which will impact the runoff volumes that flow into the LAR channel. Modeled average annual flows at Wardlow Gage dropped from 237,000 AF to between 63,000 and 111,000 AF (a reduction of 53 to 71%) with the implementation of various BMP scenarios. We also observed a reduction in modeled seasonal flows, from 97,000 to 136,000 AFY (baseline) to between 63,000 and 72,000 AFY (with BMPs, Table 3.12). Implementing these BMPs will also impact the runoff ratio as less water runs off the watershed as a result. For example, the runoff ratio of modeled scenarios in our analysis was roughly equivalent to the runoff ratio in the 1950s and 60s when far less of the watershed was paved.[78]

Season	Modeled Baseline Flows (2003-2014)			With BMPs (2003-2014)		
	CFS	MGD	AFY	CFS	MGD	AFY
Fall	134	87	97,000	91	59	66,000
Winter	188	122	136,000	100	65	72,000
Spring	178	115	129,000	89	58	64,000
Summer	142	92	103,000	87	56	63,000

Table 3.12. Modeled median seasonal flows for Wardlow Gage with and without BMPs.

In addition, the recent focus on increasing local water supplies makes it likely that a higher percentage of the treated effluent currently being discharged to the LAR will be diverted to reuse. The annual minimum flows at Wardlow Gage and the Glendale Narrows did go to zero in our modeled analysis when treated effluent flows were fully diverted to reuse (no effluent was discharged to the LAR) and stormwater BMPs were implemented across the watershed to manage the 85th percentile storm volume (Table 3.13). Therefore, there is the theoretical potential for flows in the LAR to go to zero through implementing these programs. Additional research is needed to better characterize the potential impacts on low flows.

Annual Minimum Flows	Glendale Narrows			Wardlow Gage		
	CFS	MGD	AFY	CFS	MGD	AFY
Baseline Flows	60-80	38-52	43,000-58,000	82-118	53-76	59,000-85,000
BMPs + 100% WRP	38-43	25-28	28,000-31,000	45-60	29-39	33,000-43,000
BMPs + 50% WRP	18-23	12-15	13,000-17,000	20-30	13-19	16,000-23,000
BMPs + 0% WRP	0	0	0	0		0

Table 3.13. Annual minimum flows at Glendale Narrows and Wardlow Gage with increased reuse of effluent.

The City has committed to maintaining the Sepulveda Basin lakes, which flow through to the LAR. In 2015, an annual average of 27 MGD (30,000 AFY) was discharged from DCTWRP.

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[78] See Mika et al., Sustainable LA Water Project LA River Watershed report for full discussion of flow study, including runoff ratio analysis. https://escholarship.org/uc/item/42m433ps

Additional work should be done to assess whether continuing to discharge an annual average of 27 MGD (30,000 AFY) of effluent is necessary or desirable to support the desired uses and needs of the LAR year-round. With the current volumes of effluent discharge into the LAR, we found low flows in the LAR to be approximately 100 cfs (2003 to 2014 data) at Wardlow Gage. These flow levels, however, are far higher than what was occurring at Wardlow Gage in the early to mid-20th century. Historical low flows (1956-2013) were noted to be an order of magnitude lower, approximately 10 cfs (~10th percentile). Elsewhere in the LAR, TNC found contemporary dry weather flows to be approximately 107 cfs (median) at Station F57C in the LAR (above Arroyo Seco).[79] In addition, TNC found median historical flows to be less than 13 cfs (pre-1966, median, above the Arroyo Seco).[80] If watershed stakeholders want the LAR to better mimic the historic flow regime, then average minimum flows would have to be significantly reduced.

TNC's LAR study also describes a variety of environmental benefits that could result from lower, slower flows. Examples of benefits identified by TNC include: this flow is more consistent with historical ecological conditions such as ephemeral surface flows and intermittent sedimentation; lower flows may foster increased diversity in in-channel vegetation as slower moving waters could increase the variety of available habitats; and this habitat diversity may in turn favor native animals while also allowing urban tolerant generalists to persist.[81] Lower flow requirements in the LAR could also free up additional volumes of wastewater for advanced treatment and reuse in the watershed. However, lower flows during the summer would also greatly impact recreational uses in the LAR, especially kayaking and wading or bathing. Therefore, the impact on water supply and habitat in the LAR system of sustaining lower flows (e.g., in the 10-13 cfs range) in the LAR that more closely reflect historical flows needs to be assessed.

These analyses show that different watershed management approaches will result in different flows available to support the various needs and uses along the LAR. With this in mind, it is critical to accurately define the minimum required flows in the LAR. With the current volumes of effluent discharged into the LAR, we found recent low flows in the LAR to be approximately 100 cfs (2003 to 2014 data) at Wardlow Gage (based on analysis of daily average flows). Historical low flows (1956-2013), however, were noted to be an order of magnitude lower, approximately 10 cfs (~10th percentile). The ramifications to aquatic life and public recreation from these changed flows are substantial. A wide variety of research efforts have been and are occurring in the region to better understand the current state of the LAR (existing habitats, flows, etc.) and identify opportunities to redevelop and revitalize this important, regional, natural resource. A comprehensive study on the flows needed to create and maintain a healthy riparian ecosystem (and to define what that healthy ecosystem looks like in the highly urbanized LAR), while still supporting the LAR's recreational beneficial uses and augmenting our local water supplies, is the critical next step in designing a future vision for the LAR.

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[79] TNC LA River report, Figure 3-26, p.3-30
[80] TNC LA River Study 2016 p.4-46
[81] TNC LA River Study 2016 p. 5-23

E. Post-Modeling Analyses

a. Low Impact Development

As described earlier, modeling areas only included ‘urban public’ land use types for BMP implementation. Sufficient BMPs to manage the full 85th percentile storm volume were then placed on these land use types. However, ‘urban private’ land uses will also be important in attaining the region’s water quality and potential local water supply goals. One mechanism by which LID will become integrated on private land uses to a greater degree is through the implementation of the City of LA’s LID Ordinance, which became effective in May 2012. Under this LID ordinance, if private properties redevelop 500 ft^2 of impervious land or more, then they are required to capture the greater of the ¾-inch storm or the 85th percentile storm volume for that site.[82] The volume of stormwater managed through the implementation of this ordinance will affect the volume of water that must be managed on ‘urban public’ land uses. To better understand the impacts of this type of ordinance if it were to be implemented across the entire watershed, we conducted a post-modeling analysis to quantify the potential impact of ‘urban private’ land use changes on watershed-scale stormwater management requirements.

Our analysis assumed all redevelopment is greater than 500 ft^2 and the projected redevelopment rate was maintained throughout the analyzed periods (ranging from through 2021 to through 2035). Redevelopment rates used by the City in earlier research efforts (rates ranged from 15% to 34% for different land uses) were used to project the amount of stormwater that could be captured in three scenarios.[83] The first analysis considered LID implementation on private properties by 2021, 2028, and 2032 (the final metals TMDL compliance deadlines for the BC, LAR, and DC watersheds, respectively, Table 3.14).[84] The impacts of LID ordinance implementation were also assessed with a post-redevelopment year of 2035 to determine how much additional stormwater volume could be managed by the final goal date in the City’s pLAn.[85] The first two scenarios apply the redevelopment rates throughout the whole watershed. The third scenario repeats the second (a post-redevelopment year of 2035) but only applies the redevelopment rates to land within the actual City limits (Table 3.14).

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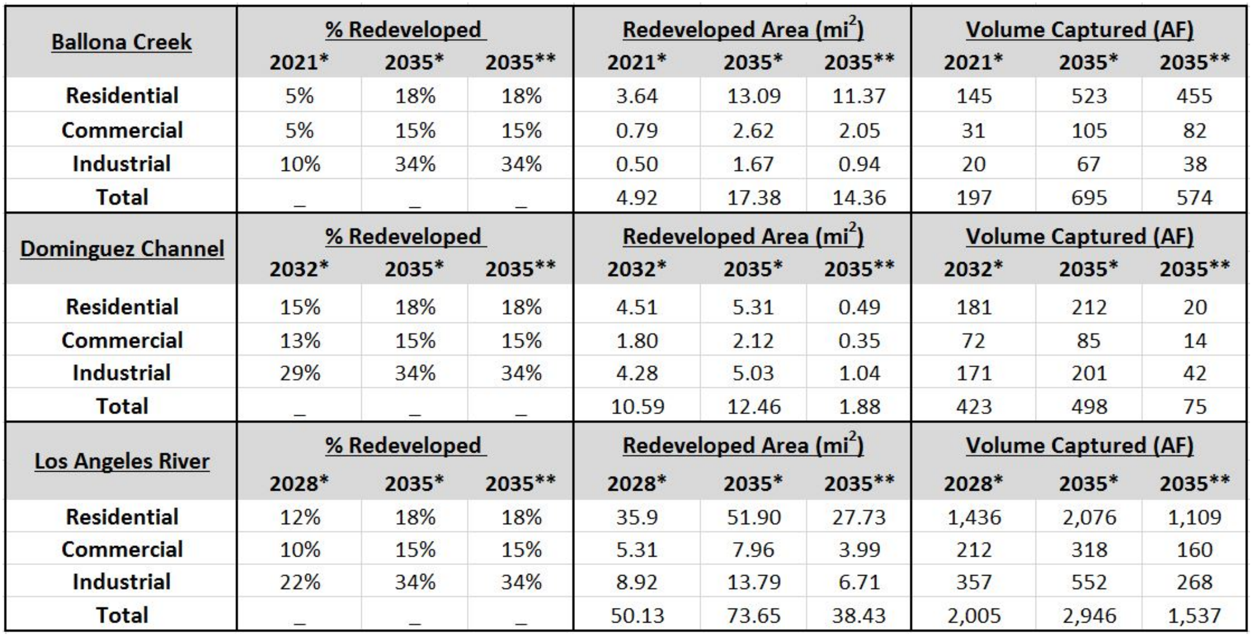
[82] Planning and Land Development Handbook for Low Impact Development (May 9, 2016) p. 15 http://www.lastormwater.org/wp-content/files_mf/lidmanualfinal.pdf

[83] Redevelopment rates - LADWP SCMP (page 67) and LASAN EWMPs

[84] City of Los Angeles Stormwater Program (LA Stormwater). 2012. Blog. Watersheds. LA River. City Marks Completion of First Northeast LA Stormwater Capture Facility. Accessed Online (1 January 2016): http://www.lastormwater.org/blog/2012/03/city-marks-completion-of-firstnortheast-la-stormwater-capture-facility/ . March 15.; Redevelopment rates - LADWP SCMP on page 67 and LASAN EWMPs

[85] https://www.lamayor.org/plan



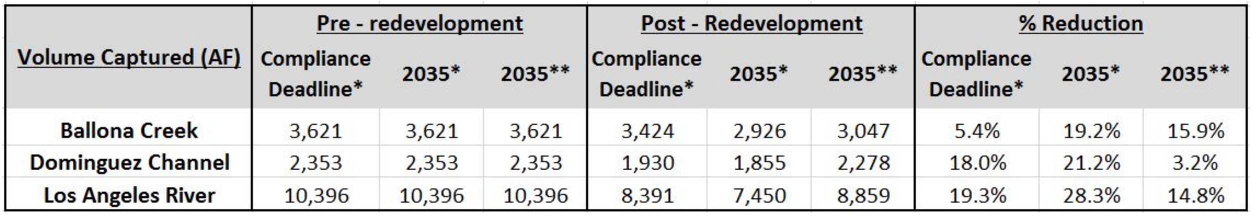
Ballona Creek	% Redeveloped			Redeveloped Area (mi^2)			Volume Captured (AF)		
	2021*	2035*	2035**	2021*	2035*	2035**	2021*	2035*	2035**
Residential	5%	18%	18%	3.64	13.09	11.37	145	523	455
Commercial	5%	15%	15%	0.79	2.62	2.05	31	105	82
Industrial	10%	34%	34%	0.50	1.67	0.94	20	67	38
Total	_	_	_	4.92	17.38	14.36	197	695	574
Dominguez Channel	**% Redeveloped**			**Redeveloped Area (mi^2)**			**Volume Captured (AF)**		
	2032*	2035*	2035**	2032*	2035*	2035**	2032*	2035*	2035**
Residential	15%	18%	18%	4.51	5.31	0.49	181	212	20
Commercial	13%	15%	15%	1.80	2.12	0.35	72	85	14
Industrial	29%	34%	34%	4.28	5.03	1.04	171	201	42
Total	_	_	_	10.59	12.46	1.88	423	498	75
Los Angeles River	**% Redeveloped**			**Redeveloped Area (mi^2)**			**Volume Captured (AF)**		
	2028*	2035*	2035**	2028*	2035*	2035**	2028*	2035*	2035**
Residential	12%	18%	18%	35.9	51.90	27.73	1,436	2,076	1,109
Commercial	10%	15%	15%	5.31	7.96	3.99	212	318	160
Industrial	22%	34%	34%	8.92	13.79	6.71	357	552	268
Total	_	_	_	50.13	73.65	38.43	2,005	2,946	1,537

Table 3.14: Projection of private use redevelopment rates and the resulting changes in required storm capture. The redeveloped year represent the compliance deadlines for each watershed. *Redevelopment rate applied to the whole watershed. **Redevelopment rate applied to area only within the LA City boundaries.

Generally, the BMP capacity required to manage the 85th percentile storm volume and, thus, the number of BMPs required, decreases markedly as more private lands are redeveloped with LID practices (assuming a similar LID ordinance covered the entirety of each watershed). The smallest benefit from ‘urban private’ LID redevelopment is observed in BC, in part due to the fact that the 2021 compliance deadline is the soonest and thus offers the least amount of time for redevelopment to occur. The 85th percentile storm volume is only reduced by approximately 5% in the BC watershed as a result of LID implementation as compared to 18-19% in the LAR and DC watersheds (Table 3.15).

Each land use type has its own redevelopment rate and the composition of land uses varies among the watersheds. As a result, the rate at which the LID ordinance is implemented in each watershed overall also varies. For example, since residential land uses are a large percentage of the BC watershed, redevelopment of residential land uses represents the majority of the stormwater managed as a result of the LID ordinance there. The DC watershed, however, is comprised of a large percentage of commercial and industrial land uses; as a result, the redevelopment of these land uses contributes the most to managing stormwater on ‘urban private’ land uses in the DC watershed. These differences point to the importance of tailoring programs to increase LID implementation to specific land use types depending on the dominant features, such as land use, of each watershed.

The volumes of stormwater that could be managed if a LID ordinance similar to that in the City of LA were established across the watersheds was even greater looking out to 2035. Implementation of a watershed-wide LID ordinance similar to that in the City of LA lead to the capture of approximately 695 AF in the BC watershed, 498 AF in the DC watershed, and 2,946 AF in the LAR watershed (Table 3.14). For example, managing 2,946 AF through LID installation on ‘urban private’ land uses represents managing 28% of the 85th percentile storm volume in the LAR watershed (Table 3.15).



Volume Captured (AF)	**Pre - redevelopment**			**Post - Redevelopment**			**% Reduction**		
	Compliance Deadline*	**2035***	**2035****	**Compliance Deadline***	**2035***	**2035****	**Compliance Deadline***	**2035***	**2035****
Ballona Creek	3,621	3,621	3,621	3,424	2,926	3,047	5.4%	19.2%	15.9%
Dominguez Channel	2,353	2,353	2,353	1,930	1,855	2,278	18.0%	21.2%	3.2%
Los Angeles River	10,396	10,396	10,396	8,391	7,450	8,859	19.3%	28.3%	14.8%

Table 3.15: Applying the total volume captured from Table 3.14 to the existing 85th percentile storm to estimate the 85th percentile storm needed to be captured by the City post-redevelopment. *Redevelopment rate applied to the whole watershed. **Redevelopment rate applied to area only within the LA City boundaries.

We also evaluated the effect of the LID ordinance on the average annual pollutant loading and channel flow in post-modeling analyses. The area, percent impervious, and calibrated event mean concentrations (EMCs) for each land use, as well as the total depth of rain and volume of baseflow for WY 2002-2011, were used to determine an estimate of pollutant load and flow reduction.[86] Baseline pollutant AAL and total flow, the estimated AAL, and the total flow due to the projected private land stormwater capture were calculated (Table 3.16). The flow and load reductions resulting from the expected redevelopment gives an estimate of how much the baseline flow and pollutant loads will decrease due to the LID ordinance requirements. Lead was not included in this analysis as lead exceedances were not present in all watersheds.

In addition to reducing the volume of stormwater that BMPs placed on public land would need to capture, a watershed-wide LID ordinance would also contribute to reducing average annual metals loads to the waterbodies, thereby increasing the likelihood of water quality standards attainment in the receiving waters. For example, reductions in the average annual copper loads in the BC and DC watersheds are approximately 17% by 2035; the average annual copper load reduction in the LAR watershed is 8.7% (Table 3.16).

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[86] Further description on how the values seen in Table 3.16 were calculated are in the DC/ML Report p. 50

Ballona Creek	Pre - redevelopment			Post - Redevelopment			% Reduction		
	2021*	2035*	2035**	2021*	2035*	2035**	2021*	2035*	2035**
Zn AAL	22,418	22,418	22,418	21,271	18,593	19,489	5.1%	17.1%	13.1%
Cu AAL	4,164	4,164	4,164	3,948	3,445	3,603	5.2%	17.3%	13.5%
AAFV (Ft^3)	2.07 E09	2.07 E09	2.07 E09	1.97 E09	1.73 E09	1.79 E09	4.8%	16.4%	13.5%
Dominguez Channel	Pre - redevelopment			Post - Redevelopment			% Reduction		
	2032*	2035*	2035**	2032*	2035*	2035**	2032*	2035*	2035**
Zn AAL	15,218	15,218	15,218	12,461	11,974	14,628	18.1%	21.3%	3.9%
Cu AAL	3,200	3,200	3,200	2,721	2,637	3,111	15.0%	17.6%	2.8%
AAFV (Ft^3)	1.01 E09	1.01 E09	1.01 E09	8.62 E08	8.35 E08	9.86 E08	14.7%	17.3%	2.4%
Los Angeles River	Pre - redevelopment			Post - Redevelopment			% Reduction		
	2028*	2035*	2035**	2028*	2035*	2035**	2028*	2035*	2035**
Zn AAL	206,170	206,170	206,170	185,436	175,767	189,003	10.1%	14.7%	8.3%
Cu AAL	33,826	33,826	33,826	31,484	30,869	31,282	6.9%	8.7%	7.5%
AAFV (Ft^3)	1.24 E10	1.24 E10	1.24 E10	1.07 E10	1.05 E10	1.15 E10	13.7%	15.3%	6.5%

Table 3.16: Projecting future baseline pollutant loads and flow considering only BMP implementation due to the LID ordinance. *Redevelopment rate applied to the whole watershed. **Redevelopment rate applied to area only within the LA City boundaries.

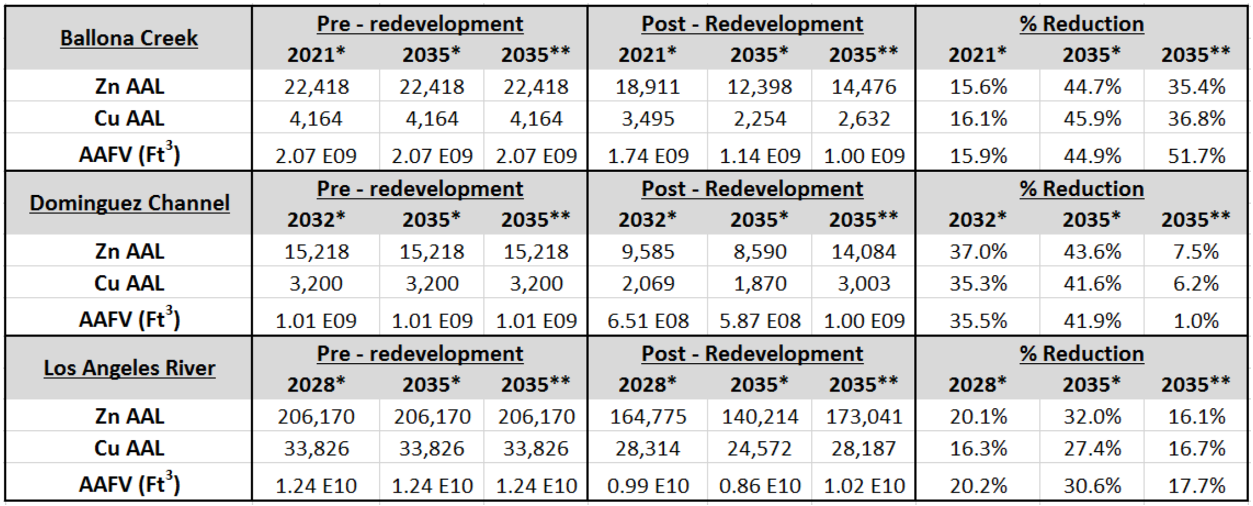
Increasing the redevelopment rates (which could occur if, for example, this ordinance was expanded to include retrofit upon resale requirements as well) greatly increased the volumes captured and pollutant load reductions. For example, assuming a 50% redevelopment rate for all land uses across the watershed, LID implementation managed almost 5,000 AF, or about 47% of the 85th percentile storm volume in the LAR watershed (Tables 3.17, 3.18). LID implementation was also calculated to result in reductions in average annual copper loads of approximately 46%, 42%, and 27% in the BC, DC, and LAR watersheds, respectively, by 2035 (Table 3.19).

Total Private Land	% Redeveloped			Redeveloped Area (mi^2)			Volume Captured (AF)		
	Compliance Deadline*	2035*	2035**	Compliance Deadline*	2035*	2035**	Compliance Deadline*	2035*	2035**
Ballona Creek	18%	50%	50%	9.64	27.55	22.86	386	1102	914
Dominguez Channel	43%	50%	50%	14.66	17.25	2.55	586	690	102
Los Angeles River	33%	50%	50%	81.29	123.17	58.59	3251	4926	2343

Table 3.17: Projection of private use redevelopment rates (50% redevelopment rate for all landuses) and resulting changes in required storm capture. The redeveloped year represent the compliance deadlines for each watershed. *Redevelopment rate applied to whole watershed. **Redevelopment rate applied to area only within LA City boundaries.

Volume Captured (AF)	Pre - redevelopment			Post - Redevelopment			% Reduction		
	Compliance Deadline*	2035*	2035**	Compliance Deadline*	2035*	2035**	Compliance Deadline*	2035*	2035**
Ballona Creek	3,621	3,621	3,621	3,235	2,519	2,707	10.6%	30.4%	25.3%
Dominguez Channel	2,353	2,353	2,353	1,767	1,663	2,251	24.9%	29.3%	4.3%
Los Angeles River	10,396	10,396	10,396	7,145	5,470	8,053	31.3%	47.4%	22.5%

Table 3.18: Applying the total volume captured from Table 3.11 to the existing 85th percentile storm to estimate the 85th percentile storm needed to be captured by the City post-redevelopment. *Redevelopment rate applied to the whole watershed. **Redevelopment rate applied to area only within the LA City boundaries.



Ballona Creek	Pre - redevelopment			Post - Redevelopment			% Reduction		
	2021*	2035*	2035**	2021*	2035*	2035**	2021*	2035*	2035**
Zn AAL	22,418	22,418	22,418	18,911	12,398	14,476	15.6%	44.7%	35.4%
Cu AAL	4,164	4,164	4,164	3,495	2,254	2,632	16.1%	45.9%	36.8%
AAFV (Ft^3)	2.07 E09	2.07 E09	2.07 E09	1.74 E09	1.14 E09	1.00 E09	15.9%	44.9%	51.7%
Dominguez Channel	Pre - redevelopment			Post - Redevelopment			% Reduction		
	2032*	2035*	2035**	2032*	2035*	2035**	2032*	2035*	2035**
Zn AAL	15,218	15,218	15,218	9,585	8,590	14,084	37.0%	43.6%	7.5%
Cu AAL	3,200	3,200	3,200	2,069	1,870	3,003	35.3%	41.6%	6.2%
AAFV (Ft^3)	1.01 E09	1.01 E09	1.01 E09	6.51 E08	5.87 E08	1.00 E09	35.5%	41.9%	1.0%
Los Angeles River	Pre - redevelopment			Post - Redevelopment			% Reduction		
	2028*	2035*	2035**	2028*	2035*	2035**	2028*	2035*	2035**
Zn AAL	206,170	206,170	206,170	164,775	140,214	173,041	20.1%	32.0%	16.1%
Cu AAL	33,826	33,826	33,826	28,314	24,572	28,187	16.3%	27.4%	16.7%
AAFV (Ft^3)	1.24 E10	1.24 E10	1.24 E10	0.99 E10	0.86 E10	1.02 E10	20.2%	30.6%	17.7%

Table 3.19: Projecting future baseline pollutant loads and flow considering only BMP implementation due to the LID ordinance. *Redevelopment rate applied to the whole watershed. **Redevelopment rate applied to area only within the LA City boundaries.

These analyses demonstrate the importance of including all land-use types and programs to increase the capture and reuse of stormwater as they can provide significant additional benefits. These benefits could be greatly magnified by extending the reach of an LID ordinance and increasing the voluntary implementation of these practices. For example, a LID retrofit upon sale ordinance that requires stormwater capture or infiltration for all parcels should be developed. The proliferation of LID projects can also be accelerated through the use of non-governmental organizations (NGOs) and other partners working with the City. NGOs in particular can help on community engagement, implementing LID projects on private property, schools, parks, alleys, and in parkways, and LID BMP maintenance. The combination of watershed-scale BMP programs in concert with multiple efforts to reduce sources to the watershed and ramp up BMP implementation on private properties will result in greatly improved water quality as well as provide additional local water supply potential.

This also points to the critical need to design any centralized stormwater capture projects taking into consideration the potential impacts of any planned or existing distributed LID programs; a reduction in the volume of available stormwater by almost 1/3 (as calculated for the LAR watershed) could have significant impacts on the flow volumes being routed to centralized systems within the same watershed and, thus, on the needed size of those systems. In addition, pollutant load reductions from widespread LID implementation over a decade or two can greatly increase the likelihood that water quality standards will be met in LA watershed receiving waters. This could also have implications for potential water supply as distributed stormwater capture could also decrease the runoff volumes available for diversion to WRPs for treatment and reuse.

b. Infiltration Trenches versus Dry Wells

Although ITs were used in our modeling, another commonly-used infiltration BMP is a dry well, which can provide similar capture capacity with a smaller areal footprint. Thus, an additional post-modeling analysis was done to assess the quantity of dry wells and/or ITs that would be required to manage the 85th percentile storm in these watersheds as well as to identify the overall footprint required to install the number of BMPs needed. To quantify the efficacy of dry wells in the Los Angeles area, an analysis was performed using equations in the County of Los Angeles County Department of Public Works (LACDPW) LID Standards Manual.[87]

Several sizes of potential ITs were defined and the number needed to retain the 85th percentile storm in the DC watershed was calculated; trenches were defined to have a depth of 8 feet (Table 3.20). Based on the number of ITs needed, the total surface area required to capture the 85th percentile was calculated. The DC watershed had the smallest storm volume of 2,353 AF (Table 3.21) and thus the lowest total IT surface area to capture this volume (approximately 68 million ft^2 or 1,561 ac).[88] The number of ITs required for DC ranged between 21,000 and 340,000, depending on the dimensions of each IT. For example, to shrink the needed number to 21,000 ITs, each IT needed to be 8 ft deep, 80 ft long, and 48 ft wide, which is too large for available land spaces in most urban areas. At a more readily implementable scale, 8' x 80' x 10', approximately 85,000 ITs would be required to infiltrate the 85th percentile storm in the DC watershed (Table 3.20).

Size 1		Size 2		Size 3		Size 4		Size 5	
h (ft)	8	h (ft)	8	h (ft)	8	h (ft)	8	h (ft)	8
l (ft)	20	l (ft)	40	l (ft)	80	l (ft)	40	l (ft)	80
w (ft)	10	w (ft)	20	w (ft)	40	w (ft)	10	w (ft)	10
SA$_1$ (ft^2)	200	SA$_2$ (ft^2)	800	SA$_3$ (ft^2)	3200	SA$_4$ (ft^2)	400	SA$_5$ (ft^2)	800
# Required	341,945	# Required	85,486	# Required	21,372	# Required	170,973	# Required	85,486

Table 3.20: IT Count for Basin Sizes for Dominguez Channel; h=height, l=length, w=width, SA=surface area

	85th Percentile Storm (acre-feet)	Infiltration Surface Area Required (acres)	# of 10 ft by 20 ft Infiltration Trenches Required	# of 10 ft by 80 ft Infiltration Trenches Required
Ballona Creek	3,621	2,414	525,768	131,374
Dominguez Channel	2,353	1,570	341,945	85,486
Los Angeles River	10,396	6,931	1,509,496	377,374

Table 3.21: Number of mid-sized IT required to capture 85th percentile storm volumes.

At 8' x 80' x 10', approximately 131,000 ITs in BC, approximately 85,000 ITs in DC, and approximately 377,000 ITs in LAR were required to infiltrate the 85th percentile storm (Table

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[87] dated Feb 2014 (Standards Manual).; The analysis used volume and surface area requirements to determine the number of IT or dry wells required to capture the 85th percentile storms for the BC, DC, and LAR watersheds. Analysis assumed that 100% of the storm volume was captured at an infiltration rate of 1 inch/hour (in/hr) for both stormwater capture technologies being analyzed. As a site in the LA area had a 1 in/hr infiltration rate the BMP database, 1 in/hr per hour was selected as a generous rate. The Standards Manual required at least 0.3 in/hr infiltration of the soils below; calculations in the Standards Manual also required designs to drain within 96 hrs.

[88] Divide total square footage (68*10^6) by the SA in the table to get the # required.

3.21). Given the compliance deadlines in BC (2021), DC (2032), and LAR (2028), approximately 26,000 ITs in BC, 5,300 ITs in DC, and 31,000 ITs in LAR would need to be installed annually between 2016 and the compliance deadlines in each watershed. This implementation rate is infeasible with current funding and staffing levels and points to the need for multiple, concurrent approaches to meet water quality standards. Multiple efforts are occurring in the region to address water quality needs; better collaboration among these plans and programs could facilitate building projects that provide more benefits for a lower cost, especially where projects meet the needs of multiple agencies and cost-sharing is possible.

In addition to requiring very rapid and large-scale implementation, ITs require relatively large pieces of land for their installation. Dry wells, however, perform the same function but have a much smaller footprint per BMP and thus can be more readily located throughout urbanized watersheds. The potential to implement dry wells across these watersheds was also assessed; dry wells were defined to be 4 to 8 ft in diameter and as deep as 20 ft (Table 3.22).[89] With these dimensions, approximately 500,000 (at 6 ft diameter and 20 ft deep) to 4.4 million dry wells (at 4 ft diameter and 5 ft deep, Table 3.22) were needed to meet infiltration requirements in the DC watershed. A 6 foot diameter dry well with a depth of 10 ft or 20 ft was chosen for the analysis in each watershed (Table 3.23).

Size 1		Size 2		Size 3		Size 4	
D (ft)	4	D (ft)	6	D (ft)	6	D (ft)	8
h (ft)	5.3	h (ft)	10.0	h (ft)	20.0	h (ft)	10.0
SA (ft^2)	12.6	SA (ft^2)	28.3	SA (ft^2)	28.3	SA (ft^2)	50.2
Total A	54,955,515	Total A	29,309,590	Total A	14,592,600	Total A	29,309,590
# Required	4,375,439	# Required	1,037,140	# Required	516,369	# Required	583,392

Table 3.22: Dry Well Count for Varying Precast Dry Wells for Dominguez Channel*
* D=diameter, h=height, SA=unit surface area, V_T=total volume, Total A= total surface area req'd in watershed

	85th Percentile Storm (AF)	Infiltration Surface Area Required (acres)	# of 6 ft Diameter & 10 ft Deep Dry Wells Required	Infiltration Surface Area Required (acres)	# of 6 ft Diameter & 20 ft Deep Dry Wells Required
Ballona Creek	3,621	1,035	2,290,077	517	797,137
Dominguez Channel	2,355	673	1,037,140	335	516,369
Los Angeles River	10,396	2,970	4,578,392	1,478	2,279,478

Table 3.23: Number of mid-sized dry wells required to capture 85th percentile storm volumes

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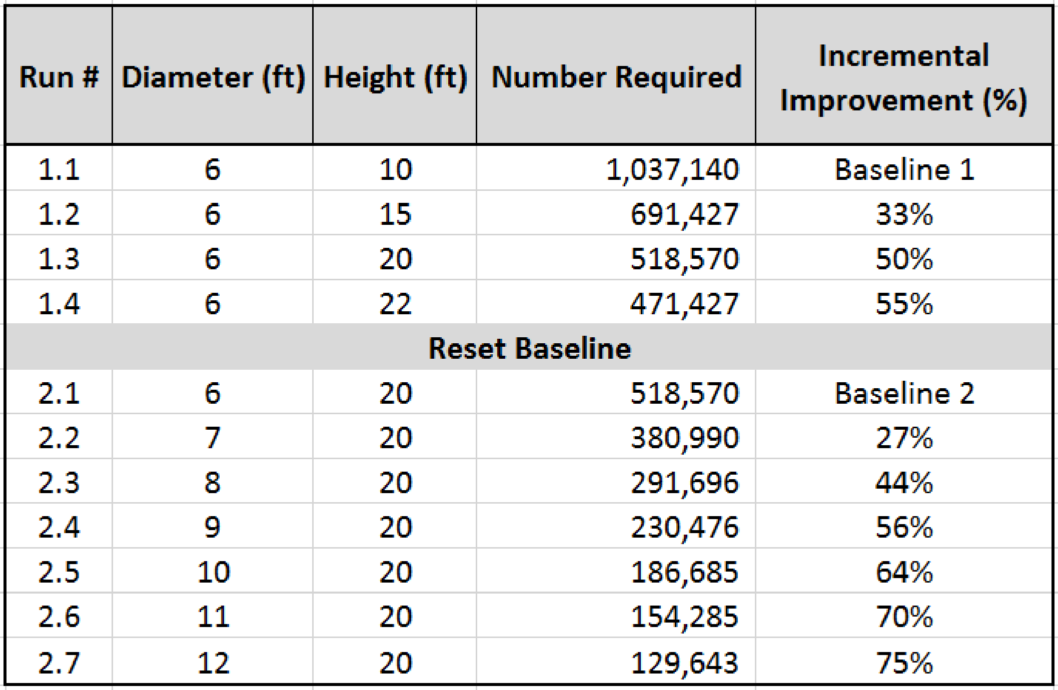
[89] The initial sizing analysis for dry wells used dimensions from 3 different precast dry wells, as found for sale on the Grimm Modern Building Material Co. Inc.'s website. (http://www.grimmbldg.com/precast_catalog.php). Also, using the method outlined in the Standards Manual for dry wells applied to precast structures that may or may not be filled with media like gravel results in a conservative estimate as calculations assume flow impedance from media.

Approximately 8 million 6 ft diameter by 10 ft deep dry wells (with a total footprint of 4,068 acres) would be required to capture the 85th percentile storm in all three watersheds; increasing the depth to 20 ft resulted in approximately halving the required number of dry wells to 3.6 million with a surface area of 2,330 acres (Table 3.23). While smaller in footprint, the quantity of dry wells also requires a rate of installation that is infeasible with current funding and staffing levels, and so must only form part of the solution. However, increasing the depth and diameter of dry wells can also reduce the number of dry wells required.

Therefore, an additional sizing analysis was performed for dry wells to compare the incremental changes associated with increased diameters and increased depths of dry wells using the DC storm volume. Runs 1.1 to 1.4 held the surface area of the dry well constant while varying the depth (Table 3.24). Using the Standards Manual, the maximum height was limited to approximately 22 feet. Increasing the depth of the well from 10 ft to 22 ft resulted in a 55% reduction in the number of dry wells required, from approximately 1 million to about 470,000 (Table 3.24). In areas of greater depth to groundwater and where there is no risk of spreading existing contamination, however, even deeper dry wells should be explored as an option to potentially decrease the number of dry wells further and contribute to groundwater recharge.



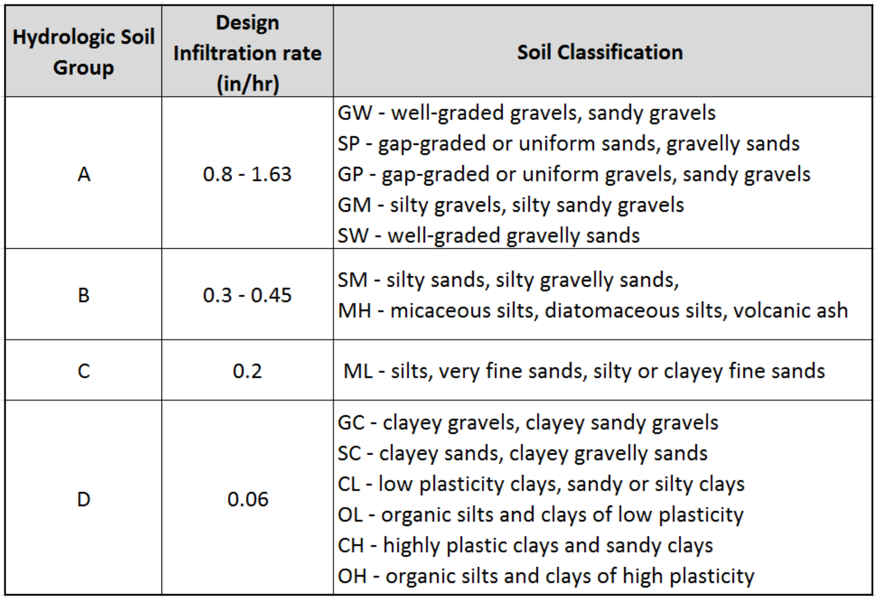
Run #	Diameter (ft)	Height (ft)	Number Required	Incremental Improvement (%)
1.1	6	10	1,037,140	Baseline 1
1.2	6	15	691,427	33%
1.3	6	20	518,570	50%
1.4	6	22	471,427	55%
Reset Baseline				
2.1	6	20	518,570	Baseline 2
2.2	7	20	380,990	27%
2.3	8	20	291,696	44%
2.4	9	20	230,476	56%
2.5	10	20	186,685	64%
2.6	11	20	154,285	70%
2.7	12	20	129,643	75%

Table 3.24: Incremental Changes of Dry Well Count for the Dominguez Channel with Varied Height and Diameter

The impacts of increasing the diameter of the dry wells were also assessed using a depth of 20 ft since the maximum depth of 22 ft only resulted in a 5% improvement over 20 ft. Dry wells also need to be recessed approximately 1 ft below ground surface. Assuming that at the site selected a depth of 20 feet would be sufficiently protective of groundwater, Runs 2.1 to 2.7 incrementally varied the diameter of the dry well (Table 3.24). The number of dry wells required was substantially reduced with each foot of diameter added; going from a 6 ft to 12 ft diameter resulted in a

75% reduction in the number of dry wells required, from 518,570 to 129,643. Therefore, the installation of wider dry wells should be assessed in areas with the potential to install larger dry wells, especially if the presence of a shallow groundwater table prohibits the installation of deeper dry wells.

As a result, infiltration rates become more important given that the surface area at the bottom of the dry well can govern its efficiency. In the modeled dry well, it was assumed that stormwater flowed through gravel in the dry well with a design infiltration rate of 1 in/hr. The rate of 1 in/hr would be limited by the infiltration rate of the soils below the installed dry well. If soil infiltration rates were less than 1 in/hr, the stormwater in the dry well would back up and thus the effective infiltration rate of the dry well would be the same as the native soil below it. Looking at the design infiltration rates in Table 3.25, the majority of soil types fall into hydrologic soil groups that have rates slower than 1 in/hr. Since the City has a patchwork of diverse soil types, it is likely that the receiving soil would be the limiting factor. Site-specific analyses should be conducted at each site being considered to identify limiting factors and thus the most appropriate size and shape of infiltration BMP to achieve maximum benefits for that site's footprint and geology.



Hydrologic Soil Group	Design Infiltration rate (in/hr)	Soil Classification
A	0.8 - 1.63	GW - well-graded gravels, sandy gravels SP - gap-graded or uniform sands, gravelly sands GP - gap-graded or uniform gravels, sandy gravels GM - silty gravels, silty sandy gravels SW - well-graded gravelly sands
B	0.3 - 0.45	SM - silty sands, silty gravelly sands, MH - micaceous silts, diatomaceous silts, volcanic ash
C	0.2	ML - silts, very fine sands, silty or clayey fine sands
D	0.06	GC - clayey gravels, clayey sandy gravels SC - clayey sands, clayey gravelly sands CL - low plasticity clays, sandy or silty clays OL - organic silts and clays of low plasticity CH - highly plastic clays and sandy clays OH - organic silts and clays of high plasticity

Table 3.25: Different Design Infiltration Rates for Different Soil Types

As described above, dry wells require less infiltration surface area than ITs but require more individual installations (Tables 3.21, 3.23). Dry wells can collect water from rooftops in backyards or be installed on public lands. In some cases, pretreatment such as a charcoal filter or other media may be required to address water quality concerns. In the presented analysis, all of the stormwater was routed through dry wells. When routing all stormwater through dry wells that are sensitive to infiltration rates, water quality becomes more important, especially if organics, debris, and particulates clog or impede flow through the media. For dry wells to collect all stormwater on a large scale, additional research into and extensive monitoring of dry wells would be required to determine whether some level of pretreatment (filter media or a settling basin) was necessary to address water quality in the influent water or prevent excessive maintenance needs (e.g. frequent clogging).

Dry wells present a greater opportunity to increase potential local water supply through stormwater recharge as their greater depth may also include greater connectivity to groundwater basins, but present a greater risk for groundwater contamination for the same reason. As described in the LAR report, dry wells are regulated through the EPA's Underground Injection Control program in some parts of California.[90] To assess the full potential of increasing the use of dry wells in the LA region, additional research questions should be answered. Some examples include: where are the best locations to install dry wells? Are dry wells best suited to be installed in areas where excavation is easy and in the absence of other utilities? Is retrofitting storm sewers to add dry wells feasible or are construction and refurbishment costs too high? Are dry wells best sited in areas in which only landscaping must be excavated and replaced? What would the installation costs and maintenance needs of a dry well incentive program for landowners be at the scale required? A particular challenge lies in the fact that, unlike other conservation efforts and rebates, landowners would not see any savings in their water bill and thus it may be harder to garner interest. How does a dry well program compare to an IT program of, for example, installing strips of IT along lot borders throughout the City? Any such program would need tailoring based on depth to groundwater and soil characteristics to maximize the benefits of dry wells and protect water quality.

F. Improving Model Predictions

Given the important role that stormwater modeling is now playing in mapping pathways to obtain water quality compliance in southern California, there are multiple additional components that must be incorporated into these models to improve their predictions to reflect not only current, but also potential future weather conditions. The severe damage of the emergency spillway at the Oroville Dam in February 2017 provided a clear demonstration of the need to include future weather conditions in these planning efforts to ensure expected challenges can be met, rather than solely planning on meeting historical conditions.

Various climate modeling studies project increasing extreme events, including increasing precipitation intensity and temperature, as well as the frequency and severity of floods.[91,92] Effective planning and management of green infrastructure under changing climate conditions requires robust estimates of future flood risks.[93] Computerized tools for the development of Intensity-Duration-Frequency (IDF) curves under climate change are being developed.[94] The developed SWMM Climate Adjustment Tool (SWMM-CAT) allows climate change projections to be incorporated using location-specific adjustments derived from Global Climate Models (GCMs) of the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3) archive. Integration of statistical or dynamic climate projects from models developed specifically

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[90] Please see Mika et al., Sustainable LA Water Project LAR Report for more detail on drywells. Available at: https://escholarship.org/uc/item/42m433ps

[91] (IPCC 2013; US GCRP 2014)

[92] (IPCC, 2013)

[93] (Kopytkovskiy et al. 2014)

[94] (e.g., Srivastav et al. 2015)

for regions of interest can also be utilized as input to developed stormwater models to better quantify the impact of implemented BMPs on future flood risk.[95]

Further, ET values that reflect local complexities must be collected and incorporated into the modeling efforts to obtain a complete picture of the water balance. In urban areas, ET is one of the largest components of the water balance, but is extremely difficult to estimate leading to large uncertainties.[96] Flux towers and meteorological data allow for point estimates of ET, but spatial heterogeneity poses a difficult problem for upscaling; this has been the focus of numerous studies.[97] Given the high cost of weather stations, the creation of a network of stations with adequate coverage to accurately represent the heterogeneity of ET is highly unlikely. To address this issue, satellite remote sensing methods have been identified as one of the most efficient and economic approaches for ET estimation over large areas.[98] The main problem with applying remote sensing based ET methods over urban areas originates from the complexity and extreme variability of urban land cover type over short distances (<1m). Studies evaluating changes in ET due to urbanization have produced varying results.[99]

ET is highly dependent on land cover composition and available water, highlighting the need for more research. In addition, climate models predict increasing temperatures throughout much of Los Angeles by mid-century, which will result in increased ET values throughout the City.[100] While improving ET estimates is important for informing outdoor irrigation practices and predicting water demands, understanding how different compositions of land cover type impact ET rates is critical for water management and development planners. Proposed green infrastructure (to capture stormwater) or landscape change (i.e. from native to non-native plants) will alter urban water budgets depending on species composition and irrigation needs of the altered landscape. High spatial and temporal resolution ET is also critical for validation of hydrologic models used to predict stormwater behavior and capture.

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[95] Huang, HY. & Hall, A. (2016) A physically-based hybrid framework to estimate daily-mean surface fluxes over complex terrain, Climate Dynamics, 46: 3883. doi:10.1007/s00382-015-2810-zA

[96] Pataki, D.E., McCarthy, H.R., Litvak, E., Pincetl, S., 2011b. Transpiration of urban forests in the Los Angeles metropolitan area. Ecol. Appl. a Publ. Ecol. Soc. Am. 21, 661–677.; Nouri, H., Beecham, S., Kazemi, F., Hassanli, A.M., 2013. A review of ET measurement techniques for estimating the water requirements of urban landscape vegetation. Urban Water J. 10, 247–259. doi:10.1080/1573062X.2012.726360; Shields, C.A., Tague, C.L., 2012. Assessing the Role of Parameter and Input Uncertainty in Ecohydrologic Modeling: Implications for a Semi-arid and Urbanizing Coastal California Catchment. Ecosystems 15, 775–791. doi:10.1007/s10021-012-9545-z

[97] McCabe, M.F. and Wood, E.F., 2006. Scale Influences on the remote estimation of evapotranspiration using multiple satellite sensors. *Remote Sensing of Environment*, 105(4), 271-285.

[98] Mauser, W. and S. Schädlich, 1998: Modelling the spatial distribution of evapotranspiration on different scales using remote sensing data, Journal of Hydrology, Vol. 212–213, 250–267.

[99] Grimmond, C.S.B., T.R. Oke, and D.G. Steyn, 1986: Urban Water Balance: 1. A Model for Daily Totals, Water Resources Research, DOI: 10.1029/WR022i010p01397

[100] Hall, A. Climate Change in the LA Region. https://www.ioes.ucla.edu/project/climate-change-in-the-los-angeles-region/

More data must also be collected to accurately reflect BMP impacts in these models; this is true not only for newly developed and developing technologies, but also for commonly-used, well-established BMPs. Scientists and engineers have been developing alternative, innovative technologies to improve BMP treatment efficiencies and enhance performance of distributed (e.g., LID) and regional systems. Efforts are focused on improving reliability, reducing costs and addressing emerging contaminants of concern that traditional BMPs may not treat.

In an effort to improve pollutant control, emerging research is embedding engineered treatment pathways into natural systems to target runoff pollutants and improve water quality (e.g., open-water treatment cells[101]) and the BEST technology.[102] However, more work is needed on integration of new technologies and improved efficiencies into stormwater models. Current BMP parameterizations in most models are limited by available LID/BMP type (vegetation swale, dry ponds, wet ponds, etc.) and standard treatment parameters (decay coefficients or EMC values). Although these parameters can be adjusted to reflect improved BMP efficiencies, more work is needed on explicit parameterization of new media (i.e., biochar) and new treatment design (i.e., BEST) in operationally-used BMP models (SWMM, SUSTAIN, etc.).

As the implementation of integrated water management systems progresses, for example with the implementation of stormwater BMPs intended to improve water quality and increase stormwater capture, an increased capacity to gather, store, and share relevant data broadly will be critical to ensure implemented programs are generating expected benefits and to provide guidance on refining these programs over time to maximize the target benefits as well as minimize costs. There is a broad movement in academia and in government towards open data that may provide some options to follow for more broadly sharing data.

The data needed to analyze water systems across regions of complex jurisdiction such as Los Angeles cover a wide range of topics. Examples include increased monitoring of stormwater BMPs, both their internal pollutant removal efficiency and pollutant removal and their impact on the water quality of receiving water; more data on BMP construction and O&M costs; more flow data; increased data on the potential sources of pollutants to the watersheds (e.g., more accurate and up-to-date EMC data by more specific land uses and geographic areas); increased data on surface water and groundwater interaction in this region to better characterize the water supply benefits of stormwater capture projects; and a framework in which this evolving data set can be managed and shared both within the City and without.

More specifically, the current approaches to siting distributed and regional LID BMPs in the Los Angeles Region are limited by the lack of explicitly coupled surface-to-groundwater models

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[101] Jasper, J.T., M.T. Nguyen, Z.L. Jones, N.S. Ismail, D. L. Sedlak, J.O. Sharp, R.G. Luthy, A.J. Horne, and K.L. Nelson, 2013: Unit Process Wetlands for Removal of Trace Organic Contaminants and Pathogens from Municipal Wastewater Effluents, Environmental Engineering Science, 30 (8): 421-436.; Jasper JT, Jones ZL, Sharp JO, Sedlak DL. (2014) Biotransformation of trace organic contaminants in open-water unit process treatment wetlands. Environ Sci Technol. 48(9), 5136-44.

[102] Herzog, S.P., C.P. Higgins, and J.E. McCray, 2015. Engineered streambeds for induced hyporheic flow: Enhanced removal of nutrients, pathogens, and metals from urban streams. J. of Environ. Eng. In Press. BEST (Biohydrochemical Enhancement structures for Streamwater Treatment)

that can accurately predict the percentage of infiltrated water that will recharge regional aquifers from implemented BMPs. Currently, no such modeling framework exists in the LA basin. Development of physically-based, coupled surface water - ground water models that accurately represent stormwater capture and subsurface properties are critical for quantifying regional recharge and providing information to better optimize local water supplies.

Along with increasing data collection efforts, incorporating the above techniques – running models with both historical and future predicted weather scenarios, incorporating the highest quality ET data, and improving the ability of widely-used modeling tools to incorporate the efficiency of a wide variety of BMPs over time – will greatly improve our ability to predict the water quality impacts of various suites of BMPs under various climate change scenarios.

G. Increasing Capture and Reuse of Runoff

a. Potentially Available Volumes

The total volume of water available for capture and supply can be estimated through an analysis of the annual volumes [which include both dry weather (baseflow) and wet weather flows], after BMP implementation within the BC, DC, and LAR watersheds. The modeled baseline flows, without the implementation of any BMPs, are illustrated for reference. The particularly wet water year of 2005 and dry year of 2007 can be seen for all three watersheds (Table 3.26). This shows that without the implementation of BMPs a volume of up to 175,000 AF, 68,000 AF, and 800,000 AF can be captured during a wet year for BC, DC, and LAR respectively. Even during 2007, a much drier year, 40,000 AF, 10,000 AF, and 100,000 AF were available to be captured in the BC, DC, and LAR Watershed, respectively (Table 3.26). Further, these volumes are greater than the 85th percentile storm volumes that are captured for water quality purposes. Thus, additional opportunities should be explored to capture more stormwater to supplement local water supply.

Watershed	2005 Total Precipitation (in)	2007 Total Precipitation (in)	2005, very wet year (AF)	2007, very dry year (AF)	85th percentile storm (AF)
LAR	66.4[103]	2.3	800,000	100,000	10,396 (w/o forest); 16,342 (w/ forest)
DC	23.6	2.6	68,000	10,000	2,353
BC	26.8	3.0	175,000	40,000	3,621

Table 3.26. Annual average volumes available for capture in wet and dry years in LAR, DC, and BC watersheds.

We also looked at the impacts of the various watershed BMP scenarios described above (Section III.D.a) on flows in all three watersheds. In BC, the watershed-wide BMP Scenario 5, which only routed water from public land uses, left the most water in the channel for other uses, but also provided very little in the way of water quality benefits. Scenario 3 in the BC watershed routed

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[103] Actual inverse distance-weighted precipitation for each watershed in 2005 & 2007. LAR is higher because it includes the forested region, which has more rain per year than the urban areas. LADPW Stormwater Monitoring data.

85% of the watershed to the treat-and-release BMP, DPs, and thus left a higher volume of water in the channel than BC Watershed Scenario 2, which routed 85% of the watershed to the infiltration BMP, ITs (Figure 3.8). The implementation of Scenario 2 (DP+VS) in the LAR and DC watersheds left the highest volume of water for other uses out of all modeled BMP scenarios (Figures 3.9, 3.10). This again shows the importance of considering all aspects of water management in planning for stormwater management. In regions with good infiltration rates over groundwater basins that are utilized for water supply, installing more infiltration-type BMPs may make more sense even though less water would remain in the channel for other uses (assuming such flow reductions would not negatively impact aquatic life or other beneficial uses). For example, implementing treat-and-release BMPs could be the more appropriate choice where infiltration potential is low, a risk of introducing or spreading contamination in the groundwater basin exists, or habitat requiring some level of flow in the downstream channel that requires some level of flow is present. Opportunities to recapture that water further downstream could also be explored.

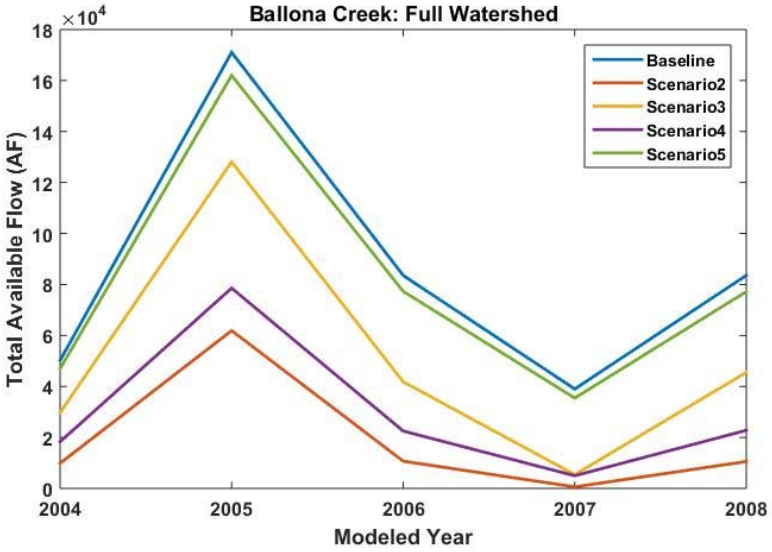

Figure 3.8: Ballona Creek annual flow volumes at the watershed outlet for the modeled time period (2004-2008) without BMPs compared to post-BMP implementation.

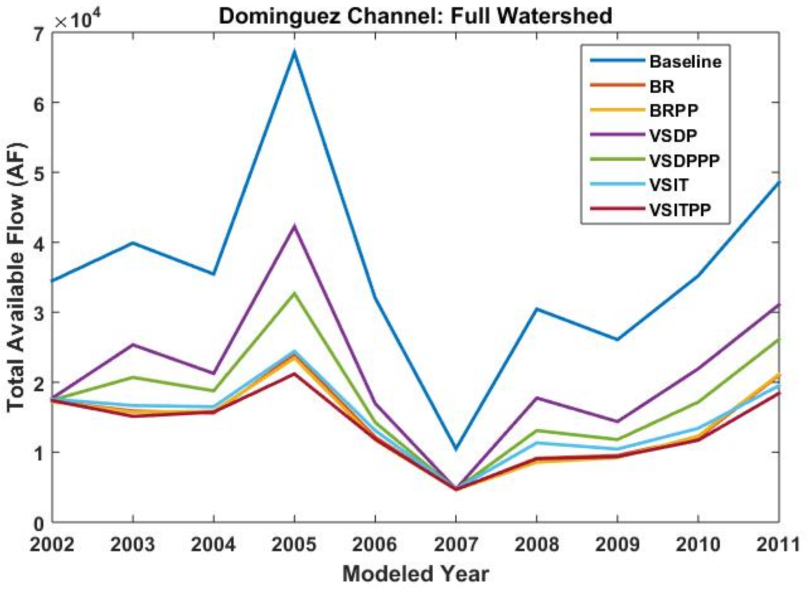

Figure 3.9: Dominguez Channel annual flow volumes at the outlet for the modeled time period (2002-2011) without BMPs compared to post-BMP implementation.

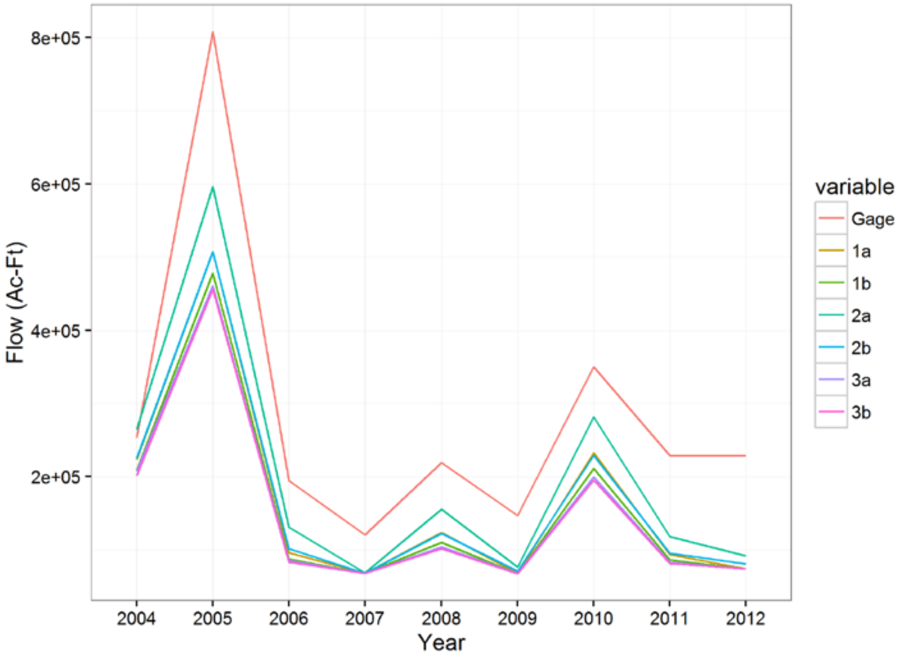

Figure 3.10: Los Angeles River annual flow volumes at Wardlow gage for the modeled time period (2004-2012) without BMPs compared to post-BMP implementation. It should be noted that Scenario 1a, 2a, and 3a in this figure are the same as Scenario 1, 2, and 3 in Tables 3.6 and 3.10.

b. Maximizing Storage and Use of Rainfall and Runoff

Substantial flows are available for capture and potential reuse in the four studied watersheds; opportunities to increase the use of runoff through increased diversion to WRPs and also through increased groundwater recharge are discussed in greater detail in following sections. Another opportunity to increase the use of runoff and precipitation is through increasing the on-site use of both for indoor and outdoor demands. Increasing the use of cisterns and rain barrels to capture and reuse rainwater on-site is an additional opportunity to increase the use of precipitation before it picks up pollutants, flows into the stormwater system, and is routed out to rivers and the sea. In 2012, CA's Rainwater Recapture Act made it legal to capture and use rainwater harvested from rooftops as it exempted this activity from the SWRCB's permitting authority over water appropriations. This change made it clear that residential users and public and private entities could capture water that could then offset some of their potable demand.[104] While on-site rainwater capture and reuse is an opportunity to increase the volumes of stormwater managed, how large of an opportunity this is, given the weather patterns in the Los Angeles region, requires further study.

One estimate of the potential to utilize rainwater capture was calculated in a 2015 National Academy of Science report assessing the potential increased use of graywater and stormwater. In this study, researchers modeled the impacts of implementing stormwater capture systems and estimated the resultant reduction of household potable water demand in six U.S. cities, including Los Angeles, using climate data from 1995 to 1999 to simulate the potential potable water savings.[105] When evaluating stormwater capture, researchers used a Windows-based Source Loading and Management Model (WinSLAMM) to model the potential capture of stormwater on roofs for six different major land use categories including commercial, high density residential, medium density residential, low density residential, industrial, and institutional.[106] Medium density residential results were the focus of the consequent analysis across the six cities.[107]

Assumptions included the following: analysis was performed on a hypothetical 100-acre area of medium-density residential land with 12 people per acre[108] and indoor demand was held constant at 46 gallons per capita day (gpcd).[109] For stormwater capture analysis, three potable water demand-alleviating scenarios were evaluated: irrigation, toilet flushing, and combined irrigation

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[104] https://www.lexisnexis.com/legalnewsroom/top-emerging-trends/b/emerging-trends-law-blog/archive/2013/02/04/california-s-rainwater-recapture-act-lets-state-residents-capture-use-harvested-rainwater.aspx

[105] National Academy of Sciences, 2015 Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits. P. 43.

[106] In 2015 NAS report, WinSLAMM was used to simulate tank volumes over the 5 year period using rainfall data associated with the 1995 to 1999 climate period used to calculate the ET deficit for turf grass demand.

[107] Ibid. P. 191.

[108] According to a 2012 United States Census press release, the Long Beach – Los Angeles – Anaheim urbanized area has nearly 7,000 people per square mile.* This converts to approximately 11 people per acre which is within the planning range of the study, but the classification of "medium density residential" may be misleading for the other areas in the study as the Los Angeles urbanized area is the most densely populated in the United States.; *Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports - 2010 Census - Newsroom - U.S. Census Bureau." http://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html

[109] Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits. P. 42.

and toilet flushing. Irrigation demands were calculated to barely meet the evapotranspiration deficit of turf grass; this practice is recommended when trying to reduce water use, but is often not reflected in common practice.[110] Using the three water demand scenarios, researchers calculated the household potable water savings associated with installing either a 70 gallon rain collection system (two 35 gallon barrels) or a 2,200 gallon cistern.[111]

In the context of stormwater capture in a 100-acre medium density residential area in Los Angeles, potable water savings for the irrigation and toilet flushing scenario were 1.8% of total demand using a 70 gallon collection system.[112] Use of a larger 2,200 gallon cistern resulted in 5.4% potable water savings for the same combined scenario.[113] Of the 6 cities studied, Los Angeles had the lowest percentage of potable water savings using stormwater roof capture due to the misalignment of rainfall events and the long, dry irrigation season. Larger tank size could help capture more rain during the intense rainfall events in Los Angeles; modeling found that the 2,200 gallon cistern was only able to collect 42% of roof runoff during storm events.[114] It is important to note that this section focuses only on stormwater capture.

While larger cisterns may help households gather more rain during intense rainfall events, cisterns may run out of supplemental water during the long, dry months in Los Angeles. The modeled 2,200 gallon system was 8 feet in diameter and 6 feet tall.[115] Cisterns larger than the 2,200 gallon systems used in the NAS study may capture a higher percentage of roof run off during storm events, but area requirements and capital costs are increased. For an improved economy of scale, grouped systems may help with this burden, but a more comprehensive life cycle analysis that includes benefits beyond potable water savings would need to be performed to analyze the short term benefit of meeting demand in the beginning period of long, dry months. The study assumed indoor and outdoor water use would remain constant with the installation of supplemental water systems.[116] This assumption, however, needs additional research to determine the impacts of supplemental water on household level consumption. Conservation messaging and educational programs would need to be implemented concurrently with this supplemental water source to optimize potable water use reduction.

This study provides some insight into the potential water supply benefits that can be obtained through implementing stormwater capture BMPs on residential land uses, but represents a lower bound of the potential for the City as only residential land uses were considered in the analysis. LADWP’s SCMP included on-site direct use (e.g., through a residential or commercial cistern

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[110] Ibid.
[111] Ibid. P. 53.
[112] Ibid. P. 54.
[113] Ibid.
[114] Ibid. P. 55.
[115] Ibid. P.53.
[116] Ibid. P. 44.

program), and sub-regional direct use (e.g., through a Park Subsurface Storage and Irrigation Program), as potential distributed program alternatives that could be implemented.[117] SFR, MFR, commercial, industrial, educational, and institutional were all included as potential land uses on which to implement these direct use programs. The SCMP-estimated 2035 stormwater capture potential for distributed direct use was 2,000 AFY (conservative) and 7,000 AFY (aggressive).[118]

TreePeople has also done extensive work examining this question of the potential contribution that captured stormwater can make to increase the City's local water supply.[119] Case studies are underway in the region to better quantify the potential of these on-site systems. Several agencies, including LADWP, LASAN, and LACFCD, are involved in the Greater LA Collaborative, which consists of cisterns at 6 homes (in some cases, installations also included other stormwater management practices such as rain gardens). These cisterns are also novel as they are linked to the cloud to enable real-time tracking and management of the water contained in the cisterns. As of March 2017, around 37,000 gallons had been collected at these homes.[120]

Lessons on the potential to increase on-site use of rainwater can also be gained by assessing the various water management policies that Australia implemented during their Millennium drought to dramatically reduce consumption, increase treated wastewater reuse, and increase the use of stormwater and rainwater as a part of local supply.[121] Decentralized sources can increase water system resilience by offering a fit-for-purpose (e.g., captured rainwater for landscape irrigation) water source that can, in many cases, be brought online much more quickly than a larger-scale, centralized system.[122] An important piece of increasing the use of this source of water is ensuring there is minimal regulatory uncertainty and clear guidelines in place that ensure public health is protected as these systems are constructed and maintained over time. For example, the governments of South Australia and Victoria now mandate that water is treated to fit-for-purpose and have developed a comprehensive regulatory framework to provide specific guidelines for the use and reuse of most water sources.[123]

This shift toward providing additional clarity on opportunities to safely use and reuse rainwater and stormwater on-site and elsewhere is now occurring in LA County. In early 2016, updated 2011 guidelines to outline the permitting, water quality, treatment, monitoring, and reporting requirements of using rainwater and stormwater for both indoor and outdoor uses were released by

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[117] LADWP SCMP (2015) p. ES-8 www.ladwp.com/scmp

[118] LADWP SCMP (2015) p. ES-10 www.ladwp.com/scmp

[119] https://www.treepeople.org/resources/publications

[120] https://www.treepeople.org/lawatercollaborative accessed October 2017

[121] https://www.treepeople.org/sites/default/files/pdf/publications/TreePeople%20-%20Transferring%20Lessons.pdf; https://www.treepeople.org/sites/default/files/pdf/publications/TreePeople%20-%20Lessons%20from%20the%20land%20of%20Oz%20e-%20version.pdf

[122] Treepeople (2016) Transferring Lessons from Australia's Millennium Drought to California: Accelerating Adaptation to Drought, Flood and Heat. P. 4 [Treepeople Australia 2016]

[123] Treepeople Australia 2016; Grant et al. "Adapting Urban Water Systems to a Changing Climate: Lessons from the Millennium Drought in Southeast Australia." Environmental Science and Technology (2013): 10727-10734.

the LA County Department of Public Health (LACDPH). In these guidelines, rainwater is defined as precipitation on any parcel that has not entered an off-site storm drain system or engineered channel; stormwater is defined as rainwater that has left the parcel and entered an MS4 or other conveyance that discharges to Waters of the United States.[124]

According to these guidelines, rainwater may be used at SFR, apartments, hotels, commercial, institutional, and municipal facilities; stormwater may only be used indoors at commercial, institutional, municipal, and industrial facilities. Rainwater may be readily used indoors for laundry washing, urinal and toilet flushing, and trap primers and cooling tower makeup; stormwater may only be used for the latter two uses.[125] Outdoors, rainwater from rain barrels or cisterns may be used for surface or subsurface landscape irrigation or vehicle washing with no treatment; some applications with pressurized rainwater catchment systems would require some treatment for on-site use. Outdoor uses of stormwater would require some level of treatment, potentially through package or design-build units as determined needed on a case-by-case basis for each project.[126]

However, Matrix 2.0 should be updated to reflect LACDPH's first rainwater matrix and increase the ease of irrigating landscapes outside where land uses permit. For example, the 2011 rainwater matrix had no requirements for rain barrel water used on-site in gravity flow systems (for landscape irrigation or car washing) and in most cases only pre-screening was required for use of water collected in cisterns and used on-site for drip or sub-surface irrigation. Only bacterial limits needed to be met for on- or off-site collection of rainwater, stormwater, and urban runoff in cisterns for other on- or off-site uses (e.g., spray irrigation, non-interactive outdoor water features, street sweeping).[127] The 2016 Matrix 2.0 requires stormwater to meet the more rigorous NSF 350 or CCR Title 22 recycled water equivalence with additional requirements depending on whether stormwater is distributed offsite.[128]

When the need is great and the path forward to increasing the safe use and reuse of rainwater on-site is clear, the pace of installing onsite rainwater harvesting can rapidly increase. For example, the number of households using rainwater tanks in Australia overall increased from 24% in 2007 to 34% in 2013; in Brisbane, cistern adoption rates increased by two and a half times from 18.4% to 47%.[129] However, care must be taken to consider the impacts of increasing captured rainwater and stormwater on vector control (e.g. the risk of creating mosquito breeding habitat in

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[124] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0)

[125] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0)

[126] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0)

[127] http://phasocal.org/wp-content/uploads/2015/06/ep_cross_con_RainwaterMatrix.pdf

[128] Matrix 2.0 https://www.smgov.net/uploadedFiles/Departments/OSE/Contact_Find_Us/Guidelines%20for%20Alternate%20Water%20Sources_2-10-16.pdf

[129] Treepeople Australia 2016; Australian Bureau of Statistics. "Rainwater Tanks." Environmental Issues: Water Use and Conservation. March 2013.

standing water in rain barrels or stormwater BMPs), another critical public health issue.[130] There is some evidence that stormwater infrastructure may be one of the greatest sources of mosquitos in many urban areas.[131] In a national study that surveyed 329 agencies that were responsible for stormwater, mosquito control, or both, 95% of surveyed agencies had BMPs within their jurisdictions and mosquitos had been found in those structures in almost every state.[132] The surveyed BMP types found to have harbored mosquitos are very frequently used; these BMPs included detention/retention basins, grass swales, stormwater treatment wetlands/ponds, infiltration basins/trenches, below-ground proprietary systems, and bioretention systems.[133] Therefore, it is critical to find a balance between maximizing the water quality and potential water supply benefits from widespread implementation of BMPs versus the potential to increase the public health risk from facilitating the growth of potentially disease-carrying insects such as mosquitos.

Further, surveyed agencies that were multi-functional knew more about both mosquitos and BMPs than individual agencies (e.g. a mosquito control agency did not know as much about BMPs in their region as did a multi-functional agency). This shows that fostering collaboration between the regional agencies that are responsible for stormwater and those that are responsible for insect control can help ensure that implementing BMPs for vector control as well as water management are considered in these projects. Increasing interagency communications and raising awareness of the association between stormwater and mosquitos were the most commonly recommended suggestions by the surveyed agencies.

Good BMP management can ameliorate some of these risks. Examples of good management strategies include ensuring that all cisterns and rain barrels are tightly sealed, rain barrels and cisterns are periodically cleaned out, infiltration BMPs are checked to ensure they percolate rapidly and don't pond water, etc. Therefore, education and monitoring programs are an important part of increasing BMP installation programs to ensure that BMPs are appropriately maintained and also that the most effective practices for both vector control and stormwater management are identified.

IV. Wastewater Recycling and Reuse

A. Introduction

Increasing the reuse of our wastewater is a critical mechanism for increasing the City's percentage of local water supplies. Unlike stormwater in the Los Angeles area, which is extremely variable in flow, wastewater offers a more reliable flow that can be reused year round. While relatively consistent day to day, flows going through WRPs are susceptible to longer term changes

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[130] Wide variety of resources on vector control in LA County available at:http://www.westnile.ca.gov/resources.php

[131] Harbison, J. E., M. E. Metzger, C. G. Neumann, O. Galal, R. Hu, and V. L. Kramer. 2010. "The Need for Collaboration Among Government Agencies to Reduce Mosquito Production in Mandated Stormwater Structures." *Journal of the American Mosquito Control Association* 26. Cited in Justin E. Harbison and Marco E. Metzger; We Want You to Fight Stormwater Mosquitos 'A call for interagency and interdisciplinary collaboration' September 2010 www.stormh2o.com (Harbison and Metzger 2010)

[132] Harbison and Metzger 2010

[133] Harbison and Metzger 2010

such as increased indoor conservation or increased use of distributed on-site treatment facilities or graywater systems. City water management plans must accurately assess the impacts of gray water systems and distributed on-site treatment systems on the sewer system and water recycling facilities. City documents issued in the last several years such as the LADWP UWMP and Recycled Water Master Planning Documents (RWMP) include plans and projects as well as potential customers that will facilitate the increased reuse of treated wastewater going forward.

B. Current Projects, Plans, and Practices

Locally, the City has set several goals to increase the use of recycled water within its boundaries. The 2010 UWMP target was to use at least 59,000 of recycled water as part of its local water supply portfolio by 2035; this goal has been accelerated to 72,200 AFY in the 2015 UWMP.[134] The 2012 RWMP was developed to identify opportunities to meet the goals of 59,000 AFY stated in the 2010 UWMP and included reports that focused on non-potable reuse (NPR) opportunities, groundwater replenishment (GWR) opportunities, and long-term opportunities (LTCR) to maximize recycled water reuse. The focus through 2035 is on developing the additional 39,650 AFY (through implementing projects that will result in 30,000 AFY from GWR and 9,650 AFY from assorted NPR uses required to meet the 59,000 AFY goal.[135]

Beyond the 2035 goals, an additional goal described in the LTCR is offsetting imported water to the maximum extent possible by 2085 (up to 168,000 AFY based on the MWD volume used in the LCTR). In an executive directive issued in late 2014, Mayor Garcetti identified an additional goal for recycled water: converting 85% of public golf course acreage to recycled water by 2017.[136] The ongoing One Water LA (OWLA) research efforts are also investigating opportunities to increase the reuse of recycled water at the four City-owned and co-owned WRPs: HWRP, TIWRP, DCTWRP, and LAGWRP.

HWRP is located just south of the LA World Airport (LAWA) and just east of El Segundo. HWRP treats wastewater from the Hyperion Service Area (HSA), which covers a tributary area of about 515 mi². Approximately 420 mi² are within the City.[137] HWRP is also responsible for processing solids for the entire HSA, including the solids generated by the two inland WRPs: DCTWRP in Van Nuys and LAGWRP near Griffith Park. Both WRPs divert raw wastewater from the system for wastewater treatment and return solids back to the system for treatment at HWRP. Average daily flows going through HWRP were 279 MGD for FY 2013-2014; average flows in 2015 were down to 240 MGD.[138]

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[134] 2010 LADWP UWMP, Ch. 4, p.81, 2015 UWMP ES-19

[135] Non-Potable Reuse Master Planning Report Executive Summary, p. ES-1, March 2012

[136] Mayor Eric Garcetti, Executive Directive #5, Issue Date: October 14, 2014. Page 2.

[137] Wastewater Treatment TM Admin Draft, LTCR appendix P.11

[138] OWLA meeting presentation Feb 16, 2017

In 2013, 32 MGD of secondary treated effluent from HWRP went to the WBMWD ECLWRF for further treatment to produce waters ranging in quality from disinfected tertiary effluent to advanced treated recycled water for a variety of uses both in their service area and in the Westside recycled water system in the City. Plans at WBMWD describe scenarios to increase production at ECLWRF to about 62 MGD (70,000 AFY) by 2020 with an ultimate described demand of approximately 70 MGD (78,400 AFY).[139] In addition, LASAN plans to install the capacity for additional treatment of 2 to 5 MGD at HWRP by 2019 to generate advanced treated recycled water for use in the terminals and cooling towers at LAWA.[140] Eventual potential at HWRP could include upgrading the facility to tertiary plus NDN treatment processes or even advanced treatment for indirect potable reuse (IPR) / direct potable reuse (DPR).

TIWRP, which has an average dry weather capacity of 30 MGD, treats an average flow of 14.5 MGD.[141] Until recently, approximately 5 MGD of flow was treated at the TIWRP Advanced Water Purification Facility (AWPF); the remainder of the tertiary effluent was discharged to the LA Outer Harbor. AWPF capacity was expanded to treat the entire flow at TIWRP and produce 12 MGD of advanced treated recycled water in early 2017.[142] As a result of this expansion, only brine and residuals from water reclamation at the plant will continue to be discharged into the harbor through the existing outfall. LAGWRP and DCTWRP discharge tertiary-treated effluent into the LAR.[143] Recycled water from these WRPs is also currently used for NPR uses such as landscape irrigation, golf course irrigation, in-plant uses, power plant cooling, and other industrial uses.

The City plans to increase the reuse of recycled water from DCTWRP. One example is the GWR Project, which is expected to result in up to 30,000 AFY of recycled water being recharged into the San Fernando Basin to increase groundwater resources.[144] Recycled water from DCTWRP will be recharged through two major water conservation facilities in the SFB that are operated by Los Angeles County Flood Control District (LACFCD): the Hansen Spreading Grounds and the Pacoima Spreading Grounds. In addition to the GWR Project, LADWP plans to increase recycled water production at WRPs, expand distribution pipelines, and enhance spreading grounds to achieve the goals set out in the UWMP.

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[139] OWLA presentation February 16, 2016; WBMWD. Capital Implementation Master Plan Ch. 8 Future Systems Analysis, p. 8-4, June 2009; http://www.westbasin.org/water-reliability-2020/recycled-water/master-plan

[140] OWLA presentation, February 16, 2017

[141] Prepared by Larry Walker Associates, Inc.; Todd Groundwater; Nellor Environmental Associates, Inc.; and Trussel Technologies, Inc. Prepared for City of LA DPW Bureau of Sanitation. Amended Engineering Report for the Terminal Island Water Reclamation Plant Advanced Water Purification Facility Expansion: Dominguez Gap Barrier Project (August 2015) p. 1-1. *Available at: http://san.lacity.org/pdf/TIWRP_AWPF_Dominguez_Gap_Barrier_ER.pdf* [TIWRP AWPF DGB Engineering Report (August 2015)]

[142] https://www.lacitysan.org/san/faces/wcnav_externalId/s-lsh-sp-awpf-ep?_adf.ctrl-state=ljtyw8si3_4&_afrLoop=16304453241277602#!; http://www.tellmeladwp.com/go/doc/1475/2915446/

[143] Recycled Water Table FY 2013-2014 LASAN

[144] LADWP GWR DEIR p. ES-4

C. Moving Toward Total Reuse

To maximize the potential to source water locally, the final goal for recycled water in the City should be the reuse of the total volume of wastewater treated within the City (except for the brine and residuals generated through the process). Average flows to the four City-owned WRPs in 2015 were as follows: 240 MGD at HWRP (capacity 450 MGD), 32 MGD at DCTWRP (capacity 80 MGD), 19 MGD at LAGWRP (capacity 20 MGD), and 14 MGD at TIWRP (capacity 30 MGD).[145] These flows represent a decrease from the 2013-2014 flows at three WRPs[146]: 7% at TIWRP (down from 15 MGD), 9% at DCTWRP (down from 35 MGD), and 14% at HWRP (down from 279 MGD).[147] Flows at LAGWRP increased 26% from 15 MGD to 19 MGD. In general, flows have decreased at WRPs throughout the LA region since the 1990s. For example, flows at HWRP were 300 MGD in 1992 and 330 MGD in 1993.[148]

We defined maximum reuse based on the entire available volume of treated wastewater, 385,280 AFY, in FY 2013-2014. Of this volume, 75,400 AFY is expected to be sent to WBMWD for treatment and reuse mainly outside of the LADWP service area. Additionally, approximately 6,720 AFY is expected to go to the Dominguez Gap Barrier; neither of these volumes are available for reuse within the City. We further assumed a very conservative 20% reduction in wastewater flows by 2035 due to the pLAn conservation / gpcd goals and that all recycled water would be treated with MFRO (applying a very conservative recovery rate of 71% after MFRO treatment). Therefore, as described in the LA Water Supplies section above, a potential maximum recycled water goal is approximately 161,000 AFY. This is a starting place, but it is important to note that the available volumes for wastewater reuse could be higher if the majority of conservation potential that remains in the City is linked to outdoor use as conservation in this area would have a reduced impact on flows to WRPs. Further, the recovery rate used in our analysis was highly conservative and would likely be higher in practice and as technologies for water reuse continue to improve. Challenges and opportunities to expanding wastewater reuse are discussed below.

Challenges to maximizing reuse within the City are linked to issues of both spatial distribution and available flows. In the current framework of City wastewater distribution and WRPs, there is potentially more demand for recycled water than current supply at certain facilities (e.g., at DCTWRP and at TIWRP). At HWRP, there is more potential recycled water supply than demand. Increasing volumes of wastewater recycled at HWRP is further complicated by its location downhill from much of the City-based demand. Future studies to identify the most effective strategies to maximize reuse of HWRP water should include assessments to increase IPR to capitalize on the additional storage space identified for use in West Coast and Central Basins (described in more detail in Section V.B.a). These studies should also assess potential partnerships with one or more

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[145] OWLA presentation, February 16, 2017

[146] 2013-2014 flows were used in the Sustainable LA water project analyses presented in this and previous watershed reports to determine the maximum recycled water potential in the presented work

[147] These flows were kept to maintain consistency with all watershed reports, the first of which began in 2014, and also because FY2013-2014 is the pLAn baseline year. 2013-2014 flows data from LASAN recycled water table FY2013-2014

[148] Characteristics of Effluents from Large Municipal Wastewater Treatment Facilities in 1993. SCCWRP. P. 10 ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/AnnualReports/1993_94AnnualReport/ar01.pdf

agencies including MWD, West Basin MWD, Central Basin MWD, and WRD to upgrade HWRP to tertiary plus NDN treatment processes or even advanced treatment and to become part of a regional recycled water distribution system that will greatly increase local resources.

The City is currently investigating opportunities to move flows around within the City infrastructure to maximize the reuse of recycled water based on the current misalignments of local supply and demand for recycled water. As part of the One Water LA efforts, the City is exploring options such as augmenting sewer flows with runoff to increase the volumes available for recycling, reconfiguring sewer alignments to channel wastewater flows to WRPs closest to the most local demand, and building City-owned satellite WRPs to create new recycled water supply where sufficient local demand is present.[149]

Low flow diversion facilities (LFDs) are already in use to divert some or all dry weather flows from certain channels to WRPs. There are 20 operating LFDs that are City-owned, eight of which have no sewer system connections, and 14 additional LFDs that are not City-owned. In many cases, these LFDs are in place to improve beach water quality where the channels would otherwise discharge their water during the high-use beach months. However, this diverted runoff also offers water supply potential as these flows can increase the flow volumes available for treatment and reuse from the WRPs. For example, HWRP currently accepts dry weather urban runoff from 23 LFDs in the area year-round, including 8 City-owned LFDs as well as LA County and City of Santa Monica LFDs. Runoff is diverted to HWRP except during a storm event that generates greater than 0.1 inch of storm runoff and for the following three days after the storm.[150] As part of identifying opportunities to increase flows for treatment and reuse at centralized WRPs, the potential for LFDs is being investigated through the One Water LA process.

At the time of this writing, 45 potential initial sites for LFDs with a potential flow of 8.6 cfs (5.5 MGD) have been identified for further study; these flow volumes could be folded into the existing sewer system with minimal impacts. These potential LFDs would either route flows to a WRP or treat runoff onsite for local reuse applications. The final destination of these flows may change as plans to reroute wastewater through the system to areas with higher local demand for recycled water (e.g. the potential east-west valley interceptor sewer that would route additional flows to DCTWRP) are developed.[151] Modifying management guidelines on runoff flow diversions to allow flows from small to moderate precipitation events, or expanding dry weather runoff diversion capacities could greatly increase potential influent volumes to WRPs, especially at HWRP with its large unused capacity.

Based on the modeled results presented above in the stormwater section, the annual average flows available for capture in these watersheds are significant even in dry years. Without BMPs, annual average flows in 2007 were 10,000 AF in the DC Watershed, 40,000 AF in the BC watershed, and 100,000 AF in the LAR watershed, the driest year modeled and one of the driest years

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[149] OWLA homepage; OWLA presentation, February 16, 2017

[150] http://www.lastormwater.org/blog/2015/06/outta-sight/, Water for LA Becoming a Green-Blue City, ASCE December 2014 article, List of Existing and Planned Diversions for Santa Monica Bay, LASAN.

[151] OWLA personal communication.

on record. Even after implementing BMPs to capture the 85th percentile storm in the DC watershed, which has the lowest available volume of the three watersheds, approximately 8,600 AF would have been available for diversion to WRPs (or other opportunities to capture and reuse this stormwater). The City should continue to investigate the potential to divert runoff for treatment and reuse at WRPs not only during dry weather, but also during small to moderate sized storms. As indoor conservation efforts continue to reduce flows to WRPs, additional space may become available in the sewer system for runoff flows to be conveyed to WRPs for treatment, even during wet weather. Care must be taken, however, to assess any potential impacts of these runoff diversion flows on influent quality to ensure that effluent water quality requirements are still being met and that the chemistry is not changed to a degree that different treatment trains would be required to effectively treat the wastewater/stormwater influent.

In addition to blending runoff with wastewater in the sewer systems, stormwater capture can be combined with smaller satellite treatment facilities where there is demand for recycled water. Two case studies have been identified as potential near-term opportunities through the OWLA efforts that involve both recycled water and stormwater at the same site: a project at the LA Zoo and at Rancho Park. Recycled water will be used at the zoo for irrigation, exhibits, and restrooms while additional stormwater capture opportunities within the zoo are investigated.

Two alternatives are being explored at Rancho Park. The first includes an on-site WRP and stormwater capture project; after treatment the water will be used for irrigation at the site.[152] This project would consist of three components to provide multiple benefits and facilitate the co-location of the stormwater capture and treatment system and the satellite WRP to allow the sharing of infrastructure and centralize O&M at the site. Component 1 involves the installation of a stormwater capture and treatment system that produces water of a sufficient quality for NPR as required under California Code of Regulations Title 22. Capturing this water will not only offset potable water use by providing water for irrigation, but also improve water quality in the BC watershed by removing polluted runoff. Component 2 consists of installing a satellite WRP to treat wastewater to the same quality. The initial wastewater treatment capacity will be 2.5 MGD, which is not sufficient to meet peak demands. Therefore, component 3 will consist of increasing the treatment capacity to approximately 4.2 MGD to eliminate the need for potable water.[153] The second alternative being explored includes two smaller facilities (one at Rancho Park and the other at UCLA) that would accommodate demands in the surrounding UCLA and Rancho Park areas.

In addition to smaller scale satellite treatment plants, larger regional projects would provide the opportunity to reuse large volumes of recycled water. MWD is currently exploring the "Regional Recycled Water Program (RRWP), which would include an advanced water treatment facility (AWTF) at JWPCP in Carson. RRWP implementation could potentially result in the pro-

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[152] OWLA presentation, February 16, 2017

[153] Technical memorandum No. 12.1, Task 12 Special Studies, Rancho Park Project Concept report. September 2016, final draft, p. 3

duction of up to 150 MGD (168,000 AFY) of purified water for delivery to as many as 4 groundwater basins (Orange County, WCB, CB, and Main San Gabriel); conveyance would require up to 60 miles of pipeline and three pumping plants. The currently planned end use would largely be groundwater recharge, but the potential exists to expand to different uses (including DPR when regulations are in place) in the future as conditions and regulations evolve.[154] This project was found to be feasible but very complex, with a base case cost estimate of approximately $1,600 / AF (ranging from $1,368 to $2,013 in 2016 $). Construction of a 0.5 MGD AWT demonstration plant is underway; the selected treatment train consists of MBR, MF (through micro- or ultrafiltration), RO, and UV/AOP, but MWD will also test alternative processes (such as elimination of the MF step) that could result in cost savings if approved by regulators.[155] In addition to investigating the potential to inject and extract HWRP advanced treated water from West Coast and Central Basins (WCBCB), future studies to determine the most cost-effective and beneficial opportunities to maximize reuse of HWRP wastewater should include the potential to integrate HWRP flows into the RRWP distribution system.

Increasing the use of recycled water indoors as well as outdoors presents another opportunity to increase the volumes that are reused. The LACDPH released a set of guidelines (Matrix 2.0) for using alternate water sources (including rainwater, stormwater, recycled water, and graywater) for both indoor and outdoor NPR in February 2016.[156] Currently, recycled water may be used at commercial, institutional, municipal, industrial, and certain larger and professionally managed residential complexes, but may not be used at single-family residences or non-professionally managed apartments. This document defines the allowable types of recycled water, provides guidance on the allowed uses such as toilet and urinal flushing or laundry and allows for other uses pending LACDPH review, and identifies the regulatory and design requirements that are necessary to safely use recycled water indoors. For example, the minimum water quality standard for recycled water use indoors is "CCR Title 22 Recycled Water Quality Equivalence at point of use.[157] "

Following the guidance outlined in the Matrix 2.0 will streamline the process of using recycled water for indoor uses and thus facilitate the increased use of recycled water for additional uses beyond outdoor irrigation. Outdoor use of recycled water is also included; recycled water can be used outdoors at all of building types that are eligible for indoor use, plus the residential building types.[158] Recycled water use is also incentivized through a 2016 City of LA ordinance that allows

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[154] MWD Potential Regional Recycled Water Program Feasibility Study, January 2017.,Page i.

[155] MWD Potential Regional Recycled Water Program Feasibility Study, January 2017. Executive summary.

[156] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0)

[157] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0) p. 10

[158] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0)

exemptions (e.g., to requirements to reduce potable water use by 20%) if, for example, 100% City-recycled water is used for water closets, urinals, floor drains, and process cooling and heating.[159]

D. Graywater

Graywater is a potential distributed component of a local water supply portfolio that is more reliable than rainwater capture in Mediterranean regions such as Los Angeles, where the annual rainfall is relatively low and can be unpredictable. Graywater, however, also has many of its own challenges. Domestic graywater is generated from a variety of sources within buildings, including bathrooms (tubs, sinks, and showers), kitchens (sinks and dishwashers), and laundry rooms (washing machines).[160] Between 127 and 151 liters (33 to 40 gallons) of graywater is generated daily per person in the United States;[161] this can represent up to 70% by volume of indoor wastewater generation.[162] Further, graywater can provide a relatively clean water source as it contains only 23% of the mass of suspended solids in the wastewater leaving the house.[163]

Graywater can be defined in two different ways, heavy graywater and light graywater. Light graywater is wastewater from bathroom sinks, bathtubs, showers and washing machines, while heavy graywater is wastewater from kitchen sinks and dishwashers.[164] The CA plumbing code does not allow the use of untreated heavy graywater at residences, but has streamlined the process for simple light graywater systems such as laundry to landscape. Graywater systems that do not require cuts to the existing plumbing pipe system, deal with the volume of water from a single laundry machine, serve two families or less, and are only used for subsurface irrigation for nonedible crops or landscaping are not required to get a permit under the CA plumbing code.[165]

Water quality criteria have also been established in CA for two types of onsite graywater reuse. For subsurface irrigation, a primary treatment level is required that carries no specific, numeric water quality criteria. For aboveground non-potable reuse, disinfected tertiary (Title 22 Recycled

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[159] City of LA Ordinance 184248, Effective June 6 2016. http://clkrep.lacity.org/onlinedocs/2015/15-0458_ORD_184248_6-6-16.pdf

[160] Zita L.T. Yu, Anditya Rahardianto, J.R. DeShazo, Michael K. Stenstrom, Yoram Cohen. Critical Review: Regulatory Incentives and Impediments for Onsite Graywater Reuse in the United States (2013). Water Environment Research, Volume 85, Number 7. P. 651

[161] Mayer, P.W., DeOreo,W. B. (1999) Residential End Uses ofWater; Report No. 1583210164; American Water Works Association: Denver, Colorado.

[162] Abu Ghunmi, L.; Zeeman, G.; Fayyad, M.; van Lier, J. B. (2011) Grey Water Treatment Systems: A Review. Crit. Rev. Environ. Sci. Technol, 41, 657–698. Friedler, E. (2004) Quality of Individual Domestic Graywater Streams and Its Implication for On-site Treatment and Reuse Possibilities. Environ. Technol., 25, 997–1008.

[163] Abu Ghunmi, L.; Zeeman, G.; Fayyad, M.; van Lier, J. B. (2011) Grey Water Treatment Systems: A Review. Crit. Rev. Environ. Sci. Technol, 41, 657–698. Friedler, E. (2004) Quality of Individual Domestic Graywater Streams and Its Implication for On-site Treatment and Reuse Possibilities. Environ. Technol., 25, 997–1008.

[164] http://www.environment.ucla.edu/reportcard/article4870.html Graywater - A Potential Source of Water

[165] Information on current graywater allowances and requirements. Graywater plumbing codes: http://ladbs.org/LADBSWeb/LADBS_Forms/InformationBulletins/IB-P-PC2011-012Graywater.pdf

Water Quality) criteria must be met.[166] Since tertiary treatment levels are difficult and expensive to meet at a typical residence, subsurface irrigation with minimal to no additional treatment has a great deal more potential for City-wide use. However, the guidelines for using alternate water sources (including rainwater, stormwater, recycled water, and graywater) for both indoor and outdoor NPR released by LACDPH in February 2016 may facilitate the increased use of graywater by streamlining some of the processes and clearly defining requirements to safely implement these projects.[167] Recent changes to parts of the LA Municipal Code through Ordinance No. 184248 also require that alternate waste piping is installed to permit discharge from light graywater sources to future irrigation systems and count graywater as an eligible source to offset potable water use.[168]

As described above, the National Academy of Sciences published an overview of stormwater and graywater as potential water supply sources (NAS study) that included the City of LA as a case study. In the case study, researchers modeled the impacts of implementing graywater systems and estimated their reduction of household potable water demand for six cities including Los Angeles using the same assumptions as in the stormwater analysis described earlier.[169] For the NAS graywater reuse analysis, per capita use was broken down into total graywater production, laundry, and toilet flushing at 21, 7.6, and 11 gpcd, respectively.[170] Total graywater production was defined as water from sinks, showers, and clothes washers and excluded water from dishwashers and kitchen sinks.[171] For the hypothetical 100-acre medium-residential area, the study assumed 100% adoption of graywater systems and that all the graywater produced was available for use because of the inclusion of a sufficiently sized storage tank.[172] The study also assumed that indoor water use did not change with the installation of a graywater system.[173]

Using these assumptions and LA climate data, authors found that potable water demand could be reduced by up to 13% in the combined irrigation and toilet-flushing scenario.[174] Graywater's potential in LA varies widely depending on assumptions, however, and additional research is

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[166] Zita L.T. Yu, Anditya Rahardianto, J.R. DeShazo, Michael K. Stenstrom, Yoram Cohen. Critical Review: Regulatory Incentives and Impediments for Onsite Graywater Reuse in the United States (2013). Water Environment Research, Volume 85, Number 7. p 655.

[167] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses, LA County Dept Public Health February 2016 (Matrix 2.0)

[168] City of LA Ordinance 184248, Effective June 6 2016. http://clkrep.lacity.org/onlinedocs/2015/15-0458_ORD_184248_6-6-16.pdf

[169] A hypothetical, medium-density residential, 100-acre plot of land and an indoor demand of 46 gpcd was used for the NAS analysis. Three potable water demand-alleviating scenarios were evaluated: irrigation, toilet flushing, and combined irrigation and toilet flushing. Irrigation demands were calculated to barely meet the evapotranspiration deficit of turf grass; this practice is recommended when trying to reduce water use but is often not reflected in common practice. *Using Graywater and Stormwater to Enhance Local Water Supplies: An Assessment of Risks, Costs, and Benefits*. P. 42.

[170] Ibid.

[171] Ibid. P. 11.

[172] Ibid. P. 41.

[173] Ibid. P. 44.

[174] Ibid. P. 45.

needed to characterize its potential benefits and consequences. For example, Yu et al. found that the volume of graywater in LA available for reuse (mainly in the non-potable uses of irrigation, toilet flushing, and laundry) represented an estimated 25% of the City's 2013 water supply. Thus, Yu et al. calculated that graywater could displace approximately 50% of irrigation water and reduce potable water demand by 27% in single-family residences (SFR) and replace all irrigation water demand and reduce potable water demand by 38% at multifamily residences (MFR).[175]

Of the cities analyzed in the NAS study, LA had the highest irrigation demand; under the irrigation-only scenario, 11% of potable water demand was reduced, but graywater was only able to meet 17% of total irrigation demands.[176] Reducing irrigation demands with the installation of more water efficient landscaping like native plants and / or xeriscaping would increase the fraction of potable demand that could be met by graywater, but research is needed to determine if native or drought resistant plants are impacted by the constituents present in graywater. In addition, the study's assumption that indoor and outdoor water use would remain constant with the implementation of graywater reuse may not hold true in practice.[177] The study also evaluated the savings realized with a simple laundry-to-landscape system in which only clothes washers are used for irrigation. This retrofit option resulted in 4.1% potable water savings in LA.[178]

In the NAS study, these simple laundry-to-landscape systems showed the best potential for potable water demand reduction. Since graywater production is constant throughout the year, installing graywater reuse systems could provide for a more reliable supplemental water source throughout the year than captured stormwater, even if the daily volume of graywater generated is small. Training on the appropriate cleansers and conditioners and system maintenance is also necessary to ensure that harmful chemicals are not being washed with the graywater out into the landscapes and that the systems function appropriately. To assess the actual potential that graywater has to supplement LA's local water supply landscape, a more comprehensive analysis also needs to be performed on treatment and maintenance costs of graywater systems, which can vary depending on the household, system, detergents, and its residents, and on the impact of on-site graywater use on flows (and thus potential reuse) at downstream centralized treatment plants.

For example, increasing use of onsite treatment and disposal systems such as graywater will remove the cleanest residential water from the wastewater system as well as decrease the flow of wastewater that is available for treatment and reuse. Therefore, wide-spread adoption of graywater systems could have unintended negative effects on the wastewater system by concentrating the waste stream and making compliance with discharge regulatory limits more challenging. In addition, the best use of water in the system overall should be included in assessing the costs and benefits of increased use of graywater systems. One important consideration is whether graywater is of more value remaining in the system for treatment and reuse at a centralized location where

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[175] Zita L.T. Yu, J.R. DeShazo, Michael K. Stenstrom and Yoram Cohen. Cost-Benefit Analysis of Onsite Residential Graywater Recycling – A Case Study: the City of Los Angeles (2014) p. 3; These results were based on the following estimates: 627,000 SFR (using 1,320 L / day - assuming 3 residents) and 764,400 MFR (using 810 L / day) are present in the City, and outdoor water use is 52% and 18% at SFR and MFR, respectively.
[176] Ibid. 43.
[177] Ibid. 44.
[178] Ibid. 46.

uses can evolve over time (e.g., water can be routed to IPR uses rather than irrigation as new treatment systems come online or new demands are identified) or in distributed on-site systems that have a more rigid use once installed (e.g., in on-site laundry to landscape systems).

Further investigation into the benefits as well as the risks of long-term use of graywater systems should be completed before implementing large-scale programs to require the installation of these systems broadly across the region as there is currently limited information on the potential impacts. However, encouraging residents to install simple laundry to landscape systems and get educated on the proper operation, maintenance, and use of that system, could prove to be an effective way to reduce potable water demand.

E. 'Surface Water Augmentation Indirect' and 'Direct' Potable Reuse

The feasibility of implementing regulations that will potentially allow IPR with augmentation of a surface water reservoir with recycled water (SWA) and DPR are currently being assessed by the SWRCB. Regulations for SWA IPR were recently released and the public comment period closed December 18, 2017. A public hearing on the proposed final regulations will be heard in early 2018.[179] For DPR, an advisory group of stakeholders and an expert panel were convened as required under Senate Bills 918 and 322 to assist the SWRCB in developing a report to assess multiple factors around the current state of DPR and the feasibility of developing uniform water recycling criteria for DPR. The factors examined included the potential hazards of potable reuse, public health impacts, available analytical methods to assess a wide variety of water quality parameters, the reliability of treatment trains with multiple barriers and sequential treatment, levels of monitoring necessary to protect public health, and existing DPR regulations or projects that have been implemented elsewhere.[180] The final report was submitted by the SWRCB to the California Legislature in December 2016 and addressed only the feasibility of developing DPR criteria, not the specific criteria for DPR.[181] California Assembly Bill 574 would require the SWRCB to adopt uniform water recycling criteria for DPR on or before December 31, 2023.[182]

The passing of state-wide regulations that broadly permit the use of SWA IPR would expand the opportunities to reuse additional recycled water even further as pumping recycled water to filtration plants for brief storage followed by additional filtration and disinfection becomes an op-

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[179] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/RecycledWater.shtml; https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Surface_Water_Augmentation_Regulations.shtml; https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/swa/notice_surface%20water_15day_with%20reg%20text.pdf

[180] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf p. 14

[181] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/rw_dpr_criteria.shtml; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf p. 1

[182] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB574

tion. This option may be more practical in some areas than the currently utilized IPR via infiltration or injection into groundwater; a regional example of this type of project exists in San Diego and was being reviewed by the SWRCB at the time of this writing.[183] The four North City projects included in "Pure Water San Diego Phase 1," if approved, will deliver 30 MGD of advanced treated wastewater to Miramar Reservoir for mixing with imported and local water sources prior to being sent to a drinking water treatment plant for additional treatment and then into the distribution system.[184] A similar project that could be assessed in LA for its potential is whether DCTWRP advanced treated water could be sent to north San Fernando Valley storage facilities for mixing with other local or imported water sources. This blended water could then be sent to the nearby LAAFP for final polishing before entering the distribution system. Depending on a variety of factors (e.g., reservoir size and the duration of the blending), this project could potentially be considered DPR.

Although the timeline for state-wide DPR regulations is longer, the outlook for DPR in CA is relatively positive. The expert panel found that "it is technically feasible to develop uniform water recycling criteria for DPR and that those criteria could incorporate a level of public health protection as good as, or better than what is currently provided by conventional drinking water supplies, IPR projects using groundwater replenishment, and proposed IPR projects using surface water augmentation in California.[185]" To obtain this quality and provide public health protection similar to a traditional environmental buffer such as a groundwater basin, however, multiple reliability features (e.g, multiple, independent treatment barriers composed of a variety of processes; the ability to divert inadequately-treated water; frequent monitoring; and rigorous response protocols for implementation if treatment at any stage is found to be poorer than expected) must be included in DPR treatment.[186] The SWRCB ultimately determined that the outstanding research questions and data gaps raised and highlighted by the expert panel, such as what treatment types are adequate and how many barriers are protective, must be addressed before DPR regulations can be drafted, and therefore research to address these questions must occur concurrently with the development of DPR criteria to inform those criteria.[187]

For any DPR uses, constituents/contaminants of emerging concern (CECs) should continue to be assessed and monitored as described in findings of the "blue ribbon" advisory panel when determining the impacts of this issue. At a minimum, the bioanalytical techniques described in the subsequent SWRCB-sponsored research conducted by the Southern California Coastal Water Research Project (SCCWRP) should be included.[188] However, since there is public concern about

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[183] https://www.sandiego.gov/water/purewater/purewatersd/phase1; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf p. 3

[184] https://www.sandiego.gov/water/purewater/purewatersd/phase1 Accessed February 19, 2017.

[185] https://www.sandiego.gov/water/purewater/purewatersd/phase1; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf p. 14,15

[186] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf p. 14-18

[187] http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/final_report.pdf p. 14-18

[188] SCCWRP. (2014). Development of Bioanalytical Techniques for Monitoring of Constituents/Chemicals of Emerging Concerns in Recycled Water Applications for the State of California.; Anderson, P., Denslow, N., Drewes, J. E., Olivieri, A., Schlenk, D., Scott, G. I., et al. (2010). Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water: Recommendations of a Science Advisory Panel. Sacramento, CA: SWRCB.

the health risks posed by advanced treated water used for DPR, the initial CEC monitoring process should include an extensive list of CECs to provide consumer confidence. If this extensive screen approach demonstrates that CECs are consistently removed during treatment to non-detect levels or levels below a public health or ecological concern, then the water treatment agency can reduce the CEC monitoring program to the levels recommended by the California Water Recycling Policy CEC Blue Ribbon Task Force.

The impacts on the system of incorporating regulations and guidelines that take into consideration the impact of treating water to various levels based on the end use should also be included. For example, if there is any direct human exposure to the reclaimed water, then advanced treatment should be required, but perhaps if all water is going to irrigation, then a lower level of treatment could be utilized without increasing the public health risk. The ability to treat the wastewater only to the degree required for its end use could greatly lower both the financial cost and the GHG emissions of treatment while increasing the volumes of wastewater recycled.

The importance of being able to treat water to the level needed for the intended use leads to planning questions on whether and how to commingle water (from both the perspective of customer needs and water sources) within pipelines. For example, the presence of a few relatively low-volume NPR customers who require fully advanced treated water impacts the type of water treatment that is required for the entire volume flowing through the pipe. In addition, the water quality needs of NPR customers can make it more challenging to blend stormwater into the recycled water due to different requirements. Thus, the likely potential to see DPR regulations in the next several years should have a significant impact on planning decisions regarding any additional implementation or construction of additional purple pipes to supply NPR needs. The potential costs and benefits of moving current NPR customers back onto potable water should also be assessed where a relatively small volume of water use is a limiting factor to increasing the flow volumes or changing the treatment requirements of a larger volume of water that could significantly impact our local water supply resiliency.

V. Increased Use of Groundwater Basins

A. Introduction

Groundwater throughout California is a critical resource that provides water supply resiliency for the state's variable climate. For many basins in the state, there is an urgent need to evaluate (or reevaluate) sustainable yields and aquifer overdraft status, especially given changes in hydrology, climate change, and changing trends in the management and use of groundwater for water supply. This has been proposed statewide through the Department of Water Resources' Bulletin 118 update.[189] While the first legislation regulating groundwater in the state, SGMA, was passed in late 2014, many of the groundwater basins in the Los Angeles region are managed through

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[189] From CA water action plan: California Statewide Groundwater Elevation Monitoring Program

adjudications that govern total extractions from the basins and oversee individual pumpers' rights to pump, store, or transfer water from the basins.

Groundwater basins are the single-most important asset to facilitating the movement of the City towards a more local and sustainable water supply. They supply readily accessible water storage capacity and infiltration can provide ancillary water quality benefits. In this section we will discuss potential opportunities in these groundwater basins to maximize their potential use to support greater local water supply, and assess the impacts of statewide policies such as Salt and Nutrient Management Plans (SNMPs) and SGMA on managing these basins.

Groundwater basins underlying the City provide opportunities to store advanced treated recycled water and captured stormwater for local use. However, contamination by legacy pollutants and complex political, legal, and regulatory environments present challenges that can constrict managers' ability to fully utilize this local water supply opportunity. The potential to expand groundwater use in the basins partially underlying the City, West Coast Basin (WCB), Central Basin (CB), Santa Monica Basin, Hollywood Basin, and the Upper LA River Area (ULARA) basins, was assessed during the watershed reports generated during this project (Figure 5.1).[190]

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[190] Sustainable LA Water Project reports, available at https://grandchallenges.ucla.edu/happenings/2015/11/13/100-local-water-for-la-county/

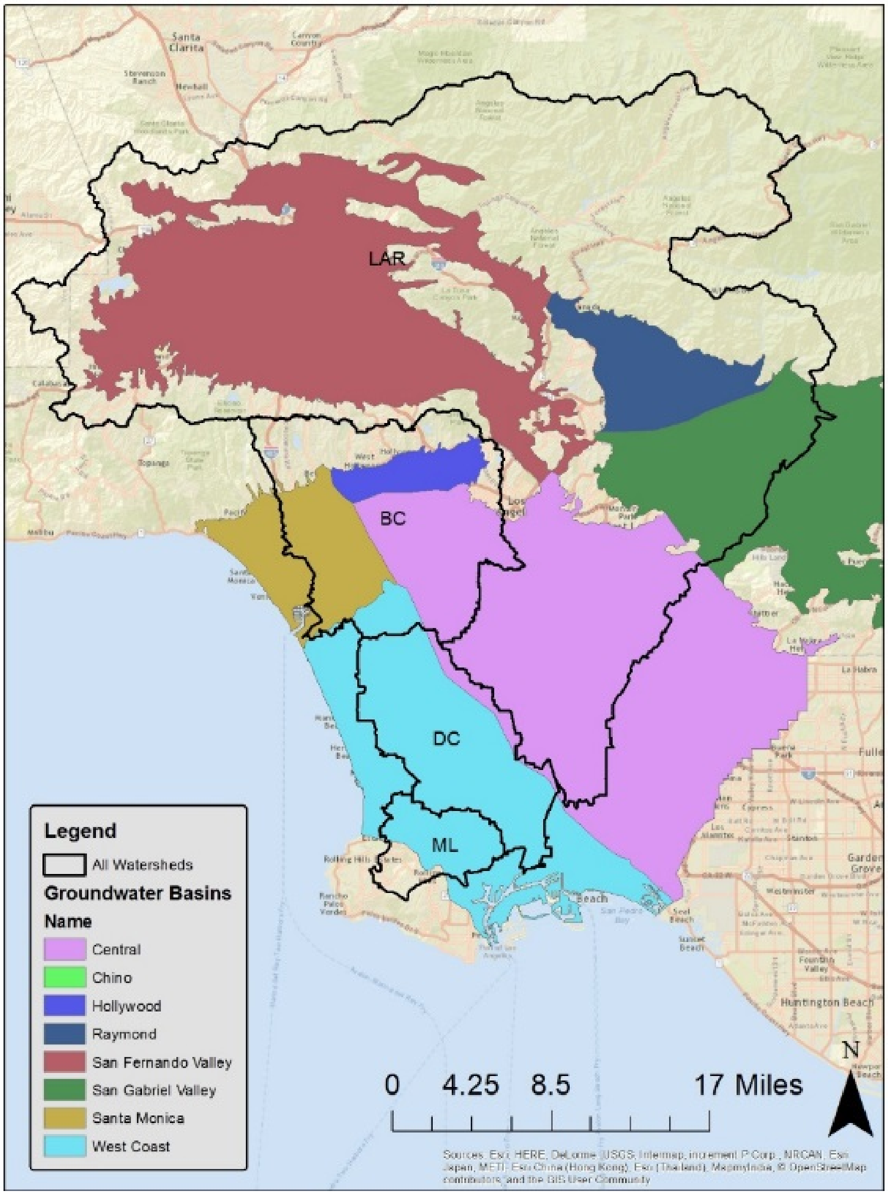

Figure 5.1: Groundwater Basins underlying the four watersheds.

B. Maximizing Conjunctive Use of Groundwater Basins

a. West Coast and Central Basins

There are several opportunities through which the City of LA can increase its utilization of WCBCB. First, the City must increase its capacity to extract the entirety of its groundwater pumping rights from WCBCB. The LADWP UWMP defined strategies to increase its capacity to pump its full groundwater pumping rights from CB through, for example, improvements at the Manhattan Well Field and the 99th St. Well Field.[191] LADWP is also evaluating opportunities to extract greater volumes from CB given the potential to accrue storage. The agency also intends to study options to restore groundwater pumping in WCB to be able to pump water from WCB again.[192]

As the City's ability to pump groundwater from these basins increases, the City can purchase or lease pumping rights from other rights holders in the groundwater basins to increase their groundwater pumping rights in WCBCB. The City has been purchasing pumping rights from other rights holders; in the last few years, the City's Allowed Pumping Allocation (APA) in CB has increased from 15,000 AFY to 17,236 AFY as a result of three purchase transactions.[193] An additional management strategy that the City could pursue, offering recycled water to industrial users in exchange for a lease on their groundwater pumping rights, was described in WRD's WCBCB Groundwater Basin Master Plan (GBMP). Approximately 29,000 AFY (25.9 MGD) of industrial rights were described in this potential WCBCB opportunity, including 22,500 AFY (20.1 MGD) of unused industrial rights and 6,600 AFY (5.9 MGD) of currently used industrial rights.[194] It may also be possible to lease (or purchase) the unused industrial rights without providing in lieu recycled water as those rights are not currently necessary for operations at those properties.

Further, the City can take advantage of opportunities to increase its storage capacity through individual storage space in WCB or to increase its capacity to extract additional groundwater from WCBCB through proposing water augmentation projects in which all rights holders in these groundwater basins would have the opportunity to participate. Identifying projects that would facilitate working with other jurisdictions with established City relationships through the DC EWMP process such as Carson, LA County, El Segundo, Hawthorne, Inglewood, Lawndale, and Lomita, would increase the potential volume of additional individual WCB pumping rights (including storage rights of 200% to up to 250%, with approval) to approximately 26,000 AFY.[195]

Water augmentation projects provide additional opportunities to increase the conjunctive use of these basins by providing an avenue to establish partnerships with potentially all other rights holders in the groundwater basins. Partnerships are critical to implement these multi-benefit projects so that both the costs and benefits can be shared among parties. A 2012 WRD study examined the feasibility of stormwater recharge through distributed and sub-regional stormwater projects and identified multiple catchments in which potential water supply benefits were the greatest and potential constraints were the lowest.[196] Pilot catchments resulted in the identification of multi-

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[191] draft LADWP UWMP 2015 P. 6-15, 6-16

[192] draft LADWP UWMP 2015 P. 6-15, 6-16

[193] LADWP UWMP 2015 P. 6-2

[194] WRD WCBCB GBMP draft PEIR 2015 p. 3-13, 3-14

[195] rights and storage capacities from WCB adjudication; DC EWMP compiled APA's to discuss potential water supply benefits of injected stormwater.

[196] The Council for Watershed Health, Geosyntec Consultants, and Santa Monica Bay Restoration Commission for WRD. Stormwater Recharge Feasibility and Pilot Project Development Study August 20, 2012 (Stormwater Recharge Feasibility Study 2012)

agency collaborations, one of which turned into the Broadway Neighborhood Stormwater Greenway Project in CB, and serves as an excellent example of potential partnerships that can result in implementing these types of projects.

The Broadway Neighborhood Stormwater Greenway Project was the result of a collaboration between LASAN, BoE (Bureau of Engineering), LADWP, WRD, and others, and began operation in 2015 in South Los Angeles along 47th Street, 47th Place, and 48th Street between Broadway and Main Street and along Broadway. It consists of a number of private and public infiltration BMPs that include rain gardens, dry wells, and ITs on 60 parcels; parkway swales and vegetated curb extensions on 3 residential streets and 2 blocks of commercial streets; and a sub-regional scale infiltration facility for 30 acres of mixed land use.[197] This implementation measure covers a 32-acre tributary area and is expected to capture 30 to 40 AFY from this combination of residential, commercial, and sub-regional BMPs.[198]

The Broadway project shows the potential for infrastructure improvements to improve water quality, but it is also being monitored to quantify the potential water supply benefits of infiltration. The additional priority catchments described in the 2012 WRD study provide an excellent starting point to plan future projects and identify partnerships that will provide the highest potential water supply benefit for early distributed or sub-regional stormwater projects. This could also help inform the process of implementing BMPs as discussed above in the stormwater section by providing information on which stormwater quality projects also offer the greatest potential water supply benefit (e.g., if a potential project is in a priority catchment). A study conducted by the U.S. Geological Survey in cooperation with WRD in late 2016 assessed recharge and runoff; this study and the associated daily precipitation-runoff model are additional important resources to better understanding how water moves through these basins.[199]

Finally, the legacy saltwater plume in WCB offers both a challenge and opportunity to the City and the region. Managing water quality issues associated with potential saltwater plume expansion must continue. But, it also presents readily implementable solutions. This brackish (saline) groundwater can be extracted and treated for use slowly over time. Example scenarios to remediate the plume include projects that could extract 15,000 to 20,000 AFY over the next 30 to 40 years. Additionally, as saline water is pumped, groundwater space becomes available for additional storage in WCB. The total estimated volume of this plume is approximately 600,000 AF (which is not currently included in the additional storage space identified through the adjudications in WCBCB). In the future as the plume is remediated, at least some of this additional space could

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[197] California Natural Resources Agency, Bond Accountability Website http://bondaccountability.resources.ca.gov/Project.aspx?ProjectPK=2735&PropositionPK=4, accessed on 6/13/2016

[198] "Neighborhood-Scale Water Quality Improvements The Broadway Neighborhood Stormwater Greenway Project" Stacy Luell, Geosyntec Consultants Co-Authors: R. Batchelder, W. Tam, M. Hanna, M. Sadeghi; Mar 30 2015; SNMP for Central and West Coast Basin 2015 Appendix J p. 42

[199] https://ca.water.usgs.gov/pubs/2016/Hevesi-recharge-runoff-los-angeles.html

be utilized for storing additional water, whether it be recycled water, increased stormwater, or excess imported water during wet years.

It is important to note that all of the above scenarios are subject to regulatory requirements, including those described throughout this and previous reports, that are necessary to protect water quality in both surface waters and groundwater. Further, implementing these projects will require partnerships and interactions among the multitude of jurisdictions and agencies that are involved in these projects. Site-specific constraints such as proximity to structures or utilities, existing contamination, risk for soil liquefaction, steepness, groundwater levels, or dewatering activities must also always be considered before implementing on-site projects.[200]

It is also necessary to demonstrate that the recharged water is 'new' water that would not otherwise have made its way into the groundwater basin through natural processes (e.g., advanced treated wastewater that would otherwise have been discharged to the ocean would qualify where diverted stormwater that would have fallen on pervious surfaces such as parks above the groundwater basin may not). It must also be verified that the recharged water is actually increasing the sustainable yield for that basin (e.g., that the water is reaching portions of the basin accessible for water supply). The conditions under which the relevant adjudications would allow rightsholders to extract the additional recharged water must also be identified.

However, implementing these types of projects will become easier over time as best practices emerge, results are monitored, and partnerships are established. Even now, projects exist that have been permitted for the recharge of recycled water into the groundwater basins through the barrier projects, and captured stormwater is being quantified from a water supply lens at the Broadway Neighborhood Stormwater Greenway Project. As these projects become more common, the regulatory and permitting framework will become clearer, practices more established for how to quantify the groundwater recharge benefits of increasing stormwater capture at a variety of scales, and collection and management of data will improve. Increased monitoring of these projects will be critical to better understand the impact of these projects on water quality as well as water supply for the City and others who wish to participate in these multi-benefit projects.

b. Upper LA River Area Basins

i. Planned and Potential Projects

ULARA overlies four distinct groundwater basins and includes the entire watershed of the Upper Los Angeles River. From largest to smallest, the basins are: San Fernando Basin (SFB), Sylmar Basin (SB), Verdugo Basin (VB), and Eagle Rock Basin (ERB). The City holds water rights in SFB, SB, and ERB. The City has rights to approximately 47,510 AFY of native safe yield

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[200] Stormwater Recharge Feasibility Study 2012 P. 13

(43,660 in SFB and 3,850 in SB).[201] But the City also has codified rights to as much as 91,070 AFY collectively of additional pumping when including the estimated “returns” to groundwater basins that result from using imported water to irrigate landscapes.[202] ERB does not have a safe yield; the safe yield is equal to the water imported by LADWP (ERB is incorporated into the 91,070 by contributing 500 AF).

ULARA is a critical source of groundwater for the City, comprising 89% (59,621 AFY) of its local groundwater supply on average from FY11 to FY15.[203] SFB is the largest source of groundwater for the City, of the 59,621 AFY extracted from ULARA, 58,741 AFY was extracted from SFB and 880 AFY was extracted from SB.[204] The basin, however, is potentially vulnerable. The estimates of native safe yield and recharge through returns are decades old. Currently, pumpers in the basin have agreed to voluntary cutbacks in pumping allocations to help replenish the large volume of available storage caused by groundwater overdraft.

LADWP has been unable to extract its full pumping rights of groundwater, in particular from SFB, due to the presence of contamination from historic uses of the overlying lands. To remediate ULARA basins and fully utilize its pumping rights, LADWP has conducted multiple studies and begun implementing projects and exploring partnerships such as: the Groundwater System Improvement Study (GSIS), the Mission Wellfield Improvement Project, and the groundwater interconnection project with Burbank Water and Power (BWP). Thus, multiple efforts are ongoing in the region to remediate contaminated groundwater and increase groundwater recharge to more fully utilize the ULARA basins to maximize their local groundwater supply potential.

More than 30,000 AFY of remediation efforts are ongoing in ULARA basins to address historical contamination issues and facilitate the full extraction of rights holders’ groundwater volumes in ULARA. These ongoing remediation projects (Table 5.1) are managed by multiple agencies with water rights in the ULARA Basins, including LADWP, Glendale, Burbank Water and Power, and the Crescenta Valley Water District (CVWD). Some projects, such as the interconnection project between BWP and LADWP, are joint efforts to increase the volumes of water that are treated to become part of the water supply of both participants.

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[201] ULARA judgement p.11 ‘3,850 AF native safe yield.’; There is some variation in how much of this volume LADWP can pump based on stored water credits etc: Sylmar Basin production will increase to 4,170 AFY from 2015-16 to 2038-39 to avoid the expiration of stored water credits, then go back to its entitlement of 3,570 AFY in 2039-40.’ p. ES-22 LADWP UWMP 2015. Using 3,570 AF for SB yields 47,230 AFY (instead of 47,510).

[202] LADWP UWMP 2015 p. 6-2

[203] LADWP UWMP 2015 p. 6-4, Exhibit 6B

[204] LADWP UWMP 2015 p. 6-4, Exhibit 6B

Agency	Current Remediation ULARA	Approx. treatment volume (AFY)[205]
LADWP/MWD	Tujunga Wellfield Treatment Study project	12,000
LADWP	North Hollywood Operable Unit	<1,300
Burbank	Burbank Operable Unit	10,000
LADWP/BWP	Burbank and LA Departments of Water and Power Interconnection Project	500-3,000
Glendale	North and South Operating Units	7,200
Glendale	Verdugo Park Water Treatment	0-300
CVWD	Glenwood Nitrate Water Treatment Plant	400
LADWP	Pollock Wells Treatment Plant	2,580
Total		33,500

Table 5.1. Ongoing remediation efforts in the ULARA groundwater basins.

In addition to the ongoing projects described above, there is an additional potential for almost 150,000 AFY of remediation to occur through pump and treat facilities in the ULARA basins through either currently planned projects or through reactivating facilities that are currently not operating or operating under their full capacity due to contamination (Table 5.2). For example, the Pollock Wells Treatment Plant has the capacity to treat approximately 4,700 AFY of VOC-contaminated groundwater, but only pumped 333 AFY in WY2012-2013 due to a need to characterize the growing presence of hexavalent chromium.[206] At up to 123,000 AFY, the groundwater treatment facilities LADWP is building in SFB (based in part on their GSIS efforts) will contribute the majority of the planned remediation volume. Although there may be some overlap among these projects, these current and planned remediation efforts together equate to over 150,000 AFY of remediated groundwater being extracted from the ULARA basins (for context, this is more than 1/4 of the 500,000 to 600,000 AFY that LADWP supplies each year).

Agency	Planned or potential remediation	Completion Goal	Potential Volume (AFY)[207]
LADWP	Mission Wells Improvement	2017	3,000 to 4,000
GWP/CVWD	Connect Rockhaven Well to Nitrate treatment plant	2018	500
LADWP	Pollock Wells Improvement	2020[208]	4,700
LADWP	SFB Treatment Facilities	2021	123,000
CVWD	Well 2 reactivation	n/a	240
Burbank	Burbank GAC Treatment Plant Reactivation	n/a	14,000
Total			145,440 to 146,440

Table 5.2. Planned or potential remediation in the ULARA basins.

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[205] LADWP UWMP Chapter 6 p. 6-10 & 6-11; ULARA Watermaster Annual Report WY 2013-14 (2017) p 3-12.

[206] ULARA Watermaster Annual Report WY 2012-13 (2014) p. 3-12

[207] ULARA Watermaster Annual Report WY 2012-13 (2014) p. 3-12 (Pollock); ULARA Watermaster Annual Report WY 2013-14 (2017) p. 3-13 (Burbank GAC); ULARA Watermaster TM No. 4 Draft for Salt and Nutrient Management Plan, March 2016 p. 41, 42 (SFB, Mission Wells, Rockhaven, Well 2)

[208] "San Fernando Groundwater Basin – Remediation Program Summary" on page 8. www.ladwp.com/remediation

In addition to the remediation efforts described above, which will greatly increase the volumes of water that can be extracted from the basin, there are multiple opportunities to increase the volumes of water being recharged into the basins to increase the amount of groundwater in storage. Ongoing improvement projects at spreading grounds that overlie SFB such as Tujunga, Hansen, Pacoima, Lopez, and Branford will greatly increase the volumes of recycled water and stormwater that can be recharged, as will sediment removal at Big Tujunga and Pacoima Dams. The main City-led recycled water groundwater recharge project that is already in progress will result in the recharge of up to 30,000 AFY of recycled water from DCTWRP to the Hansen and Pacoima Spreading Grounds when there is space available.

In addition to recharging recycled water, the City is planning to increase the recharge of stormwater into these basins to increase the groundwater levels and eventually be able to extract additional water in a sustainable way. As described earlier, the SCMP identifies conservative and aggressive goals by which the City can increase stormwater capture by 2035. These SCMP goals are 132,000 AFY (conservative) and 178,000 AFY (aggressive); both goals include 64,000 AFY of existing baseline stormwater capture. Stormwater capture potential identified in the SCMP for 2099 is even higher, at 258,000 AFY.[209] Regional efforts could also expand stormwater recharge into these basins; the LACFCD and USBR LA Basin Study considered both the enhancement of 15 existing spreading grounds (including those mentioned above) and the creation of 8 new spreading grounds. Potential locations for 8 new spreading grounds, including four in the San Fernando Valley, were identified in the LA Basin Study (Figure 5.2).[210] Building these spreading grounds would require acquiring 682 acres (approximately 1 square mile) and could result in an additional 29,930 AFY of stormwater recharge.[211]

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[209] LADWP SCMP p. 19

[210] LA Basin Study, Task 5, Appendix B, Regional Stormwater Capture http://www.usbr.gov/lc/socal/basinstudies/LABasin.html

[211] LA Basin Study, Task 5, Appendix B, Regional Stormwater http://www.usbr.gov/lc/socal/basinstudies/LABasin.html

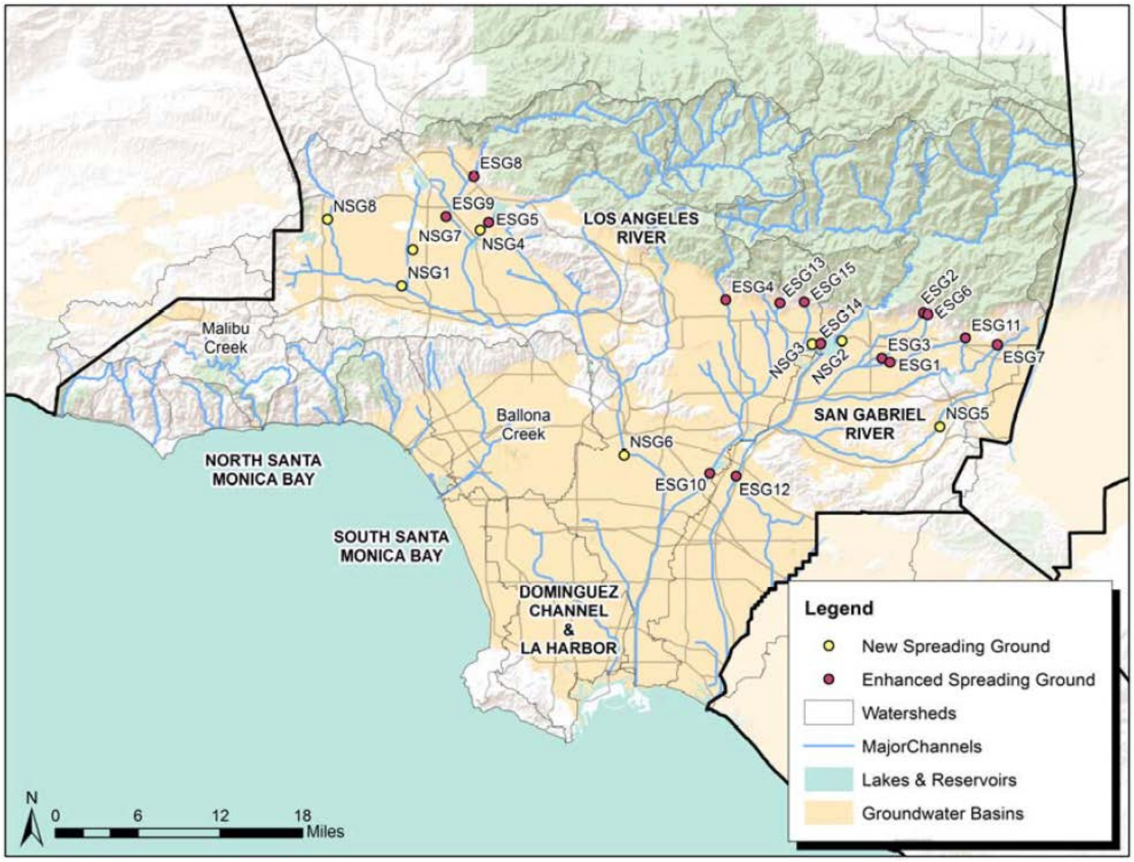

Figure 5.2. Figure from the USBR & LACFCD LA Basin Study showing locations for new and enhanced spreading grounds.[212]

Enhancing or creating new spreading grounds is one opportunity to increase the capacity to store and recharge water into ULARA. Working with the US Army Corps of Engineers (USACE) to identify if there are any opportunities to add storage capacity for water supply as well as flood control behind the Sepulveda Basin Dam is another. Both physical adjustments (e.g. 4 of the 8 gate openings are currently ungated) and political adjustments (an act of Congress would be required to provide funding and allocate space for both water supply and flood control, etc.,) would be required. Existing land uses and habitats must also be preserved. If all needs can be met, however, substantial flows from an approximately 150 square mile drainage pass through the Sepulveda Basin Dam. Even capturing some volume for storage that could then be pumped up to Hansen Spreading Grounds for recharge or to the DCTWRP to increase recycled water production could provide a substantial water supply benefit and merits further study.

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[212] LA Basin Study, Task 5, Appendix B, Regional Stormwater Capture http://www.usbr.gov/lc/socal/basinstudies/LABasin.html

ii. West San Fernando Basin

The potential to increase the conjunctive use of the western portions of SFB (mainly located west of the 405) could also be explored to identify any opportunities to increase additional use of these groundwater basins. However, there are many factors that must be considered in assessing potential in the western part of the basin. First, according to maps in the annual ULARA Watermaster reports, almost all of the water supply wells are located in the eastern part of the basin; wells in the western part of the basin are mainly dewatering or remediation wells (at sites such as Honeywell International, the Boeing Santa Susana Facility, Raytheon, and others).[213]

The presence of dewatering wells in this portion of the basin points to another important factor relevant to increasing the use of these basins, and in particular SFB. Groundwater levels in the western portion of SFB are significantly higher than those in the eastern portion. The depth to groundwater in SFB ranges between 24 and 400 feet; based on these contours, the groundwater flows are mainly from west to east and then southward towards CB. Looking at contour graphs of the 5 wells with hydrographs west of Interstate 405, groundwater levels in recent years have been less than 20 feet below ground surface in the wells that are farthest to the west (1,15) and between 200 and 250 feet below ground surface at the wells closer to Interstate 405 (2, 16, 17).[214] Along with shallow groundwater levels, the western portion of SFB is subject to rising groundwater levels, high liquefaction potential, naturally occurring high TDS, and finer sediments.[215] In FY2012-2013, the Reseda No. 6 Well in the western portion of the SFB had a TDS of 595 mg/L, [216] comparable to the salinity levels from Colorado River Aqueduct supplies.

As previously described, historical contamination in the eastern part of SFB (e.g., TCE, PCE, nitrates, and chromium) is significant and multiple planned or ongoing efforts are in process to pump and treat this water out of SFB. Any efforts to increase the use of groundwater in the western portion of SFB must not: impact remediation efforts, change net groundwater flows in the basin, impact pumping rights, or contribute to increases in already high groundwater levels in the western SFB. Although any increase in use of the western portion of SFB would be complex and may not currently be the most promising opportunity to expand on local water supply, the context is changing as the recent drought, increasing demand for local water supplies, and persistent water quality issues in the region provide an impetus to manage water differently. Many planned remediation efforts and the implementation of large-scale stormwater management plans such as the EWMPs will further slowly change the face of SFB and how it is managed and recharged. In addition, more distributed BMPs are likely to go in at single family homes and smaller properties throughout the basin, which may also impact groundwater levels, as the region moves towards capturing more stormwater locally.

An additional study to address opportunities to increase the use of the western portion of SFB is important to understand how to fully utilize the potential of this basin. The study should include assessing the impacts of increased distributed recharge on areas of shallower groundwater and how

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[213] ULARA Watermaster Annual Report, FY2012-2013. Plate 3. ULARA Location of Individual Producers.

[214] ULARA Watermaster Annual Report, FY2012-2013. P. 2-22 to 2-29

[215] MWD 2007 groundwater basin assessment reports

[216] ULARA Watermaster Annual Report, FY2012-2013 Appendix D. Representative Mineral Analyses of Water.

best to manage groundwater levels as the implementation of these types of projects becomes more frequent. The study should assess whether adding pump and treat capacity for moderately salty, shallow groundwater in the portion of the basin west of Interstate 405 could potentially increase the use of this water as well as create space in which to recharge water from additional stormwater capture projects. Regional examples of groundwater desalting such as the Calleguas MWD's Salinity Management Pipeline and associated treatment facilities and the Inland Empire Utility Agency's (IEUA) Chino Desalter and Inland Empire Brine Line, could inform whether pump-and-treat capacity is the most appropriate way to address salinity issues in the western half of SFB. In both the Calleguas and IEUA cases, brinelines allow for increased use of local brackish groundwater basins for local water supply and also remove salt from the watershed and basins by transporting the brine out of the area for discharge into the ocean.[217]

This study to examine the best opportunities to increase the conjunctive use of ULARA should also incorporate the flows of dewatered groundwater that are already being disposed of through the stormwater drainage system. For example, in a few areas of the SFB, the groundwater levels are close to the surface and pumping is required to artificially lower groundwater levels to maintain depths that are several feet below the bottom of the buildings or subterranean parking structures. In particular, this condition is present along Ventura Blvd on the south side of the SFB. Currently, building owners are required to meter the extracted groundwater, report the extractions to the Watermaster, and enter into an agreement with an affected rightsholder in the basin (such as the City) to pay for the extracted volumes.[218] For example, in FY 2012-1013, the BFI Sunshine Canyon Landfill dewatered 79.03 AF, Glenborough Realty dewatered 10.62 AF, and MWD dewatered 138.20 AF; the total dewatered volume charged to the City's water rights was 310.61 AF.[219] In most cases, this water is pumped out and sent to stormwater drains but it could be channeled either to on-site reuses or to the wastewater system for treatment and reuse.

Other aspects that could be included in the study include the potential to increase recharge to SFB through infiltration or runoff diversion BMPs in or adjacent to the LAR channel and its tributaries that would not interfere with flood control needs. SFB is a complex environment with multiple ongoing efforts to recharge, remediate, and manage the basin sustainably. Therefore, concerns such as the potential impacts on subsurface gradients of pumping more in the western portion of SFB should also be assessed to determine the potential to move the contaminant plumes west into the remaining operational supply wells and how these efforts might impact any ongoing or planned groundwater remediation activities. The City and other regional entities have conducted extensive research efforts such as the SCMP, GSIS, SNMP, LA Basin Study, RWMP, and many more that look at pieces of the puzzle that must be put together to maximize the conjunctive use of ULARA to reach its local water supply potential. Results from these studies should be

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[217] http://www.calleguas.com/images/docs-documents-reports/crsmpbroc.pdf; https://www.ieua.org/facilities/chino-desalters/

[218] ULARA Annual Watermaster Report FY 2012-2013 p. 1-31

[219] ULARA Annual Watermaster Report FY 2012-2013 Table 2-5: 2012-2013 Private Party Pumping – SFB

assessed, combined, and interpreted to identify opportunities to push the use of these basins forward while also preserving and improving their water quality and maintaining a sustainable yield.

C. Sustainable Yields and SGMA

As described above, many of the basins that underlie the City have been managed through adjudications, but groundwater management in California (for unadjudicated basins) as a whole is changing. Traditionally, groundwater has been governed by common law principles, under which landowners have been able to extract any amount of groundwater underlying their land and apply it to any reasonable use.[220] This has led to significant impacts statewide – declining groundwater levels, land subsidence, and groundwater quality degradation and salinization. In response to these impacts, many basins in Southern California have been adjudicated since the 1960s.[221] These basins operate under Watermasters that manage groundwater via court-imposed groundwater rights allocations. These allocations, or how much water can be pumped annually, are determined at the time of adjudication and are based on the concept of a basin safe yield. Generally, safe yield is defined as the maximum amount of water that can be extracted annually without exceeding natural replenishment from precipitation or interconnected surface water (e.g., MWD water).[222]

For those basins that did not undergo adjudication processes, a new groundwater management paradigm is beginning with SGMA, which became California state law in 2014. SGMA requires all non-adjudicated groundwater basins to establish Groundwater Sustainability Agencies (GSAs) that are tasked with developing groundwater management plans that promote long-term aquifer sustainability and regulate groundwater pumping. SGMA emphasizes the role of local GSAs, supported by regional and state expertise, to devise plans for managing and monitoring their groundwater resources. Respecting existing groundwater rights and preserving City- and County-level authority to manage their groundwater were core components of the law.[223] For GSAs that do not assemble effective governance structures, state agencies will step in.

Under SGMA, GSAs will manage annual groundwater use by determining their basin's sustainable yield, an extension of the concept of safe yield that is intended to prevent and remediate some of the dramatic impacts to groundwater basins seen statewide.[224] Sustainable yield serves as the primary mechanism to allocate annual groundwater use under SGMA and is comparable, but different, to safe yield allocations in adjudicated basins. SGMA defines "sustainable ground-

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[220] The Water Rights Process. State Water Resources Control Board. http://www.waterboards.ca.gov/water-rights/board_info/water_rights_process.shtml

[221] Groundwater Adjudication. Water Education Foundation. http://www.watereducation.org/aquapedia/groundwater-adjudication

[222] An Evaluation of California's Adjudicated Groundwater Basins 2016 p. 73

[223] https://www.opr.ca.gov/docs/2014_Sustainable_Groundwater_Management_Legislation_092914.pdf

[224] California Department of Water Resources. Best Management Practices for Sustainable Management of Groundwater. Water Budget BMP. 2016.

water management" in Water Code Sec. 10721 as "management and use of groundwater in a manner that can be maintained … without causing undesirable results.[225]" This departs from the classic definition of safe yield by focusing on more than just groundwater recharge and depletion, adding the requirement of mitigating undesirable results.

These varying concepts of how much groundwater can be extracted annually in a basin – safe yield and sustainable yield – are calculated by applying knowledge of basin hydrology and geology to groundwater models or water balances. Generally, annual basin safe and sustainable yields relate water extractions to groundwater levels. Yield calculations are often limited by the amount of well data available on a given basin. In addition to taking into consideration the relationship between groundwater well levels and annual groundwater use, safe and sustainable yields are both dependent on how much water infiltrates into, or recharges, groundwater in a given year.[226] Estimates of recharge from precipitation and interconnected surface water as well as artificial recharge from return flows and imported water also factor into yield calculations.

While the concept of sustainable yield is relatively new to California as a whole, basin adjudications have long applied varying forms of the concept of safe yield to determine annual groundwater allocations.[227] Earlier adjudication processes in LA devised many terms to describe various aspects of the potential pumping volumes that could promote long-term groundwater preservation. In particular, safe yield, operational safe yield, and native safe yield were all terms used in LA County groundwater basin adjudications to quantify aggregate pumping allocations.[228] These terms differ in their planning horizons and the management interventions considered (artificial recharge). Sustainable yield builds off of the idea of a basin safe yield by expanding on the definition of what constitutes undue damage to groundwater. Sustainable yield defines damages to groundwater basins from excessive pumping, termed "undesirable results" as chronic lowering of groundwater levels, loss of storage, land subsidence, decreased water quality, seawater intrusion, and reduced stream flow.[229] Adjudications of groundwater basins were often a response to these damages and an attempt to manage them, however the concept of safe yield did not formally include them in its definition.[230]

As described above, the City overlies a number of adjudicated groundwater basins, including WCBCB and four ULARA basins: SFB, SB, VB, and ERB (Table 5.3). The City also overlies two unadjudicated basins, Hollywood Basin and Santa Monica Basin (Table 5.4). It is estimated that there is approximately 520,740 AF of groundwater storage space available in SFB that "can

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[225] http://www.water.ca.gov/groundwater/sgm/definitions.cfm

[226] California Department of Water Resources. Best Management Practices for Sustainable Management of Groundwater. Water Budget BMP. 2016.

[227] An Evaluation of California's Adjudicated Groundwater Basins, University of California, Santa Cruz, 2016

[228] MWD Groundwater Assessment Study 2007 p. III-3

[229] California Department of Water Resources. Best Management Practices for Sustainable Management of Groundwater. Water Budget BMP. 2016.

[230] An Evaluation of California's Adjudicated Groundwater Basins 2016 p. 11

be used to capture and store additional native water or imported water supplies during wet (above-average rainfall) years.[231]"

	Native/Natural Safe Yield	Average Annual Extractions	Estimated Storage Volume
West Coast Basin	26,300 AFY[232]	64,468 AFY[233]*	6,500,000 AF[234]
Central Basin	125,805 AFY[235]	217,367 AFY[236]*	13,800,000 AF[237]
San Fernando Basin	43,660 AFY[238]	69,768 AFY[239]**	3,200,000 AF[240]
Sylmar Basin	7,140 AFY[241]	4,295 AFY[242]	310,000 AF[243]
Verdugo Basin	7,150 AFY[244]	5,082 AFY[245]	160,000 AF[246]
Eagle Rock Basin	n/a[247]	169 AFY[248]	unknown

**In the WCB and CB, adjudicated allowable extraction volumes were set higher than the estimated safe yields of the basins. Under the California Water Code, these basins are managed to make up for this overdraft through managed aquifer recharge.[249]*

***In the San Fernando Basin, the City of Los Angeles holds the exclusive right to extract the safe yield of the basin. In addition, the cities of Burbank, Glendale and Los Angeles can extract an amount equal to approximately 20 percent of delivered surface water.[250] The San Fernando Basin annual water balance includes a volume of managed recharge of, on average, 26,800 AFY that is infiltrated on spreading basins.[251]*

Table 5.3. Safe yields and extraction volumes in adjudicated groundwater basins

SFB experienced a long-term decline in groundwater storage, losing 108,245 AF between 1985 and 2004.[252] During WY 2012-2013, groundwater in storage in SFB decreased by 12,157 AF,

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[231] ULARA Watermaster Annual Report WY 2013-14 (2017) p. 2-34
[232] Groundwater Assessment Study, Metropolitan Water District of Southern California p. 4-3
[233] Water Replenishment District of Southern California Engineering Survey and Report 2016 p. 7.
[234] California's Groundwater Bulletin 118. Coastal Plain of LA Groundwater Basin, West Coast Subbasin, 2004
[235] Groundwater Assessment Study, Metropolitan Water District of Southern California p. 3-2
[236] MWD 2007 p. 3-4
[237] California's Groundwater Bulletin 118. Coastal Plain of LA Groundwater Basin, Central Subbasin, 2004
[238] Introduction to ULARA Groundwater Basins TM-1 SNMP Draft 2016 p. 16; ULARA adjudication 1979 p. 11
[239] Upper Los Angeles Area Watermaster, Annual Report. 2013. p. 31.
[240] MWD Groundwater Assessment Study 2007 p. 2-2
[241] Introduction to the ULARA Groundwater Basins TM-1 Draft for the SNMP 2016 p. 18
[242] Upper Los Angeles Area Watermaster, Annual Report. 2013. p. 31.
[243] Upper Los Angeles Area Watermaster, Annual Report. 2013. p. 33.
[244] MWD Groundwater Assessment Study 2007 p. 2-3, Table 2-1
[245] Upper Los Angeles Area Watermaster, Annual Report. 2013. p. 31.
[246] MWD Groundwater Assessment Study 2007 p. 2-3, Table 2-1
[247] ULARA adjudication
[248] Upper Los Angeles Area Watermaster, Annual Report. 2013. p. 31.
[249] Groundwater Assessment Study, Metropolitan Water District of Southern California p. 3-4
[250] Groundwater Assessment Study, Metropolitan Water District of Southern California p. 2-5
[251] Groundwater Assessment Study, Metropolitan Water District of Southern California p. 2-3
[252] MWD Groundwater Assessment Study 2007 p. III-16, Table III-6

which followed a similar 10,338 AF decrease in WY 2011-2012.[253] These decreases are generally associated with the below-average rainfall received and the corresponding decrease in stormwater available for infiltration at spreading grounds. Groundwater in storage in SFB decreased by much more, 59,010 AF, in WY 2013-14 as there was an increase in SFB groundwater extraction in another low rainfall year that limited stormwater spreading.[254]

	Native/Natural Safe Yield	Average Annual Extractions	Estimated Storage Volume
Hollywood Basin[255]	3,000 AFY[256]	968 AFY[257]	400,000 AF[258]
Santa Monica Basin	7,500 AFY[259]	10,038 AFY[260]	1,100,000 AF[261]

Table 5.4. Safe yields and extraction volumes in non-adjudicated groundwater basins

Groundwater levels in SB appear to be rising according to measurements from key wells, while measurements from VB key wells demonstrate a long-term decline. ERB had insufficient data to make a determination.[262] WCBCB saw a 27,101 AF increase in storage between 1985 and 2004, a less than 0.5% change.[263] SGMA requirements, including drafting a Groundwater Sustainability Plan (GSP), will apply to Santa Monica Basin and also to the northern portion of CB, which is not included in the area covered by the CB adjudication and thus falls under SGMA.

Tables 5.3 and 5.4 detail the safe yields, annual extraction volumes, and estimated storage capacities in the region's groundwater basins. Varying management strategies among the adjudicated basins have allowed for annual extractions that exceed natural safe yield values – namely through artificial recharge. In CB, for example, the natural safe yield (synonymous with native safe yield) was calculated as the maximum amount of water that can be extracted annually without exceeding "natural replenishment," or recharge from precipitation, interconnected surface water, or subsurface flow.[264] The managed safe yield of the basin is a higher allowable yield that takes into account the increased water stored in the basin through artificial recharge. This yield was equal to the APA amount of 217,357 AFY and is the yield under which CB currently operates.[265] Within SFB and SB, the adjudicated parties (including the City) also have the right to recharge

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[253] ULARA Watermaster Annual Report WY 2012-13 (2014) p. 1-34

[254] ULARA Watermaster Annual Report WY 2012-13 (2014) p. 1-34; ULARA Watermaster Annual Report WY 2013-14 (2017) p. 1-33

[255] California's Groundwater Bulletin 118. Coastal Plain of LA Groundwater Basin, Hollywood Subbasin, 2004

[256] MWD Groundwater Assessment Study 2007 p.6-2, Table 6-1

[257] Average based on 2015 and 2010 Urban Water Management Plans, City of Beverly Hills.

[258] MWD Groundwater Assessment Study 2007 p.6-2, Table 6-1

[259] MWD Groundwater Assessment Study 2007 p.5-2, Table 5-1

[260] City of Santa Monica. Sustainable Water Master Plan. 2014.

[261] California's Groundwater Bulletin 118. Coastal Plain of LA Groundwater Basin, Santa Monica Subbasin, 2004

[262] MWD Groundwater Assessment Study 2007 p. III-16, Table III-6

[263] MWD Groundwater Assessment Study 2007 p. III-16, Table III-6

[264] An Evaluation of California's Adjudicated Groundwater Basins 2016 p. 73

[265] MWD 2007 p. 3-4

groundwater into the basin and extract the equivalent amount.[266] The parties can also choose to reduce their pumping and store, or "carry over," any unused water rights into future years.[267]

Local water managers are already considering how local groundwater resources can decrease dependence on imported water. WRD is taking steps to increase local water supply in WCBCB through various projects developed under the Water Independence Now (WIN) program. The WCB and CB adjudications permit a pumping rate that exceeds the estimated native safe yield, but requires WRD to make up the deficit with "artificial" water recharge, a source that has historically been mainly comprised of imported water. In WY 2015-16, for example, the annual groundwater pumping in the WCB and CB, as managed by WRD, was 214,367 AF, and natural inflows from surface water, storm water infiltration, and subsurface flows totaled 104,316 AF.[268] WRD supplemented groundwater recharge with imported and recycled water that totaled 110,051 AF, bringing the total managed and natural inflows in WY 2015-16 to 214,367 AF and resulting in a loss of groundwater storage of 500 AF.[269] CB's and WCB's baseline operations function under an APA that incorporates artificial replenishment; the current and planned composition of replenishment sources and WRD's plans to move away from imported and towards local water to recharge WCBCB are discussed in greater detail in our previously released DC watershed report.[270]

In both SGMA-eligible and adjudicated basins, a large part of basin management is regulating how much water should be extracted and recharged in a given year. Determining the safe yield of a basin enables groundwater basin management entities to work toward the ultimate goal of sustainable operation. This goal ensures that in the long-term, the recharge and extraction of groundwater are balanced. One approach for groundwater basin management could be maintaining a fixed maximum amount of groundwater extraction above safe yield from year to year by ensuring supplemental recharge volumes. Another strategy could be to establish an annual operational safe yield that allows for variations in groundwater extraction based on hydrologic conditions.

There are many reasons that the idea of a fixed safe yield can be problematic in understanding and managing groundwater resources. The main difficulties lie in that there are an "excessive number of factors" that are neither fully captured by groundwater models or water budgets, nor easily quantifiable.[271] There is also the argument that some groundwater systems are not and cannot be made sustainable.[272] Safe yield also fails to take into account the potential physical impacts

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[266] Introduction to the ULARA Groundwater Basins TM-1 Draft for the SNMP 2016 p. 17

[267] ULARA Watermaster Annual Report 2014 p. 2-32

[268] WRD Engineering and Survey Report 2017, Water Replenishment District, p. 12

[269] WRD Engineering and Survey Report 2017, Water Replenishment District, p. 16.

[270] Mika K. et al, Sustainable LA Water Project: Dominguez Channel and Machado Lake watersheds. Available at: http://escholarship.org/uc/item/2w1916p4

[271] Kalf, F. et al. 2005. Applicability and methodology of determining sustainable yield in groundwater systems. *Hydrogeology*. 13:295-312

[272] Kalf, F. et al. 2005. Applicability and methodology of determining sustainable yield in groundwater systems. *Hydrogeology*. 13:295-312

of storage depletion and declining groundwater levels that could directly impact the utility of local water sources.

Sustainable yield incorporates secondary physical impacts of groundwater extraction through the concept of "undesirable results." Where safe yield is primarily focused on extraction and recharge, sustainable yield requires consideration of groundwater levels, storage volumes, water quality, salinity, streamflow depletion, and land subsidence. As groundwater agencies develop, they must determine what constitutes an undesirable level for each of these potential secondary impacts or "undesirable results.[273]" These levels are termed threshold values. Because these thresholds can directly impact the amount of water extracted in a given year, SGMA mandates these thresholds must be determined locally.[274] By connecting these thresholds to extraction amounts, groundwater managers can manage more than just water volumes, they can manage to preserve water quality, prevent salinization of aquifers, lessen interconnected surface water depletion, and prevent subsidence that would remove future storage capacity.

Determination of these thresholds for basins subject to SGMA is not required until 2020, but threshold values can potentially dramatically impact the amount of water extracted in a basin. The City can ensure the success of the sustainable yield concept in the SGMA-eligible groundwater basins in which it is a participant by encouraging the following across all involved groundwater management agencies: 1) development and maintenance of adequate monitoring networks for groundwater levels, storage, water quality, land subsidence, streamflow, and salinity; 2) annual analysis of the relationship of these "undesirable results" to sustainable yield and readjustment of thresholds, if necessary; 3) inclusion of threshold values into the management structure of adjudicated basins.

The success of sustainable groundwater management will directly impact the region's ability to depend on local water sources. The implementation of SGMA will require the City to work with other parties and develop a GSP to manage the Santa Monica and Hollywood groundwater basins by determining annual groundwater allocations and artificial recharge strategies through the concept of sustainable yield. The overall shift in groundwater management statewide presents an opportunity not only for the City but also for other regional groundwater basins to develop a comprehensive groundwater management strategy for the region as a whole. This type of strategy could embrace the idea of groundwater resources as a source of local storage (via stormwater capture) as well as a source of local water supply (e.g., increased groundwater extraction as a result of increased stormwater and other water recharge).

One potential mechanism to develop a regional groundwater strategy that should be explored is for the SWRCB and RB4 to convene a regional groundwater coordinating group with the goal of maximizing storage from stormwater and recycled wastewater. This group would include both groundwater management agencies and regulators to discuss a regional, better managed approach to maximize sustainable yields from our groundwater basins through, for example, increased

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[273] California Department of Water Resources. SGMA Definitions. http://www.water.ca.gov/groundwater/sgm/definitions.cfm

[274] California Department of Water Resources. Best Management Practices for Sustainable Management of Groundwater. Water Budget BMP. 2016.

stormwater recharge and recycled water infiltration or even injection (advanced treatment). In addition, the group would utilize GSPs and SNMPs where they have been developed. This group could also look at groundwater rights and their further transfer to public use and public entities, the costs of purchasing private water rights, and the potential to substitute certain water rights with recycled water (e.g., the industrial water rights leasing program described earlier). The overarching goal should first be to ensure that all cities have access to groundwater. Then, groundwater should be managed to maximize local self-reliance regionally and foster the ability to transfer and share groundwater resources as needed.

Critical data gaps exist that must be addressed to tie the volumes of stormwater captured and recharged to the volumes of groundwater that can then be extracted in a sustainable manner. As described previously, the modeled annual average flows in 2007 were 10,000 AF in the DC Watershed, 40,000 AF in the BC watershed, and 100,000 AF in the LAR watershed, the driest year modeled and one of the driest years on record (Table 3.26). Even after implementing BMPs to capture the 85th percentile storm in the DC watershed, which has the lowest available volume of the three watersheds, approximately 8,600 AF would have been available for recharging to WCB or CB (or other opportunities to capture and reuse this stormwater). However, more work needs to be done to more accurately understand how and where water hitting the land surface makes its way to groundwater basins. This is particularly critical for quantifying the amount of stormwater recharge into basins currently being used for water supply; accurate accounting of all inflows will impact the calculated sustainable yield for these basins. In Los Angeles, more research needs to be done to quantify the contributions to groundwater storage annually from precipitation-induced recharge and streamflow as well as from potential water available for artificial recharge.[275]

D. Salt and Nutrient Management Plans

As described in more detail in the BC and DC watershed reports, the California Recycled Water Policy requires the development of SNMPs for groundwater basins. The SNMPs are intended to ensure that the quality of the water in the groundwater basins is maintained at acceptable levels and in accordance with anti-degradation requirements as more groundwater recharge with recycled water occurs. The WCBCB SNMP was completed by WRD in collaboration with major stakeholders in these basins in early 2015; a Basin Plan amendment based on the SNMP was adopted and the WCBCB SNMP was finalized in February 2015.[276] At the time of this writing, the ULARA SNMP was being developed under the lead of the ULARA Watermaster to assess the impacts on salt and nutrient conditions of increasing the recharge of both recycled water and stormwater.[277]

SNMPs in both WCBCB and ULARA include larger scale, centralized, stormwater capture (such as at spreading grounds overlying the basins) and recycled water projects (such as the 30,000

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[275] Hevesi, J.A., and Johnson, T.D., 2016, Estimating spatially and temporally varying recharge and runoff from precipitation and urban irrigation in the Los Angeles Basin, California: U.S. Geological Survey Scientific Investigations Report 2016-5068, 192 ; Department of Water Resources. Water Available for Replenishment – Draft Report. 2017. p. 38.

[276] http://www.wrd.org/saltnutrient/

[277] Current status and available tech memos can be downloaded here: http://www.ularawatermaster.com/SNMP

AFY groundwater recharge project using recycled water from DCTWRP) in their modeling analyses. These modeling analyses provide insight on the impacts of planned projects on the concentrations of salts and nutrients across the groundwater basins to ensure that compliance with anti-degradation requirements is maintained. In WCBCB, planned projects were not found to result in excessive degradation of the basin; ULARA modeling results were still being finalized at the time of this writing. In general, distributed BMPs such as those that will be built as part of the EWMP implementation process over the coming years were not included in the modeling results. These distributed BMPs, however, were generally expected to result in lower concentrations but higher loads of nutrients and salts in the groundwater basins. This stems from the fact that stormwater is generally lower in nutrients and salts than the existing groundwater basins but any addition of salts and nutrients from infiltrated water will still result in increased basin loads.

In addition to ensuring that water quality requirements are met, SNMPs are valuable tools to identify opportunities to co-locate recycled water and stormwater recharge projects as stormwater can provide valuable dilution for recycled water that meets CCR Title 22 water quality level. Many of the planned projects, however, include the recharge of advanced treated recycled water and would not need the additional dilution as the water quality from this type of recycled water is excellent and the salt and nutrient concentrations are lower than baseline conditions in WCBCB. The ability to include stormwater capture may allow the use of a lower water quality recycled water without degrading groundwater quality. This opportunity to dilute tertiary treated water could potentially reduce the energy footprint of recharging higher quality recycled water into the groundwater basins because tertiary treatment has a lower energy footprint than advanced water treatment technologies.

The SNMPs are an iterative process; updates to the WCBCB SNMP will be assessed at least every 10 years and more frequently as needed or as new data is gathered that can offer further refinement on the modeling predictions. Another gap that must be addressed is: what quantity of applied irrigation in the heavily urbanized LA area is percolating through to the groundwater and what nitrate concentration increases are likely as a result? For example, return flow water quality in the WCBCB SNMP was based on the assumption that only 3.6% of applied irrigation percolates to groundwater.[278] Further, nitrate concentrations were calculated based on a net loading of fertilizer to groundwater of 8.9 pounds of nitrogen per acre with a 45 pounds/acre loading rate and a nitrate attenuation of 90% based on a mixing model calibration.[279,280] These rates were determined by a study conducted by the University of California, Davis in the Tulare Lake Basin and the Monterey County portion of the Salinas Valley. The land uses in the City are significantly different from the Tulare Lake Basin and Salinas Valley study area, which is predominantly irrigated cropland and includes four of the nation’s five counties with the largest agricultural production

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[278] SNMP for Central and West Coast Basin 2015 Appendix I, p. 33

[279] SNMP for Central and West Coast Basin 2015 Appendix I, p. 33

[280] Assessing Nitrate in California’s Drinking Water, Report for the State Water Resources Control Board Report to the Legislature, Technical Report 2: Nitrogen Sources and Loading to Groundwater 2012 Center for Watershed Sciences, University of California, Davis

and a population of approximately 2.65 million.[281] This 3.6% irrigation return flow assumption is generally on the conservative side of the range of irrigation return flows from agricultural lands or vegetables and flowers (3% to 20%) observed in the relatively few studies that were found on this question of return flow.[282] Importantly, these studies did not address return flows in urban areas. This highlights a need for more research in urban areas to better understand these irrigation return flows and how they transport constituents (e.g., salts and nutrients) into and through these basins.

WRD, the United States Geological Survey (USGS), and others are conducting ongoing research to better characterize the connections between surface water and subsurface hydrology to understand where drops of water go in the basin after they hit the surface as precipitation or are captured and infiltrated through distributed BMPs. This information has critical ramifications not only for understanding the more localized impacts on salts and nutrient concentrations in the groundwater basins, but also for quantifying the captured water as a water supply benefit. If infiltrated stormwater at the surface does not make it to water supply basins, then no additional water rights can be granted and it is harder to fund and implement projects as satisfying both of these critical water management needs in the City and the Los Angeles region. The lack of information regarding the connection between the surface and the groundwater in general and specifically in the Los Angeles region presents a challenge to determining the potential water supply benefits of stormwater recharge and the potential water quality benefits from co-locating stormwater recharge with recycled water recharge projects. All efforts to gather additional data and/or continue refining modeling efforts to address these questions will greatly enhance the region’s ability to conduct this type of analysis and site projects in the most appropriate locations for all potential benefits.

Future work at UCLA with Colorado School of Mines and USGS includes the development of a coupled surface-groundwater model for the southern Los Angeles County region that will be used to identify areas that are most conducive for stormwater infiltration and groundwater augmentation based on current land use, underlying geologic formations, and potential for stormwater capture (BMP/LID configurations). High resolution maps could be produced identifying the extent of groundwater water recharge potential at each cell (660 feet per side) within each watershed using a gradational “credit” score to support future project prioritization. Specific sites will be identified as prime areas for distributed and regional LID approaches as well as large scale infiltration projects. There is critical need to know how much of each infiltrated AF becomes supply. This coupled model will be the first to quantify potential new water supplies from infiltrated groundwater through stormwater capture. These more advanced estimates of augmented groundwater volumes could lead to opportunities for stormwater infiltration project proponents to apply for additional funding from water supply agencies for providing new, local supplies.

The SNMPs that have been completed and approved to date demonstrate that these plans are very helpful to quantify the impacts of planned projects on groundwater basin water quality. They

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[281] Assessing Nitrate in California’s Drinking Water, Report for the State Water Resources Control Board Report to the Legislature, Technical Report 1: Project and Technical Report Outline 2012 Center for Watershed Sciences, University of California, Davis p. 4

[282] Sukhija et al. 1996; Combined estimation of specific yield and natural recharge in a semi-arid groundwater basin with irrigated agriculture by J.C. Marechal et al. Journal of Hydrology. 329 (2006) pg. 281-293; “Quantifying Return Flow to Groundwater: What’s in the Tool Box?” Southern Illinois University Carbondale 2006.

further show that the region can recharge significantly larger volumes of recycled water and stormwater than are currently being recharged while remaining in compliance with California anti-degradation regulations. The impacts of large scale recharge projects and how recycled water, imported water, and stormwater blend are well-understood at large-scale, centralized infiltration projects (such as spreading grounds). Additional work needs to be done, however, to understand and simulate the potential impacts on water quality and local water supply of ramping up distributed recharge as well as identify the most promising locations and combinations of projects to maximize both the water quality and supply benefits.

VI. Conservation

A. Introduction

Water conservation is an often affordable urban water demand management option that is highly responsive to annual droughts.[283] In Los Angeles, it also plays a critical role in creating a metropolitan region that primarily depends on locally sourced water. Many efforts, both statewide and local, have been implemented over the past few decades to encourage water conservation both indoors and outdoors. These efforts have resulted in relatively stable regional urban water demand in past decades despite rapid population growth over the same time period. Additional conservation, including boosts in turf replacement funding, were undertaken to rapidly reduce water demand during recent drought.

In October 2014, Mayor Eric Garcetti released Executive Directive 5, which called for a 20% reduction in overall per capita water use from a July 2014 baseline of 130 gpcd to 104 gpcd by January 1, 2017.[284] This goal was met in January 2017; per capita water use was at 104 gpcd.[285] Then, in April 2015, the Governor issued Executive Order B-29-15, which directed the SWRCB to take a variety of actions to help California conserve water; this included a mandatory 25% urban conservation rate across California.[286] However, this requirement was recently relaxed to allow urban water suppliers to set their own conservation rates. As a result, it is critical to identify opportunities locally to maximize conservation and continuee the progress made under mandatory conservation requirements.

In addition to the conservation goals in Executive Directive 5, the Mayor of Los Angeles set a 25% conservation requirement in the pLAn that must be met by 2035 for the City.[287] This goal is for overall use; it is also important to measure and track residential use. One of the requirements

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[283] Hanak et al 2011

[284] Executive Directive 5, City of LA. https://www.lamayor.org/sites/g/files/wph446/f/page/file/ED_5_-_Emergency_Drought__Response_-_Creating_a_Water_Wise_City.pdf?1426620015

[285] Progress on 2017 pLAn outcomes http://plan.lamayor.org/portfolio/local-water/

[286] https://www.gov.ca.gov/docs/4.1.15_Executive_Order.pdf

[287] pLAn p. 20

of the statewide water conservation program (that larger urban water suppliers report their data to the SWRCB monthly) has resulted in the generation of a database of residential gallons per capita per day (r-gpcd) that allows the tracking of water conservation efforts.[288] For example, Los Angeles residents used an average of 79 r-gpcd in May 2017, down from 88 r-gpcd in May 2013, according to the State Water Resources Control Board (SWRCB).[289] Overall annual use in LA for 2016 and 2017 (not just residential but also including additional industrial, commercial, and institutional end-uses), however, was approximately 104 gpcd.

Conservation efforts to date have been further enhanced by turf replacement programs subsidized by rebates (through agencies such as LADWP or MWD) that have resulted in landscape replacement as quickly as funding becomes available. To build on and maintain the impressive strides in conservation to date, much more needs to be done. There are multiple avenues to increase water conservation, ranging from installing advanced metering infrastructure or submeters, implementing water neutrality ordinances, encouraging the installation of water-efficient devices, expanding education and outreach programs, and minimizing non-revenue losses. A current UCLA Grand Challenges research project is expanding on this analysis to incorporate a broader swath of conservation practices and quantify actual water savings from implemented programs where possible. A white paper highlighting recommendations for LA County to maximize its water conservation effort based on this additional research is expected in 2018. In this section, we will examine a subset of these opportunities to further increase water conservation.

B. Water Demand

As mentioned above, water use can be measured in a variety of ways, including overall per capita use (in which total demand from all uses, industrial, residential, commercial, etc. is divided by the total population) and water demand for separate use categories (e.g., residential). Different metrics complicate comparisons, especially in combination with the variability of conditions across cities. There is also a need to better understand the patterns of water use across sectors and geographies. Further, it can be challenging to differentiate between indoor and outdoor water use; this is a critical gap that must be filled to make informed policies to increase conservation efforts.

The City, compared to even its regional neighbors, shows the potential for greater water conservation. Current language in CA State Bill 606 (Water Management Planning) calls for a provisional standard of 55 gpcd for indoor residential water use.[290] LADWP should aim for an annual indoor average of 55 gpcd by 2020 and 45 gpcd by 2035 for SFR and for 40 gpcd by 2020 and 30 gpcd by 2035 for MFR above 4 units. Sufficient outdoor water to maintain outdoor trees would

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[288] http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/docs/2017jul/supplierconservation_070517.pdf

[289] May Supplier Conservation Data, http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/docs/2017jul/supplierconservation_070517.pdf accessed 07/05/17

[290] SB 606 Water Management Planning Skinner and Hertzberg. 2017-2018. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB606

represent an additional 9-25 gpcd plus approximately 2-5 gpcd per property for landscapes.[291] While this will require a significant additional increase in conservation, it has been successfully implemented elsewhere and is doable here.

In Melbourne, for example, demand started at 121 gpcd at the beginning of the Millennium drought and by the end of the drought was averaging about 65 gpcd for all land uses.[292] In 2005, residential use in Melbourne dropped even lower, to about 40 gpcd.[293] Similarly, in Adelaide, water demand dropped from around 87 gpcd in 2003 to about 60 gpcd in 2009.[294] Local examples exist of this level of conservation as well. Santa Cruz, for example, averaged 46 r-gpcd, and Long Beach used 65 r-gpcd. Demand in Lynwood dropped from 82 r-gpcd in May 2013 to 33 r-gpcd in May 2017; Torrance saw a drop from 114 r-gpcd to 49 r-gpcd in the same time period.[295] In a very wet January 2017, r-gpcd for LA was at 53.[296]

Reductions in outdoor water use offer significant potential for reducing demand. Outdoor water use, particularly in the SFR sector, is estimated to account for over 50% of total residential water use.[297] LADWP's Water Conservation Potential Study, released in late 2017, identified landscaping irrigation as an area with the most potential to increase water savings at both residential and commercial / industrial / institutional (CII) land uses.[298] As the SFR sector is LADWP's largest customer group (approximately 450,000 accounts),[299] the City must develop a more detailed understanding of indoor and outdoor water use needs across the diverse areas of the city. This principally involves understanding water consumption in relation to indoor use habits and outdoor landscapes. Monthly billing data must be combined with irrigated, non-irrigated, and impervious area data (a land cover database available from high resolution satellite imagery and aerial

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[291] Porse, Erik, Kathryn B. Mika, Elizaveta Litvak, Kimberly F. Manago, Kartiki Naik, Madelyn Glickfeld, Terri S. Hogue, Mark Gold, Diane E. Pataki, and Stephanie Pincetl. "Systems Analysis and Optimization of Local Water Supplies in Los Angeles." Journal of Water Resources Planning and Management 143, no. 9 (2017): 04017049.

[292] Treepeople (2016), Transferring Lessons from Australia's Millenium Drought to California: Accelerating Adaptation to Drought, Flood and Heat.

[293] Cahill, R and Lund, J. "Residential Water Conservation in Australia and California" Journal of Water Resources Planning and Management Technical Note (2013).

[294] Treepeople Lessons from Australia 2016 P. 19

[295] May Supplier Conservation Data, http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/docs/2017jul/supplierconservation_070517.pdf accessed 07/05/17

[296] January Supply Conservation Data http://www.waterboards.ca.gov/water_issues/programs/conservation_portal/docs/2017mar/suppliercompliance_030717.pdf

[297] Mini, C., T.S. Hogue, and S. Pincetl, 2014: Patterns and Controlling Factors of Residential Water Use in Los Angeles, California, *Water Policy*, 16, 1054-1069; Mini, C., T.S. Hogue, S. Pincetl, 2015: The effectiveness of water restriction policies on single-family water use in Los Angeles, California, *Resources, Conservation and Recycling*, 94, 136-145

[298] https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB620807&RevisionSelectionMethod=LatestReleased Cooling towers and condensate were identified as large indoor opportunities at CII land uses and clothes washers for residential land uses.

[299] LADWP Water Conservation Potential Study Presentation, 2015 https://www.watersmartinnovations.com/documents/sessions/2015/2015-W-1524.pdf

photography at high spatial resolution, or County LARIAC data) to identify outdoor land cover. Further, adding urban vegetation greenness, which can be estimated using the NASA Landsat Thematic Mapper 5 satellite data that provides remote sensing products at 30 m resolution every 16 days, enables the analysis of greenness and greenness change in relation to water use (NDVI).

NDVI is a readily available and highly scalable product. It can be estimated for various geographical boundaries, including smaller census tracts or larger neighborhoods, revealing trends over time. Using water delivery records (water use by parcel), along with the Landsat NDVI product, outdoor water use by area can be estimated.[300] These calculations require 3 end members that each distinctly represent NDVI values from homogeneous land cover types: irrigated landscaping, non-irrigated landscaping, and impervious areas.[301] While the approach is data intensive and requires modeling expertise, new tools and data are quickly evolving to make such methods more accessible for water utilities.[302] For example, numerous researchers at UCLA, CSM, and elsewhere are currently investigating changes in NDVI in both protected natural areas and urbanized areas in LA County. A more direct method that can also provide the customer with needed information about their water use is to install dual meters for indoor and outdoor water measurement where possible, including new residential and CII buildings. With dual meters, the City would be able to communicate directly to the customer the amount of water used outdoors, and also introduce differential pricing for indoor, and essential water use, from outdoor water use.

Residential properties constitute more than half of water demand in the City; approximately 66% of water demand in the City from 2011-2014 stemmed from SFR and MFR uses.[303] Institutionalizing processes to characterize landscape change over time using remote sensing would enable the City to evaluate the impact of water use change on urban vegetation. This should be coupled with research that determines ET at the detailed geographic scale to support the development of effective and achievable per capita water use targets, particularly if the City prioritizes the maintenance of existing tree canopy cover that evolves over time to include a greater mix of native and drought tolerant species. This transition will be, of course, slow, and will require the nursery industry to provide trees that are climate appropriate, and to grow the palate of native low water trees that is available. Availability of tree stock is a major constraint today. There are also developments for state-wide water efficiency targets and water budgets (e.g., parcel-based water budgets) occurring through implementing Governor Brown's Executive Order B-37-17, 'Making Water Conservation a Way of Life.[304]'

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[300] Mini C., Hogue T.S., Pincetl S., 2014. Estimation of residential outdoor water use in Los Angeles California. Landscape and Urban Planning 127: 124-135.

[301] Johnson, T. D., & Belitz, K. (2012). A remote sensing approach for estimating the location and rate of urban irrigation in semi-arid climates. Journal of Hydrology,414, 86–98. http://dx.doi.org/10.1016/j.jhydrol.2011.10.016

[302] see Mini et al (2014) for methods

[303] LADWP UWMP 2015, p. 2-3

[304] http://www.water.ca.gov/wateruseefficiency/conservation/docs/20170407_EO_B-37-16_Final_Report.pdf

Ordinances offer another powerful tool to reduce water demand. The City of LA has adopted several water conserving ordinances, including an emergency water conservation plan ordinance, a high-efficiency plumbing fixture ordinance, and a citywide water efficiency standards ordinance.[305] The emergency water conservation plan ordinance provides a mandatory water conservation plan and adopts provisions to reduce the consumption of water over time (since voluntary conservation efforts had been found insufficient). One section of this ordinance deals with the unreasonable use of water, and states that SFR customers that enter the highest rate tier during Phase II-VI (phases of water conservation) may be subject to a water use analysis performed by LADWP.[306] After receiving an onsite water use analysis, customers will get a plan that includes a visit summary, recommendations to improve their water use, and a monthly water budget. If the onsite water use analysis finds the property is violating the Ordinance's unreasonable use of water prohibitions, then the customer must stay within the water budget. Penalties for not complying with the customer's plan start at $1,000 per month and can go up to $4,000 per month with continued non-compliance (under Phase 2 water use restrictions). Penalties increase in higher phases and, for example, could be as high as $40,000 per month under the severe water use restrictions in Phase V of the ordinance.[307]

C. Water Neutral Urban Growth

Ensuring that the City can accommodate future population growth without increasing the need for new water requires innovative strategies. Cities and counties across the US have been developing 'water demand offset' policies, such as water neutral urban growth, to mitigate the impact on the total water demand in a utility service area.[308] Water neutrality or net zero water policies and programs involve offsetting new water demand by investing in water conservation to ensure no new water is required for new development. Some California examples include the cities of Santa Monica, Napa, Morro Bay, and San Luis Obispo County. Areas of Massachusetts and New Mexico have also instituted such policies, showing that it is a strategy that spans climates.[309]

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[305] https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-water/a-w-conservation/a-w-c-ordinance-andcodes?_adf.ctrl-state=14rio7yjlp_4&_afrLoop=975366597415542

[306] Emergency Water Conservation Plan Ordinance. Effective May 3, 2016. https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=LADWP004832&RevisionSelection-Method=LatestReleased (link goes to pdf)

[307] LADWP to begin enforcement of unreasonable water use ordinance on City's top water users; October 6, 2016 http://www.ladwpnews.com/ladwp-to-begin-enforcement-of-unreasonable-water-use-ordinance-on-citys-top-water-users/

[308] Alliance for Water Efficiency, Water Offset Policies for Water-Neutral Community Growth: a literature review and case study compilation. 2015

[309] Alliance for Water Efficiency, Water Offset Policies for Water-Neutral Community Growth: a literature review and case study compilation. 2015

New development in water neutral programs can minimize on-site demand and facilitate off-site actions to increase supply or reduced demand elsewhere in the supplier's service area.[310] Water neutral policies and programs are predicated on sound methodologies for estimating water demands of new development and for calculating credits resulting from the savings of on- and off-site water efficiency measures. These can include mitigation programs or fees for mitigation. For example, Denver Water allocates saved water to supply storage.[311]

Higher offset ratios than 1:1 may be required to ensure that water neutrality is achieved as many factors require further study. For instance, variability in demand estimates or diminishing efficiency of water saving fixtures over time all affect demand of new sites. In another example, the impacts on actual water consumption of implementing a graywater system for on-site use are highly variable and additional research is required to quantify the actual water savings of these systems.[312] The state of Massachusetts recommends at least a 2:1 ratio for mitigation as 1:1 simply preserves the status quo in already water-scarce areas and measuring gains from water offset measures is often imprecise.[313] Thus, a safe strategy is to aim for a 2:1 ratio. LADWP would need to develop methodologies for estimating water demands of new development based on transparent and accepted measurement of water use by different types of buildings to implement a water neutral policy; this could potentially build on the method used by LADWP in their UWMP to conduct Water Supply Assessments for larger developments.[314] San Francisco's water demand calculator and Santa Monica's water neutrality ordinance and compliance approach may also provide a good starting point for LA.

Among other benefits, water neutral programs can facilitate development in times of water shortage when new water connections may not otherwise be allowed, provide a means to bring conservation to low income residents, provide incentives for the private sector to support and develop new conservation technology and techniques, and incentivize quantitative approaches to demand management that will in turn improve how water is managed.[315] An issue of concern with such water neutral programs can arise if developers pass along increased construction costs to residents or businesses purchasing properties. It is also possible that water neutral programs only delay the impacts of additional water demand; appropriate water neutral programs must be tailored specifically to each jurisdiction to identify the best program to balance these costs and benefits.[316] In addition, sufficient data must exist and be accessible to the agency implementing the ordinance to be able to set targets and assess progress towards the goals. In large, complex governance structures such as the City or County of LA, all departments with data that would inform this

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[310] Harder, Jennifer, Demand Offsets: Water Neutral Development in California (March 1, 2015). McGeorge Law Review, Vol. 46, No. 1, 2014. Available at SSRN: https://ssrn.com/abstract=2600288

[311] Denver Water 2011

[312] Harder, Jennifer, Demand Offsets: Water Neutral Development in California (March 1, 2015). McGeorge Law Review, Vol. 46, No. 1, 2014. Available at SSRN: https://ssrn.com/abstract=2600288

[313] Alliance for Water Efficiency, Water Offset Policies for Water-Neutral Community Growth: a literature review and case study compilation. 2015

[314] LADWP UWMP 2015, Chapter 11, Water Supply Assessments. P 11-28

[315] Harder, Jennifer, Demand Offsets: Water Neutral Development in California (March 1, 2015). McGeorge Law Review, Vol. 46, No. 1, 2014. Available at SSRN: https://ssrn.com/abstract=2600288

[316] Harder, Jennifer, Demand Offsets: Water Neutral Development in California (March 1, 2015). McGeorge Law Review, Vol. 46, No. 1, 2014. Available at SSRN: https://ssrn.com/abstract=2600288

ordinance (e.g., Building and Safety, LADWP) would need to establish data-sharing practices to successfully design and implement an LID ordinance.

There are multiple strategies to implement such a program, including the creation of a dedicated water fund or banking mechanism with a clear nexus to the new development's needed water use. Offset fees can also be banked to fund efficiency programs in the same service territory based on, for example, water use per bedroom. This could also include retrofitting the landscaping and irrigation systems of City public spaces, such as parks. It could also involve a subsidy to replace leaky plumbing and old plumbing fixtures with high efficiency fixtures in low cost housing. Or even install Advanced Metering Infrastructure systems (perhaps with indoor and outdoor meters) to reduce leaks and water demand. Also, such funds might be applied to expanding purple pipe infrastructure for recycled water. In addition, there could be water use credits for the expanded use of existing connections through on-site efforts using fixture unit count values. Cost-in-lieu retrofits as well as water use credits could be used to fund stormwater capture or wastewater reuse programs. Developers might also choose to implement on-site water recycling and reuse or graywater use, entirely mitigating the need for new water in either their development or off-site. These mechanisms would have to be examined for their costs, feasibility, and nexus to water neutrality, but all have been implemented in other cities and localities. It is important to note that these policies mainly target new developments with some potential conservation offset investments in established areas.

In a local example, Santa Monica's water neutrality ordinance requires new water demand to be offset at a ratio of 1 to 1, but includes more lenient requirements for low income housing, at an offset ratio of 0.5 to 1.[317] If the required water offset cannot be achieved onsite, then offset requirements can be met through payment of an in-lieu fee or implementation of offset requirements off the building site. This ordinance applies to new developments that include buildings with plumbing fixtures, existing buildings with plumbing fixtures where more than half of the exterior walls are demolished, or new water features (pools, spas, etc.). Between 60 and 100 projects per year are expected to be required to comply with this ordinance.[318]

The baseline water demand threshold would be calculated by Santa Monica based on the five-year average water demand of the existing property. Santa Monica will also adapt San Francisco's water demand calculator, which will show comparisons of projected water demand based on different choices (plumbing fixtures, landscape, etc.) that will provide data for most development projects. A program will be available to provide technical design assistance and identify new technologies that could help applicants achieve water neutrality.[319] Santa Monica has also implemented a water demand mitigation fee that is designed to fund water efficiency measures to offset

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[317] http://santamonicacityca.iqm2.com/Citizens/Detail_Meeting.aspx?ID=1093

[318] Santa Monica Staff Report Water Neutrality Ordinance; http://santamonicacityca.iqm2.com/Citizens/Detail_Meeting.aspx?ID=1093

[319] Santa Monica Staff Report Water Neutrality Ordinance; http://santamonicacityca.iqm2.com/Citizens/Detail_Meeting.aspx?ID=1093

100% of the projected new demand of new development. This fee is charged to SFR remodels that increase square footage by more than 50%, MFR remodels that add dwelling units, and non-residential construction that changes water use or plumbing fixtures, adds seats in a restaurant, or increases the size.[320]

D. Dewatering

In certain parts of the City, dewatering must take place due to high levels of groundwater. For example, in a few areas of the SFB, groundwater levels are close to the surface and pumping is required to lower groundwater levels to depths several feet below buildings or subterranean parking structures. In particular, this condition is present along Ventura Blvd on the south side of the SFB. Building owners in the adjudicated basins of ULARA are required to meter the extracted groundwater, report the extractions to the ULARA Watermaster, and enter into an agreement with an affected rights holder in the basin (such as the City) to pay for the extracted volumes.[321] For example, in FY 2012-2013, the BFI Sunshine Canyon Landfill dewatered 79.03 AF, Glenborough Realty dewatered 10.62 AF, and MWD dewatered 138.20 AF; the total dewatered volume charged to the City's water rights was 310.61 AF.[322] In most cases, this water is pumped out and sent to the stormwater drains. In addition, numerous developments in the LA Basin from mid-Wilshire to the westside (Metro Purple Line, numerous developments with underground parking lots) also have extensive dewatering efforts. The quantity of water this represents is poorly quantified, but sending it to the ocean in storm drains is wasteful.

This policy is a legacy from the past and the water in these high water table areas should be (and is starting to be) considered as a potential part of the water supply. A City ordinance passed in April 2016 requires that "*Where groundwater is being extracted and discharged, a system for onsite reuse of the groundwater shall be developed and constructed. Alternatively, the groundwater may be discharged to the sewer.*[323]" This effort to start capturing and reusing this water rather than wasting it to the oceans should be rigorously pursued and enforced. The City is encouraged to develop funding programs to quantify flows at all dewatering sites of all sizes and types and identify opportunities to ensure the water can be recaptured for use. The LA County Metropolitan Transportation Authority (Metro) should be required to work with the City to capture and reuse as much of the dewatered water as possible from their public transportation projects. Potential mechanisms to use this water include sending the water to WRPs so it can be treated and reinjected into

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[320] Alliance for Water Efficiency, Water Offset Policies for Water-Neutral Community Growth: a literature review and case study compilation. 2015. http://www.smgov.net/Departments/PublicWorks/ContentAdminSvcs.aspx?id=10809

[321] ULARA Annual Watermaster Report FY 2012-2013 p. 1-31

[322] ULARA Annual Watermaster Report FY 2012-2013 Table 2-5: 2012-2013 Private Party Pumping – SFB

[323] City of LA Ordinance 184248, Effective June 6 2016. http://clkrep.lacity.org/onlinedocs/2015/15-0458_ORD_184248_6-6-16.pdf

groundwater near the plants or replumbing the location such that the buildings can use the water on site for non-potable uses (e.g. toilets, irrigation, cooling towers).

E. Conservation Impacts on Urban Stream Flow

Imported water has significantly altered the timing and volume of streamflow in urban Los Angeles. A recent study on the BC watershed showed runoff ratios above one (more streamflow than precipitation) prior to the implementation of conservation policies in the late 2000s, indicating that outdoor water use resulted in a significant contribution of water to urban streams.[324] Evaluation of water use during periods before and during conservation mandates showed a major decrease in streamflow in Ballona Creek with an average annual drop of 95 mm (36% of total flow).[325] The largest decreases occurred during the summer, where a decrease of 20.8 mm (69% of summer streamflow) was observed, compared to the winter decrease of 18 mm (16% of winter streamflow).

Diurnal cycles are also altered, with a slight shift to earlier daily peak streamflow noted. Since outdoor water use has been the primary target of water conservation efforts, it is likely that prior to conservation efforts, over-watering of lawns and other outdoor water use practices were contributing to streamflow in the highly urbanized areas across the City. The difference between summer streamflow pre- vs. during-conservation in the Ballona Creek watershed is enough to serve 160,000 customers annually in LA.[326] If LA returns to more watering days, educating the public on proper irrigation rates is critical for ensuring efficient irrigation and conserving water.

F. Impact of Irrigation on Evapotranspiration and Urban Temperature

Irrigated landscapes also have significant impacts on urban temperatures and feedback to the local atmosphere. Recent work demonstrates significant sensitivity of surface turbulent fluxes to the incorporation of irrigation. Introducing anthropogenic moisture to vegetated pixels results in significant increases in latent heat flux and decreases in sensible flux, confirming the irrigation-induced shift in the energy partitioning toward elevated latent heat fluxes.[327] Anthropogenic moisture contribution (i.e. irrigation) is mostly partitioned into ET and subsurface runoff. The heavily vegetated surfaces show the highest ET rates (87.08 mm month^{-1} over low intensity residential pixels) as highly developed surfaces produce lower ET rates (29.68 mm month^{-1} over industrial/commercial pixels).

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[324] Manago, K., and T.S. Hogue, 2017: Urban streamflow response to imported water and water conservation policies in Los Angeles, California, *JAWRA Volume 53, Issue 3 June 2017 Pages 626–640*

[325] In the Manago, K., and T.S. Hogue, 2017 paper, the flow was normalized to area to compare between Ballona and Topanga so the units are in depth.

[326] Manago and Hogue 2017. 20.8mm depth runoff difference = 13.8 MGD = 15,456 AFY

[327] Vahmani, P., and T.S. Hogue, 2015: Urban Irrigation Effects on WRF-UCM Summertime Forecast Skill over the Los Angeles Metropolitan Area, *JGR Atmospheres*, DOI: 10.1002/2015JD023239

The cooling effects of irrigation on near surface air temperature are also evident over various urban types, with the largest influence over low intensity residential areas (average of 1.64 °C decrease) and the smallest influence over industrial/commercial areas (average of 1.12 °C decrease).[328] The impact of irrigation on the urban energy and water cycles in arid and semi-arid regions is significant and results in significant cooling. Changes to landscapes to reduce urban vegetation and related water consumption may also impact urban temperatures, and more studies are needed to evaluate vegetation cover types (native and non-native) and related ET and urban temperature response.

G. The Language of Los Angeles' Landscapes

Cities in the Southwest such as Albuquerque and Las Vegas have achieved a sea change in landscaping aesthetics and practices. They have recognized their water-limited environment and reached into the plant palate native to those regions to vegetate their public spaces, from parks to median strips, and they have encouraged the private sector to do the same. As a result, outdoor water use has plummeted, but in addition, the landscaping reflects their climatic zone and the cities have an intrinsic identity and sense of place.

Los Angeles has seasons; it has its own patterns that tend to be obscured and erased by habits of outdoor irrigation and the importation of exotic plants. Clearly that is part of the attractiveness of the region: just about anything will grow given enough irrigation. But in the water-scarce semi-arid climate that characterizes the region, the increased reliance on imported water and the uncertainty of future supplies, it is now time to embrace the landscapes that have evolved to thrive in this area. LADWP needs to lead a cultural shift in expectations about landscapes in the city. LADWP should work with Recreation and Parks and the Bureau of Street Services to design and install landscapes on public properties throughout the City that include predominantly California native plants and landscape infrastructures that capture and reinfiltrate stormwater.

The City should embrace its bio-region and the beauty of its native plants. This will require a huge commitment and cultural shift to accepting that summers are dry and the plants adapted to these conditions can become seasonally brown, gray, yellow, and subtle colors of green. Just like people do not expect deciduous trees to have leaves in the winter, southern California's vegetation has adapted to the hot summer months in myriad ways. The landscape palate now needs to reflect LA's location. The City can lead this effort by growing natives in its nurseries and developing co-funded collaborative landscaping programs with pertinent City departments. Pricing outdoor water appropriately and attractive examples of landscaping with California natives, will help residents to shift to climate appropriate landscaping. This has been effectively done in Las Vegas and in Albuquerque, among other cities.

While developing the above recommendations, LADWP should enforce Executive Order B-29-15, whicht requires residential properties implement water efficiency measures to reduce potable water use. Ornamental turf should be replaced by native or Mediterranean climate plants on

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[328] Vahmani, P., and T.S. Hogue, 2015: Urban Irrigation Effects on WRF-UCM Summertime Forecast Skill over the Los Angeles Metropolitan Area, *JGR Atmospheres*, DOI: 10.1002/2015JD023239

public street medians. All outdoor irrigation should be delivered by drip irrigation or microspray systems that are regulated by soil moisture sensors. No automatic sprinklers that are not triggered by soil moisture information should be allowed.

LADWP should also enforce the State Model Water Efficient Landscape Ordinance and continue to provide turf replacement incentive funding for residents and businesses. One potential pathway to transform landscapes to be more water-efficient at older properties could be requiring landscape changes upon ownership transfer (perhaps supported by incentives). LADWP should continue their use of the watershed approach to provide turf replacement rebates only for properties whose new landscapes include California-Friendly plants that cover over 50% of the area, mulching to retain soil moisture, and rain capture features (e.g., rain barrel, vegetated swale, infiltration trench). Artificial turf should continue to be ineligible for City program funds.[329] It does not support healthy ecosystems and it can contribute to stormwater runoff and contamination. Further, artificial turf increases local heat gain and may contain toxic substances and shed plastic pellets. LADWP should also collaborate with and fund groups in the region providing new landscaping expertise, plants, educational courses, and job training. Courses for the garden maintenance sector that provide certificates in low water/native plant installation and maintenance that also include the use of electric or manual maintenance equipment should also be subsidized.

The maintenance of tree canopy in the City is an important climate mitigation investment to reduce the urban heat island. This will, however, require a far more rigorous approach to street tree selection, sourcing, and maintenance. If a tree is to provide shade, it must have a large canopy and access to water. LADWP will have to work closely with the Bureau of Street Services, the Mayor’s office, and other city agencies to implement a coordinated new approach to the City’s street trees, including choosing large canopy, drought tolerant trees that are placed in public median strips in ways that mitigate their exposure to traffic and damage. This will require revising the codes and conventions currently used regarding street tree placement. Also, the value of the trees to enhance LA’s urban ecology needs to be a factor in tree selection. Further, the City needs to develop a funding stream to ensure high quality maintenance of this infrastructure to ensure it is functional. Finally, LADWP and the Bureau of Street Services should start experimenting with using different plant material for different locations to reduce urban heat islands and building heat, including vertical plantings of vines, California native shrubs and small trees, and other vegetation.

H. Water Pricing

Pricing mechanisms such as tiered rates have been shown to be among the most effective mechanisms to reduce water consumption.[330] Governor Brown’s Executive Order B-29-15 also

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[329] LADWP Cash In Your Lawn informational booklet: https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB621607&RevisionSelectionMethod=LatestReleased

[330] Olmstead, S. M., W. M. Hanemann, and R. N. Stavins. 2007. “Water Demand under Alternative Price Structures,” *J. Environ. Econ. Management* 54 (2): 181–98.; Baerenklau, K, K. Schwabe, and A. Dinar. 2014a. “The Residential Water Demand Effect of Increasing Block Rate Water Budgets.” *Land Economics*. 90 (4): 683□99. ; Olmstead, S., and R. Stavins. 2008. “Comparing Price and Non-Price Approaches to Urban Water Conservation.” Discussion Paper 08-22, Resources for the Future.

directed the SWRCB to promote water conservation pricing mechanisms by directing urban water suppliers to develop rate structures and other pricing mechanisms that would be consistent with the statewide water use restrictions. Setting tiered water rates in CA is a complicated endeavor due to Proposition 218, a voter-approved initiative in 1996 that limited local government agencies' ability to raise rates without a clear nexus between the fees and the increased cost of service.

This complexity was never clearer than in April 2015, when the ruling on the San Juan Capistrano (SJC) case, in which the Capistrano Taxpayers Association sued the city of SJC for poor justification of a tiered water rate structure as required by Proposition 218, was finalized. During the same month, Governor Brown's directive was issued to the SWRCB to promote water conservation mechanisms that could include a broader use of tiered pricing. The SJC case is the most recent chapter in a series of court decisions around this question of how and where water rates fall under Proposition 218 requirements.[331] The court found that SJC had failed to demonstrate that the assigned tiers corresponded with the tiers of service, but also found that tiered rates themselves could be compatible with Proposition 218.[332]

Therefore, as described in more detail in a paper published as part of this research, it is still possible to set tiered water rates that are linked to cost of service and thus potentially more defensible from Proposition 218 lawsuits.[333] A few examples of best practices in rate-setting are described here; please see Mukherjee et al., 2016 for greater detail and discussion. First, setting rates that are based on different sources of water supply in the portfolio (e.g., advanced treated recycled water, local groundwater, etc) can be an effective way of assigning higher rates to higher demand customers as higher demand can lead to the need to tap into more expensive sources. Setting rates based on costs associated with the production (e.g., building a WRP), treatment (e.g, adding new advance treatment trains), storage, supply, and distribution (e.g., building new pipelines) is another potential option.

Rates can be set based on a longer timeframe of capital cost or through considering the costs of water conservation and efficiency programs. An alternate approach to ensure rate stability is incorporating fixed costs as a higher percentage of water rates so that agency revenues are not so tightly linked to consumption. Another approach to water pricing is to develop water budgets per capita based on numbers of persons in the household, an approach used in Orange County. This approach has been very successful in reducing water use while maintaining affordable indoor water rates.[334] Throughout all of these rate-setting mechanisms, it is of paramount importance that rates

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[331] Kelly Salt 2016

[332] Kelly J Salt (2016) Adopting Conservation-Based Water Rates That meet Proposition 218 Requirements. League of California Cities, May 4 2016 General Session, https://www.cacities.org/Resources-Documents/Member-Engagement/Professional-Departments/City-Attorneys/Library/2016/Spring-2016/5-2016-Spring-Adopting-Conservation-Based-Water-Ra.aspx

[333] Mukherjee M, Mika K, Gold M, (2016) Overcoming the Challenges to Using Tiered Water Rates to Enhance Water Conservation, The CA Journal of Politics and Policy. http://escholarship.org/uc/item/9d19z2f8

[334] Mukherjee M 2016 http://escholarship.org/uc/item/9d19z2f8

are proportional to the cost of service as required under Proposition 218, and the rates must be justifiable and clearly linked to the costs of supplying water.[335]

LADWP currently has a tiered pricing system that was updated in April 2016 after the first rate increase in seven years was approved. The average annual water rate adjustments for the time period of the rate increase, 2016 to 2020, is 5.26%.[336] Low-Use, Typical, and High-Use Residential volumes are 8 hundred cubic feet (HCF) / month, 12 HCF / month, and 27 HCF / month, respectively.[337] In FY 2014-2015, SFR rates had two tiers depending on usage, $4.96 and $5.90 per HCF (748 gallons) of water. As of April 15, 2016, as part of the 2016 to 2020 rate increase, the number of SFR tiers was expanded to four to both better align with the costs of service (as determined by the 2015 LADWP Cost of Service Study) and encourage water conservation.[338] In 2016, Tier 1 through 4 prices ranged between $4.61 and $7.52 per HCF.[339] MFR and Commercial, Governmental, and Industrial rates still consisted of 2 tiers. The 5-year water revenue needs for this time period was estimated by LADWP as $330 million, 78% of which is required for infrastructure improvements for reliability and water quality projects. Conservation will also require funding, but it is not included in this cost estimate as the costs of increasing conservation are expected to be offset by the decrease in purchased water as demand decreases.[340]

Tiered pricing has been shown to be highly effective at encouraging water conservation; DWP should look at a more steeply inclined rate structure in the near future. The Irvine Ranch Water District (IRWD) has developed a successful rate structure that could provide a good starting point for this rate study. A few components of IRWD's rate structure are described here; please see the article developed through this research for additional information on this and other regional examples of tiered rates.[341] IRWD employs a unit cost service-based approach to rate setting, in which the functional cost is divided by the number of billing units (in 100 cubic feet) of the projected water sales in the tier or tiers to which a functional cost is attributed. The rate for the low-volume tier is based on the lowest-cost water supply source and the regular conservation cost. In addition to the conservation cost, the cost of imported water and water banking are incorporated into the inefficient-tier rates, with the wasteful tier being the most expensive.

Forecasting water sales and purchases is another important component of the IRWD rate setting process; the forecast cost for water purchase is compared to the forecast revenue and rates are set to recover the cost. In addition, IRWD follows an allocation-based tier structure designed to

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[335] Mukherjee M 2016 http://escholarship.org/uc/item/9d19z2f8
[336] http://www.myladwp.com/2016_2020_rate_request
[337] http://www.myladwp.com/2016_2020_rate_request
[338] http://www.myladwp.com/2016_2020_rate_request
[339] https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-financesandreports/a-fr-waterrares/a-fr-wr-scheduleresidential?_adf.ctrl-state=1dmhku6lht_4&_afrLoop=73790368450546, http://www.myladwp.com/2016_2020_rate_request
[340] LADWP Water System Rate Action Report, available here
[341] Mukherjee M 2016 http://escholarship.org/uc/item/9d19z2f8

recover commodity costs in which customers receive individualized water allocations based on their defined reasonable indoor and/or outdoor needs. Allocations are based on property characteristics and include factors such as the number of occupants, size of irrigated area, and local climate data, based on the IRWD cost of service approach. Excessive and wasteful tiers were combined into a single wasteful tier (anything at or above 131 percent) in the 2015 rates.[342]

I. Data Needs

While the pLAn establishes an overall gpcd goal (98.25 gpcd by 2035), the City has not established spatially granular water baselines by land use type (SFR, MFR, commercial, institutional, and industrial) across its service territory by climate zones or addresses. Doing so would enable the City to understand consumption variability across the region by coupling water use with socio-demographic data, including, for example, renter/owner, number of residents, and income. In the commercial and industrial sector, water use could be coupled to industrial classification codes to determine the type of industry and what kinds of water conservation initiatives would be appropriate. Further, such a database would identify firms that may have introduced BMPs that could be replicated in the sector. With no baseline and limited ability to track water use over time, it is very difficult to accurately calculate water use per capita or by commercial or industrial sector and to keep track of changes over time.

To develop a spatially referenced baseline of water use will require the ability to match billing data to County Assessor parcel data, including parcel and building size, census data, and industrial classification code information, as well as commercial and institutional land use identification. With this data, it would be possible to conduct analyses by climate zone, industry type, household characteristics and lot size, and water prices. In addition, additional water reporting and mapping is necessary to ascertain the results of the 2016 water pricing tiers on water use by geographical location, land use, parcel size, and socio-economics.

VII. Financing Alternatives for Integrated Water Management[343]

A. Introduction

California has faced difficult constraints in financing public projects over the past several decades. California voters approved a series of constitutional reforms, starting with Proposition 13 in 1978, and followed by Proposition 218 in 1996 and Proposition 26 in 2010. These reforms have made it increasingly difficult for local water agencies and other governmental agencies to raise

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[342] IRWD Cost of Service Study, June 2015. https://www.irwd.com/images/pdf/about-us/Finance/IRWD%20Cost%20of%20Service%20%20-%20Final%20%20062215.pdf

[343] This section was largely drafted by Jim Henderson and Bob Raucher of Abt Associates as UCLA's consultants on the Sustainable LA Project; edits were made by this report's authors text to add additional detail and discussion.

funds from local ratepayers. The reforms have also set up stricter requirements for new local and state taxes to support public projects. These restrictions have been enacted at the same time that the availability of federal funding has declined under federal budget pressures.[344]

The water sector has historically relied heavily on locally generated revenues. Changes from the constitutional reforms severely limited local governments' ability to use property tax revenues that had previously been an important source of revenue. And these measures leave considerable uncertainty about which types of charges may be adopted as fees and which must be enacted as taxes. Direct voter approval, often with a two-thirds voter majority, is required for any charge that now qualifies as a tax, and voters must also directly approve many fees.

Water supply and wastewater utilities have been the least affected, in large part owing to their exemption from having to gain direct voter approval of rate increases. But flood protection and stormwater agencies must now get direct voter approval for fees related to flood protection and stormwater pollution reduction, and the burden is high for showing the direct connection to each parcel, such as by showing the depth of flooding. As an alternative, the flood control agency can try for a two-thirds majority popular vote or a majority vote of parcel owners on a special tax to support flood control and stormwater management activities. And for stormwater agencies, the burden is high because it is difficult to show proportionality of the costs to benefits on each property for stormwater control.[345] However, this burden may be lowered based on the recent California Supreme Court decision,[346] which stated that conducting an initiative process to obtain signatures from 15% of the County's population to place the funding measure on the ballot would result in the need for only a simple majority of votes to pass (rather than the 2/3 majority if placed on the ballot by local governments).[347] The application of this ruling may occur as early as 2018 for the LA County clean water measure vote in November.

In 2014, AB2403 clarified the definition of "water" to include improvements for producing, storing, supplying, treating, or distributing water from any source. As a result, stormwater management, groundwater augmentation, water conservation, and similar activities have been added to Proposition 218's definition of water. The effect is to add these activities to the list of originally exempted services including sewer, water, or refuse collection services.[348] As a result, stormwater projects that augment water supply could potentially raise funds through water rate increases. However, at the time of this writing, not one utility has attempted to increase water rates to cover

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[344] Hanak, E., B. Gray, J. Lund, D. Mitchell, C. Chappelle, A. Fahlund, K. Jessoe, J. Azuara, D. Misczynski, J. Nachbaur, R. Suddeth, 2014. Paying for Water In California. Public Policy Institute of California. March. http://www.ppic.org/content/pubs/report/R_314EHR.pdf Accessed October 2016. (Hanak et al. 2014)

[345] Hanak, et al. 2014

[346] California Cannibis Coalition vs City of Upland

[347] "Did The California Supreme Court "Rip A Huge Hole" In Prop 13 & 218?" Ethan Elkind, August 28, 2017 http://legal-planet.org/2017/08/28/california-supreme-court-rips-a-huge-hole-in-prop-13-218/

[348] Senate Governance & Finance Committee. 2014. Property Related Fees. California State Legislature. http://www.leginfo.ca.gov/pub/13-14/bill/asm/ab_2401-2450/ab_2403_cfa_20140605_144125_sen_comm.html Accessed October 2016. (Senate Governance & Finance Committee, 2014)

stormwater capture or recharge by utilizing this approach. The 2017 Assembly Bill 231 (Hertzberg), which clarified the definition of sewers to include "services necessary to collect, treat, or dispose of … surface or storm waters" may facilitate increasing rates for stormwater services as well, but it remains to be seen how widely utilized AB231 will be.[349] One of the rationales behind the push for this bill was the fact that Congress and the USEPA have regulated urban stormwater through the Municipal Separate Storm Sewer System (MS4) permits.

These California constitutional reforms have affected local government agencies' ability to use taxes and fees. To meet goals (such as those in the Mayor of Los Angeles' pLAn and the EWMPs) to significantly improve water quality, reduce imported water use, and shift towards sustainable use of local water sources by 2035, investments in water resources-related infrastructure are necessary. The current funding landscape is not sufficient to cover the future expenses of implementing these programs. By 2037, the total cumulative capital costs for the five EWMPs in which the City is either the lead or a participating agency are estimated to be $7.2 billion.[350] LASAN recently drafted a five-year stormwater capital improvement program with an estimated implementation cost of $1.5 billion, with approximately $500 million going towards regional projects and $1 billion going towards green streets.[351]

The costs of noncompliance could also be significant; per pollutant per day fines on WDRs can be levied under both the Federal Clean Water Act and California's Porter-Cologne Act. The maximum penalty per violation per day under the Clean Water Act is $32,500 and under Porter-Cologne the maximum penalty is $25,000.[352] The City participates in multiple TMDLs related to the following water bodies: LAR, LA Harbor, Dominguez Channel and Machado Lake, Santa Monica Bay, Ballona Creek and Estuary, and Echo Park Lake. Rough estimates looking at the majority of the pollutants (159) included in these TMDLs demonstrate the potential for daily fines totaling approximately $4M under Porter-Cologne and $5.2M under the Clean Water Act (if all pollutants were exceeding standards daily). The potential annual liability to the city could be in the range of hundreds of millions of dollars per year.

Currently available funding stems mainly from a 1993 Stormwater Pollutant Abatement Charge (SPAC) that generates approximately $29 million per year and a developer review fee that generates approximately $480,000 per year; both of these funding sources are fully allocated and insufficient to meet current needs.[353] An ordinance to establish an MS4 permit compliance fee

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[349] SB 231 Local government: fees and charges (2017-2018) Hertzberg. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB231

[350] Santana, Miguel, 2017. Funding Options for the Implementation Strategy for the Enhanced Watershed Management Plans. Memorandum to Los Angeles City Council and Mayor from Miguel A Santana, City Administrative Officer. January 5, 2017. (Santana, 2017)

[351] (Santana, 2017) p.6

[352] Office of Chief Council, State Water Resources Control Board, Overview of California Water Quality Law (2008) https://www.waterboards.ca.gov/board_reference/docs/wq_law.pdf

[353] (Santana, 2017) p.6

based on LASAN staffing costs was approved in 2016, but its implementation has been delayed.[354] Therefore, additional funding must be obtained to implement these programs. The City is exploring potential mechanisms to fund these important water management projects in a variety of forums, including in a recent report by the Office of the City Administrative Officer as well as in the OWLA research efforts.[355] Some financing mechanisms are available to support an integrated water resource management approach that relies on tapping local resources. Options range from new use fees imposed by local governments, to arrangements that allow collaboration between local entities to accomplish common goals, and sources of state and federal funding.

B. Taxes, Fees, and Local Bonds

LADWP and LASAN may consider what to finance internally from fees collected for water and wastewater service – also known as "pay as you go" financing. However, given the amount of investment needed over time, it makes sense to leverage LADWP's revenue with debt financing. LADWP can issue bonds, including general obligation (GO) bonds and revenue bonds. GO bonds are backed by the municipality's general property taxing authority, whereas revenue bonds are backed by revenues from water rates and charges. Proposition 13 and Proposition 218 limited the ability to increase property taxes in several ways, including a requirement for a 2/3 majority vote in a general election (or over 50% of property owners), but in some instances voters have given this 2/3 majority approval. The City currently uses GO bonds to fund stormwater projects under Proposition O Clean Water Bonds. However, bond funds cannot be used for programs or for operations and maintenance of constructed projects. The City has a limit on its capacity to use revenue bonds backed by revenue derived from rates, and this is already an important revenue source for the City's existing capital improvement needs.

Another opportunity for funding lies in measures or bond programs whose primary focus is not stormwater or water management, but which will provide opportunities to integrate these projects into those programs. Examples include the City of LA sidewalk repair program (Safe Sidewalks LA), and Measures A (County parks) and M (Metro public transit), which were both approved on November 8, 2016. Safe Sidewalks LA was approved by the LA City Council in November 2016 as a program that sets aside $1.4 billion over the next 30 years to repair sidewalks and make them more accessible; components of green street designs such as tree wells, curb cuts, and permeable pavement can be included in these repairs. Measure A, the Los Angeles County Safe, Clean Neighborhood Parks and Beaches Measure, authorizes the LA County Regional Park and Open Space District to levy a special tax annually on improved parcels to upgrade parks and recreation centers; components of integrated water management such as drought tolerant plants, recycled water use, and stormwater capture and reuse may be implemented through this funding.[356]

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[354] (Santana, 2017) p.6

[355] (Santana, 2017) p.6

[356] LA County Measure A Website; http://file.lacounty.gov/SDSInter/dpr/247410_LARPOSDParksFunding-Measure_OSDTAX_2016_06_22v7_finalSigned.pdf

Finally, Measure M is a half-cent sales tax that will allocate over $860 million per year to improving transportation and mobility options in LA County; Green Streets, which offer stormwater management benefits, and Complete Streets are included in the items that can be funded.[357] With up to $120 billion dollars in investments over the next 40 years from Measure M, it is imperative that all projects constructed with this funding meet the LID ordinance requirements. This was not the case for much of Measure R funded public transit projects such as the Exposition Line segment in the city of LA. In addition, any long-term construction project or significant street improvement project (by cost or length of street improved) should also meet LID ordinance requirements.

As mentioned above, the City has a SPAC, which is a yearly property tax that pays for part of the City's stormwater program. The tax has generated an average of $29 million per year for the City's program for the last four fiscal years.[358] The SPAC was created in 1990 and last modified in 1993, prior to the passage of Proposition 218 and well before State and USEPA approval of any TMDLs for the region. The revenues from the fee are fully allocated to the City's existing program and are not sufficient for addressing emerging water quality regulations. The Prop 218 vote requirement has limited the City's ability to consider raising stormwater fees to keep up with revenue requirements.[359] However, the City Attorney's Office has determined that due to AB 2403, a vote would not be required if the SPAC only funded stormwater projects or programs directly or indirectly related to water supply.[360] Examples of this type of project include an infiltration BMP with connectivity to a groundwater basin used for water supply or a stormwater capture cistern where the water is then used for park irrigation.

Stormwater fees are an important funding mechanism to build and maintain stormwater infrastructure nationally; based on a 2016 Black and Veatch national stormwater utility survey, 88% of utilities received more than 75% of their revenue from stormwater user fees. Average monthly fees for SFR ranged widely, between $0.71 and $32.50 monthly ($8.50 and $390 annually). It is important to note, however, that much of this variability was due to whether or not the fees covered the full "cost of service" or not. For example, Seattle Public Utilities, with a fee of $32.50 per months, has defined the full cost of service and also recovers 97% of the stormwater costs of services through stormwater user fees. San Diego, on the other hand, has a monthly stormwater fee of $0.95 ($11.40 annually), which covers approximately 50% of their stormwater fees (the remainder of the funding stems primarily from general taxes and parking citation revenue). Kansas

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[357] http://theplan.metro.net/wp-content/uploads/2016/09/factsheet_measurem.pdf; http://theplan.metro.net/wp-content/uploads/2016/09/measurem_ordinance_16-01.pdf

[358] (Santana, 2017) p.6

[359] City of Los Angeles, 2009. Water Quality Compliance Master Plan for Urban Runoff. Watershed Protection Division, Bureau of Sanitation, Department of Public Works. http://www.lastormwater.org/wp-content/files_mf/wqcmpur.pdf Accessed November 2016. (City of Los Angeles, 2009)

[360] (Santana, 2017)

City, MO's stormwater fee, at $3 per month ($36 per year) is designed to recover the stormwater 'operating' costs; their stormwater capital costs are recovered through taxes.[361]

A county-wide or City stormwater abatement fee is an important component in promoting stormwater capture. Over time, the City has considered increasing the SPAC, such as in a past proposal to increase the charge over a 5-year period starting in 2009-10. Stormwater fees have already been passed in cities in the LA region. Santa Monica, for example, has two stormwater parcel fees, the 1995 Stormwater Management User fee (flat fee) and the 2006 Clean Beaches and Ocean Parcel Tax (Measure V, which adjusts according to the Consumer Price Index).[362] Measure CW (Clean Water, Clean Beach Parcel Tax) was passed in Culver City in 2016 by an almost 74% approval rate to pay for water quality improvements via a parcel tax on property owners. The parcel taxes range by property type, starting at $69 per year for MFR, $99 per year for SFR, and ending at $1,096 per year per acre for nonresidential uses (prorated by portion of an acre). Measure CW is expected to result in approximately $2.2 million per year to put towards urban runoff quality improvement projects.[363]

After seven years of discussion and consideration, a county-wide stormwater fee, the Clean Water, Clean Beaches Initiative, was considered in 2013, but the LA County Board of Supervisors ultimately rejected the proposal to put a county-wide parcel tax on the 2014 ballot. The proposed fee was $54 per parcel, which would have generated a projected $270 million per year. With increased awareness due to the recent drought, the need to capture stormwater for local water supply is more pressing than water quality standards compliance alone, and a revised parcel tax is being considered for the countywide ballot in November 2018. In May 2017, a motion "to increase public and stakeholder engagement on the development of [the Department of Public Works'] Water Resilience Plan and to develop an associated Expenditure Plan and parcel tax that would help advance critical stormwater capture and quality projects and programs throughout the county" was unanimously passed by the LA County Board of Supervisors.[364] In addition, the legislature recently passed AB 1180 (Holden), which was signed in to law, thereby clearing the way for the LA County Flood Control District to create a stormwater fee or tax.

Under Proposition 218 requirements, passing this tax would require either a vote of the public or a mail in ballot from property owners. Each approach offers different pros and cons. There may be wide-ranging support from the public, but a 2/3rd vote is required to pass the fee in this way. A mail-in ballot to property owners, on the other hand, only requires a simple majority, but property owners often do not support taxes and fees at as high a level as the general public does.

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[361] Black and Veatch 2016 Stormwater Utility Survey. https://pages.bv.com/rs/916-IZV-611/images/2016-Stormwater-Utility-Survey.pdf

[362] Urban Runoff Stormwater Parcel Fees https://www.smgov.net/Departments/OSE/Categories/Urban_Runoff/Stormwater_Parcel_Fees.aspx

[363] http://www.culvercity.org/city-hall/information/election-information/ballot-measure-information/clean-culver-city

[364] http://supervisorkuehl.com/h2o4la/

In addition, this is a decision that affects not only property owners, but also the many people that rent in LA, and a public vote offers the opportunity for all residents to provide input. The majority required to pass may be lowered based on the recent California Supreme Court decision,[365] which stated that conducting an initiative process to obtain signatures from 15% of the County's population to place the funding measure on the ballot would result in the need for only a simple majority to pass the measure (rather than the 2/3 majority if placed on the ballot by local governments).[366]

C. Bonds

a. State General Obligation Bonds – Proposition 1

The voters of the State of California have authorized a series of bond issues since the year 2000 to help address water resource management in California. The referendum known as Proposition 1 is the latest such bond issue. In total, Proposition 1 authorized $7.545 billion in general obligation bonds for water projects including surface and groundwater storage, ecosystem and watershed protection and restoration, and drinking water protection. Money for five of the programs will be administered by the SWRCB. This includes $625 million for water recycling, $200 million for stormwater, and $800 million for groundwater sustainability.[367] Proposition 1 also allocated $260 million for drinking water grants and loans for public water system improvements and related actions to meet safe drinking water standards and/or to ensure affordability. These funds will be administered as part of the Drinking Water State Revolving Fund (DWSRF) program.

Proposition 1 also authorized $510 million to continue the state's Integrated Water Resource Management (IRWM) planning and implementation grant program. These funds are allocated to 12 hydrologic region-based funding areas in the state, and awarded based on a competitive grant application process to IRWM regions within each funding area.[368] However, none of this bond money can be spent on project O&M.

The Los Angeles region currently has approximately $719 million worth of projects on the state funding priority list for Proposition 1 dollars. If approved, this funding will leverage a total of $1.4 billion in project costs, according to the Priority State Funding List as of June 2016.[369] These applications either have been submitted already or will be submitted soon, and include a range of water sources such as groundwater, recycled water, and stormwater, as well as potential funds for LAR restoration. The region is counting on these projects to accomplish its water management goals, including being able to meet the mayor's goals for improving LA's water resource self-sufficiency by reducing water imports by 50% by 2035.

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[365] California Cannibis Coalition vs City of Upland

[366] "Did The California Supreme Court "Rip A Huge Hole" In Prop 13 & 218?" Ethan Elkind, August 28, 2017 http://legal-planet.org/2017/08/28/california-supreme-court-rips-a-huge-hole-in-prop-13-218/

[367] California State Water Resources Control Board, undated c. Financial Assistance Funding - Grants and Loans. Proposition 1. http://www.waterboards.ca.gov/water_issues/programs/grants_loans/proposition1.shtml Accessed October 2016. (California State Water Resources Control Board, undated c)

[368] (California Department of Water Resources, undated)

[369] Personal communication

b. Green Bonds

Green bonds are the same as traditional bonds, except that capital is raised to fund projects that have environmental benefits that investors choose to support. Green bonds are often climate-related, but can also be used to fund other environmentally sustainable purposes including water projects. Project types include clean energy, climate resilience, energy efficiency, low carbon transport, agriculture and forestry, and clean water/ stormwater, among others. Investors seeking socially responsible investment opportunities have expressed strong demand for green bond issuances. The bonds are marketed as "green" at the time of issuance, with a full description of the project and its benefits. Issuers can choose to have third parties verify how the funds were used and the benefits achieved. Third party verification can add cost to the bond issuance, but can also help achieve a better interest rate.

As an example, DC Water issued $350 million in taxable green bonds in 2014. These bonds were labeled "century bonds" because they were assigned a 100-year final maturity to match the expected useful life of the infrastructure, which was a deep tunnel system to transport combined stormwater and sewage to DC Water's treatment plant as part of the DC Clean Rivers Project. For comparison, DC Water typically issues 30-35 year tax exempt bonds to fund capital improvement projects. The bond issuance achieved green certification through an independent review on its green credentials for water quality benefits of remediating combined sewer overflows, climate resilience benefits related to flood mitigation, and quality of life improvements from promoting biodiversity and waterfront restoration.[370] The 100-year maturity allows the utility to support inter-generational equity by spreading the cost over time for all the generations that will benefit. The bond was also took advantage of historically low interest rates; the bond offered a better return than the historically low US Treasury rate, but still provided a low cost of capital for the utility.

c. Environmental Impact Bonds

Environmental Impact Bonds (EIBs) are another type of bond. EIBs are a 'pay-for-performance' contract that is focused on environmental issues. The context for setting up successful EIBs includes a standardized metric, consistent annual payments, and the implementation of required government regulations.[371] Stormwater, with its associated regulatory requirements and available metrics such as quantity of runoff or pollutant reduced, may offer a promising opportunity to implement EIBs. DC Water has partnered with Goldman Sachs and the Calvert Foundation on the nation's first EIB, which will fund the construction of green infrastructure to manage stormwater runoff and improve water quality. The 30-year, $25 million dollar EIB will fund the construction of green infrastructure for a project in Rock Creek.

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[370] https://www.climatebonds.net/2014/07/dc-water-issues-aa-350m-%E2%80%98green-century-bond%E2%80%99-%E2%80%93-yes-that%E2%80%99s-right-very-first-100-year-green Accessed March 2017

[371] Environmental Impact Bonds (2013) Available at: https://centers.fuqua.duke.edu/case/wp-content/uploads/sites/7/2015/01/Report_Nicola_EnvironmentalImpactBonds_2013.pdf as cited in Santana 2017.

The novelty of this EIB lies in that the cost of constructing the green infrastructure is paid by DC Water, but the performance risks of managing stormwater are shared. The risks are shared through a variety of contingent payment options. If the stormwater infrastructure performs as expected in terms of runoff reduction (between an 18.6 and 41.3% reduction), then no additional payments are due. If the infrastructure underperforms, then the investors will make a Risk Share Payment of $3.3 million to DC Water. If, on the other hand, the infrastructure over-performs, then DC Water will make a $3.3 million Outcome Payment to the investors for sharing in the risk. The payment value is based on the interest to be paid on the EIB.[372]

There are multiple potential benefits to this structure, including allowing DC Water to better manage a portion of the risk through the Risk Share Payment. This will help DC Water recoup some of its investment if the green infrastructure does not capture the expected volumes of stormwater. Even more importantly, however, making the type of payments contingent on the effectiveness of the green infrastructure creates a focus on the actual desired outcome (reducing stormwater runoff and therefore improving water quality) rather than just a quantifiable output such as a certain number of impervious acres retrofitted with the infrastructure.[373] This is a critical nuance that should be incorporated into all potential funding mechanisms as it will do two things: drive additional data collection to better characterize the relationship between outputs and outcomes and determine the effectiveness of these practices over time. Further, the structure of this EIB is replicable and scalable and could be applied to many communities that are working to manage stormwater runoff and improve water quality.[374]

d. Marks-Roos Bonds Pooling Act

The Marks-Roos Bond Pooling Act was passed by the California legislature in 1985 to allow local governments greater flexibility in financing projects. The Act allows JPAs to pool bonds to finance projects. Bond pooling combines the financing of several projects into a single bond issue, with the idea that JPAs can save issuance costs with greater economies of scale. The Act also allows the use of financing leases and installment sale agreements as alternative frameworks for public borrowing. Agencies are allowed to market these obligations to the bond market as Marks-Roos bonds rather than certificates of participation.[375]

The Act authorizes JPAs to issue Marks-Roos bonds and loan the proceeds to local governmental agencies to finance public capital improvements, working capital, and insurance programs.

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[372] Fact Sheet DC Water Environmental Impact Bond http://www.goldmansachs.com/media-relations/press-releases/current/dc-water-environmental-impact-bond-fact-sheet.pdf Accessed March 2017

[373] Fact Sheet DC Water Environmental Impact Bond http://www.goldmansachs.com/media-relations/press-releases/current/dc-water-environmental-impact-bond-fact-sheet.pdf Accessed March 2017

[374] Fact Sheet DC Water Environmental Impact Bond http://www.goldmansachs.com/media-relations/press-releases/current/dc-water-environmental-impact-bond-fact-sheet.pdf Accessed March 2017

[375] Shea, Stephen. 1998. A Review of the Marks-Roos Local Bond Pooling Act of 1985. California Debt and Investment Advisory Commission. (Shea, 1998)

In addition, JPAs can purchase the bonds of local agencies, including Mello-Roos or Assessment District bonds, with the proceeds of Marks-Roos bonds.[376] AB 850, approved in 2013, allows JPAs to issue rate reduction bonds to finance a utility project. Rate reduction bonds are asset-backed securities that are structured to minimize borrowing costs by qualifying for AAA credit ratings, which allows borrowing at below-market rates. The bill grants JPAs the power to issue rate reduction bonds through December 31, 2020. JPAs can collect a utility project charge from customers of the publically owned utility to pay the financing costs of the rate reduction bond.[377] JPAs approve Marks-Roos bonds by passing a resolution, and therefore Marks-Roos bonds do not require voter approval. However, there is a requirement for the JPA to make the finding prior to issuing bonds that the financing would result in significant public benefit.[378]

D. Benefit Assessment Districts

Benefit assessment districts were created by the California legislature in 1982. The district allows local government agencies such as cities, counties, and special districts to finance the maintenance and operation of facilities. Any local agency which is authorized by law to maintain streets, roads, or highways or maintain drainage or flood control services may impose a benefit assessment to pay for those services. The fees must directly and clearly benefit properties in the district. For flood control services, the benefit may be determined on the basis of the proportionate stormwater runoff from each parcel. A benefits assessment district is subject to Proposition 218 requirements, and must achieve a majority vote from property owners to levy a fee. These districts can be important funding mechanisms because they are one of the few mechanisms designed to fund ongoing O&M of facilities (as opposed to only capital funding).[379] For example, the LACFCD is a benefit assessment district; the LACFCD annual benefit assessment for FY 2014-2015 provided approximately $110.3 million for flood control purposes.[380]

E. Mello-Roos Community Facilities Districts

The Mello-Roos Community Facilities Act of 1982 allows local governments to establish a Mello-Roos special tax assessment district in a developing area to finance specific public facilities and services needed by that particular area. A Mello-Roos Community Facilities District (CFD) has bonding and taxing authority. Mello-Roos bonds can only be used to finance new or additional facilities and services. The bonds can be used to support public infrastructure including streets,

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[376] California Tax Data, undated. What is Marks-Roos? California Property Tax Information. Undated. www.californiataxdata.com Accessed October 2016. (California Tax Data, undated)

[377] Senate Governance & Finance Committee. 2013. Rate Reduction Bonds for Local Utilities. California State Legislature. http://www.leginfo.ca.gov/pub/13-14/bill/asm/ab_0801-0850/ab_850_cfa_20130620_162015_sen_comm.html Accessed October 2016. (Senate Governance & Finance Committee, 2013)

[378] (California Tax Data, undated)

[379] (California Tax Data, undated)

[380] LOS ANGELES COUNTY FLOOD CONTROL DISTRICT ANNUAL BENEFIT ASSESSMENT – FISCAL YEAR 2014-15 CONTINUATION May 6, 2014 http://file.lacounty.gov/SDSInter/bos/supdocs/84813.pdf

water, sewage and drainage, electricity, infrastructure, schools, parks, and police protection to newly developing areas. Revenues are used to make the payments of principal and interest on the bonds. The tax is not levied on the assessed value of real property, and therefore does not conflict with Proposition 13 (which limits property taxes based on the assessed value of real property). California Proposition 218 requires a 2/3 voter approval to pass a Mello-Roos tax. The number of registered voters in a CFD can be very small. A real estate developer could be the only "voter" in such property owner elections that approve a Mello-Roos tax.[381]

Mello-Roos financing is backed by a property lien, and that lien is superior to all mortgages, even if those mortgages pre-date the special tax or assessment lien. That superior status of the lien attracts investors to the Mello-Roos bonds.[382] The benefit of a Mello-Roos district for developers is that funding from traditional funding sources like commercial banks is limited, and the Mello-Roos vehicle preserves the developer's credit with those sources for other purposes. Property owners get the benefit of reduced financing rate because if these vehicles are used to finance publicly-owned improvements, interest on the bonds is typically exempt from federal and state income taxes. The tax-exemption can decrease the special tax or assessment lien paid by the property because of the lower interest rate paid to purchasers of these bonds.[383]

From 1992/93 through 2013/14, CFDs have issued $23.4 billion in debt on 2,039 separate bond issuances. Of the issuances reported in 2013/14, cities have issued the biggest share of Mello-Roos financing, at 44%, followed by school districts (29%), special districts (5%), JPAs (7%), community service districts, and others. LA County hosts 7% of all outstanding Mello Roos debt in California. Riverside County has the greatest share (23.6%) followed by Orange County at 15.9% and San Diego County at 10.6%.[384] The City has nine CFDs, four of which have been terminated and three of which have issued bonds. Importantly, CFDs may be used to fund O&M costs as annual special tax levies could be used to fund qualified annual O&M costs.[385] However, it is important to note that CFDs may have limited applicability in LA as much of the land is already developed.

F. Enhanced Infrastructure Financing Districts

In 2014, the California legislature created the Enhanced Infrastructure Financing District (EIFD), which is a governmental entity established by a city or county that allows access to tax increment financing to fund public infrastructure-related projects. With EIFDs, local governments must agree to allocate their tax increment to the EIFD. EIFDs can be located anywhere and do not

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[381] (California Tax Data, undated).
[382] City of Los Angeles, undated. MelloRoos Policy. City Administrative Officer. http://cao.lacity.org/debt/Mello-RoosPolicy.PDF Accessed March 2017. (City of Los Angeles, undated)
[383] (City of Los Angeles, undated)
[384] (California Debt and Investment Advisory Commission, 2014)
[385] Santana, 2017 Attachment, Section VIII

have to be in economically depressed areas.[386] EIFDs require a city or county to establish a governing board for the authority and adopt an infrastructure financing plan with project eligibility requirements. While a city or county can create an EIFD without a vote, an approval of 55% of the voters in the district is required to issue bonds.[387] EIFD bonds can be up to 45 years from the date issued.[388] An EIFD is likely to have the best funding leverage when more jurisdictions join the EIFD. In the case of the proposed LAR EIFD, the potential revenue yield of $1.9 billion was roughly halved if LA County did not participate.[389] Increasing the number of jurisdictions involved also increased the potential yield; if Burbank, Glendale, and Vernon also participated in the EIFD, then the potential 30-year bond revenue yield was found to be as high as $2.3 billion.[390]

EIFDs can fund a wide variety of project types. Traditional infrastructure projects are among the list of eligible project types – including roads, highways and bridges, parking facilities, transit stations, sewage and water facilities, flood control and drainage projects, and solid waste projects. EIFDs can also fund the purchase, construction, expansion, or improvement of properties with goals such as brownfield restoration, environmental mitigation, military base reuse, affordable housing, private industrial buildings, transit oriented development, and others.[391]

EIFDs create a separate governmental entity to finance infrastructure improvement projects with community-wide benefits within a defined area. EIFDs are authorized to combine tax-increment funding with a wide variety of other permitted funding sources. For example, they can use development agreement fees, funds from the community facilities bond, funds from state and federal grants, Proposition 1 bond monies, and hotel and sales tax reimbursements. And a significant change is that a special district is now eligible to contribute to an EIFD. That means a flood-control district, a water district, or a sanitation district can contribute non-property-tax revenues (i.e. user fee charges).[392] An EIFD can include funding from Mello-Roos districts and other special districts, but not from school districts. EIFDs are prohibited from funding O&M expenses, however, which is a critical gap in the city of LA's funding ability that must be filled.

Several potential disadvantages have been identified for EIFDs. First, the process of forming an EIFD may be lengthy and costly. Also, to satisfy Propositions 218 and 26, a proportionality analysis must be performed in the financing plan to establish the link between the tax payer and

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[386] League of California Cities, Analysis of SB 628 (EIFD). http://www.cacities.org/CMSPages/GetFile.aspx?nodeguid=d8e42eca-7647-4f12-98d4-e93383abc48c&lang=en-US Accessed October 2016. (League of California Cities, undated)
[387] (League of California Cities, undated)
[388] Santana 2017 Attachment XI
[389] LA River City of LA EIFD Study; page 18
[390] LA River City of LA EIFD Study; page 18
[391] (League of California Cities, undated)
[392] Kosmont, L. 2016. EIFDs Are A New Local 'Economic Development 2.0' Tool. The Planning Report. April 4. http://www.planningreport.com/2016/04/14/kosmont-eifds-are-new-local-economic-development-20-tool Accessed October 2016. (Kosmont, 2016)

the beneficiary. This is a potentially complex task, but one for which methods have been established.[393] Additionally, the property tax increment may already be assigned to specific purposes or be used in the general fund. In the case of the City of Los Angeles, the tax increment currently goes to the general fund and is not available for use unless it is re-assigned.[394]

EIFDs are a new funding vehicle, and only one example exists (La Verne) in LA County at the time of this writing. However, there are several projects in CA that could be supported through an EIFD, including the Bridge District Redevelopment Project in the City of West Sacramento, the Levi's Stadium for the City and County of Santa Clara, and several projects in LA including the LA River Revitalization.[395] The USACE has approved a $1.3 billion restoration plan (still awaiting the Congressional funding decision). The City is assessing opportunities to fund their share of the work involved in this plan; one potential funding opportunity is property tax increments through an EIFD along the LAR. An EIFD that encompassed 1 mile on each side of the LAR going through the City has the potential to generate $1.9 billion, which could result in annual revenue yields as high as $250 million in the 30th year.[396] The potential revenue yield would be much smaller, $460 million, if only the 11-mile length of the LAR included in the ARBOR study was included within the EIFD.[397] The LAR runs through some of the lowest-value property in LA County. The idea is that as the LAR becomes environmentally restored and aesthetically improved, with changes in the land-use of the property surrounding the river, the appreciation in the value of that property could pay for a significant portion of its restoration[398] Many of these projects could also provide stormwater quality and potential water supply benefit as well.

As these economic benefits are attained, however, care must also be taken to address the potential for gentrification and displacement of the communities that currently live nearest the LAR. Research into these questions is currently being conducted; a recent study conducted by the City regarding the potential to create an EIFD along the LAR highlighted the importance to stakeholders of ensuring that affordable housing is supported by any LAR-related EIFDs and conducted the analyses accordingly.[399] The analysis, therefore, included a 20% set-aside for affordable housing

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[393] California Economic Summit, 2014. Funding Sustainable Communities: A How-To-Guide for Using New "Enhanced Infrastructure Financing Districts" (EIFDs). https://cafwd.app.box.com/s/p8re0h7s6vkhm1st2uwq Accessed October 2016. (California Economic Summit, 2014)

[394] (Santana, 2017)

[395] Amador, C. 2016. Enhanced Infrastructure Financing Districts. Resource Guide to EIFDs. Produced by California Community Economic Development Association. February. http://cceda.com/wp-content/uploads/EIFD-Resource-Guide-Feb-20161.pdf Accessed October 2016. (Amador, 2016) This analysis states "an estimated $40 million in EIFD funds are involved to launch the initial projects to be undertaken from the LA River Master Plan."

[396] LA River City of LA EIFD Study p. 5

[397] LA River City of LA EIFD Study p. 5

[398] Pisano, M. and F. Silva. 2015. A New Tool for Urban Economic Development: EIFDs Demystified. The Planning Report. June 3. http://www.planningreport.com/2015/06/03/new-tool-urban-economic-development-eifds-demystified Accessed October 2016. (Pisano and Silva, 2015)

[399] LA River City of LA EIFD Study; page 17 http://clkrep.lacity.org/onlinedocs/2014/14-1349_misc_11-30-2016.pdf

(approximately $380 million if the City and County of LA each contribute 75% of their tax increment).[400] The study further looked at packaging the EIFD with other community development initiatives – specifically the city's two existing Promise Zones in Central and South Los Angeles. The designation gives the neighborhoods an advantage when applying for federal grants for education, job training, and economic development.[401]

A recent USC Price School Capstone project also examined this question of the potential benefits (e.g., economic investment, equal access to green space, increased ecological habitat) and burdens (e.g., gentrification, displacement, lack of affordable housing, loss of industrial land) of greening the LAR. Recommendations included supporting affordable housing and rent control units; ensuring funding is prioritized for affordable housing, workforce development, and displacement prevention; considering full cost and benefit ratios; and evaluating other revitalization efforts for best practices.[402]

G. Joint Powers Authority

A joint powers authority (JPA) is established when two or more governmental entities sign a contract under which they agree to jointly exercise any power common to those agencies. This is permitted under Section 6502 of the CA state government code.[403] JPAs can be formed as a separate entity, but a separate entity is not required. JPAs have covered a wide range of functions including water supply, transportation, open space, recreation, fire protection and others. JPAs can create a revenue stream or raise capital by selling bonds. JPAs are currently used for management of recycled water and stormwater in California, as well as for habitat conservation, redevelopment projects, regional transportation projects, regional wastewater projects, and other uses.

JPAs are flexible and easy to form – members negotiate their levels of commitment and structure their own governing boards. The terms of the JPA agreement determines its size, structure, membership, and decision making authority. JPAs can save taxpayers money by combining the resources and services of the agencies involved.[404]

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[400] LA River City of LA EIFD Study page 23

[401] LA River City of LA EIFD Study page 26

[402] Jackie Alvarado, Xuelai (Sherry) Cao, Xie (Harmony) He, Madison Thesing, USC Sol Price School of Public Policy Capstone (May 2016) A Closer Look at L.A. River Revitalization and Displacement of Residents and Businesses Summary page http://www.cityprojectca.org/blog/archives/42105 (USC LA River Capstone 2016)

[403] "If authorized by their legislative or other governing bodies, two or more public agencies by agreement may jointly exercise any power common to the contracting parties, including, but not limited to, the authority to levy a fee, assessment, or tax, even though one or more of the contracting agencies may be located outside this state" http://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=GOV&sectionNum=6502

[404] Senate Local Government Committee, 2007. Governments Working Together. A Citizen's Guide to Joint Powers Agreements. California State Legislature. August. http://sgf.senate.ca.gov/sites/sgf.senate.ca.gov/files/GWTFinal-version2.pdf Accessed October 2016. (Senate Local Government Committee, 2007)

JPAs can issue revenue bonds without holding an election provided that each of the JPA's member agencies adopts a local ordinance (cities, counties and special districts must hold elections). However, JPAs cannot levy new taxes or assessments – revenues would come from new or existing fees collected by the member agencies, and those funds could be made available to the JPA. Some NGOs can participate in JPAs even though they are not public agencies (such as mutual water companies or tribal governments). JPAs are not bound by the requirement of cities to get 2/3 approval from a vote to incur debt.

The Santa Ana Regional Watershed Project Authority (SAWPA), is a successful regional example of a JPA. The agreement to formalize the current SAWPA agency, which has a mission to plan and build facilities to protect water quality in the Santa Ana River Watershed, went into effect in 1975.[405] SAWPA is comprised of five member agencies: Eastern Municipal Water District, Inland Empire Utilities Agency, Orange County Water District, San Bernardino Valley Municipal Water District, and Western Municipal Water District.[406]

The agreement to create SAWPA includes a description of the powers that all involved agencies would have (e.g., incurring debts, issuing bonds, making and entering contracts) as part of the JPA.[407] Thus, one of the potential benefits of participating in a JPA is the pooling of powers; an agency that did not previously have the power to incur debts may gain that power through a JPA if another participating agency does have that power. The potential for conflict between member agencies of a JPA is one potential challenge for JPAs over time.

JPAs are currently being implemented and considered in a couple of different arenas in the City. LADWP has formed a JPA with Burbank Water and Power to receive low interest financing for mandated and local water supply projects.[408] The City Council adopted ordinance 184369, which authorized the establishment of a JPA for water project financing in June 2016. LADWP will be the City's lead agency and is working closely with LASAN for project alignment; this JPA could potentially fund EWMP projects (possibly in lieu of an increased SPAC) where they are also water resources projects.[409] JPAs have further been proposed by LASAN in each of the five watersheds where they are participating in EWMPs; JPA formation would require Council and Mayoral approval. JPAs could not levy fees, but could pursue taxes or benefits within the confines of Proposition 218 requirements. Although no revenue would be generated by these JPAs, the expertise and funding of all participating agencies could be leveraged to maximize benefits. This could also potentially assist on obtaining grant proposals as forming a JPA is one mechanism to demonstrate that the City is working collaboratively with other parties at a watershed-scale.[410]

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[405] http://www.sawpa.org/contact-us/
[406] http://www.sawpa.org/
[407] http://www.sawpa.org/wp-content/uploads/2012/06/JPA1975-Amends1-5.pdf
[408] www.myladwp.com/faq
[409] Santana 2017 Attachment III
[410] Santana 2017 Attachment VI

H. Public Private Partnerships

Public Private Partnerships (P3s) are a potential option that can bring private financing into public infrastructure projects, and often at the same time accelerate the timeline over which the projects can be implemented. A common form of P3 allows the private sector to design, build, operate, and finance (DBOF) a facility for all or part of the revenue from the service provided by the facility (tolls on a road, for instance) or for payments made by the public agency. The P3 approach transfers the risk associated with the project to the private sector in exchange for dedicating a revenue stream to the private entity. As a drawback, localities must prioritize these revenue payments to the private entities, which can limit funds for other crucial public services for budget-strapped California localities. LASAN is currently exploring the potential to utilize P3s to manage stormwater, including a P3 opportunity with a golf course.[411] A successful P3 at a golf course could potentially lead to partnering with other golf courses; all P3 opportunities should consider both stormwater and recycled water as potential sources wherever possible.

A regional example of a P3 exists in the City of Santa Paula, CA, which entered into a P3 with a firm that provided 100% of the financing to replace their reclaimed water facility. In exchange, the private partner owns the facility and received a 30-year concession of a monthly service fee from Santa Paula. This service fee includes capital repayments based on an agreed schedule, capital replacements, fixed O&M cost, and variable O&M cost. The P3 option was attractive because it was cheaper and well designed. The private bid saved 15% on the costs compared to the design-bid-build option the City had initially considered. The P3 option allowed Santa Paula to avoid $18 million of construction costs and $1.8 million of yearly operating costs while increasing design capacity by 25%, reducing facility footprint by 70%, and reducing energy consumption by 30%. The arrangement provided cost certainty for Santa Paula in that the private partner assumed responsibility for any overruns, and guaranteed that energy usage would be at or below a specified level. In addition, the project was delivered 7 months ahead of schedule.[412] However, the service fees on the plant contributed to rising sewer rates over time, and in 2015 Santa Paula decided it would be best to regain control by purchasing the plant from Alinda Capital Partners, the private partner. Santa Paula has started issuing rebates to its citizens.[413]

In another example, Prince George's County, Maryland partnered with a private agency that will assure compliance with the County's MS4 permit by providing design, retrofit, and maintenance of green infrastructure on an initial 2,000 acres of impervious area. There is an option for

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[411] Santana 2017 Attachment XI

[412] Perc Water, undated. Santa Paula Water Recycling Facility. Innovative Solutions to Municipal Wastewater Problems. https://issuu.com/percwater/docs/santa_paula_wrf_innovative_solution Accessed October 2016. (Perc Water, undated)

[413] Ivory, D., B. Protess, and G. Palmer. In American Towns, Private Profits from Public Works. The New York Times. December 24. https://www.nytimes.com/2016/12/24/business/dealbook/private-equity-water.html Accessed January 2017 (Ivory et al 2016)

another 2,000 acres after the initial 3-year term if the County is satisfied with the partnership. The County is expecting significant cost savings compared to the County's traditional processes.[414]

A local example of a stormwater P3 that provides benefits to multiple parties can be found with the Washington Boulevard Regional Diversion Project in Culver City. The Costco at this location purchased additional property and began a redevelopment project that triggered Culver City's requirement that new and redevelopments above 5,000 square feet implement LID practices to capture and retain the 85th percentile storm on-site. Culver City, as part of its EWMP process, was also looking at that area to construct a large regional BMP, and reached out to Costco to develop a project under their parking lot and the public right-of-way that would fulfill both Costco's LID needs and Culver City's stormwater capture goals for the Marina del Rey watershed. This P3 resulted in the opportunity to share costs on both sides. The original project goals included both on-site reuse and infiltration into the underlying West Coast Basin; however, site investigations revealed low soil infiltration rates, a high groundwater table, and the presence of brackish water, which led to changing the project to a system of sealed storage tanks to store up to 4.5 AF of water per storm. The captured runoff will have pre-treatment before storage, extensive vector control BMPs (especially for mosquitos), and be directed into a completely sealed system. The stormwater can be reused on-site for median/parkway irrigation until space is needed for subsequent storms. The remaining volume will be pumped to the City of LA's HWRP to increase their flows for treatment and discharge or reused as recycled water.[415]

Stormwater control provides other P3 examples - from stormwater credit trading programs to incentive programs that encourage green infrastructure investment. Philadelphia's Greened Acre Retrofit Program (GARP) program engages private property owners and the private sector (including stormwater solution companies, NGOs, and engineers) in stormwater management. Successful completion of stormwater control projects under Philadelphia's program allows participants to receive credits towards their stormwater fees. GARP in particular encourages project aggregators to become involved – aggregators are private entities that gather multiple private property owners with opportunities for stormwater control and apply on behalf of all of those owners to the program. Those aggregators could be companies that design, build, and operate stormwater control facilities, or they could be a business improvement district or NGO applying on behalf of multiple property owners. Aggregators reduce transaction costs and aim to achieve economies of scale in stormwater control.[416]

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[414] Clean Water Partnership, undated. Frequently Asked Questions. Prince George's County/ Corvias Solutions. http://www.princegeorgescountymd.gov/DocumentCenter/View/274 Accessed October 2016. (Clean Water Partnership, undated)

[415] Personal communication, Culver City, Young, 2017.

[416] Water Environment Federation (WEF), 2014. Innovative Financing Accelerates Stormwater Financing. Stormwater Report. September 3. http://stormwater.wef.org/2014/09/innovative-financing/ Accessed October 2016. (WEF 2014)

Credit trading programs can be set up to allow private property owners the ability to purchase stormwater credits to help meet stormwater control requirements. This can be helpful if purchasing stormwater credits is cheaper for achieving some or all of the stormwater retention required on their property. Washington D.C. established the first stormwater credit trading program in the U.S. Property owners can earn stormwater retention credits that can be used towards the stormwater retention requirements, and which can be sold to help others meet their obligations.[417] Allowing stormwater credit trading can help achieve overall stormwater reduction goals at lower total cost.

I. State Revolving Funds

California has established state revolving funds (SRFs) for both drinking water and clean water. Drinking Water SRF loans were established under 1996 amendments to the Safe Drinking Water Act, while Clean Water SRF (CWSRF) loans were authorized under the 1987 amendments to the Clean Water Act and amended under the 2014 Water Resources Reform and Development Act (WRRDA). Under these programs, the EPA provides grant funds to states, and states provide an additional 20% match to capitalize the funds. The states administer the programs as a revolving fund, receiving repayment and interest on loans and loaning the funds back out on revolving basis. States can set specific loan terms, with interest rates from zero percent to market rates and loan terms up to 30 years.

In California, loan terms for the CWSRF are one-half of the most recent state general obligation (GO) bond rate at the time of funding approval, over a period up to 30 years depending on the life of the project. Small disadvantaged communities may receive 0% loans.[418] The DRSRF loans funds at rate of 1.633% as of 2015 with repayment terms at 20 years, with 30 years allowed for disadvantaged communities.[419]

The drinking and clean water programs are similarly sized in terms of the amount of funding they have been providing. The CA CWSRF provided almost $763 million in assistance in 2015, and has provided approximately $7.6 billion in assistance since its inception.[420] The CA DWSRF provided approximately $104 million in 2015, and has provided $2.3 billion since inception.[421]

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[417] (WEF 2014)

[418] California State Water Resources Control Board, undated a. Below-Market Financing For Safe Drinking Water. Brochure. http://www.waterboards.ca.gov/drinking_water/services/funding/documents/srf/dwsrf_brochure.pdfhttp://www.waterboards.ca.gov/drinking_water/services/funding/documents/srf/dwsrf_brochure.pdf Accessed October 2016. (California State Water Resources Control Board, undated a)

[419] California State Water Resources Control Board, undated b. Below-Market Financing, For Wastewater and Water Quality. Brochure. http://www.waterboards.ca.gov/water_issues/programs/grants_loans/srf/docs/pubs/cwsrf_small_brochure.pdf Accessed October 2016 (California State Water Resources Control Board, undated b)

[420] US EPA. Undated a. Drinking Water SRF Program Information for the State of California. Federal and State Investment Data Entered by EPA. https://www.epa.gov/sites/production/files/2016-03/documents/californiadwsrf15.pdf (U.S. EPA, undated a)

[421] US EPA. Undated b. Clean Water SRF Program Information for the State of California. Federal and State Investment Data Entered by EPA. https://www.epa.gov/sites/production/files/2016-04/documents/ca.pdf (U.S. EPA, undated b)

SRF loans are a good source of below-market rate financing and can provide significant cost savings on the total cost of a project. Another advantage of SRF loans is that they can be a valuable funding source for projects that are jointly implemented with other agencies.

Some challenges exist with regards to seeking SRF assistance. Projects must be "ready to proceed" (including CEQA documentation) and are added to a priority list that determines which projects will be funded. Communities unfamiliar with the SRF application process may find the initial steps lengthy and administratively burdensome. Also, as is common with most debt, SRF funds cannot be used to support the project's O&M expenses.

California also has an Infrastructure State Revolving Fund (ISRF), which is managed by the California Infrastructure and Economic Development Bank (IBank). The ISRF provides funding to public agencies and NGOs for infrastructure and economic development projects, excluding housing. ISRF Program funding is available in amounts ranging from $50,000 to a maximum of $25 million, with loan terms for the useful life of the project up to a maximum of 30 years. The interest rate is benchmarked to the Thompson Reuters Municipal Data (MMD) Index, and potentially subsidized based on the unemployment rate of the area and median household income. Eligible applicants include any subdivision of a local government, special districts, and joint powers authorities.[422] The Transportation Investment Generating Economic Recovery (TIGER) program may also be a potential source of funding as one of its primary selection criteria for funding surface transportation projects is environmental sustainability (e.g., addressing stormwater through natural means for providing benefits such as groundwater recharge).[423]

J. Conclusions and Recommendations

The Los Angeles area, like all regions in California, historically relied on a mix of funding sources that was weighted heavily towards property tax revenue to finance public works projects. However, California local governments all face constitutional restrictions on the use of taxes and fees at a time when the availability of federal financing for infrastructure projects has been under increasing constraints. As described above, the recently passed AB2403 and AB231 and the recent California Supreme Court ruling that established the possibility of passing the stormwater fee with a 50% vote of the public may create an easier landscape to fund stormwater projects through raising rates or fees that reflect the cost of service of building and maintaining stormwater infrastructure. California voters have approved a large amount of GO bonds from the state since the year 2000, but these funds only go so far to solve regional water management funding needs. Most notably, GO bonds cannot fund infrastructure O&M. We highlight a few recommendations from the presented financing alternatives below.

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[422] California Financing Coordinating Committee, 2016. 2016 Funding Fairs. Infrastructure Financing for the 21st Century. http://www.cfcc.ca.gov/res/docs/2016/2016%20CFCC%20Workbook%20(Web%20Version).pdf Accessed October 2016. (California Financing Coordinating Committee, 2016)

[423] Santana, 2017 Attachment Section V(a) https://www.transportation.gov/tiger

a. Operations and Maintenance

The funding of O&M is critical to ensuring the success of stormwater management programs, in particular where the reduction in runoff volumes is used as a proxy for reductions in the pollutants that must be managed. Robust O&M programs are needed to not only ensure that BMPs are operating at their highest efficiency, but also to provide an avenue to collect data to better quantify the performance of these BMPs over time. In many cases, stormwater BMPs may lose efficiency over time, which would result in lower-than-expected water quality benefits. A thorough understanding of the O&M needs and costs to maintain BMPs at optimal efficiencies is critical to ensure implemented programs achieve the water quality benefits expected based on design criteria and predicted from compliance modeling efforts. However, many funding mechanisms do not allow funding to be used for O&M of BMPs once they are installed, including CA state bonds.

Outside funding for O&M is currently limited. One of the reasons that outside funding for O&M is limited is that a best practice philosophy has been that utilities should include the full cost of O&M and replacement in their rates (full cost pricing). However, this can be difficult when there is not a mechanism in place to specifically assess user charges; this is currently the case in supporting stormwater projects. Further, the current need to implement a large variety of projects over a relatively short period of time to improve water quality (driven in large part by TMDLs) and increase local water supply (driven in part by recent drought) is resulting in a great deal of capital investment into building projects at one time. This will come with correspondingly large associated O&M requirements simply because of the large number of projects that are being planned and implemented concurrently.

As a result of these existing and future O&M costs, funding mechanisms that can fund O&M must be included in the suite of funding sources that are pursued to implement these projects. Mechanisms that can fund O&M include special taxes and parcel taxes, JPAs, P3s, and Benefit Assessment Districts. P3s can pay for O&M either directly by the private entity (e.g., if that entity is contracted to operate and maintain the facility) or indirectly, if there are payments from the private entity to the public entity (such as a concession for use of a public facility/asset where the private entity charges fees) that the public entity then uses to fund O&M. JPAs can also fund O&M. JPAs may be formed to address O&M (e.g., the San Francisquito Creek Joint Powers Authority) or directed to fund O&M. However, the key with JPAs is that the rules associated with the ultimate funding source still apply. Even if the JPA is issuing revenue bonds, the funds are backed by revenues and it is usually expected that O&M is funded from revenues. Special Taxes and Parcel Taxes (a form of special taxes) can be used for O&M. Benefit Assessment Districts can be used to fund O&M or utilities that share the use of existing facilities can split O&M costs.

b. Funding and Grant Office

Local governments should continue to apply for SRF funding and money from state bond issuances. The Los Angeles region has applied, or is in the process of applying, for over $700 million of Proposition 1 funds, which would leverage an even greater amount of project funding. As grants and other sources of funding for which it is necessary to submit applications will continue to be an important source of funding to implement integrated water management projects, the City should create a central grant-writing group to streamline the process of applying for grants and ensure personnel with an appropriate technical and grant writing skill set are always available to pursue funding opportunities.

A centralized grant writing office will provide a multitude of benefits. These include the ability to assess projects occurring across a variety of departments to identify opportunities to submit multi-benefit proposals across many departments as well as ensure that grants from different departments do not unnecessarily compete against each other. Also, the grant office should be sheltered from direct pressure from City Council members to build projects within their districts. The grant office's decisions on what grants to pursue should be based on the merits of a project and independent from political pressure. This office could also provide a structure within which projects at all stages, even those at the nascent stage, are compiled and organized to identify common themes and look for appropriate funding sources. This office should not only create a database of potential funding sources and available projects to be funded, but also take a broad, programmatic view and look for novel funding sources that could fund different pieces of the puzzle for long periods of time. OWLA is also in the process of developing a potential outline for what a funding office could look like to better assist the City in competitively applying for grants to move IWM forward that will be released along with the OWLA plan.

c. Increased Agency Collaborations

The question associated with a high cost for moving towards self-sufficiency in water use is – where else can the money come from? A variety of funding mechanisms and funding sources have been outlined above. Two key themes for funding sources to be explored further are: 1) can significant funding growth be achieved by increasing cooperation between local governmental agencies to fund multiple-benefit projects? And 2) what is the potential future role of private financing in public infrastructure?

Increasing cooperation between local agencies is the key to several of the funding mechanisms that seem to have the greatest promise for increasing funding. A comprehensive funding strategy is needed to achieve the investment required. First, establishing a county-wide stormwater abatement fee to meet regional stormwater management and capture goals, and/or increasing the City's current SPAC to meet the City's stormwater program goals, is an important step for facilitating the capture and use of the volume of stormwater that will be necessary to meet the water supply and water quality goals in the region. An incentive program could accompany the fee increase. Such a program could provide credits against the stormwater fee to property owners that implement approved stormwater control measures on their properties. A credit trading program could be a potential addition to this approach, making it easier for private property owners to participate (even if installing stormwater control is too expensive on their properties) by purchasing credits that represent stormwater control on other properties and lowering the overall cost to society of stormwater control.

As described above, Washington DC and Philadelphia have innovative stormwater credit trading or incentive programs to encourage green infrastructure. Philadelphia's GARP program engages private property owners and the private sector (including stormwater solution companies, NGOs, and engineers) in stormwater management. Successful completion of stormwater control projects under GARP allows participants to receive credits towards their stormwater fees.[424] Under Washington D.C.'s stormwater credit trading program, property owners can earn stormwater retention credits that can be used towards the stormwater retention requirements and sold to help others meet their obligations.[425] The City could explore the efficacy and potential to implement a stormwater credit trading program using either a volume-based metric or concentration-based metric to allow property owners to buy and sell stormwater capacity depending on their site's characteristics. However, carefully defining acceptable stormwater projects to incentivize or require the use of multi-benefit projects will be critical at the beginning to maximize the program's potential.

Second, the City and its potential partners should consider a JPA or EIFD to provide a broader funding base. JPAs combine the authority of multiple agencies to issue bonds under a separate authority, and have flexibility in terms of the approvals needed. A particular opportunity is for the City to use a JPA under AB850 to issue rate reduction bonds to finance "utility projects." The authority to issue such bonds expires on December 31, 2020. This would allow the City (and its partners) to fund water supply projects at below-market rates.

Utilizing an EIFD should be investigated because it would potentially allow more flexible access to property tax increments from the City and the County, and the potential to combine that funding with funding from other sources. Use of a property tax increment forms the basis for an EIFD. However, for the City, the property tax increments currently go to the general fund, and are already used to fund other priorities. Therefore, use of an EIFD would require a shift in priorities for use of the tax increment that may be difficult, but represents the type of commitment that is likely to be necessary to meet overall water supply funding needs.

P3s appear to represent a source of funding that has not been tapped traditionally, and should also be investigated. Local agencies have reported overall cost savings and certainty in financing that has made P3s attractive. Part of the question for P3s is what scale of project funding is possible and appropriate given historical philosophical questions over the appropriateness of private ownership of assets operated to meet public goals, including potential long-term reduction of control over rates charged by the utility. However, a significant amount of funding is needed and P3s represent a significant potential source of financing that could help meet near term water funding needs. The region should also continue to develop local water sources under incentive programs created by MWD. The City should continue to pursue potential partnerships with one or more agencies including MWD, West Basin MWD, Central Basin MWD, and WRD to upgrade HWRP to tertiary plus NDN treatment processes or even advanced treatment and to become part of a regional recycled water distribution system that will greatly increase local resources.

Adjustments to water rates and sewer service charges could also provide funding for stormwater projects where the project benefits overlap with other agencies' needs (e.g., water supply or water quality). As mentioned above, AB 2403 offers an additional option to fund stormwater projects with a water supply nexus. The City's first step would be to identify the stormwater capture

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[424] Water Environment Federation (WEF), 2014. Innovative Financing Accelerates Stormwater Financing. Stormwater Report. September 3. http://stormwater.wef.org/2014/09/innovative-financing/ Accessed October 2016. (WEF 2014)

[425] (WEF 2014)

and infiltration projects that will also augment local water supply. Then, they would assess what the capital and O&M costs would be for these stormwater capture and infiltration projects. Finally, the City would determine the water rate increase needed to pay for these local supply projects. Similarly, sewer service charges could be used to fund fecal bacteria TMDL projects. These TMDL projects could be eligible for funding because they protect public health from exposure to pathogens through managing runoff. Again, the City would need to identify what projects fall into this category, assess what these projects cost (including O&M), and then determine what sewer service charge increase is needed to implement the projects.

VIII. Energy and GHG Impacts of Water Supplies

A. Introduction

Increased atmospheric concentrations of GHGs and aerosols drives climate change. The increased concentrations alter the energy balance of the climate system by disrupting the absorption, scattering, and emission of radiation.[426] Major GHGs include carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Although CO2 is the most prevalent of the three, CH4 and N2O also pose threats as the global warming potential (GWP) of each is higher than that of CO2. The GWPs of CH4 and N2O are 25 and 298 times more than CO2, respectively.[427] Human activities, such as the combustion of fossil fuels, are linked to the rapid increase of GHGs in the atmosphere. GHG-driven climate change is associated with future climate scenarios that predict an increase in frequency, duration, and severity of droughts.[428]

GHG emissions regulations and policies exist at both a national level and a statewide level throughout California. At the federal level, the EPA issued the Greenhouse Gas Reporting Rule in 2009. Under this Rule, the EPA required facilities with emissions equal to or greater than 25,000 metric tons (MT) of carbon dioxide equivalent (CO2e) to submit annual reports informing the agency of their GHG emissions data. Emissions from even larger facilities are covered by the Prevention of Significant Deterioration (PSD) and Title V Operating Permit Programs GHG Tailoring Rule. The PSD permitting program requires these facilities operate in compliance under a permit and covers new projects that emit GHG emissions of at least 100,000 tons/year, and modifications at existing facilities that increase GHG emissions by at least 75,000 tons/year of CO2e.[429]

At the state level, the California Global Warming Solutions Act of 2006 [Assembly Bill 32 (AB 32)] requires by law that the California Air Resources Board (CARB) adopt rules and regulations as part of a climate plan to reduce the state's GHG emissions to 1990 levels by the year 2020.[430] This decrease represents an approximate reduction of 15 percent below the emissions of a "business as usual" scenario.[431] The GHGs regulated by AB32 include CO2, CH4, N2O, sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3) as well as two groups of GHGs, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).[432] To meet the AB32 goals, CARB had to adopt

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[426] Intergovernmental Panel on Climate Change. https://www.ipcc.ch/publications_and_data/ar4/syr/en/spms2.html. Accessed 10/11/2016

[427] CalEPA Air Resources Board, GWPs; https://www.arb.ca.gov/cc/inventory/background/gwp.htm

[428] Allen et al. "A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests". Forest Ecology and Management vol. 259.4. 2010. P.660-684. http://www.sciencedirect.com/science/article/pii/S037811270900615X. Accessed 10/11/2016.

[429] HWRP DGUP Draft EIR 2013 p. 54

[430] Discussion Paper for a Wastewater Treatment Plant Sector Greenhouse Gas Emissions Reporting Protocol. CH2M Hill 2007 p. 1-1

[431] California Air Resources Board Assembly Bill 32 Overview. https://www.arb.ca.gov/cc/ab32/ab32.htm. Accessed on 08/30/2016

[432] CARB AB 32 Overview. https://www.arb.ca.gov/cc/ab32/ab32.htm. Accessed on 08/30/2016

regulations to mandate emissions reporting and verification. Further, California's Senate Bill No. 32 requires that statewide GHG emissions are reduced to 40% below the 1990 level by 2030.[433]

The Regulation for Mandatory Reporting of GHG Emissions (MRR), adopted in 2007, required electricity generation units, cement producers, lime manufacturers, nitric acid producers, petroleum refineries, geologic sequesters of CO2, and injectors of CO2 to report GHG emissions regardless of emissions levels.[434] Facilities subject to MRR are required to monitor facility emissions and submit emissions data reports to CARB.[435] Data monitoring requirements include calibration of devices and maintaining measurement device accuracy standards. This involves the installation, operation, and maintenance of all measurement equipment, such as flow meters, in a manner to ensure accuracy within +/- 5%, as well as obtaining verification services for the data from these devices.[436] MRR also required operators or facilities of stationary fuel combustion, glass production, hydrogen production, iron and steel production, pulp and paper manufacturing, petroleum and natural gas systems, geothermal electricity generation, and lead production to report GHG emissions if emissions exceed 10,000 MT CO2e for a calendar year.[437]

The Cap and Trade program, one of the measures also developed for California's climate plan that commenced in 2013, relies on data collected through MRR. Through the Cap and Trade program, CARB set goals to reduce GHG emissions by implementing a statewide limit on the sources of GHG emissions. The program will reduce GHG emissions through the use of allowances and offsets in a market system for major emitters. Entities that emit over 25,000 MT of CO2 or CO2e will be required to report their emissions and comply with the Cap and Trade Program.[438]

Multiple requirements and policy goals currently drive efforts to reduce emissions and increase the use of renewables at both City and state levels. For example, in Senate Bill 350 (SB 350), California Governor Jerry Brown set a goal to generate 50% of the state's electricity from renewable sources by 2030. Energy goals in the pLAn include complete divestment from coal-fired power plants by 2025 and a reduction in GHG emissions to 60% below the 1990 baseline by 2035.[439] By 2050, the City plans to reduce GHG emissions even further, to 80% below the 2050 baseline. In 2014, LADWP derived more than half of its energy from coal and natural gas, with the remainder coming from a combination of nuclear, renewables, hydroelectric, "generic power,"

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[433] Senate Bill No. 32 https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32

[434] CARB Unofficial Electronic Version of the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions 2015 p. 2

[435] CARB Unofficial Electronic Version of the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions 2015 p. 76

[436] CARB Unofficial Electronic Version of the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions 2015 p. 81

[437] CARB Unofficial Electronic Version of the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions 2015 p. 2

[438] California Environmental Protection, Agency Air Resources Board: Overview of ARB Emissions Trading Program 2015 https://www.arb.ca.gov/cc/capandtrade/guidance/cap_trade_overview.pdf. Accessed on 08/30/2016

[439] Los Angeles Sustainable City pLAn, p. 35

and energy efficiency. LADWP aims to reduce the GHG footprint of its power generation by eliminating coal from its power supply portfolio and increasing the percentage of power from natural gas and renewable energy. Further, LADWP included a chapter on "Climate Change and Water and Energy Nexus" assessing the energy use and emissions of the various water sources in LADWP's water portfolio in its 2015 UWMP.[440]

In the presented work, we assess the GHG emissions of the three water supply portfolios described earlier (WS 2013, WS City 2035, and WS Max 2035) in the context of two LADWP power portfolios to understand the effects of water and power sources on LADWP's carbon footprint. The 2009 Climate Registry (TCR) Electric Power Sector (EPS) Protocol for the Voluntary Reporting Program was also used to calculate GHG emissions from specific power sources.

B. Energy Footprint of Water Supplies

a. LA Water Supplies

The SWP carries water from northern California and the Bay-Delta and lifts it 2,000 feet over the Tehachapi Mountains, making it the most energy-intensive source of water. In addition to going through a series of lift stations, SWP water also passes through energy production plants and thus the system both consumes and produces energy. The LAAFP treats water at a rate of 34 kilowatt-hours per acre-foot (kWh/AF).[441] Jensen and Diemer both use ozone treatment, which requires 42 kWh/AF and 20 kWh/AF, respectively.[442] Weymouth uses chlorine treatment (46 kWh/AF), but is undergoing an upgrade to add ozone treatment to its train that is slated to be completed in 2017. Like the SWP East Branch water, CRA water is treated at Weymouth and Diemer at a treatment energy intensity of 46 kWh/AF and 20 kWh/AF, respectively.[443]

MWD imported water has the highest associated energy intensity in kWh/AF as a result of the energy required to transport the water through the SWP East and West Branches and the CRA. A total of six pumps are required to lift water from the Bay-Delta to the beginning of the West and East branch split. The West and East branches of the SWP each have one additional pump to convey the water to the respective terminuses. Each of these three imported sources (SWP East, SWP West, and CRA) has different energy requirements. Water that is pumped from the Bay-Delta through the West Branch to Lake Castaic consumes an average net energy of 2,563 kWh/AF; water conveyed from the Bay-Delta through the East Branch requires an average of 3,115 kWh/AF.[444] However, the gross energy requirements (which do not include, for example, hydropower generated at Oroville Dam) are 4,110 kWh/AF and 4,520 kWh/AF for SWP West and SWP

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[440] LADWP UWMP 2015 Chapter 12.
[441] LADWP UWMP 2015 p. 12-24
[442] LADWP UWMP 2015 p 12-24
[443] LADWP UWMP 2015 p. 12-24
[444] Embedded Energy in Water Studies Study 1: Statewide and Regional Water-Energy Relationship Prepared for the California Public Utilities Commission Energy Division (2010) Figure 3.3 and Appendix C.2; available at:

East, respectively.[445] Colorado River Water, transported through the CRA, is the third most energy intensive source of water for LA (after SWP East and SWP West). 2,000 kWh/AF is required to transport water through the CRA from Lake Havasu to Lake Mathews; this journey includes five pumping stations to achieve a lift of approximately 1,617 feet (ft). [446]

The LAA is an energy-producing gravity-fed system that supplies water from the Eastern Sierras. Therefore, no conveyance power is required to bring water into the City through the LAA. In fact, the LAA generates approximately 4,736 kWh/AF from the flowing water on average, which is directly used to generate power.[447] However, when taking into consideration the fact that not all water that flows through the LAA is used to generate power, and that some water is introduced into the LAA downstream of a few of the power plants, the energy ultimately generated through the LAA is approximately 2,429 kWh/AF.[448] For the purposes of this analysis, treatment energy intensity was not included for imported water supplies as the energy required is minimal (~33 kWh/AF) compared to that of pumping.[449] Thus, LAA energy intensity was considered to be 0 since it is gravity-driven and requires no energy to move its water. Energy generated by LAA is not included in LADWP's total water system energy because it is not used to offset energy required for sources of water (e.g., pumping) but is instead sold to customers.[450]

Extraction and treatment of groundwater accounts for about 7% of the total CO2 emissions of LADWP's water portfolio.[451] The energy intensity associated with groundwater supply in our analysis is pumping. We used the average energy intensity (580 kWh/AF) for groundwater in the LADWP UWMP.[452] It is important to note that the energy intensity of groundwater pumping can vary between locations based on groundwater levels, pump efficiencies, and the effect of water quality on well-pump operations. Currently, no additional energy is associated with groundwater treatment.[453] In addition, ramping up the volumes of groundwater in the LADWP water supply portfolio will require remediation that could increase the energy footprint associated with groundwater as a component of the local water supply. However, the energy footprint of groundwater is still expected to stay lower than, for example, imported water.[454]

The energy associated with recycled water in this analysis is the energy required to pump the water to customers and the energy required to treat water past tertiary treatment levels to advanced

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https://www.waterenergyinnovations.com/publication/view/cpuc-embedded-energy-in-water-studies-1-statewide-and-regional-water-energy-relationship/

[445] CA DWR, personal communication

[446] LADWP UWMP 2015 p. 12-20

[447] LADWP UWMP 2015 p. 12-20

[448] UWMP. Chapter 12. P. 12-21

[449] LADWP UWMP 2015 p. 12-25, Exhibit 12P

[450] LADWP, personal communication

[451] LADWP UWMP 2015 p. 12-27, Exhibit 12R

[452] LADWP UWMP 2015 Chapter 12. p. 12-23

[453] LADWP, personal communication

[454] LADWP UWMP 2015 Chapter 12. p. 12-23

treatment. As all plants that directly supply recycled water to LADWP apply tertiary treatment regardless of whether the water is reused or discharged, the energy expended up to the completion of tertiary treatment is considered a sunk cost. Only the energy intensity of pumping associated with LAGWRP (614 kWh/AF) and DCTWRP (467 kWh/AF) are considered. The energy intensity of advanced treatment after tertiary treatment, 2,318 kWh/AF, is considered at TIWRP; the energy footprint associated with WBMWD recycled water for Title 22 water that comes to the city (602 kWh/AF) is also a component of the overall recycled water calculation.[455] Thus, for consistency with the LADWP UWMP, the associated energy requirement of recycled water used in this analysis is the weighted average of the energy intensities of WBMWD recycled water, TIWRP advanced water, and pumping at LAGWRP and DCTWRP: 1,150 kWh/AF.[456]

It is important to note that the energy and GHG emissions footprints associated with recycled water are subject to change as technologies evolve and depending on which parts of the treatment trains are included in the analysis. We used 1,150 kWh/AF as the energy intensity of recycled water in this analysis for consistency with the LADWP UWMP across all water supplies. As this energy intensity is also within likely energy ranges (1,060 kWh/AF to 1,300 kWh/AF) for AWTFs,[457] we also used 1,150 kWh/AF in the 2035 scenarios to reflect the fact that some form of advanced treatment would likely be necessary to fully reuse recycled water.

Additional options to provide water quality that are equivalent to MFRO-treated water for a lower energy footprint may be possible in the future; this would in turn impact the GHG footprint of increasing the volumes of water recycled. For example, the recently released WRD GBMP outlined detailed energy intensity values for different processes of advanced treatment that could be used for groundwater recharge. For example, the treatment and conveyance energy values are reported as 980 kWh/AF for full advanced treated recycled water, 770 kWh/AF for nanofiltration, and 2,500 kWh/AF for treated imported MWD water.[458]

We used the energy required to pump water throughout the LADWP distribution system to represent the stormwater supply energy intensity in this analysis due to a lack of data and studies quantifying the energy required for centralized stormwater capture and distribution. The LADWP distribution system includes 78 pump stations and 7,263 miles of distribution main; the average energy intensity is approximately 174 kWh/AF.[459] In this analysis, we assume the only required energy associated with stormwater is the energy necessary to move it as stormwater recharge efforts currently do not require additional treatment (unlike stormwater capture and reuse projects).

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[455] LADWP UWMP 2015 p. 12-23

[456] LADWP UWMP 2015 p. 12-23; A recent study done for LASAN and LADWP that evaluated energy consumption and water flow data from 2008 to 2015 found the overall average energy intensity values for HWRP, LAGWRP, DCTWRP, and TIWRP to be 513 kWh/AF, 504 kWh/AF, 526 kWh/AF, and 970 kWh/AF respectively

[457] Framework for Direct Potable Reuse, WateReuse, American Water Works Association, Water Environment Federation, National Water Research Institute. Editors Jeffrey Mosher, Gina Melin Vartanian. 2015. P. 14 Available at https://watereuse.org/watereuse-research/framework-for-direct-potable-reuse/ (Framework for DPR 2015)

[458] WRD GBMP 2016 p. 5-30, Table 5-13

[459] LADWP UWMP 2015 p. 12-24

The energy associated with stormwater could vary depending on the specific project; for example, if rainfall flows to spreading grounds for infiltration into the groundwater basins by gravity, then no energy would be required. This assumption of zero required energy (0 kWh/AF) for stormwater is made in WRD's GBMP.[460] It is also possible in certain cases that energy intensity could be higher. For example, increasing stormwater capture to the degree that runoff from relatively contaminated sites will be captured may require additional treatment before the stormwater can be reused or infiltrated to protect water quality.

An initial study for the Goldsworthy desalter expansion reported that the CO2e emissions at the facility amount to 1,691 tons per year, which is equivalent to about 0.54 tons of CO2e/AF.[461] Based on electricity consumption and water production from June 7 to July 7, 2005, energy consumption at Goldsworthy was 1,274 kWh / AF (3.91 kWh / kgal).[462] Per the Environmental Impact Assessment for the North Pleasant Valley Desalter, the emissions for operating the desalter could be up to 3,335 tons of CO2e per year, which amounts to about 0.44 tons CO2e/AF.[463] Reverse osmosis desalting treatments like those used in the abovementioned facilities have been reported to consume less energy than thermal technologies like multi-effect distillation (7,400-12,330 kWh/AF) and multi-stage flash (16,650-28,990 kWh/AF).[464] The energy footprint for brackish water desalination was found to be as low as 1,233 kWh/AF compared to 4,564 kWh / AF for seawater desalination.[465] In one seawater desalination plant of about 15,000 AFY, the energy use was 4,465 kWh/AF; 77% of the total energy use was utilized within the high pressure system required to push water through the filter membranes.[466]

Although the energy footprint of filtration and reverse osmosis technologies is lower than thermal technologies when treating the same types of water, the energy footprint of treating seawater is higher than treating more dilute brackish groundwater or recycled water with either technology. Cornejo et al (2014) reported that energy use for water desalination via reverse osmosis ranged between 4,930 and 5,500 kWh per acre foot.[467] It is generally accepted that seawater desalination requires significantly more energy than brackish desalination. Brackish desalination has a lower

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[460] WRD GBMP 2016 p. 5-30, Table 5-13

[461] CH2MHILL. Initial Study: Robert W. Goldsworthy Desalter Expansion Project. 2013. Chapter 3. P. 3-13; calculation: 1,691 tons / 2.75 MGD

[462] Evaluation of Dynamic Energy Consumption of Advanced Water and Wastewater Treatment Technologies, AWWA, 2008 YuJung Chang, David J. Reardon, Pierre Kwan, Glen Boyd, and Jonathan Brant. Kerwin L. Rakness, David Furukawa; available at: https://www.waterrf.org/publicreportlibrary/91231.pdf

[463] Padre Associates Inc. Draft Environmental Impact Report: Environmental Assessment for the North Pleasant Valley Groundwater Treatment Facility. 2014. Chapter 5. P. 5.5-5: calculated as in footnote 95 (CH2MHILL. Initial Study: Robert W. Goldsworthy Desalter Expansion Project. 2013. Chapter 3. P. 3-13)

[464] Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination*. 2014. P. 243

[465] Semiat, Raphael. Energy in Desalination Processes. *Env Science and Technology*. Vol. 42, No. 22. 2008.

[466] Semiat, Raphael. Energy in Desalination Processes. *Env Science and Technology*. Vol. 42, No. 22. 2008. P. 8195.

[467] Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination*. 2014. P. 242

carbon footprint than seawater desalination because there is a lower level of salt rejection required to meet treated water standards.[468] A typical recovery rate for seawater desalination is 50%.[469] A local example of this recovery rate is exhibited at the Carlsbad Seawater Desalination Plant: 104 MGD of seawater inflow would produce 50 MGD of desalinated water, which yields a 48% recovery rate.[470] These seawater desalination recovery rates are much lower than the 80%-plus recovery rates described above for local brackish groundwater desalters, which contributes to the higher energy cost per AF of water supply from seawater desalination.

In addition to a lower recovery rate, studies show that seawater desalination results in higher GHG emissions. Schneider et al (2015) found that seawater desalination yields 2.4 times more CO2e/AF than water reclamation or recycling.[471] Other studies found that, depending on its salinity and pretreatment levels, the power required to desalinate water through RO emits between 0.5 to 5.4 tons of CO2e/AF. A higher pretreatment level by either conventional means (e.g., granular activated carbon) or advanced means (e.g., membrane filtration) achieves a lower footprint for the RO system. Seawater requires a higher level of pretreatment and therefore is on the higher end of the footprint (up to 5.4 tons of CO2/AF).[472]

b. Additional Wastewater Treatment Options

As briefly discussed above, the average treatment energy intensity of recycled water depends on a variety of factors, including the treatment processes at each plant. Separate studies have documented different energy intensities for a variety of treatment stages and processes. For example, Fine and Hadas (2011) found that treating water to secondary effluent standards in a 94 MGD plant in Tel Aviv required approximately 633 kWh/AF while 1,237 kWh/AF was required to treat water to tertiary standards with NdN.[473] Mo and Zhang measured energy use in a municipal wastewater system in Tampa that treats 12 MGD of recycled water with NdN at an intensity of 1,456 kWh/AF.[474] In NdN systems, a large part of the energy footprint (between 50 and 70% of the total process energy consumption) can be attributed to the aeration basins.[475] The literature on

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[468] Ibid. P. 242

[469] Semiat, Raphael. Energy in Desalination Processes. *Environmental Science and Technology*. Vol. 42, No. 22. 2008.

[470] *City of Carlsbad. Precise Development Plan and Desalination Plant Project. Section 3. P. 3-1; 3-18*

[471] Schneider et al. Impact of Direct Greenhouse Gas Emissions on the Carbon Footprint of Water Reclamation Processes Employing Nitrification–Denitrification. *Science of the Total Environment.* 2015. P. 1167

[472] Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination.* 2014. P. 242

[473] Fine and Hadas. Options to Reduce Greenhouse Gas Emissions During Wastewater Treatment for Agricultural Use. Science of the Total Environment. 2011. P. 290.

[474] Mo, Weiwei and Zhang, Qiong. Can wastewater treatment systems be carbon neutral? Journal of Environmental Mangement 2012. 112 p. 360-367

[475] Aymerich, Ignasi, et al. The difference between energy consumption and energy cost: Modelling energy tariff structures for water resource recovery facilities. 2015. P. 114.

this subject emphasizes the importance of looking at local systems for power consumption and emissions given the variety of treatment technologies that exist.

Looking in greater detail at the energy requirements of different stages of a treatment process can provide insights into the areas that require the most energy. For example, one potential breakdown of the energy expenditures for the advanced oxidation process treatment found in the literature is as follows: 3% Pumping, 4% Primary clarification, 16% Secondary clarification, 21% Microfiltration, 49% Reverse Osmosis, and 7% Advanced oxidation process. [476] This breakdown is consistent with a significant increase in energy use as a result of the higher energy needs of MFRO treatment compared to other treatment trains, but it would still be lower than importing water. The advanced oxidation process also has a lower energy footprint than MFRO in this breakdown.

An alternative treatment to MFRO and AOP is the use of membrane bioreactors (MBRs), which are currently being considered to add 5 MGD of advanced water treatment capacity at HWRP. MBR may require less energy than MFRO. For example, Fenu et al (2010) found in a study and energy audit of an MBR system that an MBR system treating approximately 2,500 AFY consumed approximately 789 kWh/AF.[477] Similar effluent flows can be handled at a similar footprint when compared to a conventional activated sludge (CAS) train with advanced treatment through ultrafiltration, RO, and ultraviolet (UV) disinfection. The CAS train at a treatment facility in Schilde, Belgium treated about 10,000 AFY at an energy intensity ranging between 620 and 731 kWh/AF.[478] The specific energy of UV disinfection ranges between 49 and 160 kWh/AF.[479]

However, it is important to note that MBR systems have widely variable energy requirements and thus care must be taken to ensure that planned MBR systems will be energy-efficient relative to other treatment trains being considered. MBR systems must also be appropriate for the size of the project. One published literature review found the energy required to run MBR facilities ranged between approximately 990 and 1,500 kWh/AF.[480] Another from 2017 found an even wider range, from 740 to 2,339 kWh/AF.[481] In addition, since MBR alone may not provide the treatment level necessary to meet all required standards depending on the intended use, an additional treatment step such as RO may be required in addition to MBR (which would increase the energy requirements substantially).

c. The Array of Water Supply Options

As a result of this wide variability in energy needs, the mix of water sources can have a large impact on the energy footprint required to supply water to the City. In general, ocean desalination is the most energy intensive potential water source in the region, followed by imported water

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[476] Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination*. 2014. P. 244

[477] Fenu et al. Energy Audit of a Full Scale MBR System. *Desalination*. 2010. P. 122

[478] Fenu et al. Energy Audit of a Full Scale MBR System. *Desalination*. 2010. P. ?

[479] Fenu et al. Energy Audit of a Full Scale MBR System. *Desalination*. 2010. P. 124

[480] Fenu et al. Energy Audit of a Full Scale MBR System. *Desalination*. 2010. P. 124

[481] Krzeminski P. et al, Membrane bioreactors – A review on recent developments in energy reduction, fouling control, novel configurations, LCA and market prospects. Journal of Membrane Science 527 (2017) p 207-227

sourced through the CRA and the SWP (Table 8.1). The energy requirements for advanced water treatment overlap with the low end of the range for desalinating brackish water. Secondary and tertiary treatment have much lower energy requirements than other more advanced treatment trains. However, the ability to reuse this recycled water would be far lower than with the other options described as this treatment level would not be high enough for all uses (e.g., potable reuse).

Energy requirements vary not only among water sources, but also within water sources (Table 8.1). For example, the high end of the energy range for AWTF (2,020 kWh/AF) is double that of the low-end (1,010 kWh/AF), and there is an even greater difference between the low and high end of the energy requirements for MBR (740 to 2,839 kWh/AF, Table 8.1). Therefore, it is important to consider the range of energy uses that are possible within treatment types as well as among treatment types in City planning efforts as these differences can be significant.

Technology / Water Source	Energy Range[482]	
	kWh/AF	
Conventional water treatment	98	130
Membrane-based water treatment	326	489
Secondary Treatment without nutrient removal	342	456
Tertiary treatment with nutrient removal and effluent filtration	521	635
Membrane Bioreactor (MBR)	740	2,839
Brackish water desalination	1,010	2,020
AWTF[483]	1,059	1,303
Inter-basin transfer of Water CO River water	2,004	2,411
Inter-basin transfer of Water CA SWP	2,581	3,232
Ocean desalination	3,096	4,806

Table 8.1. Energy requirements for a variety of water and wastewater treatment trains.

C. Power Portfolios

In addition to the variability in energy requirements among water sources, the power sources used to supply this water can also impact the GHG emissions of supplying the City with water. We assessed the impacts of a recent power mix (PP 2014) and a potential future power mix that reflects the 50% renewable energy requirements in SB 350 (PP 2035) on these emissions. LADWP's power mix was used to calculate GHG emissions for groundwater, recycled water, and stormwater. The power mix used to pump CRA water was used for the CRA portion of MWD's

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[482] Most energy sources from DPR Report 2015, see p. 14 for assumptions on energy range. MBR energy from Krzeminski et al 2017.

[483] Based on OCWD original ATW: Treatment technology includes filter screens, MF, cartridge filtration, RO, advanced oxidation, decarbonation, lime stabilization. DPR Report 2015, see p. 11

imported water. GHG intensity factors and energy requirements provided by the California Department of Water Resources were used to calculate GHG emissions of MWD's water provided by the SWP's East and West Branches.[484]

For PP 2014, the breakdown of LADWP's electricity generation was 40% coal, 22% natural gas, 20% renewables, 9% nuclear, 7% "unspecified sources of power," and 2% large hydroelectric.[485] Electricity generated by "unspecified sources of power" or "generic power" is defined as "electricity from transactions that are not traceable to specific generation sources."[486] LADWP's 2014 renewable power sector includes wind (12%), biomass & waste (5%), geothermal (1%), solar (1%), and small hydroelectric (1%).[487] The power sources used to meet MWD's CRA system's needs are composed of hydroelectricity, Southern California Edison, and third-party purchases. CRA's PP 2014 was represented by the average power contribution of each of these sources from 2005 to 2015: approximately 62% from hydroelectricity, 27% from Southern California Edison, and 11% from third-party purchases.[488] For SWP's PP 2014, the average GHG intensity of DWR's energy supplies from 2009 to 2013, 0.333 mtCO2e/MWh, was used.[489]

LADWP's 2015 IRP power profile, which reflects the goals of SB 350, is used in this analysis as the future profile (PP 2035) of electricity generation for recycled water, stormwater, and groundwater.[490] This composition of power sources is 50% renewables, 25% natural gas, 16% energy efficiency, 6% nuclear, and 3% hydroelectric.[491] LADWP's energy efficiency calculations also included projected population growth; in our analysis we assigned 0 GHG emissions to the 16% energy efficiency component. Four LADWP sources of renewable power, wind (12%), biomass & waste (5%), small hydroelectric (1%), and geothermal (1%), were held to the same percentages as in PP 2014. Solar power, however, was increased to a 31% contribution of the overall power profile. The increase in renewables was attributed solely to solar power to reflect the likely growth of solar power in the LADWP renewables portfolio over the next 15 years. Similarly, the Southern California Edison component of CRA's power sources was updated to include 50% renewable, all stemming from solar PV to reflect SB 350 for PP 2035; hydroelectric and third-party purchased percentages remained the same. SWP's GHG intensity projection for 2035, 0.063 mtCO2e/MWh, was used for PP 2035.[492]

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[484] CA DWR, personal communication
[485] LADWP Power Content Label 2014 http://www.energy.ca.gov/sb1305/ Accessed on 09/21/2016
[486] LADWP Power Content Label 2014 http://www.energy.ca.gov/sb1305/ Accessed on 09/21/2016
[487] LADWP Power Content Label 2014 http://www.energy.ca.gov/sb1305/ Accessed on 09/21/2016
[488] MWD, personal communication
[489] CA DWR, personal communication
[490] Since this analysis was conducted, LADWP has released their 2016 IRP, available at: https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB562207&RevisionSelectionMethod=LatestReleased Future work building on these analyses should consider the most current information on power and water supply mixes to fully incorporate changing plans of all involved agencies.
[491] LADWP 2015 Power Integrated Resource Plan Presentation. April 18, 2016.
[492] CA DWR, personal communication

As power portfolios continue moving towards lower-GHG power sources, additional reductions in GHG emissions without reductions in energy use will occur. For example, the City is also exploring opportunities to completely transition away from all fossil fuels, including natural gas, in addition to eliminating coal by 2025. The LA City Council unanimously approved a measure in September 2016 that will require LADWP to identify the necessary investments and priorities needed to reach 100% renewable energy.[493] If this transition to 100% renewable energy were to occur, the GHG emissions of the power portfolio would again decrease greatly as the GHG emissions factor of natural gas is second after that of coal.

D. GHG Emissions Methods

Two methods were explored for conducting the GHG emissions in the presented work. The first is a method provided through the Climate Registry (TCR), which is a non-profit organization governed by the United States (US) and Canadian provinces and territories. TCR focuses on developing and operating global voluntary and mandatory compliance GHG reporting programs to help organizations measure and verify their carbon footprint. TCR designed an Electric Power Sector (EPS) specific protocol, which is used in conjunction with the general reporting protocol. Chapter 12 of the 2009 EPS protocol provides a mechanism to calculate direct emissions from stationary combustion of various power sources.

An alternative to using the TCR EPS protocol is EPA's Emission and Generation Resource Integrated Database (eGRID) data. The eGRID is an inventory of plant-specific data for electricity generating plants throughout the US that is reported to the Energy Information Administration.[494] Using reported emissions data and generation values, eGRID produces regional emissions rates for CO2, CH4, and N2O. The eGRID also produces a Power Profiler, which uses the data to produce a breakdown of electricity generation sources for specific utility companies. The most recent eGRID Power Profile for Los Angeles is based off 2014 LADWP data and further characterized by a geographic region, Western Electric Coordinating Council (WECC), that covers most of California and parts of Arizona. The WECC region is represented by a fuel mix that includes: 18.6% Non-hydro Renewables, 8.4% Hydropower, 9% Nuclear, 62.5% Gas, and 0.4% Coal.[495]

The EPS-specific protocol provided by TCR was used in the presented analysis as the available eGRID data has a far lower contribution from coal in its power portfolio than the City's current power mix. Further, the EPS protocol provided the capacity to associate GHG emissions rates with specific power sources and thus to address GHG emission changes that result from portfolio shifts. As the eGRID provides total output emissions rates of all electricity generated rather than

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[493] September 16, 2016 Press release. http://content.sierraclub.org/press-releases/2016/09/los-angeles-takes-major-step-toward-100-clean-energy. Accessed 10/19/2016

[494] https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid-questions-and-answers#egrid1. Accessed 02/10/2017

[495] https://www.epa.gov/energy/power-profiler. Accessed 02/10/2017

emissions per power source, this power source-specific analysis would not have been possible with the eGRID numbers.

For the TCR approach, annual TCR default emissions factors are reported for fossil fuels and biomass, including the following components of LADWP's power profile: coal, natural gas, and 'biomass and waste.' 2014 TCR emissions factors were used for the PP 2014 analyses and 2016 TCR emissions factors were used for the PP 2035 analyses.[496] As mentioned above, CH4 and N2O have greater GWPs than CO2; the GWPs of CH4 and N2O are 25 and 298, respectively.[497] To compare all GHG emissions on the same scale, the total MT of CH4 emissions and N2O emissions are multiplied by their respective GWP. Coal is eliminated in LADWP's SB 350 power portfolio so the 2016 coal data is not needed for the PP 2035 analysis. The US weighted average of natural gas emissions data was used from 2014 and 2016 TCR default emissions reports.

TCR does not provide emissions data for nuclear power or the renewable energy sources included in LADWP's power portfolio such as geothermal, hydroelectric, solar, and wind. Therefore, nuclear power emissions data was used from a report by the World Nuclear Association (WNA) that compared lifecycle GHG emissions of different generation facilities through a literature review of 21 independent studies. The average emissions factor for nuclear power in the WNA report is 29 MT of CO2e per giga-watt-hour (GWh).[498]

For renewable energy sources, the emissions factors reported by the IPCC in the Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) were used in this analysis. The National Renewable Energy Laboratory (NREL) conducted a comprehensive review of lifecycle assessments (LCA) for each renewable energy source technology that was published in the SRREN.[499] The 50th percentile (median) values of the total aggregated emissions factors from this literature review were used for geothermal (45 g CO2e/kWh), hydroelectric (4 g CO2e/kWh), wind (12 g CO2e/kWh), and solar (46 g CO2e/kWh).[500] It was further assumed for the purposes of this analysis that the solar power in the LADWP power profile would originate from photovoltaic (PV) technology as opposed to concentrated solar power (CSP) technology; these values could change depending on the final composition of LADWP's solar power sources. These emissions

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[496] TCR Default Emissions Factors 2014 p. 1, Table 12.1 and p. 16, Table 12.9; TCR Default Emissions Factors 2016 p. 1, Table 12.1 and p. 26, Table 12.9

[497] CalEPA Air Resources Board, GWPs; https://www.arb.ca.gov/cc/inventory/background/gwp.htm

[498] World Nuclear Association "Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources" 2011 p. 6, Table 2

[499] The literature being reviewed had to pass through three rounds of screening by multiple experts to ensure quality and relevance of the data being presented (Intergovernmental Panel on Climate Change 2012 "Special Report on Renewable Energy Sources and Climate Change Mitigation", Annex II "Methodology", A.II.5.2.1, p. 980). A total of 984 studies passed all three screens and were reviewed for 11 technology categories (IPCC 2012 SRREN Annex II p. 981, Table A.II.3).

[500] IPCC 2012 SRREN Annex II p. 982, Table A.II.4

factors were multiplied by the total energy derived from each renewable power source for each water supply.

Finally, the nuclear emissions factor was used to represent biomass (5% of LADWP's power portfolio) emissions as there is some overlap in emissions factors based on the literature review done in the earlier referenced WNA report. Due to the wide range of potential emissions from biomass, future analyses could be strengthened by using more specific numbers for this renewable power source. This analysis could be conducted using default emissions factors in the TCR and Equations 12g and 12h in the EPS protocol to calculate GHG emissions from biomass combustion. These equations and emissions factors require facility-specific data such as steam generated in pounds per year and boiler design heat input/boiler design steam output in MMBtu per pound of steam generated at the facility being analyzed.[501]

E. Study Approach

The energy intensities, water supply sources, and power portfolios described above constitute the basis of this study to quantify the energy and GHG footprint of LADWP water supply portfolios in the context of a changing power portfolio. GHG emissions were calculated for WS 2013, WS City 2035, and WS Max 2035 using PP 2014 and PP 2035. GHG emissions for MWD water (SWP East, SWP West, and CRA) in WS 2013 were calculated using water supply volumes in LADWP's UWMP. In WS City 2035 and WS Max 2035, we assumed DWP's historical ratio of SWP East (15%), SWP West (70%), and CRA (15%) water purchased from MWD. For comparing across water portfolios, the historical ratio of MWD supplies was applied to WS 2013 to allow for parallel comparisons (actual supply mix in WS 2013 was representative of drought year).

The presented analyses also employ the use of TCR EPS Protocol, annual TCR Default Emissions Factors, WNA data, and the IPCC 2012 SRREN report. It is important to note in the following discussion that changes in GHG and energy use, as well as differences in emissions between sectors of the water portfolio, are impacted by changes in water volumes as well as in energy intensities. Therefore, a water supply with a lower energy intensity may still end up contributing a large portion of the energy footprint if it represents a very large portion of the overall supply portfolio. The energy intensities of the water supplies described here, per AF, decrease in the following order: MWD imported water, recycled water, groundwater, stormwater, LAA water.

The impacts of the changing face of the power portfolios associated with moving water to Los Angeles (e.g., as coal gets phased out and renewable energy sources increase) on the GHG emissions of these three water supply portfolios were also assessed. GHG emissions will change even in cases in which the total amount of energy required is the same, depending on the mix of power sources used. As with varying water sources, the emissions of each type of power supply can increase with the percentage of portfolio as well as through the actual emissions. The GHG emissions factors of each power source decrease in the following order: coal, natural gas, solar, geothermal, nuclear, wind, and hydroelectric (Table 8.2).

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[501] TCR EPS Protocol 2009, p. 45, Equation 12h

Power Source	Emissions Factor
Coal	3.25E-04 MT of CO2e/kWh
Natural Gas	1.81E-04 MT of CO2e/kWh
Solar	4.6E-05 MT of CO2e/kWh
Geothermal	4.5E-05 MT of CO2e/kWh
Nuclear	2.9E-05 MT of CO2e/kWh
Wind	1.2E-05 MT of CO2e/kWh
Hydroelectric	4E-06 MT of CO2e/kWh

Table 8.2. Emissions factors of power sources associated with LADWP's power portfolio.[502]

F. LADWP Water Supply Portfolio Emissions

Emissions from the assessed water portfolios generally decreased with currently planned changes such as increasing City-wide conservation and the percentage of the water supply portfolio that is sourced locally. To assess changes in GHG emissions across parallel water portfolios, LADWP's historic mix of MWD water (15% SWP East, 70% SWP West, and 15% CRA)[503] was used to determine the GHG emissions rather than the actual WS 2013 volumes as they reflected a serious drought year. Despite large decreases in volume, imported water still has the largest emissions footprint in the WS City 2035 portfolio due to its large energy requirements. However, MWD water is no longer the largest contributor to emissions in WS Max 2035 when it has been reduced to 35,000 AF (~8% of the total WS portfolio). All emissions presented in this section assume that energy is sourced through PP 2014; changes to emissions if power is sourced through PP 2035 are discussed in the following section.

The total volume of water delivered in WS 2013 was 592,352 AF, with the majority sourced from MWD, then groundwater, LAA, and recycled water. Total emissions for WS 2013 under PP 2014 were estimated to be 576,846 MT of CO2e (Table 8.3). Total emissions for FY 2014 were calculated to be 416,841 MT of CO2e in the LADWP UWMP. This difference in GHG footprint stems largely from the calculated footprint of MWD water in the two studies. The UWMP approach, which uses the eGRID numbers, found the GHG footprint of MWD water to be 333,990 MT CO2.[504] Our analysis, based on the GHG emissions factors for each power source, found the GHG footprint of MWD water to be 545,078 MT of CO2e.

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[502] TCR Default Emissions Factors 2014 p. 1, Table 12.1 and p. 16; World Nuclear Association "Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources" 2011 p. 6, Table 2; IPCC 2012 SRREN Annex II p. 982, Table A.II.4

[503] DWP personal communication, past 5-10 years of data.

[504] LADWP 2015 UWMP p. 12-27

PP 2014	Energy Required (kWh/AF)	WS 2013 Average Volume (AF)	WS 2013 Total Emissions (MT of CO2e)	WS City 2035 Volume (AF)	WS City 2035 Total Emissions (MT of CO2e)	WS Max 2035 Volume (AF)	WS Max 2035 Total Emissions (MT of CO2e)
SWP East	4,520	66,281	99,764	15,000	22,577	5,250	7,902
SWP West	4,110	309,309	423,330	70,000	95,804	24,500	33,531
CRA	2,000	66,281	21,984	15,000	4,975	5,250	1,741
MWD	-	*441,871*	*545,078*	*100,000*	*123,356*	*35,000*	*43,174*
LAA	0	61,024	-	139,400	-	91,000	-
Groundwater (net)	580	79,403	25,393	114,100	36,490	114,100	36,490
Recycled Water	1,150	10,054	6,375	88,500	56,117	161,400	102,342
Stormwater	174	n/a	-	37,000	3,550	58,000	5,565
Total	-	592,352	576,846	479,000	219,513	459,500	187,571

Table 8.3. Total Emissions of water supply portfolios under PP 2014.

MWD water was the water source with the highest supply volume (441,871 AF) and the highest overall energy intensity in WS 2013. As a result, imported MWD water produced the most emissions in WS 2013 (545,078 MT of CO2e). Groundwater was responsible for the second-most GHG emissions in WS 2013 (25,393 MT of CO2e, Table 8.3) but this footprint was due more to groundwater representing the second largest water supply volume (79,403 AF) as groundwater has a much lower energy intensity (580 kWh/AF) than recycled water. The volume of groundwater was almost eight times larger than the volume of recycled water supplied in WS 2013; recycled water was the least supplied (10,054 AF) water source and thus had the smallest GHG footprint (6,375 MT of CO2e) even though it had the second highest energy intensity (1,150 kWh/AF, Table 8.3). It is important to note that the GHG emissions associated with recycled water would be higher if the volumes of recycled water used for environmental uses such as the LAR, Lake Balboa, and the Japanese Garden were also included in WS 2013 as a recycled water use.

WS City 2035 reflects the Mayor's pLAn goals to supply 50% of the City's water from local sources. Thus, the volume of water imported from MWD is much lower in WS City 2035 (100,000 AF) than in WS 2013 and the water volumes for the remaining sources increase to make up the difference: LAA (139,400 AF), groundwater (114,100 AF), recycled water (88,500 AF), and stormwater (37,000 AF). The total required supply volume also decreases by 19% from WS 2013 as only 479,000 AF is needed to meet the demand generated by pLAn water conservation goals.

WS City 2035 produced a total emissions of 219,513 MT of CO2e, an approximately 60% decrease in emissions from WS 2013. Although the MWD water supply volume in WS City 2035 represented a 77% decrease from WS 2013, it was still the highest emitting water source in WS City 2035 with estimated emissions of 123,356 MT of CO2e. Recycled water had the second largest GHG footprint with total emissions of 56,117 MT of CO2e, or 25% of the total water supply emissions. Groundwater as a water source emitted 36,490 MT of CO2e, a 44% increase in emissions from WS 2013. And lastly, stormwater (also the smallest portion by volume of the water portfolio) had the second smallest GHG footprint (only higher than LAA water) emitting 3,550 MT of CO2e (Table 8.3).

As described above, WS Max 2035 was developed to maximize local water supply and thus has a heavy emphasis on increasing the volumes of recycled water (161,400 AF) and stormwater capture and recharge (58,000 AF) to facilitate a reduction in volumes of LAA (91,000 AF) and MWD (35,000 AF) water supplies. The reduction in MWD volume led to total emissions from imported water (43,174 MT of CO2e, Table 8.3) amounting to only 23% of the total WS Max 2035 emissions. Recycled water increased by 82% from WS City 2035 to become the largest water supply (35%) in WS Max 2035 and also produced the most GHG emissions (102,342 MT of CO2e, 54% of total emissions). The remaining emissions were derived from groundwater (19%), and stormwater (3%). Emissions from stormwater as a water supply in WS Max 2035 increased by 57% to 5,565 MT of CO2e but stormwater remained among the water supplies with the lowest energy intensity on a per AF basis. Stormwater emissions could be even lower, depending on the pumping needs to move the stormwater to, for example, an appropriate area to recharge groundwater basins used for supply.

Increasing the volume of locally-sourced water greatly reduced water supply emissions. The volume of MWD water in WS Max 2035 represents a 65% decrease from WS City 2035 (100,000 AF) and a 92% decrease from WS 2013 (441,871 AF). GHG emissions from MWD imported water in WS 2013 comprised 95% of the total emissions (in part due to its high supply volume) while groundwater and recycled water contributed only 4% and 1%, respectively, of total WS 2013 GHG emissions. When transitioning from WS 2013 to WS City 2035 (representing a 77% decrease in MWD supply), total emissions from MWD water decreased, but still remained the largest contributor to the total water portfolio’s GHG emissions at 56%. WS City 2035 supply volumes of groundwater, recycled water, and stormwater increased, which resulted in these sources contributing a greater percentage of total WS City 2035 GHG emissions: groundwater (16%), recycled water (25%), and stormwater (1%). Groundwater supply volume (114,100 AF), and thus groundwater emissions, was unchanged between WS City 2035 and WS Max 2035.

The combination of moving towards a more local water supply and decreasing the volume of water required through conservation resulted in a significant decrease in emissions compared to WS 2013. The total supply volume for WS Max 2035 decreased to 459,500 AF, a 4% decrease from WS City 2035 and a 22% decrease from WS 2013. Total emissions for WS Max 2035 were 187,571 MT of CO2e, which is approximately a 15% decrease from WS City 2035 and a 70% decrease from WS 2013. MWD imported water still had the second largest GHG footprint (43,174 MT of CO2e, Table 8.3) despite being the smallest segment of WS Max 2035 (35,000 AFY, or 8% of the total water supply). However, the total emissions produced by importing MWD water in WS Max 2035 decreased by approximately 65% from WS City 2035 and 92% from WS 2013.

Interestingly, the bulk of MWD’s GHG emissions stem from importing SWP water, due both to larger SWP volumes and the much higher percentage of 0 GHG hydroelectric power that powers CRA. For example, SWP comprised 375,590 AF (representing 523,094 MT of CO2e) and CRA comprised 66,281 AF (representing 21,984 MT of CO2e) of the MWD water supplied to LADWP in WS 2013 (Table 8.3). The difference in GHG emissions that a power portfolio can make can be seen when comparing SWP East to CRA emissions as these water sources have each historically contributed 15% of LADWP’s water supply portfolio. SWP East and the CRA were each 66,281

AF in WS 2013; however, SWP East's total emissions were 99,764 MT of CO2e and CRA's were only 21,984 (Table 8.3). As discussed in the following section, switching to a lower GHG energy mix (as CA DWR is planning to do) can greatly reduce emissions even when the energy requirements remain relatively constant.

Reducing MWD water supply volume by a third while simultaneously almost doubling recycled water volumes from WS City 2035 to WS Max 2035 only resulted in a 15% reduction in emissions. This is due to the fact that the energy intensity of recycled water used in our analysis, while less than half that of MWD water, is still the water supply source with the second highest energy intensity per AF of the examined sources. UWMP analyses also show increased energy costs from local water as recycled water becomes a larger portion of the water supply in the future.[505] Recycled water energy requirements are variable, however, as noted in the background section, and so too are their potential contributions to future emissions stemming from increased wastewater reuse. Different treatment types have different energy requirements and, thus, the selected treatment train can have a significant impact on the GHG emissions of increasing the reuse of recycled water (Table 8.4).

Treatment Type	WS Max 2035 Recycled Water Goal (AFY)	Energy Req'd (kWh /AF)[506]	Total Emissions (Recycled Water (MT of CO2e)	Total Emissions WS Max 2035 (MT of CO2e)
Tertiary w/ nutrient removal & effluent filtration	161,400	635	56,511	144,278
MBR (low)	161,400	740	65,855	153,622
Nanofiltration	161,400	770	68,525	156,292
UWMP weighted avg	161,400	1,150	102,342	190,199
AWTF (typical)[507]	161,400	1,173	104,389	192,156
MBR (high)	161,400	2,839	252,653	340,420

Table 8.4. Impact of the energy requirement of various methods of recycled water treatment on GHG emissions of the recycled water volume and WS Max 2035 overall (PP 2-14).

There is also great variability in energy requirements within each treatment type, due to factors such as scale and efficiency. For example, the range of energy required for MBR is between 740 kWh/AF and 2,839 kWh/AF, which corresponds to a commensurately large range in potential GHG emissions (65,855 MT CO2e to 252,653 MT CO2e, Table 8.4) if MBR is exclusively used to increase the reuse of recycled water. Therefore, thorough assessments of the potential treatment trains and all the underlying factors that impact their energy use must be conducted as part of the planning process to increase the reuse of recycled water going forward. The analysis presented here provides a snapshot of the energy footprint of recycled water and should be reassessed and expanded as new technologies and alternate treatment trains emerge that can provide high quality

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[505] LADWP 2015 UWMP p 12-32

[506] Energy values for AWTF from Framework for DPR 2015 p. 14; energy values for NF, Ozone/BAC/GAC from WRD GMBP p. 5-20, Table 5-13; energy values for MBR from Krzeminski P. et al, Membrane bioreactors – A review on recent developments in energy reduction, fouling control, novel configurations, LCA and market prospects. Journal of Membrane Science 527 (2017) p 207-227

[507] Based on OCWD original ATW: Treatment technology includes filter screens, MF, cartridge filtration, RO, advanced oxidation, decarbonation, lime stabilization

water for reuse. The end purpose of the water, and thus, the necessary level of treatment to satisfy the end users, should also be considered as, for example, tertiary water treatment with nutrient removal has a lower footprint than AWTF (Table 8.1).

As described in greater detail above (Section II.B.b), pushing only a little beyond the WS Max 2035 Scenario analyzed here could get Los Angeles to 100% local water. For example, a combination of reducing water demand to 75 gpcd and reaping a greater water supply benefit from planned stormwater capture projects could result in significant progress towards this goal. Reducing GHGs can provide additional motivation to achieve a sustainable local water supply. It is important to note again here that treatment energy requirements for various local water supplies vary considerably and each planned project should be compared to all other alternatives, including imported water, to identify the most energy-efficient water source.

In addition, there are additional energy components to using water in Los Angeles (e.g., heating water on-site) that contribute significantly to the energy footprint of water in this region; these components should also be investigated to identify opportunities to further reduce the GHG emissions of using water. 12% of energy use state-wide is related to water, with 2% being used for conveyance, treatment, and distribution and the other 10% being used for end uses such as heating, cooling, and industrial processes. This represents approximately 32% of statewide Natural Gas and 19% of statewide electricity.[508]

G. Power Portfolio Impacts on Water Portfolio Emissions

The changing face of the power portfolios related to water in LA also pose an opportunity to reduce the GHG emissions of these three water supply portfolios as GHG emissions vary among power sources (Table 8.2). This means that GHG emissions can change even in cases in which the total amount of power required is the same. In general, for LADWP's power portfolio, the removal of coal had the largest impact on reducing GHG emissions and that will leave natural gas as the next highest producer of GHG emissions. As described earlier, Southern California Edison and CA DWR will also be reducing GHG emissions related to their power mixes going forward.

Absolute emissions decreased for all three water portfolios when the energy was generated by PP 2035 rather than PP 2014 due to the changes in the associated power portfolios (Table 8.3, Table 8.5). For example, total emissions decreased by 73% to 50,401 MT of CO2e using PP 2035 for WS Max 2035 (compared to 187,571 MT of CO2e with PP 2014), which reflects a lower GHG power mix for all water supplies. Increasing the amount of locally sourced water to 50% from WS 2013 to WS City 2035 resulted in a decrease in total emissions by approximately 62% under PP 2014 and 57% under PP 2035 (Table 8.5).

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[508] CADWR climate change website, water-energy nexus state-wide; http://www.water.ca.gov/climatechange/WaterEnergyStatewide.cfm

PP 2035	Energy Required (kWh/AF)	WS 2013 Average Volume (AF)	WS 2013 Total Emissions (MT of CO2e)	WS City 2035 Volume (AF)	WS City 2035 Total Emissions (MT of CO2e)	WS Max 2035 Volume (AF)	WS Max 2035 Total Emissions (MT of CO2e)
SWP East	4,520	66,281	18,874	15,000	4,271	5,250	1,495
SWP West	4,110	309,309	80,089	70,000	18,125	24,500	6,344
CRA	2,000	66,281	17,474	15,000	3,954	5,250	1,384
MWD	-	*441,871*	*116,437*	*100,000*	*26,350*	*35,000*	*9,223*
LAA	0	61,024	-	139,400	-	91,000	-
Groundwater (net)	580	79,403	7,241	114,100	10,406	114,100	10,406
Recycled Water	1,150	10,054	1,818	88,500	16,003	161,400	29,185
Stormwater	174	n/a	-	37,000	1,012	58,000	1,587
Total	4,607	592,352	125,496	479,000	53,771	459,500	50,401

Table 8.5. Water supply portfolio emissions under PP 2035.

Overall produced emissions decreased for all three water portfolio scenarios with the introduction of more renewable sources of energy in power portfolios (compare Table 8.3 and Table 8.5). The CO2e emissions rates of each water source also decreased in PP 2035, but each water source kept the same relative position to other water sources (Table 8.6). For example, MWD water has the highest water supply emissions rate in WS 2013 under both PP 2014 (1.23 MT of CO2e/AF) and PP 2035 (0.26 CO2e/AF, Table 8.6). The emissions rate of SWP water greatly decreases between 2014 and 2035 (from 1.37-1.5 with PP 2014 to 0.26-0.28 with PP 2035) as a result of changes in the power mix planned by DWR. This illustrates that changing the power portfolio can significantly reduce GHG emissions even if the water supply mix remains unchanged. Although MWD water remains the most energy-intensive water supply source, higher percentages of renewable sources in PP 2035 result in a much lower rate of GHG emissions due to the composition of power sources used to provide the energy required to import the water.

Water Supply Emissions Rate (MT of CO2e/AF)	WS 2013 with PP 2014	WS 2013 with PP 2035
SWP East	1.5	0.28
SWP West	1.37	0.26
CRA	0.33	0.26
MWD	1.23	0.26
LA Aqueduct	-	-
Groundwater (net)	0.32	0.09
Recycled Water	0.63	0.18
Stormwater	-	-
Total	0.97	0.21

Table 8.6. Water supply emissions rate under PP 2035 vs PP 2014, normalized to 1 AF.

As can be seen from the change in total emissions from WS City 2035 (Table 8.7), the savings in GHG emissions from changing the power portfolio can be significant. The total emissions from WS City 2035 (with no changes in the volumes of the water portfolio) is reduced from 219,513

MT of CO2e to 53,771 MT of CO2e (Table 8.7). Thus, the City's current plans to eliminate coal as a power source also will have significant impacts on the GHG emissions of their water portfolios. GHG emissions and energy requirements of sourcing the City's water will also decrease as the City continues to implement practices to achieve and exceed pLAn gpcd goals and increase the volumes of locally-sourced water. Therefore, there are multiple opportunities to reduce GHG emissions while maintaining a sustainable and reliable water supply, many of which are already being explored or implemented by the City.

WS City 2035	PP 2014 Total Emissions (MT of CO2e)	PP 2035 Total Emissions (MT of CO2e)
MWD	123,356	26,350
LA Aqueduct	-	-
Groundwater (net)	36,490	10,406
Recycled Water	56,117	16,003
Stormwater	3,550	1,012
Total	219,513	53,771

Table 8.7: Total Emissions for WS City 2035 under PP 2014 and PP 2035. Emissions greatly decrease to source same volumes and sources of water due to change in composition of power portfolio to remove coal and increase renewables.

H. WRP Renewable Energy Sources

a. HWRP Digester Gas Utilization Project

The City is working on innovative projects to create renewable energy at their WRPs. For example, in previous years, the anaerobic digester gas (digas) produced at HWRP was piped to Scattergood Generating Station (SGS) per an agreement between SGS, HWRP, LADWP, and LASAN. SGS used the digas to generate electricity for the LADWP grid and provided HWRP with steam for use in the plant. In addition to this steam, plant operations at HWRP require 22 MW of imported electricity.[509] This agreement, however, ceased in early 2017; digas is no longer piped from HWRP to SGS. Instead, the renewable digas is used on-site through the Digester Gas Utilization Project (DGUP).

The project is located in the Energy Recovery Building at HWRP in Playa del Rey. Through DGUP, LASAN aims to produce renewable energy on site, provide all of HWRP's electrical and process steam demands, allow HWRP to operate fully "off the grid" to decrease vulnerability to natural disasters (e.g. earthquakes) and increase plant resilience; reduce the HWRP's susceptibility

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[509] Hyperion Treatment Plant Digester Gas Utilization Project Final Environmental Impact Report 2013 p. ES-1

to fluctuating electricity prices; maintain a standard of Class A biosolids in the event of a power interruption; and prevent the continuous operation of flare to dispose of excess digas.[510]

DGUP involved the installation and operation of a digester gas/natural gas-fueled combined cycle cogeneration system at HWRP. The digas will be combusted in combustion turbines to generate electricity and the heat will be recovered to create steam to generate power in steam turbines. DGUP is expected to consume all digester gas produced at HWRP, generate up to 34 MW of electricity, and provide up to 70,000 lb/hr of 90 psig saturated process steam.[511] The maximum GHG incremental change would thus be 60,052 MT CO2e/year, which would be due solely to combustion of digas, a biogenic GHG emission. Biogenic GHGs are not considered to be contributors to a net increase in atmospheric CO2.[512] Non-biogenic (fossil-fuel) GHG emissions are expected to decrease by over 50,000 MT CO2e/year.[513] Avoided indirect emissions from electricity use at HWRP were calculated to be 128,816 MT CO2e/year, based on 22 MW (192,720 MWh/year) demand.[514] Biomass-based emissions are reported separately from fossil-fuel based emissions and excluded from applicability under CARB's GHG Cap and Trade program.

The City itself has not established a GHG cumulative impacts significance threshold for industrial projects. While the Southern California Air Quality Monitoring District (SCAQMD) does have a threshold for industrial projects of 10,000 MT CO2e/year, the threshold does not apply as SCAQMD is not the lead agency on the project.[515] Regulatory agencies have not yet determined explicit policies regarding biogenic emissions. Due to this regulatory uncertainty, the cumulative impacts of the project are considered potentially significant and an EIR was prepared with mitigation measures in regards to GHG emissions. The mitigation measures include a limitation on the percent of natural gas in the total fuel combusted in the combustion turbines. Total natural gas use in combustion will be up to 10% by volume when possible, but can be up to 40% by volume when necessary based on operational needs at HWRP.[516] Volumetric gas flow data will be collected by meters and reported to the City by operators upon request.[517]

b. TIWRP TIRE Project

In 2008, TIWRP began operation of the Terminal Island Renewable Energy (TIRE) Project. Operations include injecting biosolids from anaerobic digesters into the deep geological subsurface (5,300 ft beneath the surface).[518] At these depths, the slurry mixture of treated, non-hazardous, municipal sludge and water degrade due to the high temperatures and saline environment and

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[510] HWRP DGUP FEIR 2013 p. 4
[511] HWRP DGUP FEIR 2013 p. 4
[512] Hyperion Treatment Plant Digester Gas Utilization Project Monitoring Mitigation and Reporting Plan 2013 p. 5
[513] HWRP DGUP FEIR 2013 p. 11
[514] HWRP DGUP Draft EIR 20103 p. 57
[515] HWRP DGUP FEIR 2013 p. 11; HWRP DGUP Draft EIR 2013 p. 56
[516] HWRP DGUP Mitigation Monitoring and Reporting Plan 2013 p. 6
[517] HWRP DGUP Mitigation Monitoring and Reporting Plan 2013 p. 6
[518] City of Los Angeles Terminal Island Renewable Energy Project Outcomes and Results 2013 p. 1

produce CH4, CO2, and non-volatile residual solids. The objective is for the CO2 to become sequestered in the formation brine and for the CH4 to become trapped in the subsurface reservoir and thus be readily available as a renewable source of energy.

Based on four and a half years of biosolids injection, which translates to more than 133,000 tons of biosolids, TIRE has provided a number of environmental benefits. These include the elimination of 1.1 million miles of heavy truck traffic and associated reduction of air emissions; a reduction in NOx and CO[519] from reduced transportation; the sequestration of more than 16,000 MT of CO2; and, ultimately, the generation of 3.5 MW of renewable energy.[520] Operation of this project also leads to benefits such as a decrease in the amount of brine and effluent discharged into Los Angeles Harbor, no associated odors or noise, and the protection of groundwater through the diversion of biosolids to land application.[521]

I. Conclusions, Assumptions, and Future Research Needs

As can be seen from these analyses, providing a stable, safe, and clean water supply to Los Angeles can and does require significant amounts of energy, but multiple opportunities exist to decrease both the energy required and the GHG emissions of sourcing the City’s water. Planned changes to increase the City’s local water supplies and decrease the fossil fuel-based components of the various power portfolios that power the delivery of LA’s water will together lead to lower energy requirements and thus lower GHG emissions to keep supplying the region with water. Improvement in technologies to reclaim and reuse wastewater, brackish groundwater, and otherwise contaminated groundwater may also lead to a lower energy footprint if they are more energy-efficient than currently available technologies.

The reduced demand that will result from implementing and exceeding the gpcd pLAn goals will lead to a commensurate reduction in energy as less water will be needed to satisfy the lower demand. Conservation leads to energy savings beyond just that of reducing the water that needs to be supplied; energy is also saved by a reduction of end uses that require energy for heating.[522] Even without considering heating energy savings, the approximately 700,000 AF of water saved by LADWP customers from FYE 2008 to 2015 is estimated to have reduced emissions by 780,000

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[519] https://www.lacitysan.org/san/faces/home/portal/s-lsh-sp/s-lsh-sp-tire/s-lsh-sp-tire-pf?_adf.ctrl-state=t61kg1ds0_4&_afrLoop=1881406497687675#!

[520] City of Los Angeles TIRE Project Outcomes and Results 2013 p. 9; Los Angeles Bureau of Sanitation TIRE. https://www.lacitysan.org/san/faces/home/portal/s-lsh-sp/s-lsh-sp-tire/s-lsh-sp-tire-pf?_adf.ctrl-state=t61kg1ds0_4&_afrLoop=1881406497687675#! Accessed on 09/06/2016

[521] Sothern California Carbon Sequestration Research Consortium Terminal Island Renewable Energy Project 2010. http://www.socalcarb.org/tire.html. Accessed on 09/06/2016

[522] LADWP UWMP 2015 p 12-29.

MT of CO2. The energy use of heating can be substantial, potentially representing 70% of water-related carbon emissions compared to 18% for wastewater treatment and 8% for water supply.[523]

In addition to quantifying the emissions that result from the energy use required to bring water to the City, we conducted a preliminary analysis on the additional emissions that can potentially result from a variety of wastewater treatment processes using a state protocol to assess these emissions, the LGOP. Some areas for future research involving LGOP equations are discussed here; please see Appendix C for additional information on these analyses. While these calculations provide some insight into additional potential sources of GHG emissions from the increased reclamation of wastewater, it is important to note these analyses include assumptions that leave room for both under- and over-estimations of GHG emissions. The GHG emissions values determined above may not accurately depict true emissions at the WRPs for a number of reasons, including a lack of facility-specific data that could have been plugged into available equations and should be incorporated into future analyses as available.

The LGOP methodologies themselves also contain very general assumptions. For example, Eq. 10.7 for the determination of N2O emissions utilizes an industrial-commercial factor of 1.25 that is assumed to account for the increased load to the treatment facility from industrial and commercial discharge. Without knowing the exact commercial or industrial contribution to wastewater influent it is difficult to know whether or not this is an accurate multiplier. Eq. 10.10 for the calculation of N2O from effluent discharge employs the same factor, as well as a number of assumptions about the N load per person per day and BOD5 load to the WRP. The total N load in kg N/person/day was based on the national average of protein intake and assumed fraction of non-consumed N.[524] The use of national average consumption of protein could be inappropriate depending on the demographics and culture of the WRP service area. On the power side, we used a weighted average for natural gas emissions across the US from the 2014/2016 TCR reports; more locally-specific emissions data could also help refine the emissions value. We further assumed that the entire increase in renewable energy would stem from solar and that the solar technology would be PV. Therefore, emissions from solar could be different from the analyses presented here if CSP is also included in the solar components of future LADWP power portfolios.

Overall, the presented values could be improved with additional availability of WRP data. Importantly, local factors can have a large impact on these emissions and so a better understanding of the specific region is critical to ensuring that these equations accurately reflect the actual emissions coming from WRPs. This in turn demonstrates the need to develop monitoring efforts to validate the factors in and results of these equations and analyses and ensure that the GHG footprint of changing the face of our water supply is accurately reflected. This is especially true for increasing the reuse of recycled water as there are a wide range of potential treatment trains that have varying energy requirements and, therefore, varying indirect GHG emissions. Full surveys of all

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[523] “The Carbon Footprint of Water, p. 24. In this analysis, carbon emissions resulting from water supply and treatment assumed that all energy comes from electricity, with a carbon intensity of 1.36 lbs. CO2/kWh. The carbon intensity of other energy sources varies, ranging from 0.12 lbs. CO2 per cubic foot of natural gas to 22.4 lbs. CO2 per gallon of fuel oil.” Cited in “Energy-Water Nexus: The Water Sector’s Energy Use” by Congressional Research Services. Claudia Copeland and Nicole T. Carter. January 24, 2017

[524] CARB LGOP 2010 p. 116, footnote 27

potential treatment options to identify the most appropriate technologies for use when considering all relevant factors for water quality, water supply, energy use, and GHG emissions must be conducted to shape the most effective mechanisms to increase the use of this valuable resource.

Statewide efforts to improve the quantification of emissions from wastewater treatment are also currently ongoing. The California Wastewater Climate Change Group (CWCCG) is comprised of over 40 California wastewater agencies and participated in the development of the wastewater treatment facilities chapter of the LGOP. In addition to the LGOP, CWCCG is working to create an emissions quantification protocol of all six major GHGs for wastewater treatment plants in California to depict a complete GHG profile.[525] Water reuse and recycling will have a critical role to play in increasing the volumes of available local water supply and in most cases will be a lower-emissions source of water than continuing to import water or turning to ocean water desalination. One study found that reclaiming water from a wastewater treatment facility can offset the total carbon footprint by 36-40% relative to importing water.[526] A WBMWD water reuse case study concluded that recycling treated wastewater and seawater desalination were the most viable alternatives to reduce dependence on imports by 50% while reducing wastewater discharges into Santa Monica Bay by 25% and preventing saltwater intrusion.[527] The City should fully utilize its groundwater, stormwater, and recycled water supplies as well as build partnerships to extract the brackish groundwater plume in WCB, before turning to ocean desalination (because of its high energy cost and potential environmental impacts).

Finally, as LADWP implements its plan to eliminate coal from its power portfolio and other regional power suppliers decrease their GHG emissions, GHG emissions associated with all examined water supply portfolios will go down even if the water supply portfolio does not change. The combination of increasing the percentage of water that is locally supplied, eliminating coal and other high-GHG energy sources from relevant power portfolios, and reducing water demand by implementing the conservation goals in the pLAn will greatly reduce the GHG footprint of LA's water supply. Therefore, there are a variety of ways by which the energy use and GHG emissions of LADWP's water supply portfolio can be reduced, many of which are already being pursued by the City. The pLAn goals to decrease the volumes of imported water present in the City's water supply and replace it with other local sources of water supply (with lower energy footprints) is one example where the City is well on the way to achieving a more sustainable local water supply. The pLAn goals to greatly reduce GHG emissions in the coming years will also greatly reduce the GHG footprint of LA's water supply.

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[525] CARB LGOP 2010 p. 108, Box 10.1

[526] Mo & Zhang (2012) cited in Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination*. 2014. P. 244

[527] Crook, James. Innovative Applications in Water Reuse and Desalination: 10 Case Studies. *Water Reuse Association*. P. 38-41. 2004

IX. Integrated Water Management

A. Introduction

All of the pieces described above, stormwater, groundwater, recycled water, conservation, economics and funding, and even GHGs, are critical components that must be incorporated in changing the face of how we manage water to maximize multiple benefits. Implementing a comprehensive IWM approach provides numerous critical water supply, water quality, flood control, environmental, recreational, and economic benefits to the City, its workers, and its residents. As defined in the CA Water Plan Update 2013, IWM

"is a comprehensive and collaborative approach for managing water to concurrently achieve social, environmental, and economic objectives…[that] delivers higher value for investments by considering all interests, providing multiple benefits, and working across jurisdictional boundaries at the appropriate geographic scale. Examples of multiple benefits include improved water quality, better flood management, restored and enhanced ecosystems, and more reliable water supplies.[528]*"*

Multiple efforts in the region, such as the MWD IRP and the GLAC IRWMP, have assessed the possibilities of implementing IWM to maximize multiple benefits. The City-led OWLA 2040 plan will provide planning guidance and information on a wide variety of factors that are crucial to moving forward with IWM in the City. These elements include a wastewater facilities plan, a stormwater and urban runoff facilities plan, a water balance tool, short and long-term city policy recommendations, strategies to address long term alternatives and climate change mitigation and adaptation, and a section on public engagement and strategic marketing. An environmental impact report on the OWLA plan will commence after the completion of the plan.[529]

Based on the presented research, implementing IWM within the City is feasible, and preferable, from a technological standpoint. Technologies exist to treat various water types to a sufficient quality for reuse and we have significant capacity in our groundwater basins to enable more productive and sustainable groundwater management. Novel partnerships are occurring in this realm and regulatory agencies are working to ensure that water quality is protected while also facilitating opportunities to increase local water supply within the region where possible. As more partnerships develop, these practices will become more established and the City will progress towards attaining or exceeding water oriented goals in the pLAn. In this section, we discuss a cost-benefit analysis of various water supply portfolios, potential governance structures, and potential water system changes to implement IWM to a greater degree within the region.

B. Costs and Benefits

A cost-benefit analysis of the three potential LADWP water supply portfolios described earlier, WS 2013, WS City 2035, and WS Max 2035, was conducted by Abt Associates for UCLA as part

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[528] CA Water Plan Update 2013, Highlights, P.3.

[529] OWLA presentation February 16, 2017

of this research. The technical memo and a detailed explanation of the economic analysis and assumptions is attached as Appendix A; results are briefly described. Local water was defined in our analysis to include the volumes of recycled water, stormwater, and groundwater in the three water supply portfolios, WS 2013, WS City 2035, and WS Max 2035, described earlier. Based on this definition WS 2013 included 89,457 AF of local water, WS City 2035 included 239,600 AF of local water, and WS Max 2035 included 333,500 AF of local water. To assess the costs and benefits, the net volume of local water that was required beyond WS 2013 to meet the WS City 2035 and WS Max 2035 goals was used. These volumes were 150,143 AFY for WS City 2035 and 244,043 AFY for WS Max 2035. These volumes were then further divided into their potential sources based on various plans and projects; recycled water, for example, was divided into NPR and GWR and stormwater was divided between centralized and distributed projects

Assessed benefits included the avoided cost of imported water, reduced GHG emissions, enhanced recreational opportunities, and reduced stormwater-related damage. Not all benefits, however, were quantified in monetary terms. For recycled water, the value of increased water supply reliability was also included as a benefit. Reliability was valued in two different ways. First, a range of stated preference studies have found water customers are willing to pay $100-$500+ per household per year for a 0% probability that the water supply will be interrupted during drought. Using this value, and the percentage of WS City 2035 (20%) and WS Max 2035 (37%) of imported water that is offset by recycled water in these portfolios, provided a reliability estimate of $20 per year in WS City 2035 and $37 per year in WS Max 2035. Second, a willingness-to-pay study found that households are willing to pay $20 to $35 per year to avoid Stage 2 restrictions, which reflect a highly restricted ability to irrigate landscapes.[530] Applying a value of $20 per year to the projected number of households in the LADWP service area over the study timeframe for WS City 2035 provided a reliability benefit of $632 million. Applying a value of $36 (average of $35 and $37) per year for WS Max 2035 provided a reliability benefit of approximately $1.1 billion.[531]

Overall, the estimated costs of producing local water supplies are higher than the projected cost of importing water. There are, however, large monetized benefits (as well as potentially important non-monetized benefits) associated with local water supply projects, and when we compare monetizable benefits to costs, there are positive net benefits of local water supply. The net benefit of WS City 2035 is $4.3 to $5.8 billion, and the net benefit of WS Max 2035 goal is $7.4 to $10.1 billion (Table 9.1). It is important to note that these values are based on the best available data, but there is a pressing need for additional high quality and local data on the costs and benefits of, in particular, the environmental benefits of putting in additional stormwater capture. Therefore, the exact numbers of these analyses may change as additional data is gathered, but the overall message that increasing the volumes of local water supply will provide both environmental and economic benefits to the region is clear. A large component of the monetized benefits in both WS City 2035 and WS Max 2035 stems from the ancillary benefits such as habitat associated with

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[530] Raucher, R. J. Clements, C. Donovan, D. Chapman, R. Bishop, G. Johns, M. Hanneman, S. Rodkin, J. Garrett, J., 2013. The Value of Water Supply Reliability in the Residential Sector. WateReuse Research Foundation.
[531] See Appendix B for greater detail

distributed stormwater capture (Tables 9.2 and 9.3). More information on the breakdown on costs and benefits of each potential water supply is provided in Appendix B.

	WS City 2035	WS Max 2035
Volume of local water supply, net of baseline (89,457 AFY)	150,143 AFY	244,043 AFY
PV monetized cost of additional local supply (millions of $2016)	$5,228.1	$8,336.0
PV monetized benefit of additional local supply (millions of $2016)	$9,483.6 to $11,058.3	$15,702.6 to $18,467.7
Net PV (millions of $2016)	$4,255.4 to $5,830.1	$7,366.4 to 10,131.6

Table 9.1 Comparison of monetized benefits and costs across 2035 scenarios.

	Net volume (AFY)	**Annualized cost of supply (millions $2016)**	**PV cost of supply (millions $2016)**	**PV monetized benefit (millions $2016)***	**Net PV (millions $2016)**
Groundwater (net)	34,697	18.9	420.1	1,125.8	705.7
Recycled Water – NPR irrigation & industrial	37,400	57.6	1,051.5	1,257.6	206.1
Recycled Water – GWR	41,046	49.8	846.9	1,395.6	548. 7
Stormwater – Centralized	19,000	22.8	415.5	502.3 to 586.2	86.9 to 170.7
Stormwater – Distributed (including Direct)	18,000	136.8	2,494.1	5,202.3 to 6,693.1	2,708.1 to 4,199
Total	**150,143**	**285.9**	**5,228.1**	**9,483.6 to 11,058.3**	**4,255.4 to 5,830.1**
*Potentially important but non-monetized benefits include water quality benefits, improved reliability, improved flood control, job creation, reduced damages from drought, increased resiliency to climate change, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.					

Table 9.2. Comparison of monetizable benefits and costs for WS City 2035 scenario.

	Net volume (AFY)	**Annualized cost of supply (millions $2016)**	**PV cost of supply (millions $2016)**	**PV monetized benefit (millions $2016)***	**Net PV (millions $2016)**
Groundwater (net)	34,697	18.9	420.1	1,126.8	705.7
Recycled Water – NPR irrigation & industrial use	37,400	57.6	1,051.5	1,257.6	206.1
Recycled Water – GWR	113,946	144.6	1,861.9	3,383.3	1,521.4
Stormwater – Centralized	26,000	31.2	568.5	687.4 to 802.1	118.9 to 233.6
Stormwater – Distributed (including Direct)	32,000	243.2	4,434.0	9,248.5 to 11,898.9	4,814.4 to 7,464.9
Total	**244,043**	**495.5**	**8,336.0**	**15,702.6 to 18,467.7**	**7,366.4 to 10,131.6**

*Potentially important but non-monetized benefits include water quality benefits, improved reliability, improved flood control, job creation, reduced damages from drought, increased resiliency to climate change, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.

Table 9.3 Comparison of monetized benefits and costs for WS Max 2035 scenario

It is important to note that much nuance exists in potential approaches to analyze the economics of various water supplies. For example, using these monetized benefits and a relatively short planning time horizon, the estimated cost of maximizing local water supplies is higher than the projected cost of continued imported water use. With other approaches such as using a longer planning horizon (20 years) and assuming that past increases in water supply costs from various sources continue, unit costs of imported water increase and local sources are cost-competitive or even cheaper. In addition, there are significant monetized benefits (as well as potentially important non-monetized benefits) associated with local water supply projects, and when we compare additional monetized benefits to costs, there are positive net benefits of local water supply.

These variations in calculating the economic impacts of various water supplies relate to fundamental assumptions that are inherent in any analysis of public policy. Municipal agencies must often plan based on shorter-term timeframes, while over the long-term changing economics and non-monetized benefits can be highly influential in shaping policy outcomes. For water supply in Los Angeles, local agencies will increasingly face choices of continued purchases of imported water from MWD or investing in local sources. In the short-term, imported water still looks advantageous. It is generally the cheapest water source using 2017 prices, but incorporating predicted price increases (based on past increases) reveals the long-term costliness of continued reliance on imports. In addition, agencies will increasingly need to consider the “full-cycles” of urban water supply to appropriately compare alternative supply sources. These cycles include acquisition, treatment (water supply), distribution, use, treatment (wastewater), and disposal (or reuse) of urban water resources. Doing so requires interagency collaboration and cooperative agreements.[532] Ecological impacts and multiple benefits (e.g., flood control, water quality, recreation, habitat, and/or property values) should also be included.

C. Governance

Water management governance plays an especially critical role in managing these systems both within and among the players in a region such as Los Angeles with complex jurisdictional systems. These systems are both interconnected and disconnected across the region with many technical and policy drivers governing the distribution and management of water from multiple lenses. Additional opportunities to manage interjurisdictional arenas such as groundwater basins or watershed-scale stormwater BMP implementation programs can offer water quality and potential supply benefits to participants in these complex systems.

As described throughout this work, there are a plethora of individual projects that have been identified and/or implemented to provide many of the individual benefits that are embedded within an IWM system. Implementing a comprehensive IWM system in the City, however, still faces many challenges due to the siloed structure that results from the broad range of individual agencies and other stakeholders that have emerged over time and are involved in these projects. Progress is being made in this arena, especially on the stormwater capture side, through efforts such as the EWMPs, the SCMP, and the LA Basin Study, as these efforts have built collaborations across departments and permittees in the watershed and also clearly identified a wide variety of projects. These project lists further provide an opportunity for other stakeholders to identify projects that may provide them with desired benefits and then reach out to other agencies to identify where these multi-benefit projects offer cost-sharing opportunities.

In addition, there are multiple efforts occurring in the region that will facilitate the implementation of more integrated water management programs. As described above, the fairly recent amendments to the adjudications in WCB and CB have created a framework within which rightsholders in these basins can create water augmentation projects to recharge and extract water into these basins on an annual basis. These projects are not capped by the pumping rights in the basin, but with approval can be over and above a party's adjudicated rights. SGMA offers a further opportunity to increase conjunctive groundwater use in the region as groundwater sustainability plans are developed for the Santa Monica Basin and the northern portion of Central Basin.

From the perspective of increasing the implementation of a one water / integrated water management approach, the City's OWLA research is delving into opportunities to increase local water supply and improve water quality in the City. A big part of this effort includes working with

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[532] Porse, E., KB Mika, E Litvak., K Manago, T Hogue, D Pataki, M Gold, & S Pincetl (2017). "The Dollars and Sense of Local Water Supply in Los Angeles." UC Water 2017 Workshop. URL: http://www.waterhub.ucla.edu/docs/UCWater_18Sep17b.pdf

multiple other agencies and stakeholders to identify opportunities to collaborate to maximize the diversity of input and thus characterize benefits and challenges across the region. Breaking down silos within the City structure to facilitate the implementation of a One Water approach is a critical next step to move these efforts forward.

Another pressing need is to develop a cost-benefit tool that would facilitate identifying the benefits for all participating agencies for projects in which they co-invest with other agencies was also identified.[533] A benefit-based structure in which departments would pay for a portion of the project that is commensurate with the benefits they would receive is one potential model. Conducting research to establish the water supply benefits of stormwater infiltration and management through a distributed and centralized system, which would then enable the monetization of stormwater to a greater degree, is another barrier to fully implementing stormwater capture from an increasing water supply perspective rather than just an improving water quality perspective. Recently, LADWP has begun a cost-sharing approach with LASAN for stormwater capture and infiltration projects in the San Fernando Valley that could serve as a model for this approach. Also, identifying tools that would establish a programmatic framework within which LADWP could compensate LASAN for highly treated wastewater could also help facilitate reuse.

A City reorganization to create an agency to centralize all water work in one new or existing agency would be difficult for a variety of reasons, including the requirement for a major city charter amendment, a difficult and complex reorganization, and the creation of department and bureau winners and losers in terms of funding, management, salaries, and possibly staffing. In addition, this would again limit the agencies that should be involved in the process of implementing integrated water management as it is most likely it would only include agencies that have traditionally been thought of as involved with water (e.g., LASAN, LADWP, BoE). However, truly transforming the way that water is managed in the City will require the involvement of all agencies, regardless of whether their core function includes a water-specific task. This approach has high transaction costs, although it may be easier relative to existing institutional jurisdictions.

We propose an alternate way to jumpstart this process of building a more collaborative approach that enables diverse groups of stakeholders to identify and build the multi-benefit projects needed to transform the City's infrastructure to a local water system: developing a temporary, 5 year "Local Water Director" position, ideally located in the Mayor's Office. The Local Water Director would report to an executive council led by the Mayor that also includes the Deputy Mayor and the heads of agencies such as LADWP, LASAN, and BoE. This group would jointly hire the Local Water Director to be in charge of local water infrastructure. The staff for the Local Water Director would be relatively modest, as the primary function of the position would be to work with the City to foster greater collaboration among agencies, develop a timeline with completion milestones for local water projects, manage or co-manage with designated Bureau or Department staff the projects as needed, and retain and manage consultants needed to complete the local water projects. The Local Water Director would have no jurisdiction over or responsibility

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[533] Deborah Bloome, Phoebe Lipkis. Feb 2015 A New Vision for Water Management in the Los Angeles Region https://www.treepeople.org/sites/default/files/pdf/publications/Moving%20Towards%20Collaboration_e-version.pdf (Treepeople, New Vision, 2015)

for projects or policies that were not designated as Executive Council priorities as part of the City's Local Water Plan/OWLA 2040 Plan. The Local Water Director would report back to the group on a monthly basis to elevate challenges to implementation that need resolving and also to describe progress and successes.

The Local Water Director would be responsible for implementing the path forward to fully integrated water management across the City through a combination of day-to-day work, planning and building infrastructure, and attaining CWA compliance. Qualifications for this position include an extensive experience in green infrastructure and Los Angeles. The Local Water Director would be hired and annually reviewed by the executive council. Implementing this big picture goal in this way mimics the structure of a successful consent decree in stimulating timely, measurable progress without the liability of a court case. The City's approach to implementing the Hyperion Treatment Plan Consent Decree requirements (rebuilding Hyperion, replacing major sewer infrastructure, and creating a stormwater management program) was very similar to the approach laid out here. In addition, the Mayor's office could help facilitate funding through providing temporary or permanent housing for the grant-writing office described above in the same location as the Local Water Director.

A similar program was implemented in Louisville, Kentucky; Louisville Water and Metropolitan Sewer District (MSD) are creating coordinated teams of employees to share services as part of a One Water concept under an interlocal agreement.[534] This agreement also established a One Water Board that includes representatives from both MSD and Louisville Water and one from the Mayor's office.[535]

The question of what would be needed to implement a more collaborative approach to water management has been assessed in various arenas, including City-funded efforts. For example, TreePeople wrote a report titled "A New Vision for Water Management in the Los Angeles Region" that was funded by LADWP, LACDPW, LASAN, and the California Water Foundation.[536] Part of this effort was developing a Multi-Agency Collaborative through which to assess potential benefits of a more collaborative and systemic approach to cleaning up the region's water and increasing its local water supply.

The TreePeople report identified the need to increase collaboration in the region beyond projects and into a fully developed plan for the region to facilitate more systematic collaboration. They also identified characteristics of this moment in time, the increasing interest and distributed stormwater capture from a water supply perspective, the costs of managing stormwater, and out-

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[534] http://www.louisvillewater.com/newsroom/moving-forward-one-water-concept

[535] http://www.louisvillemsd.org/about-us/one-water-initiative; http://www.louisvillewater.com/newsroom/one-water-initiative-save-over-1-million-2015

[536] Treepeople, New Vision, 2015

side factors such as the drought and new water quality regulations, which provide multiple incentives at this point to change the face of how we manage water in this region.[537] Barriers to collaboration were found to be more a result of the processes and structures of the current system than from a lack of desire for or recognition of a need for more collaboration.[538]

To conclude, creating, refining, and embedding structures that ensure more and better collaboration among agencies will be critical to implementing sustainable water programs that mesh well and complement other regional efforts. For example, one potential mechanism to develop a regional groundwater strategy that should be explored is for the SWRCB and RB4 to convene a regional groundwater coordinating group with the goal of maximizing storage from stormwater and recycled wastewater. This group would include both groundwater management agencies and regulators to discuss a regional, better managed approach to maximize sustainable yields from our groundwater basins through, for example, increased stormwater recharge and recycled water infiltration or even injection (advanced treatment). In addition, the group would utilize GSPs and SNMPs where they have been developed. This group could also look at groundwater rights and their further transfer to public use and public entities, the costs of purchasing private water rights, and the potential to substitute certain water rights with recycled water (e.g., the industrial water rights leasing program described earlier). The overarching goal should first be to ensure that all cities have access to groundwater. Then, groundwater should be managed to maximize local self-reliance regionally and foster the ability to transfer and share groundwater resources as needed.

To conclude, creating, refining, and embedding structures that ensure more and better collaboration among agencies will be critical to implementing sustainable water programs that mesh well and complement other regional efforts. The successful passage of the County-wide stormwater (LA County Safe, Clean Water Program) funding measure would have the potential to ensure that county-wide and watershed-wide collaboration is occurring in a more effective manner than has occurred to date through the IRWMP process. The IRWMP has led to the funding of some good integrated water projects in LA County, but it has not led to the needed, County-wide transformation in collaboration or local supply self-sufficiency. The City should also collaborate more with MWD (for example, local resource funding for stormwater, additional and more stable conservation funding, and local resource incentives). The potential for partnerships with MWD such as exploring opportunities to include HWRP effluent (in addition to effluent from JWPCP) in MWD's large-scale regional recycled water planning efforts, should move from assessment to implementation as soon as feasible. Other partners in the region could include other local water agencies, the USACE, the EPA, the Bureau of Reclamation, LARWQCB, SCAG, etc.

D. Current and Future Water System Impacts

When planning to increase the implementation of IWM, it is critical to consider the potential internal feedback mechanisms within the system as well as the potential impacts of external changes such as shifting climate conditions. Many of the water sources that can increase local

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[537] Treepeople, New Vision, 2015

[538] Treepeople, New Vision, 2015

supply are interconnected. Changes within each supply will impact the others. Following opportunities to increase different local water supply flows will often result in the reduction of another opportunity. For example, there are a wide variety of ways to increase the use of stormwater and urban runoff in our region, including increasing distributed / on-site reuse, increasing the volume of stormwater recharged into groundwater basins, or diverting more runoff through WRPs for treatment and reuse. However, as demonstrated in the LAR, removing runoff from the watershed with BMPs, in combination with other plans to increase local water supplies (e.g., increased reuse of WRP effluent), greatly reduced the minimum flows in the LAR. Therefore, careful planning that takes into consideration the entire system is critical to successful IWM implementation.

Combining potential water sources can create more robust supplies; for example, combining graywater and stormwater may provide a more stable supply for on-site reuse than stormwater on its own. The NAS study on graywater and stormwater in the Los Angeles area found that simple laundry-to-landscape systems have the best potential for potable water demand reduction. Even though these systems have lower potable water savings than large cisterns, they are easier to install and have minimal capital costs. While larger cisterns may help households gather more rain during intense rainfall events, cisterns are likely to run out of supplemental water during the long, dry months. Since graywater production is relatively constant throughout the year, installing graywater reuse systems could provide for a more reliable supplemental water source throughout the year, even if the daily volume of graywater generated is small. Additional study is needed on the potential costs and benefits of graywater before implementing a large-scale mandatory program, but encouraging residents to install simple laundry to landscape systems and get educated on the proper operation, maintenance, and use of that system, could prove to be an effective way to reduce potable water demand.

Overall, some combination of installing more water-efficient landscaping, installing graywater systems in new construction and laundry to landscape systems at existing residential properties, and installing roof top collection systems to existing buildings may prove to yield the most potable water savings and shave off demand during the long, dry months in Los Angeles. These programs would need to incorporate training to ensure that systems are maintained and operated correctly, appropriate detergents are used, and systems are designed with sufficient volume, treatment, and vector control BMPs to allow storage (and thus use of the captured water) for longer periods of time after rainfall. Conservation and on-site reuse offer additional possible avenues to increase the long-term sustainability of the City’s water system, but both will have impacts on the volumes, and potentially the quality, of water that are available for treatment and reuse at centralized WRPs.

Increasing indoor and outdoor conservation will reduce water demand and pressures on the City to import water; conservation programs should take into consideration their effects on other parts of the system as well as the potential implications of external changes on expected conservation gains. For example, the City’s approach to selecting vegetation for use in tree canopy and green infrastructure should consider the potentially substantial impacts of future climate change on the water needs of existing and future landscapes. ET rates are expected to continue to rise, thereby making more efficient irrigation and more strategic landscape and tree planting approaches a necessity. For example, planting of trees with very high ET rates is not sustainable. Turf removal projects must result in their replacement with climate-appropriate landscapes. Even with careful selection of plant species, extreme variability in rainfall patterns combined with increasing temperatures will result in the need for LA's residents and City staff to take even greater care maintaining these landscapes to ensure their longevity. It is critical that sufficient funding to maintain vegetation is included with the addition of any new trees or green infrastructure to ensure that the expected benefits are gained (e.g., water quality improvements, decreases in urban heat islands).

In addition to the impacts of changing flows within the system, external changes must also be considered. For example, the City is investigating climate-based infrastructure risks of wastewater treatment, and stormwater and urban runoff facilities caused by changing conditions such as sea level rise or temperature increases, but also by static conditions such as earthquakes or tsunamis as part of the OWLA research efforts. Potential threats include power outages during peak demands and generally, severe droughts and water rationing, wildfires, landslides or mudslides, localized or coastal flooding, erosion, storm surges or high tides, and others. These threats can create asset risks in a variety of ways such as damage to the assets themselves, interrupted services and process operations, inundation or loss of access, regulatory non-compliance (e.g. wastewater spills into the ocean or increased pollutant loads from runoff from burn areas), and a loss of revenue while the asset is not operating. OWLA research included assessing vulnerabilities of existing wastewater and stormwater infrastructure (such as pumping stations, pipelines, and WRPs) to impacts of climatic changes using EPA's climate science modeling tool, CREAT.[539]

Planning for climate change impacts can ameliorate some of the negative consequences. Recent RAND studies explored robust decision-making (RDM) modeling to identify key indicators for adaptive water planning with MWD and to evaluate the impact of climate change on TMDL compliance goal attainment in the Tujunga Wash sub-watershed of the LAR watershed.[540] In general, both studies found that the impacts of climate change could be largely mitigated through adaptive planning efforts. For example, while RDM modeling analyses did find that climate change could reduce the likelihood that EWMP implantation would successfully achieve compliance with water quality standards, increasing LID implementation with future land use scenarios could help offset this change.[541]

Similarly, RDM analyses looking at MWD water supply scenarios in the context of a wide range of changing factors that included climate change found that their IRP was fairly robust as long as only one uncertain factor turned out unfavorably. So, if the climate turns out slightly drier, but all other factors such as population or future delta conditions are favorable, then the scenarios and expected ability to provide the needed water supply remain robust. If more than one factor

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[539] OWLA presentation, February 16, 2017

[540] Groves, D.G.; Bloom, E.; Lempert, R.J.; Fischbach, J.R.; Nevills, J.; Goshi, B.. .Developing Key Indicators for Adaptive Water Planning, ASCE J. Water Resource Planning Management, 2014; Abdul Ahad Tariq, Robert J. Lempert, John Riverson, Marla Schwartz, Neil Berg A Climate Stress Test of Los Angeles' Water Quality Plans, RAND working paper, January 2017

[541] Abdul Ahad Tariq, Robert J. Lempert, John Riverson, Marla Schwartz, Neil Berg A Climate Stress Test of Los Angeles' Water Quality Plans, RAND working paper, January 2017

was unfavorable, however, the current IRP would likely fail to meet its goals.[542] Therefore, including the impacts of external changes is critical information to guide planning processes to implement IWM in the most effective and adaptable way throughout the region.

X. Conclusions and Recommendations

A. Top Ten

Research Recommendations

- As part of this effort, several key data and modeling needs are necessary to promote the goal of local water supply in a sustainable way that protects groundwater resources and ensures water supply reliability in future decades, including:
    - The City of Los Angeles should have an openly-accessible and well-documented **groundwater model**, developed using the best available and standard groundwater modeling tools.
    - Current estimates of **evapotranspiration** rates across the City are highly variable and at coarse resolution. Research is needed to refine current evapotranspiration rates at a fine spatial scale and downscaled climate modeling data should be utilized to estimate how these evapotranspiration rates will change by mid and end of century. Accurate evapotranspiration rates are critical to better estimate water demands throughout the city.
    - To better quantify the water supply benefits of stormwater infiltration, a high resolution, **coupled surface to groundwater model** should be developed for the entire city. The model will be an essential tool for water managers to determine where infiltration BMPs should be located to maximize water supply benefits. For example, if 1 AF of water is infiltrated in a specific location, how much water supply is generated? This research can be used to better calculate return flows. UCLA, CSM, and USGS will begin working on this project in 2018.
    - In addition, the surface to groundwater model should be linked to high resolution climate models to better estimate how stormwater will augment groundwater supplies at mid and end of the century. This includes better predictive value of climate models for local precipitation and runoff flows.
- Although there have been numerous planning efforts to revitalize the Los Angeles River, there still has not been a comprehensive study on the flows needed to create and support a healthy riparian ecosystem, while still supporting the river's other beneficial uses and augmenting our local water supplies.
- Economic studies on the ancillary benefits of water treatment strategies and projects must be performed. Currently, there are no comprehensive studies on the open space,

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[542] Groves, D.G.; Bloom, E.; Lempert, R.J.; Fischbach, J.R.; Nevills, J.; Goshi, B.. .Developing Key Indicators for Adaptive Water Planning, ASCE J. Water Resource Planning Management, 2014

habitat, recreation, real estate, urban heat island, and public health benefits of different stormwater management approaches. A large scale, willingness to pay study (or other approach that better accounts for dispersed social benefits) is needed to determine these values. Without this study, watershed management costs will continue to focus exclusively on the costs of BMP construction and O&M operations and maintenance without any accompanying benefit quantification.

- For each sewershed, determine the potential to divert both low and wet weather flows to water reclamation plants. Identify the flows that the sewer system and downstream water reclamation plants can handle and treat effectively.

Policy Recommendations

- Nearly all of the City's waterbodies are impaired and thus most of the watershed can be considered high-priority for managing stormwater. Therefore, all street and alley improvement projects over a certain square footage (for example: 250 square feet) should capture, infiltrate, or treat and release 100% of the runoff generated from an 85th percentile storm. Treat-and-release BMPs should be used where infiltration to groundwater for potential water supply is poor.
- Approve a tough City-wide landscape ordinance that applies to new and redevelopment on all land uses (residential, commercial, industrial, transportation, City facilities, etc.). The ordinance should require a connection to LID for stormwater retention and the use of climate and ecoregion appropriate California Friendly and native plants (ideally, prioritizing native plants). DWP's turf replacement guidelines provide a strong start and should be incorporated into the ordinance. A goal of this ordinance should be transforming the City's landscape by 2035. This would incentivize nurseries to increase available native or climate-appropriate plant stocks. In addition, the City should work with MWD to expand on workforce development training programs to ensure landscape transformation can occur quickly.
- The installation of smart water meters and / or sub-meters where applicable should be required through a retrofit program. These could better capture indoor and outdoor water use and characterize water use at an apartment- or office-scale in multi-unit buildings. For example, smart meters at all property types will provide real time data that would allow the City to identify leaks or customers to track their water use and make needed changes to reduce their consumption. Sub-metering apartments could similarly increase consumer awareness of their own water use and incentivize conservation. These requirements should go beyond properties undergoing new and redevelopment to maximize the potential benefits of this program.
- Net zero/water neutrality ordinance for new and redevelopment for all land uses. Santa Monica has implemented a net zero water ordinance, and the County is currently considering developing a similar ordinance.
- The City should create goals and policies that aim for 100% reuse of recycled water (except for residuals such as brine) while also maintaining flows to protect beneficial uses (e.g., aquatic life, recreation) in inland receiving waters. Create a policy goal with deadline (for example, 2035) for greatly reducing direct ocean discharges of treated wastewater.

- Jumpstart the process of building a more collaborative approach that enables diverse groups of stakeholders to identify and build the multi-benefit projects needed to transform the City's infrastructure to a local water system by creating a temporary, 5-year Local Water Director position, ideally located in the Mayor's Office. This position would lead on local water projects to ensure timelines and budgets are met and would report to an executive council led by the Mayor. This council would also include the Deputy Mayor and the heads of agencies such as LADWP, LASAN, and BoE to ensure sufficient oversight. This group would jointly hire this position to be in charge of local water infrastructure. The Local Water Director position would entail working with hired consultants and designated staff from critical departments and bureaus, and report back to the group on a monthly basis to elevate challenges to implementation that need resolving and also to describe successes.

B. Additional Research Recommendations

- The City of Los Angeles, as part of its effort to promote openly-accessible data, should strive to be a leader in developing and publishing robust, open-source data and models for water management.
- Better information on BMP performance and the costs of installation, as well as on operations and maintenance costs are needed. This information is critical to improve the accuracy of modeling analyses and for making cost-effective decisions on how to improve water quality in the city's watersheds.
- GHG emissions for the city's water portfolio need to be more accurately determined. For example, direct measurements of GHG emissions from wastewater treatment and water reclamation processes have never been performed. In addition, updated estimates of GHG emissions from all current and potential water sources including pumping, treatment, and distribution, would provide a more accurate comparison of the carbon footprint differences between those water sources.
- Collect better data on leaks from water distribution and wastewater pipes. A comprehensive AMI water metering program would help dramatically.
- Complete a study to determine the feasibility of reducing per capita water consumption to 90 gpcd, 75 gpcd, and 60 gpcd. Develop implementation strategies for the feasible water consumption targets, including those highlighted in LADWP's Water Conservation Potential Study (e.g., most of potential to reduce water use is in landscaping and clothes washers for residential land uses and in landscaping, cooling towers, and condensate for industrial land uses).
- Quantify the dewatering supply potential and create a policy to capture and reuse this water where possible. Mechanisms for reuse could include local use (e.g., irrigation or environmental uses), diversion to local treatment facilities (e.g., nearby desalters), or discharge into the sewer system to water reclamation plants. One possible mechanism to incentivize capture and use of dewatered water would be to establish pumping fees for developers that dewater and discharge to receiving waters. As a reminder, building owners in the SFB are required to meter the extracted groundwater, report the volumes to the Watermaster, and enter an agreement with an affected rightsholder to pay for the extracted volumes. Or, the City may want to consider a prohibition of

discharge if the project's discharge volumes are above a certain size (Ex: above 10,000 gallons).

- Quantify the sustainable yields of the groundwater basins in and adjacent to the City. The research would build on the existing groundwater basin adjudications, management approaches, and SGMA implementation (where applicable).
- Identify the maximum potential for infiltration in and adjacent to storm channels at locations that will not negatively impact habitat, recreation, flood control, and groundwater contamination.
- Assess the potential to better utilize the San Fernando Basin west of Interstate 405 for water supply. Identify locations that could be used for infiltration, and what level of treatment is needed to greatly increase the yield in the western portion of the basin.
- A broad analysis of Contaminants of Emerging Concern in Advanced Treated Water is needed to help determine the efficacy of direct potable reuse in the City. Also, the study could provide consumer confidence in the safety of advanced treated water used for direct potable reuse.
- Organize and analyze all existing data that can inform water management decisions (e.g., stormwater quality and quantity, water use, recycled water quantity and quality, etc). For example, to assess the effectiveness of water conservation policies to date, use parcel-level water use data to identify what interventions (rate changes, watering restrictions, turf removal, etc) have worked well. Creating a dynamic mapping platform could also make aggregated consumption data more accessible to the public.
- Increase data collection efforts to more fully inform management decisions. Examples include additional flow and water quality data, updated and more specific event mean concentrations from various specific land uses and at locations throughout the City to capture spatial variability (e.g., EMCs from parcels with light, medium, heavy industry in Wilmington, East L.A, and Pacoima). In addition, existing SMARTS data on industrial runoff should be compiled (and digitized where needed) to better characterize pollutant loads from industrial land uses and their impacts on receiving waters.
- Research the potential to implement a stormwater credit trading program with DC Water's program as a potential model. Assess feasibility of a stormwater retention credits program that could incentivize voluntary implementation of green infrastructure that infiltrates stormwater runoff.
- Assess the relationship between LA City water resources and policies and impact on County-wide water management. What are the interdependencies and potential mutually beneficial programs, policies, and changes?
- Determine the revenue generation potential of utilizing AB 2403 and sewer service charges to fund appropriate stormwater programs, including O&M. For example, an AB 2403 approach could use water rate increases to pay for stormwater recharge projects above producing aquifers, and sewer service charges could be used for the construction and O&M of runoff diversion projects into the sewer system that will reduce potential public health risks. Further, investigate the potential to increase rates for stormwater services that will result from the recently passed Assembly Bill 231

(Hertzberg), which changed the definition of sewers to include "services necessary to collect, treat, or dispose of … surface or storm waters.[543]

C. Additional Policy Recommendations

- Long-range City planning efforts must consider the impacts of changes to the water portfolio on energy, water supply, and water quality in parallel. In addition, potential impacts on water quality and water supply should be considered across the planning efforts of all departments, not just those in the water space.
- The potential to increase the annual recharge and extraction of groundwater through the West Coast and Central Basin adjudication amendments should be fully utilized to maximize local water supply potential. For example, infiltration-based BMPs could be sited where there is a greater potential for groundwater recharge or partnerships can be established to utilize groundwater rights or establish water augmentation projects in those Basins. The potential to recharge and extract recycled water from HWRP to these basins should also be investigated due to their proximity.
- Los Angeles County Department of Public Health's stormwater use requirements in their Matrix 2.0 are currently too stringent to encourage a rapid increase in the capture and reuse of stormwater on-site. Matrix 2.0 should be updated to reflect LACDPH's first rainwater matrix and increase the ease of irrigating outdoor landscapes where land uses permit.[544]
- Develop a LID retrofit upon sale ordinance that requires stormwater capture or infiltration for all parcels. The current LID ordinance, which impacts properties only upon redevelopment, could result in sending approximately 2,000 AFY of stormwater through LID BMPs (by 2028, based on current implementation rates, and if implemented across the entire LA River watershed). This benefit could be greatly magnified by extending its reach.
- Develop a formal partnership or grant program to support working with NGOs to accelerate the proliferation of LID projects throughout the City. This program will be much easier to implement if the County stormwater funding measure passes in 2018. NGOs can help on community engagement, implementing LID projects on private property, schools, parks, alleys, and in parkways, and LID BMP maintenance. This type of program could also reduce the City's cost of implementing BMPs as LID practices on private land uses would reduce the number of BMPs the City must implement to manage the 85th percentile storm.

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[543] SB 231 Local government: fees and charges (2017-2018) Hertzberg. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB231

[544] For example, the 2011 rainwater matrix only required bacterial limits to be met for on- or off-site collection of rainwater, stormwater, and urban runoff in cisterns for on- or off-site use; the 2016 matrix 2.0 requires stormwater to meet NSF 350 or CCR Title 22 Recycled water equivalence with additional requirements depending on whether distributed offsite. LACDPH 2011 rainwater matrix. http://phasocal.org/wp-content/uploads/2015/06/ep_cross_con_RainwaterMatrix.pdf; Matrix 2.0 https://www.smgov.net/uploadedFiles/Departments/OSE/Contact_Find_Us/Guidelines%20for%20Alternate%20Water%20Sources_2-10-16.pdf

- The City should provide better design guidance for a wide variety of on-site LID BMPs and other structural BMPs. This guidance would be used by any entity constructing BMPs in the City.
- All future infrastructure must be built for future conditions by incorporating not only historical weather and climate patterns but also incorporating the predicted future using state-of-the-art modeling techniques. For example, the UWMP is projecting the LAA will supply 286,200 AFY of its portfolio under average weather conditions; recent climate modeling work, however, indicates it is likely that snowpack will be greatly reduced in the future (and thus that LAA volumes will likely be lower in the future). This has critical ramifications for water supply planning, as will the increased likelihood of flashier storms and longer dry periods. A changing climate will also impact ET; these changes should be taken into consideration in planting new vegetation and in designing strategies to take care of current vegetation.
- Over and above requirements under the California General Stormwater Construction permit, all projects (and long-term construction projects lasting more than 6 months) must comply with the City's stormwater LID permit requirements. For example, all new Metro projects should capture, reuse on site, or infiltrate 100% of the runoff generated on-site from an 85th percentile storm. In addition, the City should work with Metro on a cost-sharing partnership to retrofit existing Metro transportation infrastructure in the City (e.g., Expo Line) to meet these LID performance objectives.
- Create a dedicated grant writing team to develop and generate support for grant proposals to fund City water, water quality and multi-benefit projects. The office should not develop grants that compete with each other for the same funding source. The grant developer should be aware of opportunities in the City to provide match for grant proposals.
- Continue strengthening the City's Open Data program by creating an easy platform that protects privacy concerns and facilitates the sharing information with the public and other stakeholders. This will facilitate analyses in a variety of venues that can inform future decisions.
- The City should strongly support the 2018 Los Angeles County Safe, Clean Water Program (Stormwater funding measure). The Mayor and City Council Leadership are critical for the measure to pass.
- In order to better protect the City's diminishing riparian habitats, develop and implement a stream protection ordinance that will provide moderate sized buffers (no new structures or bank hardening, but permeable trails and linear parks would qualify as buffer) for soft bottomed streams (100 feet) and small buffers (30 feet) for concrete lined streams or rivers. The ordinance would result in protected habitat, reduced pollutant loads to receiving waters, and decreased peak flows and velocities in stream systems which would greatly reduce erosion and sedimentation.

- Approve a stormwater funding measure for LA County or the City, if the County measure fails. Based on the recent California Supreme Court decision[545], consider the potential to conduct an initiative process to obtain signatures from 15% of the County's population. This mechanism of placing the funding measure on the ballot would result in the need for a simple majority to pass (rather than the 2/3 majority required to pass measures placed on the ballot by local governments).[546] The measure must establish a source of funding for new capital stormwater BMP projects, BMP monitoring efficacy, stormwater education and community engagement efforts, and O&M. Funding split among cities/watersheds/county should be similar to the proposed 2013 measure of 40% for cities, 50% for watersheds, and 10% for monitoring and administration. If the 2013 approach was followed, then this measure would generate a minimum of $100M per year for the City, and ideally $150 million. There should be a community grants program for NGOs to work with the City to develop smaller scale distributed BMPs. Where feasible, projects should be LID in nature and provide multiple benefits to the community and the City. Quantitative eligibility criteria should be developed for projects funded under the watershed allocation of funds (water quality compliance, water supply, flood control, open space, habitat and recreation benefits), as well as separate criteria for the community grants program. In light of the substantial MS4 permit and TMDL requirements, the watershed projects must provide substantial water quality benefits to be eligible for funding.
- Identify and change any building codes that could potentially slow the implementation of on-site projects that offer the potential to improve water quality, increase local water supply, or offset potable water demand. For example, permitting requirements to install graywater systems, requirements to connect gutters to storm drains, etc.
- Research the potential costs and benefits of graywater implementation at various scales (SFR, MFR, commercial, laundry to landscape or more comprehensive approaches, etc.). Collect data on water quality and assess the potential impacts on other water supplies (such as IPR) in the system before developing, incentivizing and implementing regional scale graywater programs.
- Assess opportunities to establish satellite AWTFs that can treat wastewater, urban runoff and/or groundwater in areas of significant local demand. However, consider the overall system impacts of satellite facilities on system flows and downstream treatment plant operations (e.g., impacts on effluent quality or on potential recycling opportunities at centralized facilities).
- Maximize the use of City property for stormwater retrofits and establish LID on all City properties. Assess the potential to install LID on vacant lots, alleys, street, parks, parking lots and surplus properties. Build on City's existing database of properties compiled by the Mayor's innovation team.
- Create a Citywide database that can be accessed by all City departments to identify collaborative opportunities to build and maintain water-related multi-benefit projects. Identify opportunities to share this database with other regional partners, including

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[545] California Cannibis Coalition vs City of Upland

[546] "Did The California Supreme Court "Rip A Huge Hole" In Prop 13 & 218?" Ethan Elkind, August 28, 2017 http://legal-planet.org/2017/08/28/california-supreme-court-rips-a-huge-hole-in-prop-13-218/

universities and NGOs, to maximize cost-sharing opportunities. To identify best practices to facilitate agency cost-sharing on these projects, conduct research to characterize benefits from multi-benefit projects.

- Require green streets and alleys to use native or climate appropriate vegetation that supports local biodiversity.
- Refine conservation programs to include sufficient watering for trees while reducing watering to landscapes.
- Create a vehicle that allows shared O&M among public agencies or P3s for stormwater BMPs. In addition, establish criteria for the City to identify the best P3 opportunities and best practices for establishing these partnerships.
- Refine EWMP approach to establish watershed or subwatershed specific programs to manage stormwater that target a wide variety of land uses. Land use percentages vary across watersheds. For example, in heavily industrialized areas such as the lower portion of the Dominguez Channel watershed, commercial / industrial LID programs may provide more opportunities to manage stormwater then residential programs.
- Explore the potential to develop a regional groundwater strategy through the SWRCB and RB4 convening a regional groundwater coordinating group with the goal of maximizing storage from stormwater and recycled wastewater. This group would include both groundwater management agencies and regulators to discuss a regional, better managed approach to maximize sustainable yields from our groundwater basins [e.g., through increased stormwater recharge and recycled water infiltration or even injection (advanced treatment)]. In addition, the group would utilize GSPs and SNMPs where they have been developed. This group could look at groundwater rights and their further transfer to public use and public entities and costs of purchasing private water right owners, as well as substituting certain water rights with recycled water (e.g., the industrial water rights leasing program described earlier). The overarching goal should be to ensure that all cities have access to groundwater in the first instance, and in the second instance, to manage those resources to maximize local self-reliance regionally and the ability to transfer and share that resource as needed.

XI. Appendix A – Model Optimization and Costs

The SUSTAIN optimization non-dominated sorting genetic (NSGA-II) algorithm determines optimal solutions based on cost and pollutant reduction criteria. The model finds solutions based on these two criteria and selects the number of BMP units that will optimize (lower) cost as well as achieve pollutant load reduction targets. Plotting cost vs pollutant load reduction produces a cost-effectiveness or Pareto curve. The best solutions, which minimize cost and maximize reduction, are located in the "elbow" of the curve (lower left hand corner). Optimizations were set up in slightly different manners for each watershed.

The BC Watershed optimization was set up to target a 50 to 60% reduction in the annual average copper load; the best solution will cost from $0.35 to $0.65 billion (Figure A.1). As previously mentioned, this pollutant reduction target was originally chosen for the BC Watershed Study based on the results of a BMP optimization study. This target reduction goal was only applied to the BC Watershed as the LAR and DC watersheds optimizations were set up to capture the 85th percentile storm (further described below).[547] The optimization (Scenario 1) in the BC Watershed captures 1,102 AF of water which is much lower than the 85th percentile storm volume of 3,621 AF. If the City were to implement enough BMPs to capture the 85th percentile storm volume, then the total cost to implement the BMPs would be higher.

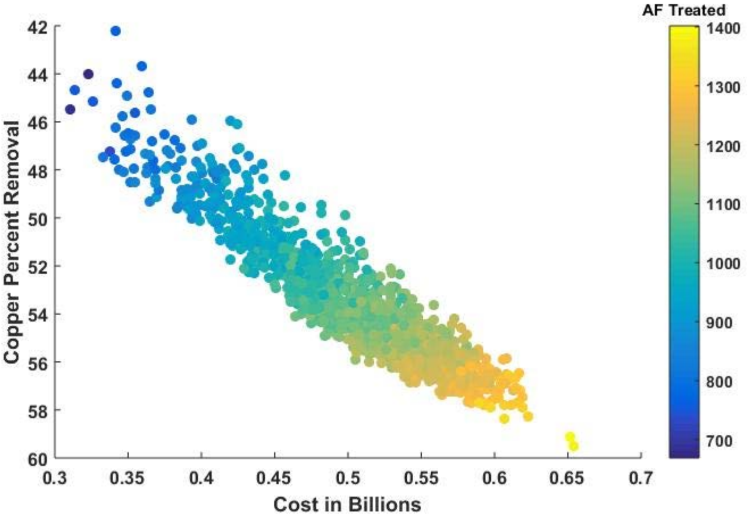

Figure A.1: Ballona Creek optimization of cost and copper pollutant load reduction, utilizing all five BMPs (BR, VS, DP, IT, PP). Color scale represents volume captured by each solution.

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[547] Beck, Drew J., Evaluating Best Management Practice Scenarios in Ballona Creek Watershed Using EPA's SUSTAIN Model (2014), Colorado School of Mines, Master's Thesis.

Unlike the BC Watershed, the DC Watershed optimization utilizes a number of BMPs in SUSTAIN to capture a range of storm volumes based on the 85th percentile storm to show the relationship between volumes of storm capture and the percent pollutant load reduction. Simulations to the left of the line capture less than the 85th percentile storm volume while simulations to the right capture greater than the 85th percentile storm volume. This change in the optimization set up resulted in modeled solutions occurring at a higher pollutant reduction than the 50-60% target as seen in the BC Watershed. The range of pollutant load reduction is a fairly small window from 80% to 83%; capturing the 85th percentile storm is expected to reduce pollutants by around 80% for a cost of around $1 billion (Figure A.2).

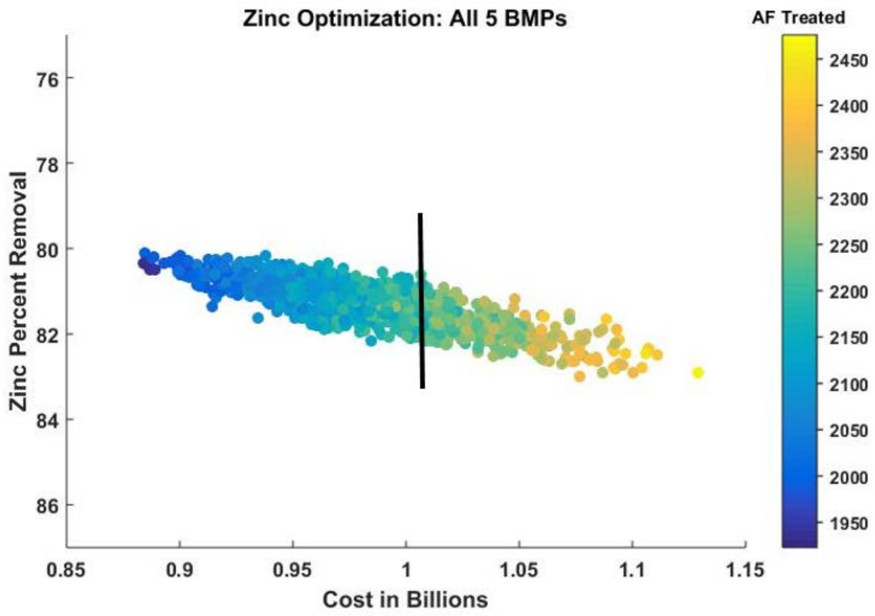

Figure A.2: DC optimization of cost and zinc pollutant load reduction, utilizing all five BMPs (BR, VS, DP, IT, PP). The black vertical line roughly estimates where solutions begin to capture the full 85th percentile storm volume.

The ML Watershed optimization was setup in the same manner as the DC Watershed. The solutions that capture the 85th percentile storm fall along the tail end of the full pareto curve (Figure A.3). Solutions that capture the 85th percentile storm do not fall within the elbow of the full Pareto Curve. Solutions that are treating the 85th percentile storm will reduce phosphorus by around 80% while costing $0.26 billion (Figure E10).

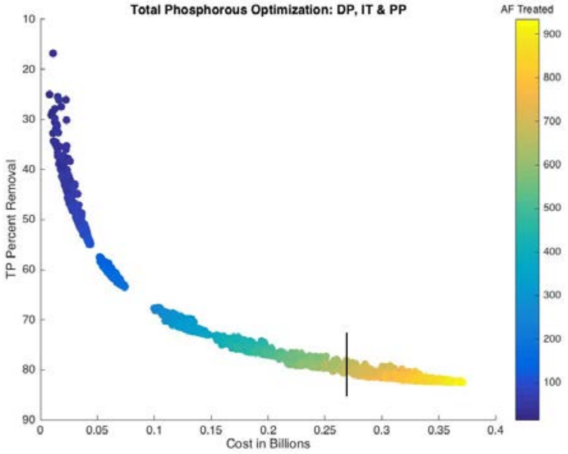

Figure A.3: ML full optimization of cost and TP pollutant load reduction for the whole ML Watershed, utilizing three BMPs (DP, IT, PP). The black vertical line roughly estimates where solutions begin to capture the full 85th percentile storm volume.

A more in-depth optimization was conducted to determine which BMP types perform best in the LAR Watershed (Figure A.4). The first optimization utilized all modeled BMPs while the other five contain only four BMP types, which are then varied in each optimization. The LAR optimization was set up to capture the 85th percentile storm as done in the DC Watershed. The resulting range of pollutant reduction for all optimizations was 50 to 70%. Optimization without PP, BR, or DP have the best performance while optimizations without IT or VS do not perform as well. Optimizations without PP or BR are the most cost efficient.

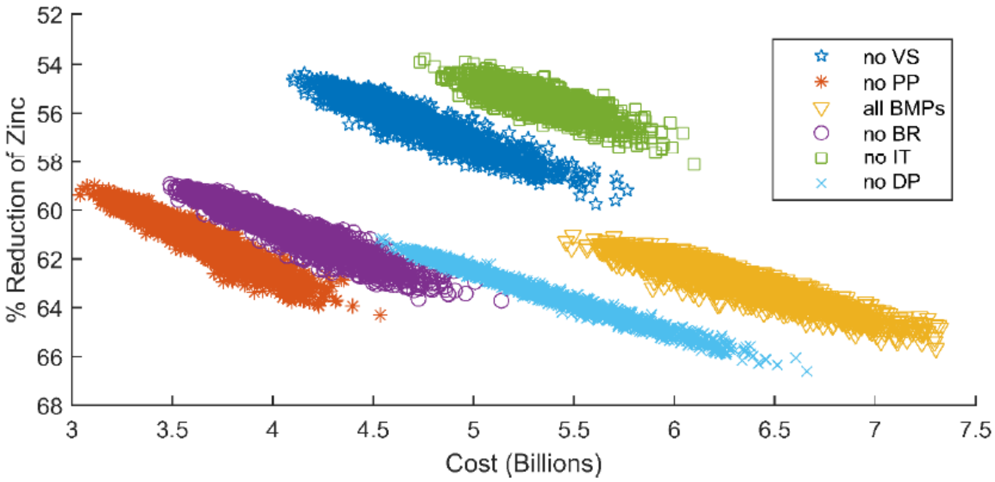

Figure A.4: Los Angeles River leave-one-out optimization of cost and percent reduction for zinc, where the absence of each BMP type is represented by a shape.

The range of costs associated with a pollutant removal of 60% for the BC, DC, and LAR watersheds were identified to compare watershed optimizations to one another (Table A.1). The range of costs and watershed area routed to BMPs were used to calculate the cost per square mile in each watershed. The ML Watershed optimization is not used in this comparison. As mentioned above, the ML watershed optimization utilizes only DP, IT, and PP because these BMPS are effective at removing nutrients, while the BC, DC, and LAR watersheds utilize all five BMPs because they all remove heavy metals. As seen in the LAR optimization (Figure E11), when different suites of BMPs are optimized the cost shifts higher or lower based on the BMPs utilized. Thus, the ML watershed optimization cannot be directly compared to the others.

Watershed	% Land routed to BMPs	% Reduction of Pollutants	Cost (Billions)	Area Routed* (mi^2)	Cost per mi^2 (Millions)	Cost per Acre (Thousands)
Ballona Creek	90%	60%	0.65 - 0.75	113	6.07 - 7.01	8.9 - 10.4
Dominguez Channel			0.40 - 0.55	63.9	6.26 - 8.61	9.8 - 13.4
Los Angeles River			5.00 - 5.50	609	8.21 - 9.03	12.8 - 14.1

* Total area routed to BMPs in SUSTAIN

Table A.1: Comparison of the BC, DC, and LAR Watershed optimization results when a 60% reduction of pollutants is achieved. The range of costs were extracted from the optimization plots. Machado Lake is not included in this comparison due to the utilization of a different suite of BMPs and a different pollutant of concern.

XII. Appendix B – Costs and Benefits of Water Supply Portfolios Technical Memo

Date:	03/10/2017
To:	Mark Gold and Katie Mika, UCLA
From:	Carolyn Wagner, Jim Henderson, Bob Raucher, Abt Associates
Subject:	Revised cost-benefit analysis of water portfolio

In the following memorandum, we present an analysis of the costs and benefits associated with the potential future water supply portfolios for the City of Los Angeles containing three local water sources: stormwater, recycled water, and groundwater. We present total annualized costs and a comparison of benefits and costs over time across all water sources and project types. The purpose of this memorandum is to enhance our understanding of the economic benefits and costs of integrated water management (IWM) scenarios that will help Los Angeles meet the Mayor's goal for water use self-sufficiency by 2035.

Overview

In the remainder of this memorandum, we provide an overview of the findings, present the annualized costs of each scenario, and compare the benefits and costs over time using present values.

Our approach to estimating the costs and benefits of the two water supply portfolio goals was to:

- Organize the analysis by water source, and consider the project types that will be needed to meet each water source goal
- Identify available existing cost and volume estimates, and apply those costs to the volume of water supply specified. The identified estimates supplied volumes less than the volumes in the scenario goals of this analysis. Thus, to estimate the costs to produce the additional volumes needed to reach the scenario goals, we calculated and applied annual unit costs per acre-foot by water source type.
- Calculate the benefits by project type used to meet the goals for each water source
- Aggregate the benefits and costs for each scenario goal
- Compare the changes in benefits and costs over time using present value estimates

Our inputs and key assumptions include:

- We calculate annualized capital costs using a 3% discount rate and 50-year time period
- Total annualized costs equal annualized capital costs plus annual operation and maintenance (O&M) costs
- All costs are converted to 2016 dollars using the construction cost index (USACE, 2016), except where noted
- We compare benefits and costs over time using present value (PV) calculations that include the following:
    - Time period: 2017-2066 (50 years)
    - Base year: 2016
    - We assume all capital investments provide 50 years of benefits. Benefits include avoided costs of imported (MWD) water, as well as applicable ancillary benefits

including reduced GHG emissions, enhanced recreational opportunities, and reduced stormwater-related damage. Not all applicable benefits are quantified or expressed in monetary terms.

- The analysis is in real terms – any escalation is in addition to the assumed rate of inflation of 2.5%[548]
- We use a 3% real discount rate for the present value analysis.

Several benefit types apply to all water sources, and methods for addressing them are introduced here. Methods for valuing benefit types specific to each water source are addressed in the following sections on each source (sections 2, 3 and 4).

One benefit type that applies across all water sources is avoided cost of imported water purchases. We assume that imported water prices will escalate through the year 2021 at a 6% nominal rate, or 3.5% real rate (assuming a general rate of inflation of 2.5%). For the year 2022 and years thereafter, we will escalate at a rate of 1.5% per year in real terms, or 4% in nominal terms. This is also conservative, given that observed 10 to 20 year escalation rates have been in the 1.9% to 5.2% range in real terms. (See Appendix A1 for a detailed description of this analysis, which is based on historical MWD rate increases).

Avoiding water imports from MWD results in reduced energy usage from avoided pumping of water to southern California. This reduced energy use avoids associated emissions of GHGs and local air pollutants. Avoiding each AF of water imports avoids approximately 1.29 MT of GHG emissions[549]. We value the avoided GHG emissions using the “social cost of carbon,” which is an estimate of the monetized damages, now and into the future, associated with an incremental increase in carbon emissions emitted now. These damages “include but are not limited to the impact on agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change” (IWG, 2010). The mean of the range of social cost of carbon estimates is $41 per MT of avoided emission (value is for avoiding emissions in 2015, in 2016 dollars). Thus, to estimate the benefit of avoided emissions, we apply $52.89 per AF (1.29 MT/AF x $41 per MT = 52.89 $/AF).

Additional information on our approach to individual water sources and key assumptions are included in the corresponding sections of this memorandum.

In Table 1, we present a summary of the water portfolio goals for both the “city-based” and “maximize local” (hereafter referred to as “max local”) scenarios.

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[548] The Federal Reserve Bank of Philadelphia indicates an anticipated annual average consumer price index (CPI) inflation rate of 2.3% over the next ten years, from its survey of professional forecasters (Federal Reserve Bank of Philadelphia, 2017). The historical 30-year average is higher, so we round up to 2.5%.

[549] Estimate provided by Katie from GHG analysis – used baseline 2013/2014.

Table 1: Supply volumes by scenario goals

Supply scenario	FY 2013 – 2014 (Baseline) (AFY)	2035: city-based goal (AFY)	2035: max local goal (AFY)
MWD (Import)	441,871	100,000	35,000
LA Aqueduct (LAA)	61,024	139,400	91,000
Groundwater	79,403	114,100	114,100
Recycled Water (NPR)	10,054	45,400	161,400
Recycled Water (GWR)		43,100	
Stormwater – Centralized	included in groundwater	19,000	26,000
Stormwater - Distributed		18,000	32,000
Total Water Supply	592,352	479,000	459,500
Total – Local Sources	**89,457**	**239,600**	**333,500**

Stormwater

We evaluated several potential data sources to use in our stormwater analysis (e.g., Geosyntec, 2015; Gold, et al. 2015), and determined that the LA Basin Study (CH2M, 2015) was the most appropriate to use to estimate benefits and costs of stormwater as a source of water supply. For example, as part of the broader study under which we conducted this analysis, BCWMG (2016) evaluated several scenarios to meet water quality standards, and thus water quality rather than quantity was the focus.

The LA Basin Study provides cost and benefit information on several types of stormwater capture projects/programs. These projects are based on the project types, and associated costs, in the SCMP (Geosyntec, 2015). The projects/programs identified in the LA Basin Study provide a greater volume of water supply than the scenario goals of this analysis. For example, the LA Basin Study estimated that distributed projects could provide 157,133 AFY[550], whereas the city-based and max-local water supply goals are 18,000 and 32,000 AFY, respectively. To apply this

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[3] From CH2M, 2015, Appendix D: AppendixDRegional1Cost.xls. We used the sum of annual recharge reported on sheets “Local Stormwater Capture 1”, “Low Impact Development”, and “Complete Streets”. The LA Basin Study includes the Malibu Creek and San Gabriel River watersheds in addition to the Ballona, Dominguez Channel, and LA River watersheds that are included in the study area of this analysis. 63% of the implementation area (in acres) is within the study area (CH2M, 2015. p. 47, Table 9).

information to the scenario goals, we have calculated unit costs for the various types of programs and apply them to the volumes needed to reach the city-based and max local scenario goals.

We include the centralized and distributed project/program types presented in the LA Basin Study, which are defined as follows (CH2M, 2015):

- Distributed programs (local solutions)
    - *Local stormwater capture* consists of infiltration projects distributed throughout the watershed where there are favorable conditions for recharge. Potential projects include green infrastructure such as infiltration chambers at parks, golf courses, small vacant private parcels, government, and institutions.
    - *Low impact development* consists of small BMPs throughout the residential, commercial, industrial, and institutional areas. Projects include:
        - "Urban acupuncture" (Many small projects over the basin)
        - Construct distributed BMPs upstream of lower efficiency spreading grounds
        - Rain gardens
        - Parking lot storage and connectivity
        - Green roofs
    - *Green streets* [551] consists of small BMPs throughout the transportation land use portion of the LA Basin, with potential projects including:
        - Green streets and stream tributaries stormwater capture
        - Parkways and road medians stormwater capture
        - Under street infiltration
- Centralized programs (regional solutions)
    - *New stormwater recharge sites* for new spreading basins identified based on previous reports and a search of vacant properties near main channel features in recharge areas.
    - Enhanced maintenance practices at *existing recharge sites*

The LA Basin Study estimated the volume of additional water supply for each of the sub-categories. The estimated volumes were apportioned across the distributed programs in the following proportions[552]:

- Local stormwater capture: 20%
- Low impact development: 60%
- Complete streets: 20%

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[551] The LA Basin Study refers to these projects as "complete streets", but we refer to them as "green streets" following the nomenclature used in Abdulla and Blyth, 2016; in which "green streets" are defined as "streets that use a natural systems approach to reduce stormwater flow, improve water quality, reduce urban heating, enhance pedestrian safety, reduce carbon footprints, and beautify neighborhoods".

[552] We calculated these proportions from annual recharge amounts reported in CH2M, 2015, Appendix D: AppendixDRegional1Cost.xls, sheets "Local Stormwater Capture 1", "Low Impact Development", and "Complete Streets".

We use these same proportions in this analysis to divide the total distributed program volume goal between these sub-categories. That is, we assume 20% of the scenarios goal will be met through local stormwater capture, 60% through low impact development, and 20% through complete streets.

1.1 Annualized costs

Table 2 shows the inputs used from the LA Basin Study (CH2M, 2015) and annualized unit cost ($/AF) for each project/program type. The annual yields, upfront costs, and annual O&M costs are from the LA Basin Study[553], which were derived from the SCMP (Geosyntec, 2014) (CH2M, 2015[554]). Annualized upfront costs are calculated using a 3% discount rate and 50-year time period.

Table 2: Inputs and annualized unit costs for stormwater capture

Project type	Annual yield (AFY)	Capital costs ($M)	Land costs ($M)	Total upfront cost[1] ($M)	Annual O&M cost ($M)	Annualized upfront cost ($M)	Total annualized cost ($M)	Annual cost per AF ($)
Local stormwater capture	31,123	3,086.2	1,327.5	4,413.7	76.5	171.5	248.3	7,977
Low impact development	94,533	9,696.0	-	9,696.0	216.8	376.8	594.1	6,285
Green streets	31,477	5,970.3	-	5,970.3	119.7	232.0	352.1	11,185
Total distributed	**157,133**	**18,752.5**	**1,327.5**	**20,080.0**	**413.1**	**780.4**	**1,194.4**	**7,601**
New large stormwater recharge sites	29,930	371.2	341.0	712.2	7.0	27.7	34.7	1,160
Enhanced maintenance at existing recharge sites	13,381	280.8	-	280.8	6.3	10.9	17.3	1,289
Total centralized	**43,311**	**652.0**	**341.0**	**993.0**	**13.3**	**38.6**	**52.0**	**1,200**

[1] Capital and land acquisition cost

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[553] "Capital costs include construction costs, engineering, project management, legal and permitting, and contingency. An additional property acquisition cost was assumed for purchase of private open space parcels for the use of Local Stormwater Capture concepts…. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014)" (CH2M, 2015. p 69).

[554] From Appendix D: AppendixDRegional1Cost.xls, sheets "Local Stormwater Capture 1", "Low Impact Development", and "Complete Streets"; adjusted to 2016 dollars.

Next, we apply the annualized cost per AF to the volume of water supply needed to meet the city-based and max local goals for the distributed and centralized stormwater capture. We scale the volumes across project types using the same distribution presented in the LA Basin Study. The results are summarized in Table 3.

It should be noted that some of the stormwater capture costs shown above will be incurred by private property owners. Private property owners that create, add or replace 500 ft^2 or more of impervious area will be required to recapture the three-quarter inch rain event for infiltration or reuse on site. Geosyntec (2015) estimated the required *capture* volume (AF) for the LAR watershed from redevelopment to be 2,178 AF. Applying the ratio of volume captured to the volume needed to meet the city and max goals to the watersheds in our study area, we estimate that approximately 3,379 AF will be captured by private property owners. This equates to 31% and 18% of the stormwater needed to meet the city-based and max local goals, respectively. However, these estimates do not account for translation of capture volume into available supply.

Table 3: Total annual costs to meet stormwater supply goals

	City based		**Max local**	
Source	**Volume**	**Cost ($M)**	**Volume**	**Cost ($M)***
Distributed	18,000	136.8	32,000	$243.2
Centralized	19,000	22.8	26,000	$31.2
Total	**37,000**	**159.6**	**58,000**	**$274.4**

A portion of the distributed costs will be incurred by private property owners.

1.2 Comparing benefits and costs over time

To compare benefits and costs over time, we assume that new stormwater projects will be added over time to meet the water supply goal so that the volume of stormwater captured will show a linear ramp up from 2017 to 2035. Capital costs are distributed evenly across this time period, and any remaining service life is credited at the end of the 50-year analysis period; we assume all expenditures of capital accrue benefits for 50 years.

Benefit categories include the avoided cost of imported water, the associated reductions in CO2 emissions, and several categories of ancillary benefits. The PV benefit of the avoided cost of importing water is $896.2 million and $1,404.9 million for the city-based and max local scenarios, respectively. The PV benefit from avoided GHG emissions over the 50-year period is $58.9 million under the “city-based” goal, and $92.3 million under the “max local” goal.

The ancillary benefits associated with stormwater capture vary across project type. Table 4 shows the benefit categories that apply to each of the project types for distributed and centralized stormwater capture.

Table 4: Monetized benefit categories applied to stormwater capture projects

Project type	**Monetized benefit categories additional to avoided imported water and associated GHG reductions***

Distributed projects	
Local stormwater capture	Recreation and habitat
Low impact development	Recreation and habitat; avoided stormwater runoff costs, carbon sequestration, urban heat island mitigation, improved air quality, aesthetic value, increased liability from trees (negative)
Green streets	Avoided stormwater runoff costs, carbon sequestration, urban heat island mitigation, improved air quality, aesthetic value, increased liability from trees (negative), recreation and habitat
Centralized projects	
New large stormwater recharge sites	Recreation and habitat
Enhanced maintenance practices at existing recharge sites	None
*Potentially important but non-monetized benefits include water quality benefits, improved flood control, job creation, reduced damages from drought, increased resiliency to climate change, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.	

As shown in Table 4, we apply recreation and habitat benefits to regional spreading grounds, local stormwater capture, LID, and complete streets project types. The LA Basin Study estimated that these project types include recreation and habitat enhancements that result in an estimated 1,698 acres of habitat and 830 miles of recreational trails. To estimate habitat and recreation benefits for this analysis, we scaled the habitat and recreation trails in the LA Basin Study using the ratio of the volume of stormwater in the LA Basin Study to the volume of water supply needed to meet the scenario goals. The estimated quantities are:

- City-based goal: 208 acres of habitat, 99 miles of recreation;
- Max local goal: 362 acres of habitat, 174 miles of recreation.

To monetize the benefits of the recreation and habitat improvements, we apply the following inputs:

- Average trail use per mile, annually (Piper, 2016): 22,490
- Consumer surplus value for leisure bicycling, running/jogging, and walking: $44.12 (Rosenberger, 2011)
- Wetland banking value for south coastal CA (applied as 1-time benefit in first year): $205,000
- Range of annual per acre habitat benefit (Piper, 2016): $141 to $719.

This approach results in estimated recreation and habitat benefits ranging from $223.1 million to $1,797.8 million.

As shown in Table 4, we applied the following additional benefits to the green streets and LID project/programs:

- Avoided storm water runoff costs
- Carbon sequestration
- Urban heat island mitigation
- Improved air quality
- Aesthetic value

We monetized the ancillary benefits associated with green streets based on information in the Living Streets study (Abdulla and Blyth, 2016), in which the authors monetized benefits associated with the stormwater capture elements of green streets[555]. To apply these monetized benefits to the project/program types from which our water supply volumes are derived, we scaled the monetized benefits using the estimated volume of stormwater capture. Abdulla and Blyth (2016) estimated that 2,782 acres would be converted and that 0.95 AF of stormwater would be captured per acre, which implies 2,643 AFY would be captured by the green street elements. We use this volume estimate to scale the monetized benefits to the volumes needed to meet the scenario goals. We calculate a per unit benefit using the volume of stormwater capture – 2,643 AFY - and apply the unit benefits ($/AFY) to the volumes needed to reach the scenario goals[556]. This approach introduces uncertainty for the following reasons:

- Abdulla and Blyth (2016) assumed the average annual capture volume per acre, which we scaled to meet total volume goals, in AF. This implicitly assumes benefits are linear; whereas in reality, benefits could realize diminishing returns. Our estimates are highly sensitive to this assumption. For example, if we instead assume only 50% of benefits are realized per AF, our estimated monetary benefits are cut in half.
- The capture volume may not accurately reflect (and most likely overstates) the actual volume of additional water supply that would result from the project.
- We applied the same unit benefits to the LID and green street projects using the benefit per scaled volume in AF. This assumes uniform benefit accrual across both project types. At least some of the ancillary benefit categories such as improved air quality could vary across these project types (e.g., street trees provide considerable air quality benefits whereas under-street drainage does not).
- Few studies have monetized similar benefits, and we were unable to identify a study that monetized benefits that would allow for an “apples-to-apples” comparison Abdulla and Blyth’s calculations. However, Abdulla and Blyth rely on peer reviewed or authoritative governmental sources for the individual benefit components, including McPherson (2011) for avoided stormwater costs as well as carbon sequestration and aesthetic value estimates, the Interagency Working Group (IWG, 2013) and Rosenfeld (1997) for urban heat island mitigation, and Akbari (2005) for improved air quality.

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[555] The “green street elements” are described in Abdulla and Blyth, 2016 (p. 22) as: “Green Streets use an environmental services approach to reduce stormwater flow, improve water quality, reduce urban heating, enhance pedestrian safety, reduce carbon footprints, and beautify neighborhoods. Green Streets use vegetation, soils, and natural processes to manage water and create healthier urban environments. Green Streets can incorporate a wide variety of design elements, yet their functional goals are the same: provide source control of stormwater, increase infiltration by limiting its transport, reduce pollutant conveyance to the collection system, and provide environmentally enhanced roads”.

[556] Following Abdulla and Blyth, 2016, we have included the increased liability from street trees (due to increased trips and falls) as a cost in our benefit calculations.

To account for this uncertainty, we apply these benefits as a range – that is, we present the totals with and without these benefits included.

Table 5 summarizes the benefits associated with avoided imported water purchases, recreation, habitat, and the sum of ancillary benefits associated with green streets, and compares them to the PV costs of producing local stormwater supply.

Table 5: Comparison of PV monetized benefits and costs of local stormwater supply

Benefit/cost category	City-based ($million)	Max local ($million)
Avoided cost of imported water	896.2	1,404.9
Value of avoided CO_2 emissions	58.9	92.3
Recreation	1,795.1	3,152.1
Habitat	0.54 to 2.7	0.93 to 4.8
Other benefits of green streets and LID	4,526.4	8,046.9
Total monetized benefits[1]	**5,704.6 to 7,279.3** (1,178.2 to 2,752.9 excluding street benefits)	**9,935.9 to 12,701.1** (1,888.9 to 4,654.1 excluding street benefits)
Total costs	**2,910**	**5,003**
Net monetized benefits	**2,795 to 4,370**	**4,933 to 7,699**

[1] Potentially important but non-monetized benefits include water quality benefits, improved reliability, improved flood control, job creation, reduced damages from drought, increased resiliency to climate change, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.

2. Using the unit volume to scale benefits, 25% of the benefits are assumed from green streets and 75% from LID. This results in ranges of $1,130.7 to $2,010.1 and $3,395.7 to $6,036.8 (all in $million) for green streets and LID, respectively.

In addition to the monetized benefits described above, stormwater capture projects/programs also provide water quality benefits such as reducing trash, sediment, and vegetation loading, reducing bacteria loading, and reducing toxic pollutant loading to receiving waters. These potentially important benefits could not be readily quantified or monetized for this analysis.

The LA Basin Study modeled the quantity of stormwater available for use[557]. Applying their quantities to our analysis results in the implicit assumption that 100% of the stormwater captured is available for supply. The results of our analysis, specifically the comparison of benefits to costs, are sensitive to this assumption. To demonstrate this sensitivity, we can arbitrarily assume that some percentage of the water captured would be available for supply. For example, if 20% of the water captured is available for supply, the costs increase by 80%; that is, we would need to implement 80% more of each project to reach the water supply goals. The benefits of avoided cost of imported water and associated GHG emissions remain the same, as we are analyzing the same quantity of water supply. The ancillary benefits associated with the scale of the project (e.g., recreation and habitat benefits) increase proportionally with the increase in the project scale, specifically 80% in our example. Understanding how much of a certain project type could

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[557] See for example, Task 6 (Piper, 2016), page 6, in which the authors use the quantity of water provided in Task 5 as the quantity of water supply.

be conducted is another area of uncertainty. There are limiting factors such as land availability and economies of scale that make it difficult to scale the unit costs and benefits if recovery is less than 100%.

Recycled water

To compare costs to benefits of recycled water produced across the three water supply portfolios, we need an estimate of the volume of recycled water by use category (NPR, GWR, and DPR), and the costs associated with producing those volumes. We base our analysis on information presented in the Recycled Water Master Plan (RWMP) (City of LA, 2012) and Raucher and Tchobanoglous (2014).

The additional volumes of recycled water needed to achieve the city-based and max local scenario goals are presented in Table 7 (assuming 10,054 AFY of recycled water is currently provided under the baseline). Recycled water projects are split between non-potable reuse (NPR) which includes irrigation and industrial process use, and groundwater replenishment (GWR) which includes indirect potable reuse (IPR) and, potentially, direct potable reuse (DPR).

Table 7: Recycled water scenario goals

	Net volume, City-based	Net-Volume, Max local
NPR	37,400	151,346
GWR (IPR/DPR)	41,046	
Total	**78,446**	

1.1 Annualized costs

The RWMP provides volume and cost estimates for a volume less than the goals of our analysis. The RWMP NPR report (City of Los Angeles, 2012) provides volume and cost estimates for NPR based on existing demand. The RWMP GWR report (City of Los Angeles, 2012) provides a cost estimate for providing 30,000 AFY of GWR. We use their estimates for the volumes provided and summarize our approach as follows:

- Step 1: Assume that NPR will be provided first. We calculate the NPR volumes and associated costs using the information provided in the RWMP NPR report, scaled up to the volume estimates in the scenario goals.
- Step 2: Assume that planned GWR is the second priority. We calculate the costs of GWR for the 30,000 AFY for which costs are estimated in the RWMP GWR report.
- Step 3: Assume the remaining volume needed to meet the scenario goals comes from a combination of DPR and IPR, for which we estimate costs using the costs provided in Raucher and Tchobanoglous, 2014. We use an average of the cost range to value future IPR and DPR supply. The cost range is the same for DPR and IPR, thus we do not make assumptions regarding the allocation between the two.

NPR

The RWMP NPR report provides capital and O&M cost estimates for the planned and ultimate potential[558] NPR volumes. In Table 8, we present the volume, capital and O&M costs, and annualized costs using a 3% capital recovery rate and 50-year time period, and the annualized cost per AF for the planned and the ultimate potential.

Table 8: NPR Annualized cost estimates

	Annual yield (AFY)	Total capital cost	Total annual O&M	Annualized capital cost	Total annualized cost	Annual cost per AF
Planned	11,350	$312,554,273	$11,036,227	$12,147,576	$23,183,803	$2,043
Ultimate potential	18,453	$425,623,540	$7,860,709	$16,542,069	$24,402,778	$1,322

To estimate the costs for the remaining 7,597 AFY needed to reach the scenario goal, we apply the annualized cost per AF associated with potential volume ($1,322/AF). The total estimated cost of producing the goal volume of 37,400 is **$57.6 million**.

GWR

The RWMP GWR report presents capital and annual O&M costs for 30,000 AFY of planned GWR assuming use of the existing plants and spreading grounds and injection wells. We present these below, along with the unit costs and total annualized costs:

- Capital: $432.1 M
- O&M: $18.6 M
- Annualized capital cost: $16.8 M
- **Total annualized cost: $35.4 M**
- Annual cost per AF: $1,180

To reach the city-based goal of 41,046 AFY of GWR, the city needs an additional 11,046 AFY. To reach the max local goal of 113,946, the city needs an additional 83,946 AFY. We assume the remaining volume needed to meet the scenario goals is provided through a mix of DPR and IPR, for which we estimate costs using the ranges provided in Raucher and Tchobanoglous, 2014. The annualized costs for IPR and DPR range generally range from $1,100 to $1,500 per AF, assuming that transmission costs are not large for future projects in the area. We used the average of the range to represent future IPR or DPR costs. This results in annualized costs of $14.3 M and $109.1 M for the city-based and max local goals, respectively. Table 9 presents the total volume and annualized costs of recycled water.

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[11] The RWMP NPR report provides separate estimates for the “planned”, “potential” and “ultimate” NPR volumes, where ultimate is the full volume of identified demand, and potential is a scaled-down version of ultimate that is used for planning purposes. Because our goal volumes for this analysis are higher than both the planned and potential, we used the ultimate volume of 18,453 AFY, and corresponding costs.

Table 9: Costs of additional supply of recycled water

Source	Volume (AF)	Annualized cost per AF	Total annualized cost to meet scenario goals ($ million)
NPR	37,400	$1,541	57.63
GWR	41,046 for city-based goal;	$1,181 for first 30,000 AF; $1,300 for remaining AF	49.8 for city-based goal;
	113,946 for max local goal		144.6 for max local goal
Total	**78,446 for city-based goal;**	**n/a**	**107.4 for city-based goal;**
	151,346 for max local goal		**202.2 for max local goal**

1.2 Comparing benefits and costs over time

The largest monetized benefit associated with recycled water is the avoided cost associated with imported water. Recycled water use is assumed to avoid 78,446 AFY of imported water purchases under the “city-based” goal, and 151,346 AFY of imported water purchases under the “max local” goal. This results in a present value benefit from avoided imported water purchases over the 50-year period of $1.9 billion under the “city-based” goal, and $3.3 billion under the “max local” goal. The PV benefits of reduced CO_2 emissions associated with avoided imported water are $107.9 and $195.8 million for the “city-based” and “max local” scenarios, respectively; where avoided emissions are net of estimated emissions for recycled water, which we estimate to be 0.179 MT/AF. Table 10 summarizes the present value costs and benefits of recycled water.

Another important monetized benefit for increased recycled water use is the value of improved water supply reliability compared to imported water. Recycled water yields are not linked to the hydrologic cycle and annual precipitation patterns; instead, the yield from recycled water is driven by a stable supply of regionally generated wastewater. As a climate-independent water supply option, recycled water offers some added economic reliability values to the region compared to imported sources that depend on snow pack, precipitation, and storage.

Although interest in water supply reliability is increasing (e.g., due to increasing water demands and concerns over climate-related events), only a few studies have directly attempted to quantify its value (i.e., through nonmarket valuation studies, see for example Carson and Mitchell, 1987, CUWA, 1994, Griffin and Mjelde, 2000, Wolfe, 2007, and Raucher et al, 2013). The results from these studies indicate that residential and industrial (i.e., urban) customers seem to value supply reliability quite highly. These and related stated preference studies have found that water customers are willing to pay $100 to more than $500 per household per year for *total* reliability (i.e., a 0% probability of their water supply being interrupted in times of drought).

The challenge in applying these values to determine a value of increased reliability as a result of the increased reliance of recycled water within the City’s future water supply portfolio is recognizing how to reasonably interpret these survey-based household monetary values. Most of the monetary values noted above reflect a willingness to pay per household to ensure *complete reliability* (zero drought-related use restrictions in the future), whereas the increased share of recycled water in LA only enhances overall reliability, but does not guarantee 100% reliability. Thus, if applied directly to the number of households within the City of Los Angeles service area, the dollar values from the studies would overstate the reliability value provided by the offsetting some imported water with increased use of recycled water.

A simple way to roughly adjust for this "whole versus part" problem is to attribute a portion of the total value of reliability to the portion of the problem that is solved by the project. To adjust for the partial improvement in reliability from the increased use of recycled water, it is assumed that household willingness to pay for improved reliability is directly proportional to the amount of recycled water that will offset imported water, as a percentage of the total potable water supply. This represents the percentage of total supply that has been improved in terms of overall reliability (i.e., by offsetting imported water demand with local sources).

The proposed recycled water portfolio will offset more than 88,500 AFY of imported water under the 2035 city-based goal, and 161,400 AFY under the 2035 max local goal. To place this volume in perspective, baseline (FY 2013-2014) imported water demand is 441,871 AFY. Thus, about 20% (88,500/441,871=20%) of imported water will be offset by recycled water use under the city-based goal, and 37% (161,400/441,871=36.5%) of imported water baseline demand will be offset by recycled water use under the max local goal. To obtain a lower bound estimate for the value of improved reliability associated with this water, it may be assumed that households within the City are willing to pay about $20 per year for improved reliability of supplies ($100 multiplied by 20%) under the city-based goal, and $37 under the max local goal. Applying the lower end per household dollar value to the approximately 1.7 million households within the City service area in 2040 (LADWP 2015) would result in $30 million per year in enhanced reliability benefits for the city-based goal, and $63 million per year for the max local scenario.

A second approach yields roughly the same estimate of the value of residential water supply reliability gain. Raucher et al. (2013) offers estimated willingness to pay values for a more realistically defined increase in supply reliability. The research indicated that households are willing to pay between about $20 and $35 per year for each year that a water supply portfolio that reduces the likelihood of "Stage 2" water use restrictions by one year out of the next 20 (stage 2 restrictions reflect a highly restricted ability to do any landscape irrigation).

For this study, we apply $20 per year estimate common to both valuation approaches for the city-based scenario, and $36 per year for the max local scenario (an average of the $35 per year and $37 per year estimates from the two approaches). After applying this range of reliability values to the projected number of households in the LADWP service area over the timeframe of the study, and discounting the result to 2016 dollars, this approach shows $632 million in reliability benefit for recycled water supplies for the city-based scenario, and $1,139 million for the max local scenario. Monetized costs and benefits for recycled water are summarized in Table 10.

There are several additional valuable benefit categories associated with recycled water use that are not quantified here. Those include hard-to-quantify environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction (or more water available for other importers), the opportunity to reuse a water resource that would otherwise be lost, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs (compared to imported water use).

Table 10: Comparison of PV monetized benefits and costs of recycled water

Benefit/cost category	City based ($million)	Max local ($million)
Avoided cost of imported water	1,912.6	3306.3
Value of avoided CO_2 emissions	107.9	195.8
Value of improved water supply reliability	632.6	1,138.7
Total monetized benefits *	**2,653.1**	**4,640.8**
Total costs	**1,898.5**	**2,913.4**
Net monetized benefits	**754.6**	**1,727.4**

*Potentially important but non-monetized benefits include improved job creation, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.

Groundwater

1.1 Annualized costs

The groundwater supply goal is 114,100 AFY for both the city-based and max local scenario goals. The current groundwater supply is 79,403 (LADWP, 2015); thus, we focus the groundwater analysis on the costs and benefits of supplying an additional 34,697 AFY.

LADWP's Urban Water Management Plan (UWMP) provides a current overview of groundwater supplies and current usage. Per the UWMP, we assume that additional groundwater supplies from the Sylmar and Central basins will be met through existing groundwater right/credits and that the additional volume from the San Fernando basin will be met through treatment of contaminated groundwater.[559] We allocate the additional groundwater volumes across the groundwater basins using the current distribution provided in the UWMP (Table 11).

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[559] According to the UWMP, "Sylmar Basin production will increase to 4,170 AFY from 2015-16 to 2038-39 to avoid the expiration of stored water credits" "Industrial contamination issues are the principle reason for restricted use of local groundwater pumping by the City. Much of LADWP's pumping capacity has been impaired by contaminants, primarily volatile organic compounds (VOCs)." (LADWP, 2015 p. 6-1).

Table 11: Additional supply of groundwater to meet goals

Basin	Total projected yield AFY (From Exhibit 6I, p. 6-24)	Percent of total	Net AFY	Basis for cost estimate
San Fernando	92,000	80%	27,837	Treatment of contaminated groundwater
Sylmar	4,170	4%	1,262	Additional pumping through existing credits
Central	18,500	16%	5,598	Additional pumping through existing credits
Total	114,670		34,697	

Over the past 5 years, the average cost to pump, treat and convey groundwater has been $341 per AF (varying from $312/AF in 2011/2012 to $392/AF in 2014/2015[560]). We apply this unit cost to the additional yield from the Sylmar and Central basins, assuming constant real pumping costs into the future (this is equivalent to assuming the future pumping costs increase at the general rate of inflation).

The cost of cleaning up the contaminated groundwater is less certain. Current estimates provided by the City of Los Angeles for contaminated groundwater cleanup in the San Fernando Valley, are:

- Capital: $600 M (LADWP, 2014)
- Annual O&M: $50,000 (LADWP, 2015)
- Yield: 123,000 AFY (LADWP, 2014)

Annualizing these costs using a capital recovery rate of 3% over 50 years, the annual unit costs of additional pumping and cleaning up contaminated groundwater are $596 and $341 per AFY, respectively. Next, we apply these annualized costs to the volumes for each basin to estimate the total cost of the city-based and max local groundwater IWM portfolios. As shown in Table 12, the total annualized cost of producing an additional 34,697 AFY of groundwater by 2035 is $18.9 million.

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[560] "Costs include operating and maintaining water well pumps, conveyance piping, disinfection treatment systems, electrical services, associated repairs, annualized depreciation of fixed infrastructure, and related financing and overhead costs." (LADWP, 2015, p. 6-23)

Table 12: Costs of additional supply of groundwater

Source	Volume	Annualized cost per AF	Total annualized cost to meet scenario goals ($ million)
Treatment of contaminated groundwater	27,837	$596	$16.59
Additional pumping	6,860	$341	$2.34
Total	**34,697**	**n/a**	**$18.93**

1.2 Comparing benefits and costs over time

The benefits associated with additional groundwater withdrawals include the avoided cost of imported water, water quality benefits (willingness to pay estimates for reduced quantity of contaminated groundwater), resiliency benefits, and improved local water supply reliability (reduced damages from drought).

The present value cost of producing an additional 34,697 AFY of groundwater over the 50-year period from 2017 to 2066 is $420.1 million. We estimated the present value benefit of avoiding the purchase of imported water following the same methodology described in Section 1. The present value benefit over 50 years of avoiding the purchase of imported water to supply that volume is $1.06 billion. The PV benefit of the associated reduction in GHG emissions is $63.9 million where avoided emissions are net of estimated emissions for ground water, which we estimate to be 0.09 MT/AF[561].

Table 13 presents the present value monetizable benefits and costs of groundwater use.

Table 13: Comparison of PV monetized benefits and costs of groundwater

Benefit/cost category	City-based and max local ($million)
Avoided cost of imported water	1,061.9
Value of avoided CO_2 emissions	63.9
Total monetized benefits*	**1,125.8**
Total costs	**420.1**
Net monetized benefits	**705.7**

*Potentially important but non-monetized benefits include water quality benefits (reduced discharge of effluent to coastal waters), improved reliability, job creation, reduced damages from drought, increased resiliency to climate change, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.

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[561] Estimate provided by Katie from GHG analysis – used 2030 estimate.

1.3 Brackish groundwater recovery

The UWMP includes brackish groundwater recovery as a potential water supply, noting that it is "merely in the concept phase" (LADWP, 2015 p. 9-6). According to the Gold, et al. 2015, "roughly 600,000 to 650,000 acre-feet of space in the West Central Basin (WCB) is currently taken up by the saltwater plume." However, the report also notes that this is around 10 times the annual adjudication rights in the basin and greater than the City of LA's annual water use and thus offers a very significant source of additional storage for fresh water as the brackish plume is remediated. Thus, the potential volume of brackish groundwater available for desalting in the three watersheds is uncertain. We present an analysis of the costs and benefits of desalting between 5,000 and 20,000 AFY.

Cost

Raucher et al., 2010 suggest a cost range between $1,000 and $1,450 per AF ($2016) for the unit costs of groundwater desalting. Discounting at 3% over a 50-year timeframe, the present value cost for a 5,000 AFY brackish groundwater recovery project ranges from $139.0 to $200.8 million, and the cost for a 20,000 AFY project ranges from $556.1 to $803.3 million.

These costs represent a range currently available in the literature; however, the costs of desalting are decreasing with improvements in technology. For example, researchers at UCLA recently designed a technology to desalt water at $0.30 per 1,000 liters, which equates to $370 per AF (University of California Press, 2016).

Benefits

Following the same approach described in previous sections, the present value monetized benefit of avoiding 5,000 to 20,000 AFY of imported water is $205.3 and $821.1 million, respectively. The present value of the avoided associated GHG emissions is $10.1 and $40.5, respectively; for total benefits of $215.4 million for 5,000 AFY and $861.5 million for 20,000 AFY. And, as in the case of recycled water, there also may be hard to quantify environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction (or more water available for other importers), and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs. There also are likely to be beneficial values associated with the enhanced reliability of the water supply, given that groundwater supply yields are largely climate-independent and locally controlled, compared to imported waters.

Conclusions

The results of our analysis indicate that the estimated costs of producing local water supplies are higher than the projected cost of importing water. However, there are large monetized benefits (as well as potentially important non-monetized benefits) associated with local water supply projects; and when we compare monetizable benefits to costs, there are positive net benefits of local water supply. We estimate the net benefit of the city-based scenario goal as $4.3 to $5.8 billion, and the net benefit of the max local scenario goal as $7.4 to $10.1 billion.

In Table 14, we present the comparison of the costs and monetizable benefits for the city-based and max local scenarios. In Tables 15 and 16, we present the comparison of costs and monetizable benefits by water supply type for the city-based and max-local scenarios, respectively.

Table 14. Comparison of monetized benefits and costs across scenarios

	City-based scenario	Max-local scenario
Volume of local water supply, net of baseline (AFY)	150,143	244,043
PV monetized cost of additional local supply (millions of $2016)	$5,228.1	$8,336.0
PV monetized benefit of additional local supply (millions of $2016)	$9,483.6 to $11,058.3	$15,702.6 to $18,467.7
Net PV (millions of $2016)	$4,255.4 to $5,830.1	$7,366.4 to 10,131.6

Table 15: Comparison of monetizable benefits and costs for city-based scenario

	Net volume (AFY)	**Annualized cost of supply (millions $2016)**	**PV cost of supply (millions $2016)**	**PV monetized benefit (millions $2016)***	**Net PV (millions $2016)**
Groundwater (net)	34,697	18.9	420.1	1,125.8	705.7
Recycled Water – NPR irrigation & industrial	37,400	57.6	1,051.5	1,257.6	206.1
Recycled Water – GWR	41,046	49.8	846.9	1,395.6	548. 7
Stormwater – Centralized	19,000	22.8	415.5	502.3 to 586.2	86.9 to 170.7
Stormwater – Distributed (including Direct)	18,000	136.8	2,494.1	5,202.3 to 6,693.1	2,708.1 to 4,199
Total	**150,143**	**285.9**	**5,228.1**	**9,483.6 to 11,058.3**	**4,255.4 to 5,830.1**

*Potentially important but non-monetized benefits include water quality benefits, improved reliability, improved flood control, job creation, reduced damages from drought, increased resiliency to climate change, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.

Table 16: Comparison of monetized benefits and costs for max local scenario

	Net volume (AFY)	**Annualized cost of supply (millions $2016)**	**PV cost of supply (millions $2016)**	**PV monetized benefit (millions $2016)***	**Net PV (millions $2016)**
Groundwater (net)	34,697	18.9	420.1	1,126.8	705.7

Recycled Water – NPR irrigation & industrial use	37,400	57.6	1,051.5	1,257.6	206.1
Recycled Water – GWR	113,946	144.6	1,861.9	3,383.3	1,521.4
Stormwater – Centralized	26,000	31.2	568.5	687.4 to 802.1	118.9 to 233.6
Stormwater – Distributed (including Direct)	32,000	243.2	4,434.0	9,248.5 to 11,898.9	4,814.4 to 7,464.9
Total	**244,043**	**495.5**	**8,336.0**	**15,702.6 to 18,467.7**	**7,366.4 to 10,131.6**

*Potentially important but non-monetized benefits include water quality benefits, improved reliability, improved flood control, job creation, reduced damages from drought, increased resiliency to climate change, the opportunity to reuse a water resource that would otherwise be lost, environmental benefits associated with reduced stress on the Bay-Delta resources due to lower demands for water extraction, and reduced human health risks associated with reduced energy-related emissions of air pollutants other than GHGs.

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Appendix A1 – Avoided cost of imported water

Water produced by stormwater capture, conservation, recycling, groundwater extraction, and other “local sources” will offset the need to use imported water supply. Imported water supply in Los Angeles is derived from the State Water Project (SWP) and/or Colorado River Aqueduct (CRA), and is delivered by the Metropolitan Water District of Southern California (MWD) as a wholesale supplier to member agencies, including LADWP.

MWD recovers its costs through a two-tiered pricing approach. MWD’s Tier 1 supply rate recovers the cost of maintaining a reliable water supply. Each member agency has a predetermined allocation that can be purchased at the lower Tier 1 rate. Member agencies can make purchases in excess of this limit at the higher Tier 2 rate. The Tier 2 rate reflects MWD’s cost of purchasing water that is transferred from north of the San Francisco Bay-Delta. The Tier 2 rate is designed to encourage the member agencies to maintain and develop cost-effective local supply resources and conservation. Thus, by design, most of MWD’s supply is expected to be sold at a Tier 1 rate. For the seven years from 2009 to 2015, LADWP’s purchase of Tier 1 water averaged 88% of the total, with Tier 2 purchases averaging 12% (LADWP, 2015).

In addition, MWD sells Tier 1 and Tier 2 water with or without treatment. Over the past seven years, LADWP purchased 70% of its MWD supplies as untreated, and 30% as treated supply (LADWP, 2015). MWD charged approximately $350 per AF for treatment in 2016. Table 1 shows projected full service treated and untreated cost per AF for Tier 1 and Tier 2 supplies.

Table 1. MWD Rates 2016-2018

Full Service Untreated Volumetric Cost ($/AF)	2016	2017	2018
Tier 1	$594	$666	$695
Tier 2	$728	$760	$781
Treatment Surcharge ($/AF)	$348	$313	$320
Full Service Treated Volumetric Cost ($/AF)	2016	2017	2018
Tier 1	$942	$979	$1,015
Tier 2	$1,076	$1,073	$1,101

Source: MWD 2016.

The value of adding new local supplies can thus be estimated based on the costs avoided by reducing local demands for imported water, at the margin. For this study Tier 1 treated water is considered the marginal source, with a cost of $942 per AF in 2016.

An important aspect in monetizing the value of avoided imports entails predicting the future cost of imported SWP water (which is the marginal imported source with the CRA allocation for California capped). Various factors have led to rate increases that have considerably outpaced general inflation over the past two decades. This trend of real price increases for imported water (i.e., above the projected CPI) is likely to continue in the future as well, because the same factors that have driven these prices upward will remain relevant for several years to come. These factors principally include limitations on overall supply, due to a variety of factors primarily linked to the declining health of the Bay-Delta ecosystem from which these waters are extracted, and protracted drought conditions. These factors -- and the associated investments that MWD and other water agencies have needed to make in infrastructure and potable water treatment – have resulted in dramatic increases in the cost of water that MWD wholesales throughout southern California.

For example, Tier 1 rates in the 2008 through 2012 period increased by over 56%, which is 8.5 times greater than the CPI over the same period. A very similar result is evident for Tier 2 rates. This indicates that the real rate of price increase (the rate of increase above general inflation rate) for MWD water has been between 9.4% and 10.2% over the five years from 2008 to 2012 (as shown in the right-most column in Tables 2 and 3).

Table 2: MWD Tier 1 Treated Rates compared to CPI

		cumulative change			average annual change		
time interval	# years	Tier 1	CPI	ratio	Tier 1	CPI	Real Tier 1
2008 - 2012	5 years	56.3%	6.6%	8.5	11.8%	1.6%	10.2%
2003 - 2012	10 years	94.6%	24.8%	3.8	7.7%	2.5%	5.2%

Table 3: MWD Tier 2 Treated Rates compared to CPI

		cumulative change			average annual change		
time interval	# years	Tier 2	CPI	ratio	Tier 2	CPI	Real Tier 2
2008 - 2012	5 years	51.8%	6.6%	7.8	11.0%	1.6%	9.4%
2003 - 2012	10 years	88.1%	24.8%	3.6	7.3%	2.5%	4.8%
1993 - 2012	20 years	123.3%	58.9%	2.1	4.3%	2.5%	1.9%

Sources: MWD, 2010; MWD rate schedules, various years.

Over a longer timeframe, similar escalations are evident as well. The 10-year average annual cost increase for MWD water from 2003-2012 has been from 4.8% to 5.2% per year above inflation, for Tier 2 and Tier 1, respectively. The 20-year price trend indicates a real annual increase in imported water costs of nearly 2% above inflation.

Based on this evidence, we conservatively assume that imported water prices will escalate through the year 2021 at a 6% nominal rate, or 3.5% real rate (assuming a general rate of inflation of 2.5%). For the year 2022 and years thereafter, we will escalate at a rate of 1.5% per year in real terms, or 4% in nominal terms. This is also conservative, given that observed 10 to 20 year escalation rates have been in the 1.9% to 5.2% range in real terms.

XIII. Appendix C – Preliminary - Additional Emissions from Wastewater Treatment

Water Reclamation Plant Background

The discussion up to this point has focused on GHG emissions from the energy required to treat wastewater after it has undergone tertiary treatment; GHGs, however, can also be emitted during the earlier stages of wastewater treatment. Therefore, in addition to assessing the GHG footprint of the energy required to treat wastewater flows at City-owned (or co-owned) WRPs, we assessed GHG emissions from the treatment processes themselves at HWRP, DCTWRP, LAG-WRP, and TIWRP. HWRP is the largest City-owned WRP, and 85% of the wastewater collected and treated at HWRP comes from the City (not including the Wilmington – San Pedro area, the strip north of San Pedro, and Watts); the remaining 15% of the influent comes from a few cities and agencies under contract.[562] HWRP is part of the Hyperion Treatment System, located in Playa del Rey. This treatment system consists of a joint outfall system that includes the wastewater collection system, HWRP, and three upstream WRPs: DCTWRP, LAGWRP, and BWRP.[563]

HWRP treats wastewater to secondary levels through a high purity oxygen activated sludge process that uses 9 secondary reactor modules and 36 secondary clarifiers.[564] With each secondary reactor having a treatment capacity of 50 MGD, the total treatment system capacity is 450 MGD of primary effluent.[565] HWRP currently does not have tertiary treatment processes. After clarification, undisinfected secondary effluent is discharged through a five-mile outfall pipe into the Santa Monica Bay. Approximately 30 to 35 MGD of the secondary effluent is sent to WBMWD's Edward C. Little Water Reclamation Facility (ELWRF) for additional treatment for multiple re-uses, mainly outside the City's boundaries. Plans are also underway to install approximately five MGD of MBR treatment at HWRP to provide additional reclaimed water for NPR uses and up to 70 MGD of additional MBR treatment to help WBMWD meet their recycled water goal.[566]

Located in San Pedro, TIWRP has a 30 MGD design capacity and a treatment system that includes primary treatment, secondary treatment, NdN, tertiary, and advanced treatment (capacity to produce 12 MGD of advanced treated water). Tertiary treatment at TIWRP includes coagulation and sand filtration. The on-site AWTF further treats the tertiary-treated wastewater through MFRO. LAGWRP is located in the City and jointly owned by the Cities of LA and Glendale. LAGWRP and DCTWRP both have secondary treatment and NdN aeration tanks combined with clarifiers. LAGWRP then further processes the wastewater through dual-bed or tetra denite sand filters, and DCTWRP further processes the wastewater through diamond shaped cloth filters. All

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[562] Hyperion Treatment Plant National Pollutant Discharge Elimination System Permit 2005 p. 3
[563] BWRP is not discussed further in this report as it is not a City of LA-owned WRP.
[564] HWRP NPDES Permit 2005 p. 5
[565] HWRP NPDES Permit 2005 p. 5
[566] City of LA, personal communication

sludge is diverted downstream to HWRP as neither LAGWRP nor DCTWRP have the facilities to process solids.[567]

Based on a 2015 LASAN hydraulics model, TIWRP serves a residential population of 133,435 people and an employment population of 36,292 people.[568] The residential population uses on average 78 gpcd, while the employment population uses an average of 23 gpcd; this represents about 30% of residential population use.[569] To obtain a representative total service population size, the residential population was added to 30% of the employment population. This resulted in a population of 144,323 people served by TIWRP. Similarly, DCTWRP and LAGWRP had an adjusted total population of 656,926 and 429,338, respectively. HWRP serves a residential population of approximately 3,358,266 people and an employment population of 2,006,584 people.[570] However, as HWRP also receives and treats sludge from DCTWRP and LAGWRP, the adjusted populations of DCTWRP and LAGWRP were also added to HWRP, resulting in a total adjusted population served by HWRP of 5,046,504 people (Table 8.8).

LASAN Modeled Population Numbers				
Reclamation Plant	Residential Population	Employment Population	Adjusted Employment Population	Total Adjusted Population
HWRP	3,358,266	2,006,584	601,975	5,046,504[571]
DCTWRP	557,385	331,802	99,541	656,926
LAGWRP	376,879	174,863	52,459	429,338
TIWRP	133,435	36,292	10,887	144,323

Table 8.8. Residential, Employment, and Total adjusted populations for 4 City WRPs

Local Government Operating Protocol and GHGs

Wastewater treatment processes can produce GHGs in multiple ways. Treatment processes can produce GHGs indirectly through the energy required to operate those processes. GHGs can also be produced directly from both the treatment mechanism itself (process emissions) and from unintended releases due to leaks or structural inefficiencies (fugitive emissions). We assessed emissions from CO2 as well as from the non-CO2 GHGs that are commonly emitted from domestic wastewater treatment, N2O and CH4.

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[567] Los Angeles Bureau of Sanitation Virtual Tour. https://www.lacitysan.org/san/faces/home/portal/s-lsh-wwd/s-lsh-wwd-cw/s-lsh-wwd-cw-p/s-lsh-wwd-cw-p-tiwrp/s-lsh-au-ti?_adf.ctrl-state=31b29ghwm_4&_afrLoop=345798317070558 57#! Accessed on 08/31/2016

[568] LASAN Personal Communication Aug 2016

[569] LASAN Personal Communication Aug 2016

[570] LASAN Personal Communication Aug 2016

[571] Total adjusted population reflects the sum of HWRP adjusted population (3,960,241) and adjusted populations of DCTWRP and LAGWRP

Direct emissions associated with the wastewater treatment process have been found to be approximately 0.005 tons of CO2e/AF of treated water, which represents about 0.38% of the total carbon footprint of a treatment plant.[572] While the emissions associated with the process are small, the increasing volumes of water treated as populations grow will result in a commensurate increase in emissions. A 2015 study found that "urbanization, economic development, and population growth may result in CH4 and CO2 emissions on the order of 10^7 kg-CO2e/year from wastewater systems in emerging nations by 2025.[573]" Emissions reported for tertiary treatment ranged between 0.82 to 3.26 tons of CO2 per acre-foot.[574] Emissions of 1.39 tons of CO2/AF were reported in a plant that uses NdN in their treatment process.[575]

Findings from a Global Water Research Coalition (GWRC) study showed that CH4 emissions mainly form in sewers and sludge handling processes. N2O emissions mainly stem from nitrification as nitrite accumulation in aerobic zones given low oxygen levels, high temperatures, and sudden changes in NH4 load.[576] Emissions were also found to vary widely from plant to plant and even through different times of the day and year.[577] These emissions ranged from 5% to 40% of the total carbon footprint of a wastewater treatment plant for CH4 and 2% to 90% for N2O.[578] Given this variability, specific water treatment systems should ideally be analyzed to achieve an accurate depiction of the emissions based on rigorous monitoring and data collection.

However, as there is a lack of monitoring data for many plants and processes, CARB, the California Climate Action Registry (CCAR), and Local Governments for Sustainability (ICLEI), developed the Local Government Operations Protocol (LGOP) in 2010 to provide a method to quantify GHGs in collaboration with TCR. The LGOP provides principles, approaches, methodologies, and procedures to help local governments quantify and report GHG emissions associated with specific processes of their operations.[579] GHG-emitting government operations analyzed in the LGOP include facilities, power generation facilities, vehicle fleets, solid waste facilities, and wastewater treatment facilities. The ability to record and track GHG emissions allows local governments to critically evaluate their activities and create a strategy to reduce their carbon footprint

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[572] Schneider et al. Impact of Direct Greenhouse Gas Emissions on the Carbon Footprint of Water Reclamation Processes Employing Nitrification–Denitrification. *Science of the Total Environment.* 2015. P. 1171

[573] Schneider et al. Impact of Direct Greenhouse Gas Emissions on the Carbon Footprint of Water Reclamation Processes Employing Nitrification–Denitrification. *Science of the Total Environment.* 2015.

[574] Cornejo et al. Carbon Footprint of Water Reuse and Desalination: A Review of Greenhouse Gas Emissions and Estimation Tools. *Journal of Water Reuse and Desalination*. 2014.

[575] Schneider et al. Impact of Direct Greenhouse Gas Emissions on the Carbon Footprint of Water Reclamation Processes Employing Nitrification–Denitrification. *Science of the Total Environment.* 2015.

[576] Global Water Research Coalition. N2O and CH4 Emission From Wastewater Collection and Treatment Systems. Chapter 2. P. 4; P. 10

[577] Global Water Research Coalition. N2O and CH4 Emission From Wastewater Collection and Treatment Systems. Chapter 2. P. 4; P. 10

[578] Global Water Research Coalition. N2O and CH4 Emission From Wastewater Collection and Treatment Systems. Chapter 7. P. 96

[579] California Air Resources Board Local Government Operations Protocol 2010 p. 3

in a transparent and quantifiable way. The LGOP is intended to help local governments in California determine and report consistent and accurate GHG inventories in support of the AB 32 program, including the Cap and Trade Program and its objectives.

The LGOP contains methodologies to calculate CH4 emissions from digester gas and N2O emissions from wastewater treatment without NdN, wastewater treatment with NdN, and effluent discharge. Using these equations, we analyzed the CH4 and N2O emissions of current processes and future potential processes at HWRP, TIWRP, DCTWRP, and LAGWRP. The analyses in the following sections focus on direct emissions; the scope and scale of fugitive emissions is a critical area for future research to understand the complete picture of GHG emissions that might result from increasing the reuse of wastewater. Additional work (and substantial data collection) is also needed to determine how accurately these generalized LGOP equations reflect site-specific emissions as additional monitoring data becomes available.

Methane Emissions

CH4 can be emitted from several wastewater treatment sources in a community: septic systems, poorly-managed aerobic systems, anaerobic treatment, anaerobic digesters, and facultative treatment lagoons. The wastewater treatment systems in the City do not use facultative lagoons, nor do they own or operate any septic systems (although there are thousands of private septic systems in the city of LA.). Emissions from poorly-managed aerobic systems were omitted from the LGOP as the amounts were considered to be negligible by the EPA.[580] HWRP and TIWRP both use anaerobic digesters to treat biosolids. Anaerobic digesters produce CH4 that can either be piped to a power station to generate electricity or flared at the treatment plant. Small but embedded inefficiencies make these digesters a source of CH4 emissions from incomplete combustion of digester gas during flaring. There are two LGOP methodologies to calculate digester gas emissions – one based on population served and one based on digester gas volumes produced daily.

Based on populations served, CH4 emissions from incomplete combustion of digester gas at HWRP and TIWRP were estimated to be 47,137 MT of CH4 as CO2e and 1,348 MT of CH4 as CO2e, respectively, for a total of 48,485 MT of CH4 as CO2e. It is important to note that most, if not all of the digester gas at HWRP is burned at a cogeneration plant (as described below in Section VIII.I.a), which would greatly reduce these estimates. Emissions were also calculated using approximate TIWRP values for digester gas produced per day (ranging from approximately 200,000 ft^3/day to 250,000 ft^3/day) and the fraction of CH4 in biogas (ranging from approximately 50% to 65%) for comparison to the population-based values.[581]

Emissions were generally higher using digester gas data than population; using the lowest range of biogas produced (200,000 ft^3/day) and lowest percent CH4 of biogas (50%) yielded a calculated CH4 emissions of 1,436 MT of CO2e as compared to the population-based value of 1,348 MT of CO2e. The CH4 emissions for the other three combinations of the range of digester gas produced per day and fraction of CH4 in biogas were as follows: 1,868 MT of CH4 as CO2e (low, high), 1,796 MT of CH4 as CO2e (high, low), and 2,335 MT of CH4 as CO2e (high, high).

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[580] CARB LGOP 2010 p. 108, Box 10.2
[581] LASAN Personal Communication Sep 2016

This analysis could be expanded in the future for HWRP by using specific information on the volumes of biogas produced and fraction of methane. These results point to the importance of having a dataset that is as complete as possible, and of ensuring that monitoring programs are occurring to assess the results of tools such as the LGOP equations utilized here. This digester gas is also a renewable energy source, as described in Section VIII.H.

Nitrous Oxide Emissions

N2O emissions stemming from WRPs with and without NdN processes, as well as N2O emissions from effluent discharge, can be calculated using LGOP equations. NdN is the process of removing nitrogen (N), usually in the form of organic nitrogen, ammonia (NH3), or urea from wastewater using bacteria. Microorganisms convert NH3 to nitrate (NO3) through nitrification, then through denitrification convert NO3 to gaseous nitrogen (N2), an inert gas that is released into the atmosphere. N2O is produced during both of these processes as an intermediate form.[582] Currently the wastewater treatment systems at TIWRP, DCTWRP, and LAGWRP all use NdN processes to remove nitrogen. Although HWRP does not currently have NdN, we included a future scenario where all FY2013-2014 flows through HWRP would undergo NdN to provide insight into the impacts on N2O emissions that could result from increased implementation of NdN.

Based on the population served, TIWRP was estimated to produce 3,915 MT of N2O as CO2e, DCTWRP was estimated to produce 17,819 MT N2O as CO2e, and LAGWRP was estimated to produce 11,646 MT N2O as CO2e. The total N2O as CO2e currently produced by NdN processes at TIWRP, LAGWRP, and DCTWRP is 33,380 MT. If NdN processes were applied to the entire flow of the population served at HWRP, then 107,422 MT N2O as CO2e would be produced using LGOP equations. In this potential future scenario, the total N2O emissions from NdN at all four WRPs would be much larger, at approximately 140,802 MT N2O as CO2e (Table 8.9).

Total N2O Emissions from NdN		
WRP	Current Emissions (MT of CO2e)	Potential Future Emissions (MT of CO2e)
HWRP	0	107,422
TIWRP	3,915	3,915
DCTWRP	17,819	17,819
LAGWRP	11,646	11,646
Total	33,380	140,802

Table 8.9. Total N2O emissions from current flows treated with NdN and potential future emission if all HWRP flow is treated through NdN.

However, N2O is still emitted through the other wastewater treatment processes occurring at HWRP even though NdN is not currently in use at HWRP. Based on the LGOP methodologies available to assess emissions from non-NdN processes, HWRP is expected to emit 49,107 MT

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[582] Townsend et al. 2011 “Nitrous Oxide Emissions from Wastewater Treatment and Water Reclamation Plants in Southern California”

N2O as CO2e. Thus, total N2O emissions of all four WRPs with current treatment activities (NdN at TIWRP, LAGWRP, and DCTWRP) is estimated to be 82,487 MT of N2O as CO2e.

Finally, N2O is also emitted by effluent discharge through chemical reactions between N in the effluent and in the receiving aquatic environment. Two equations are provided in the LGOP to calculate N2O emissions from effluent discharge – one based on population and one on N concentrations in effluent. Both equations were utilized in this analysis to better understand the scale of the differences that might result depending on the type and quality of available data to conduct these analyses.

First, N2O emissions were calculated using Effluent N data from the SWRCB's Integrated Water Quality System Project electronic Self-Monitoring Reports (eSMR), which indicated that the total N loads of TIWRP, DCTWRP, and LAGWRP were 549 kg/day, 994 kg/day, and 305 kg/day, respectively. As only organic N data was available for HWRP, the total N number for HWRP was calculated using the ratio of total organic N and total N at the other WRPs. This provided an estimate for the total N load at HWRP of 18,287 kg N/day. The N2O emissions based on these total N loads are expected to be: 162,545 MT N2O as CO2e at HWRP; 4,879 MT N2O as CO2e at TIWRP; 8,834 MT N2O as CO2e at DCTWRP; and 2,709 MT N2O as CO2e at LAGWRP. Thus, based on N effluent concentrations, all four WWTPs together emit a total of 178,966 MT N2O as CO2e from effluent discharge (Table 8.10).

	N2O Emissions from Effluent Discharge (population) (MT of CO2e)	N2O Emissions from Effluent Discharge (TN data) (MT of CO2e)
HWRP	1,124,201	162,545
TIWRP	55,945	4,878
DCTWRP	30,767	8,834
LAGWRP	10,343	2,709
Total	1,221,256	178,966

Table 8.10. N2O emissions from effluent discharge based on population or TN data.

Next, N2O emissions were calculated using the population-served methodology, which led to much higher calculated emissions. Based on population served, N2O emissions are 1,124,201 MT N2O as CO2e for HWRP; 55,945 MT N2O as CO2e; 30,767 MT N2O as CO2e for TIWRP; 30,767 MT N2O as CO2e for DCTWRP; and 10,343 MT N2O as CO2e for LAGWRP, for a total of 1,221,256 MT N2O as CO2e. These values are generally an order of magnitude higher than those based on the actual effluent N data (Table 8.10). This scale of difference between results could lead to very different decisions being made based on the emissions of these treatment processes and again points to the critical need for monitoring data at these plants to obtain a more accurate picture of current and future emissions from these processes.

We also assessed the impacts on N2O emissions from effluent discharge of the future scenario in which the total flow at HWRP were treated through NdN as N levels would be lower in the effluent after NdN. For this scenario, we assumed that total N levels in the effluent after NdN would be 5 mg / L (the effluent limit in inland plants). Using this concentration, N2O emissions from effluent discharge at HWRP were 40,005 MT of CO2e, which is much lower than the current emissions of 162,545 MT of CO2e. Therefore, using LGOP equations, the implementation of

NdN at HWRP would actually reduce overall emissions at HWRP by 64,224 MT of CO2e to 194,564 MT of CO2e at HWRP (Table 8.11, Table 8.12).

	CH4 Emissions from Digesters (pop.) (MT of CO2e)	N2O Emissions no NdN (MT of CO2e)	N2O Emissions from NdN (pop.) (MT of CO2e)	N2O Emissions from Effluent Discharge (TN data) (MT of CO2e)	Total Emissions (MT of CO2e)
HWRP	47,137	49,107	--	162,545	258,789
TIWRP	1,348	--	3,915	4,878	10,141
DCTWRP	--	--	17,819	8,834	26,653
LAGWRP	--	--	11,646	2,709	14,355
Total	48,485	49,107	33,380	178,966	309,938

Table 8.11. Emissions summary of current treatment processes at City of LA WRPs

Future Scenario	CH4 Emissions from Digesters (pop.) (MT of CO2e)	N2O Emissions from NdN (pop_future) (MT of CO2e)	N2O Emissions from Effluent Discharge (TN data) (MT of CO2e)	Total Emissions (MT of CO2e)
Hyperion	47,137	107,422	40,006	194,564
Terminal Island	1,348	3,915	4,878	10,141
Tillman	--	17,819	8,834	26,653
LAG	--	11,646	2,709	14,355
Total	48,485	140,801	56,427	245,713

Table 8.12. Emissions summary of 'future' treatment processes at City of LA WRPs

Total Direct Emissions

These analyses demonstrate that it is not only the energy requirements to treat wastewater but also the direct emission of GHGs from the treatment processes themselves that can contribute to the footprint of increasing the reuse of recycled water. The resulting total emissions for each of the four WRPs under current treatment processes (no NdN at HWRP) from highest to lowest is: HWRP with 258,788 MT of CO2e, DCTWRP with 26,653 MT of CO2e, LAGWRP with 14,355 MT of CO2e, and TIWRP with 10,141 MT of CO2e.

The introduction of NdN at HWRP would substantially improve water quality by reducing the levels of ammonia and nitrogen in the effluent. This is not only beneficial for the aquatic environment into which the effluent is discharged, but also for the additional treatment and reuse of HWRP effluent. According to LGOP calculations, applying NdN to HWRP wastewater flows would reduce GHG emissions at HWRP and, thus, the total emissions from all WRPs (Table 8.11, Table 8.12). Based on LGOP equations, total emissions under current treatment processes are 309,938 MT of CO2e; with NdN at HWRP, total emissions drop to 245,713 MT of CO2e. It is important to note again here that LGOP equations include highly generalized assumptions and additional monitoring data is required to verify the actual emissions based on these processes at each WRP.

This reduction in emissions at HWRP stems mainly from the reduction in N2O emissions coming from the effluent discharge at HWRP using the LGOP equations. The mechanisms or chemistry that are responsible for the very large emissions that stem from effluent discharge in the LGOP are not immediately apparent. This represents an area that needs additional study to determine the accuracy of this broadly applicable methodology to reflect site-specific conditions. If the GHG footprint from effluent discharge is indeed this significant, and/or discharges are exacerbating localized ocean acidification and/or hypoxia impacts, then the reduction of GHG emissions that would result from NdN at HWRP is another important driver that would be a step towards the goal of increasing the reuse of recycled water from HWRP. In a current modeling study led by UCLA with the University of Washington, the National Oceanic and Atmospheric Administration, and SCCWRP, researchers will determine the potential impacts of coastal sewage treatment plant nitrogen species discharges on localized ocean acidification and hypoxia.

It is important to emphasize that the LGOP equations are based on broadly applicable, generalizable values such as population, and that there is an urgent need for additional monitoring of actual emissions coming from WRPs to appropriately characterize both the direct emissions from the treatment processes and the potential GHG contributions of fugitive emissions from, for example, leaking digesters. The lack of measured WRP-specific data to assess these emissions is a critical gap that must be filled to accurately assess and identify the best pathways forward to moving the region to full reuse of its wastewater.

The need for additional data can also be seen in the different results for N2O emissions at the same plant for the same process, effluent discharge, that are obtained using the two equations provided in the LGOP (Table 8.10). The concentration-based approach is the more rigorous approach of the two equations as it is based on effluent-specific data, and also offered a capacity to assess changes caused by implementing NdN at HWRP that the population-based process did not. The discrepancy, however, between results using these two LGOP equations for effluent discharge emissions points to a critical need for monitoring to assess actual emission rates and better understand the chemistry that occurs when effluent meets the receiving aquatic environment. Data must be collected to assess the impacts on emissions of changing the treatment trains to increase water reclamation as we move towards a more locally-sourced water future.