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# Water Partnerships between Cities and Farms in Southern California and the San Joaquin Valley

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## SUMMARY

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Technical appendices to this report are available on the PPIC website.


The San Joaquin Valley and urban Southern California are worlds apart in many ways. Yet each face growing water challenges and a shared interest in ensuring reliable, affordable water supplies to safeguard their people and economies. Both regions' water futures could be more secure if they take advantage of shared water infrastructure to jointly develop and manage some water supplies.

Increasing climate volatility is heightening concerns about droughts of the future. And two major shifts in California's water landscape have generated new opportunities for collaboration between urban and agricultural interests. For urban areas, significant declines in water demand have reduced pressure on supplies during normal and wet years for many agencies, making reliability for future droughts the primary concern. For the overdrafted San Joaquin Valley, the requirement to manage groundwater sustainably has heightened interest in expanding water supplies and underground storage.

Partnerships between Southern California cities and San Joaquin Valley farms could help alleviate groundwater overdraft in the valley while building drought resilience in Southern California. More flexible supplies can help agencies adapt to changing conditions. By coordinating the location of infrastructure investments, agencies can use partnerships to bring the water where and when it is most needed, at least cost.

This report explores a variety of solutions that could benefit both regions. For the San Joaquin Valley, we look for ways to augment water supplies to ease the transition to groundwater sustainability, while for Southern California we explore options that would increase cities' ability to deal effectively with extended droughts. By diversifying water supplies, building connections to share water more flexibly, and preparing for the extreme events to come, such partnerships would support Governor Newsom's Water Resilience Portfolio, and pave the way for a shared effort to make the state's water system more resilient to a changing climate.

# Introduction

Although the San Joaquin Valley and urban Southern California are neighbors, their economies are quite distinct. The valley is California's largest agricultural region, accounting for more than half of its farm output, while Southern California is the state's largest urbanized region, home to more than half of all residents. Yet these regions have a common interest in ensuring the reliability and affordability of water supplies to safeguard their people and economies. Their water futures could be more secure if they take advantage of shared water infrastructure to jointly develop and manage some water supplies.

The San Joaquin Valley's diverse crop and animal products are an important part of the nation's food supply. But its water system is under stress. Groundwater overdraft—pumping groundwater in excess of the rate at which it is replenished—has been a problem for decades (Faunt et al. 2009). During the 2012–16 drought, farmers pumped groundwater at an unprecedented rate (Xiao et al. 2017; Escriva-Bou 2019). This caused thousands of domestic wells to run dry, reduced water infrastructure capacity from sinking lands, increased energy requirements for pumping, and reduced flows in some rivers (Hanak et al. 2017; 2019a).

To avoid such undesirable effects in the future, the 2014 Sustainable Groundwater Management Act (SGMA) requires local water users to manage groundwater sustainably by the early 2040s. This law will have little effect on most coastal urban areas, where groundwater has generally been managed for decades by water masters or special management districts. But in the San Joaquin Valley, SGMA will result in major changes. Solutions will likely require a combination of two approaches: reducing pumping and increasing other water supplies. The likely socio-economic consequences of these adaptations are significant. More than half a million acres of farmland may need to go out of production, reducing farm-related income and jobs across the region (Hanak et al. 2019a). To limit land fallowing, water users are exploring options to increase water availability.

For the past few years, the PPIC Water Policy Center has been examining potential solutions to the San Joaquin Valley's water problems.[1] We found that increasing groundwater recharge from high-flow storms is the most promising option for expanding supplies at a cost farmers can afford, followed by more flexible operation of surface and underground storage within the Central Valley.[2] However, there is another supply option that could help bring water to the valley.

Interregional partnerships between coastal urban communities and farmers in the San Joaquin Valley could ease the transition to groundwater sustainability for farms, while boosting urban drought resilience. In particular, investments in urban conservation and alternative water supplies could allow cities in Southern California, the Central Coast, and the Bay Area to reduce the water they now import from Northern California through the Sacramento–San Joaquin Delta. Because this water passes through the San Joaquin Valley before reaching these regions, this shift would allow more of it to remain in the San Joaquin Valley in some years. Infrastructure and operational improvements could also facilitate more underground storage and trading, enabling urban areas to receive increased supplies in dry years.

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[1] *Water Stress and a Changing San Joaquin Valley* (Hanak et al. 2017) highlights the importance of water in the valley's economy and describes a range of water-related challenges and potential solutions. *Replenishing Groundwater in the San Joaquin Valley* (Hanak et al. 2018a) analyzes the potential for expanding groundwater recharge to help reduce the valley's overdraft. *Water and the Future of the San Joaquin Valley* (Hanak et al. 2019a) explores three key challenges facing the San Joaquin Valley—balancing water supplies and demands, addressing groundwater quality challenges, and fostering beneficial water and land use transitions—and reviews the most promising approaches to address them. Hanak et al. (2020) reviews groundwater sustainability plans in 11 overdrafted basins in the region.

[2] We use the term "underground storage" to refer to what is also commonly called "groundwater storage." Underground storage is a more general concept, which recognizes the potential for storing native groundwater that naturally replenishes the aquifer as well as surface water from local and imported sources that is actively recharged into the aquifer by spreading water on the land and other methods (Hanak et al. 2018). There are legal distinctions among these sources from a water rights perspective (Littleworth and Garner 2019).

Such partnerships could be of interest in all urban regions that use water exported from the Delta as part of their water supply portfolio. Here we focus on Southern California, which is the largest urban user of Delta exports.[3]

The idea of transferring some water supplies from Southern California to the San Joaquin Valley might seem counterintuitive, as recent history shows the opposite trend. Since the early 2000s, a rising share of water exported from the Delta has gone to cities in Southern California, while the San Joaquin Valley's share has declined—primarily the result of Southern California's investments in water storage, which allowed the region to take and store more of the water it had rights to under its longstanding State Water Project contracts. But significant drops in urban water demand, investments in alternative water supplies within Southern California, and a growing need to bolster urban resilience to droughts as the climate changes might open up new opportunities for partnerships.

This report provides an exploratory analysis of solutions that could benefit both regions. For the San Joaquin Valley, we look for ways to augment water supplies to ease the transition to groundwater sustainability, while for Southern California we explore options that would increase flexibility to deal effectively with extended droughts. Given the high energy requirements to pump water from the Delta to Southern California, we also examine whether approaches that leave a greater share of Delta exports in the San Joaquin Valley would reduce greenhouse gas (GHG) emissions or be eligible for financial incentives through California's GHG cap and trade program.

To ground-truth the analysis, we workshopped these ideas with more than a dozen water agencies in Southern California and a similar number of farmers and other stakeholders in the San Joaquin Valley, and found that there is interest in exploring mutually beneficial partnership opportunities.

We begin with some background on the opportunities for interregional partnerships, and review existing partnerships. Then we explore Southern California's evolving water demand and supply context, including future plans. Next we develop the concept behind these new partnerships. We present some promising partnership options, while also noting their limited potential for GHG emissions benefits. Finally, we highlight challenges that must be overcome to build new partnerships.

Several technical appendices provide more details on our analysis of Southern California water planning (Technical Appendix A), the costs of new water supplies (Technical Appendix B), and the potential for GHG emission benefits through water partnerships (Technical Appendix C).

## A New Window of Opportunity for Partnerships

In recent years, two major shifts occurred in California's water landscape, generating new opportunities for collaboration between urban and agricultural interests. For agriculture—particularly in the overdrafted San Joaquin Valley—the enactment of SGMA has heightened interest in expanding water supplies and underground storage to help attain groundwater sustainability. For coastal urban areas, significant declines in water demand have reduced pressure on supplies during normal and wet years for many agencies, making reliability for future droughts the primary concern. Together, these two shifts could break the long-term pattern of Delta water moving out of the San Joaquin Valley and toward coastal cities.

[3] We use the term "Delta exports" to refer to the total amount of water exported from the pumps at the south of the Sacramento–San Joaquin Delta to the Bay Area, the San Joaquin Valley, the Central Coast, and Southern California. We generally use "Delta imports" when referring to the contribution of these exports to water supply portfolios in each of the receiving regions.

From 1988–2017, agricultural water use in the San Joaquin Valley exceeded sustainable supplies by nearly 2 million acre-feet (maf) per year, and Southern California received an average of 1.3 maf of Delta exports through the State Water Project (SWP) (Figure 1). During this time, the San Joaquin Valley—which received Delta exports through both the SWP and the federal Central Valley Project (CVP)—saw its share of exports fall, while Southern California's share rose.[4] The primary reason for this shift is Southern California's increased ability to take and store water it had rights to under long-standing SWP contracts, thanks to investments in surface storage (e.g., construction of Diamond Valley Lake) and underground storage. SWP supplies also became more important for Southern California's urban areas starting in the early 2000s, as the region was required to reduce its reliance on Colorado River flows. In earlier decades, water users in the San Joaquin Valley were able to access Southern California's unused SWP supplies at low cost when those supplies exceeded urban demands and could not otherwise be stored. Another factor in this shift is water trading. In a pattern that has become increasingly common globally as growing cities seek to meet their freshwater needs, some San Joaquin Valley irrigation districts sold water to urban agencies in Southern California that were bolstering their supplies to accommodate population growth.[5]

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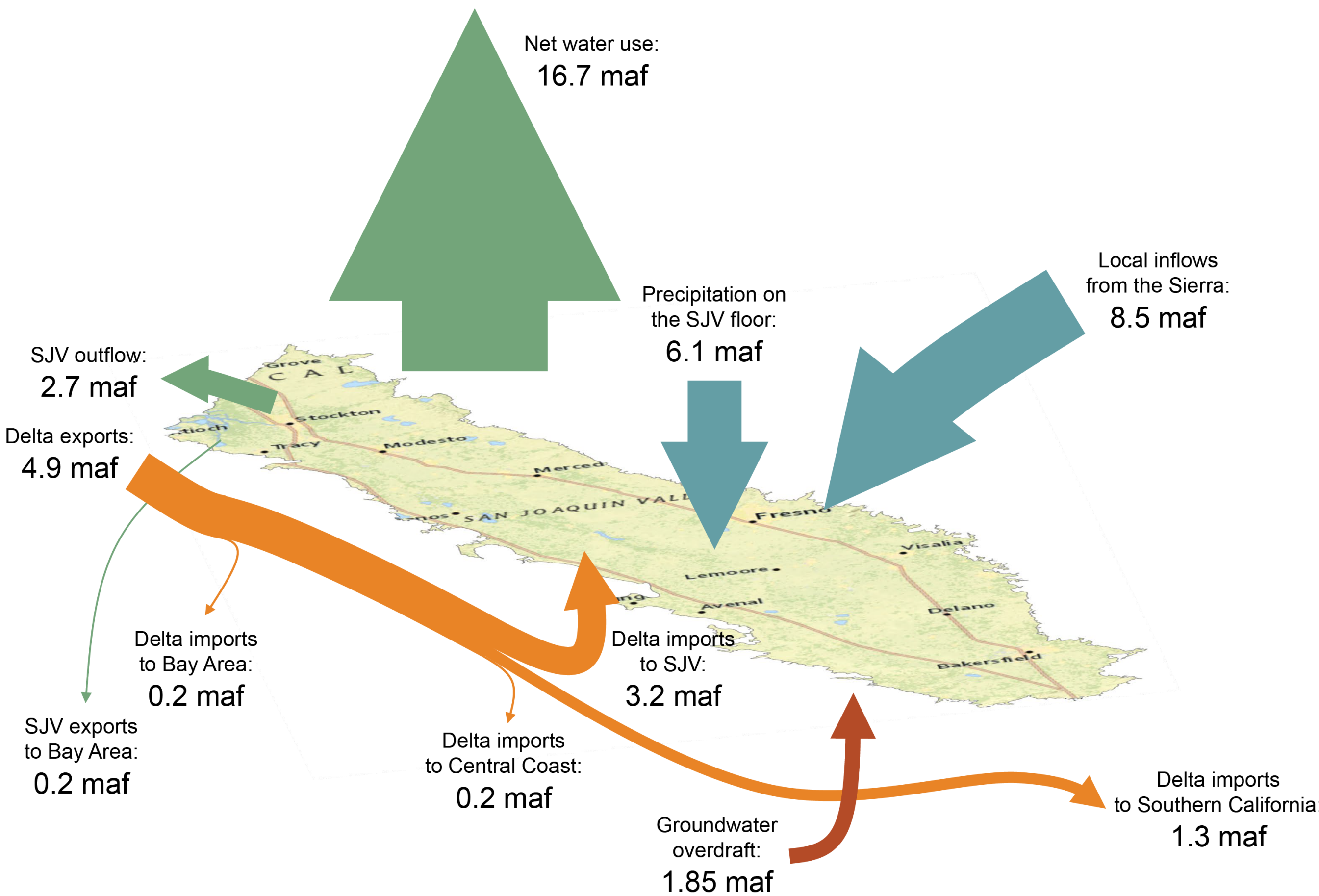
[4] From 1988–2002, the San Joaquin Valley received an average of 69 percent of all Delta exports; that share fell to an average of 60 percent in 2003–17. Meanwhile, Southern California's share rose from 21 percent to 30 percent. On average, this shift represents an increase of roughly 400,000 acre-feet per year going to Southern California. Deliveries to the San Francisco Bay Area and Central Coast remained fairly stable, with each receiving just under 5 percent (Escriva-Bou 2019).

[5] From 1998–2009, San Joaquin Valley irrigation districts sold SWP contracts with a face value of 110,000 acre-feet to Southern California agencies and negotiated long-term lease agreements for more than 12,000 acre-feet. The average annual volume of water transferred through these agreements totaled 83,000 acre-feet from 2003 to 2011. San Joaquin Valley irrigation districts also permanently transferred 50,000 acre-feet of contracts to San Francisco Bay Area agencies, and agreed to long-term transfers of more than 13,000 acre-feet. Transfer data are from Hanak and Stryjewski (2012), Technical Appendix Tables B6c and B8. For a discussion of global rural-urban trading patterns, see Garrick et al. (2019).

**FIGURE 1**
Transferring some Delta water from Southern California to the San Joaquin Valley could help the valley reduce groundwater overdraft




SOURCE: Escriva-Bou (2019).

NOTES: SJV is San Joaquin Valley. Maf is million acre-feet. The figure shows the average water balance in the San Joaquin Valley for the 1988–2017 period. This assessment focuses on the valley floor. This mostly flat landscape—limited by the foothills of the Sierra Nevada to the east, the Tehachapi Mountains to the south, the coastal range to the west, and the Delta to the north—is where most water is used. Irrigated agriculture accounts for 87 percent of net water use, cities 3 percent, and native and riparian landscapes 10 percent. The width of the arrows is proportional to the flow represented. Delta exports include both the State Water Project and the Central Valley Project, although only the SWP reaches Southern California.

Although coastal urban areas significantly reduced water use per capita in recent decades, the 2012–16 drought spurred another major drop, especially after the state imposed a conservation mandate in April 2015.[6] Despite some post-drought rebound, per capita water demands are not expected to rise again to 2013 levels. This will reduce the need for water supply development to accommodate continued growth.

The water supply mix of urban areas has also evolved, especially following the 1987–92 drought (Mitchell et al. 2017). In addition to expanding their surface and underground storage and conveyance systems, urban agencies

[6] See Mitchell et al. (2017) for a more detailed analysis of policies related to urban water use, which have generally become more stringent during and after major droughts. Beginning in the late 1970s, efficiency standards and utility-sponsored retrofit programs have resulted in new and remodeled homes having a much smaller "water footprint" than older homes. The Water Conservation Act of 2009 (SB X7-7) required urban water suppliers to reduce per capita water use by 20 percent by 2020 relative to a 10-year historical baseline. The 2012–16 drought brought the first-ever mandated curtailment of urban water use in April 2015, with various individual restrictions targeting a statewide goal of 25 percent average savings compared to 2013. In 2018 AB 1668 and SB 606 were enacted; they set new drought planning and reporting requirements for utilities and require the state to establish new indoor and outdoor water use efficiency standards for urban areas.

have invested in recycled water, stormwater capture, and desalinated seawater and brackish groundwater.[7] Over the past two decades, these alternative sources have provided roughly 20 percent of Southern California's water supply, and they have been growing rapidly.[8] Large-scale agricultural-to-urban transfers with agricultural districts in Imperial County have also diversified the water supply mix.

A variety of considerations—including concerns over potential reductions in reliability of imported water during droughts and recognition of the potential for continued expansion of alternative water supplies—have prompted some urban agencies to rethink their future water portfolios. In 2019, Los Angeles Mayor Eric Garcetti presented a plan to locally source 70 percent of the city's water by 2035.[9] Other communities are enacting similar policies.[10]

Meanwhile, increasing climate volatility is heightening concerns about droughts of the future, which are expected to be both hotter and more intense (Box 1).

### Box 1. Climate change will affect water demands and supplies

California's climate is changing. Hotter temperatures, a shrinking snowpack, shorter but more intense wet seasons, rising sea level, and more volatile year-to-year precipitation—with wetter wet years and drier, more intense droughts—are stressing the state's water management system. Recent climate projections indicate that the pace of change will increase (Swain et al. 2018; Mount et al. 2018).

Higher temperatures in both Southern California and the San Joaquin Valley are likely to increase crop water demands—studies for the Central Valley estimate a 4–9 percent increase by 2100—and water required to maintain urban landscapes could also rise (Purkey et al. 2007; Joyce et al. 2011). The combination of a shrinking snowpack, shorter and more intense wet seasons, and more volatile precipitation will challenge the current operation of reservoirs, which will need more space for managing larger floods, resulting in less water available for cities and farms in both regions.

These climate pressures, along with increased salinity in the Sacramento–San Joaquin Delta from sea level rise, will also affect Delta imports to the San Joaquin Valley and Southern California, which are expected to shrink by 10 percent by mid-century (Wang et al. 2018). Similarly, runoff in the Colorado River Basin might decline between 10–30 percent by 2050, affecting Colorado River imports to Southern California (Barnett and Pierce 2009). And although anticipated changes in average precipitation are small, storms of greater intensity will make local stormwater capture more difficult, requiring larger surface storage and groundwater recharge areas in Southern California (Hall et al. 2018). In the San Joaquin Valley these larger storms will also complicate efforts to capture flood flows for recharge.

Although these pressures will increase water planning and management challenges for agencies in both regions, they could also increase the benefits of partnerships. More flexible supplies can help agencies adapt to changing conditions. By coordinating the location of infrastructure investments, agencies can use partnerships to bring the water to where and when it is most needed, at least cost.

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[7] By recycled water we mean highly treated wastewater that can be used for other purposes, such as irrigation and groundwater replenishment.

[8] This share is based on average water use of 4.9 million acre-feet for the South Coast hydrologic region (1998–2015), and approximately 660 thousand acre-feet (13%) of recycling, reuse, and ocean desalination in recent years. Stormwater capture adds 325 thousand acre-feet per year (7%); this water is principally stored underground, and shows up in the data as groundwater withdrawals. McCann et al. (2018) provide statewide estimates, and find that roughly 2.5 percent of annual urban and farm water use comes from recycled water and desalination. There are no statewide estimates of stormwater capture.

[9] See LA's Green New Deal, Sustainable City Plan (Garcetti 2019). Local sources include groundwater production, historical and future conservation savings, centralized and distributed stormwater capture and recharge, and all recycled water produced in the city.

[10] For instance, the City of Santa Monica is planning to stop using imported water by 2023.

With all these changes, the bigger challenge for urban water planning is not to ensure that water supplies meet demands during normal years, but to have enough supply and demand flexibility to deal effectively with extended droughts.

This changing urban water landscape creates an opportunity to find complementary solutions for the agricultural sector in the San Joaquin Valley and cities in coastal regions. The valley's long-term overdraft problem could be eased by increasing average annual water availability. If San Joaquin Valley water agencies manage aquifers well, groundwater can replace some surface water during droughts. Meanwhile, coastal cities might be willing to exchange some of their average long-term supplies if they can access increased supplies during droughts. If these parties act separately, there's a risk that cities will over-invest in supplies that they might only need on a few occasions. Partnerships that encourage flexibility, where cities and farms share water, can benefit both parties.

In fact, there is already a history of partnerships between agricultural and urban agencies in California (Box 2). This includes substantial co-investments by Southern California urban communities in underground storage in the San Joaquin Valley since the 1990s. These agreements increase water availability in the valley and help urban communities weather droughts. Some of the partnerships we propose in this report are based on these experiences, but we also explore options involving co-investments in local supplies and demand management in Southern California, as well as long-term water trading arrangements.

Interregional partnerships that ease the transition to sustainability in agricultural regions while boosting urban drought resilience are the kind of solution envisaged in Governor Newsom's Water Resilience Portfolio (CNRA, CalEPA, and CDFA 2020). Such partnerships would diversify water supplies, build connections to share water more flexibly, and prepare for the extreme events to come—three of the four main pillars of increased water resilience.[11]

[11] The fourth pillar is to protect and enhance natural ecosystems. These partnerships could indirectly alleviate some pressures on natural ecosystems, and potentially also be a model for water sharing partnerships between environmental, urban, and farm interests.

## Box 2. Examples of Water Supply Partnerships

Water supply partnerships already help California's urban and agricultural communities manage droughts, growing water scarcity, and the high costs of water infrastructure. These partnerships often take advantage of the state's water grid—a network of surface and underground storage and conveyance facilities.

- **Underground storage**. Underground storage projects (also called groundwater banks) store water in aquifers during relatively wet years for use in dry years. The state's largest banks are located in Kern County; others exist elsewhere in the southern San Joaquin Valley and in Southern California (Hanak and Stryjewski 2012; Jezdimirovic et al. 2019). The Metropolitan Water District of Southern California (MWD) partners with several banks in Kern County and in Southern California. San Diego County Water Authority, an MWD member, also has a partnership with Semitropic Water Storage District in Kern County. Irvine Ranch Water District, a retail agency within the MWD system, also stores water in Kern (Irvine Ranch Water District 2020). Some Bay Area agencies also store water underground in San Joaquin Valley banks.
- **Water exchanges between SWP and Colorado River users**. The Coachella Valley Water District and Desert Water Agency are SWP contractors in inland Southern California. They are not connected to SWP infrastructure, but they are connected to Colorado River infrastructure. They get their SWP allocation by exchanging water with MWD, which lets them use MWD's Colorado River water in exchange for their SWP water. Water quality can be a consideration in such exchanges: water from the lower Colorado River has a much higher concentration of salts (~200 mg/l) than SWP water (~75 mg/l).
- **Long-term transfers of Colorado River water.** In the early 2000s, California had to end a decades-long practice of using more than its share of the Colorado River. A program known as the Quantification Settlement Agreement (QSA) made water available for transfer from farms to cities by lining earthen canals, improving irrigation efficiency, and fallowing farmland. Although the QSA helped cities avoid even deeper cutbacks, there were some trade-offs. Funds were established to mitigate local economic impacts from land fallowing. Canal lining saved water for California, but reduced groundwater supplies for Mexican farmers. And irrigation efficiency in the Imperial Valley reduced runoff into the Salton Sea, accelerating environmental problems there (Hanak et al. 2018b).
- **Long-term transfers of dry-year water from the Yuba River.** The 2008 Yuba Accord created an integrated system of surface and groundwater management within the Yuba Water Agency's service area that provides an array of benefits. During dry years, local farmers switch from surface water to groundwater, enabling higher river flows on the Lower Yuba River to support salmon. These flows are subsequently sold to water users downstream of the Yuba, generating local revenues for water infrastructure and mitigating water shortages south of the Delta (Mount et al. 2017).
- **Interstate and bi-national partnerships to increase flexibility on the Colorado River.** MWD has stored water in Arizona aquifers (AWBA 2014). It has also partnered with the Southern Nevada Water Authority to find solutions to water quality challenges and to study alternative supply investments (The Nevada Independent 2019; MWD 2019b). Most recently, cities across the Colorado basin have partnered with farmers to pilot water trades to alleviate system-wide shortages by increasing the amount of water stored in reservoirs. Mexico is also able to participate in water exchanges tied to investments in water efficiency.

# Southern California's Water Supply Outlook

Southern California is home to more than half of California's population and some important agricultural areas. It includes three distinct hydrologic regions, which vary considerably in water availability and use (Figure 2a). The highly urbanized South Coast hydrologic region has a diverse water supply portfolio and uses almost 5 maf of water annually.[12] The South Lahontan hydrologic region—a vast inland desert with less than a million inhabitants—relies heavily on groundwater to supply 700 thousand acre-feet (taf) for agricultural and urban uses. The Colorado River hydrologic region—the state's most arid—relies principally on senior Colorado River water rights to supply 4.6 maf of water to more than half a million acres of irrigated cropland and 800,000 residents.

In this report we focus primarily on the South Coast hydrologic region, where most people live and most urban water demands are concentrated (Figure 2b).[13] Most of this region is served by the Metropolitan Water District of Southern California (MWD), a vast wholesale water network that supplies water to about 19 million people—about 8 of 10 Southern California residents (Figure 2c). MWD is a cooperative of 26 members—14 cities and 12 special districts—supplying roughly half of the water used in its service area. Below we draw on detailed data for MWD's service area, in addition to information about the broader Southern California region, to provide regional insights.

Southern California also has 24 other water wholesalers (some within and some outside of MWD's service area) and 207 urban water retailers.[14] Urban utilities manage a diverse portfolio of local and imported water supplies, making use of an extensive water storage and conveyance system (Figure 2c).

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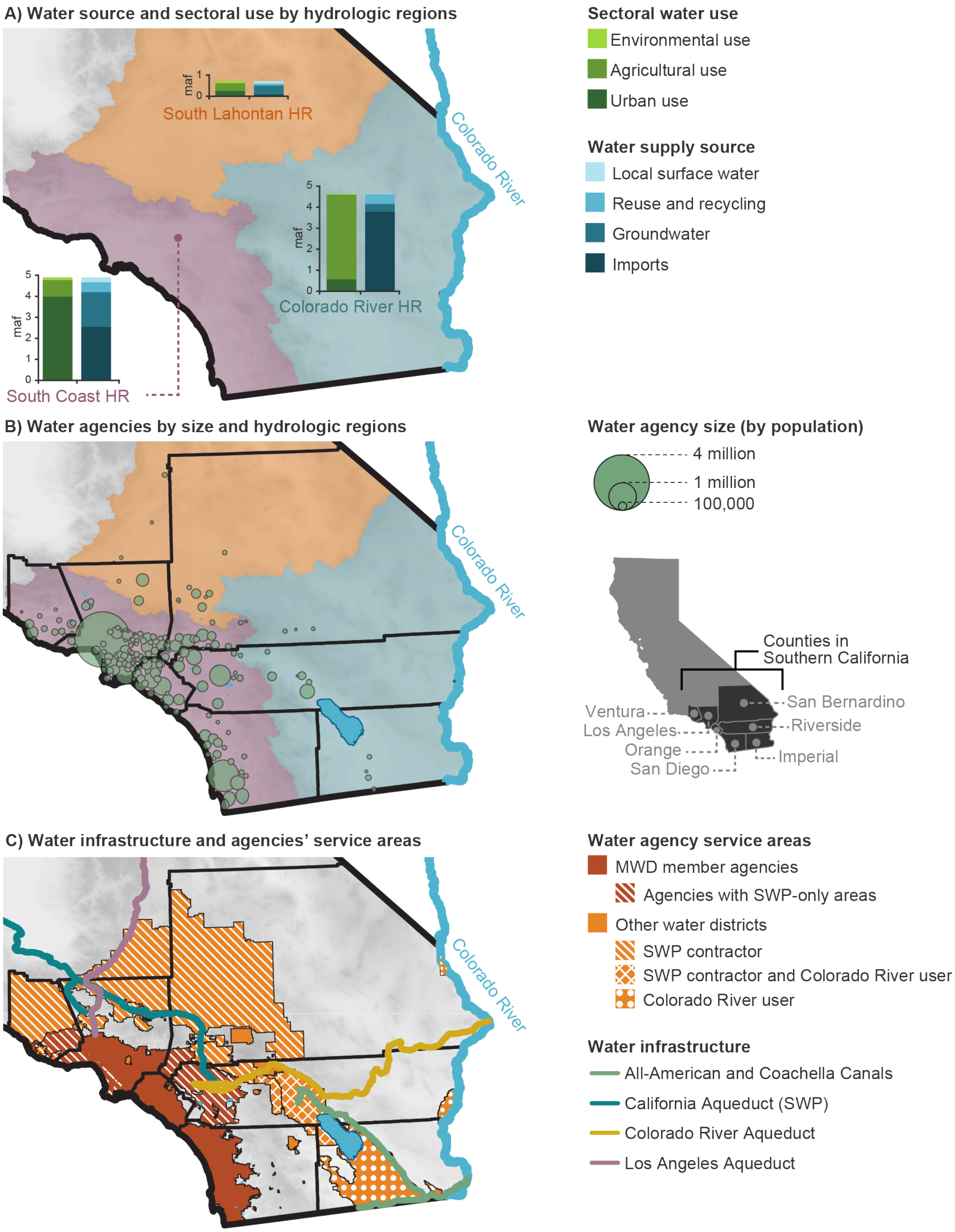
[12] Most of this information comes from the Water Resilience Portfolio (CNRA, CalEPA, and CDFA 2020). Population is for 2017, and water use is average for 1998–2015. Acreage for the Colorado River hydrologic region comes from the Imperial County Agricultural Commissioner's Report (Imperial County 2018).

[13] Most of the remaining water goes to a small and shrinking agricultural sector; water dedicated for environmental purposes is almost negligible

[14] Utilities classified as urban retailers serve at least 3,000 homes and businesses or deliver at least 3,000 acre-feet of water annually. Statewide, they supply water to about 93 percent of the state's population (Mitchell et al. 2017). In Southern California, which has fewer small rural communities, this percentage is likely greater.

**FIGURE 2**
Southern California's water landscape




SOURCES: Developed by the authors from various sources. Water supplies and demands in Figure 2a are from California Department of Water Resources (2018).

NOTES: Maf is million acre-feet. HR is hydrologic region.

# A Diverse and Evolving Water Portfolio

Both supplies and demands have been evolving in urban Southern California, reflecting efforts to diversify the supply portfolio and encourage long-term reductions in per capita demand.

## South Coast Hydrologic Region

Over the 1998–2015 period, imports made up 52 percent of the 4.9 maf of this region's water supplies. Groundwater accounted for 34 percent, 10 percent came from water reuse and recycling, and the remaining 5 percent from local surface sources (Figure 2a).

Imports come from several sources (Figure 2c). The SWP's California Aqueduct brings in water exported from Northern California through the Delta, and the Colorado River Aqueduct brings in supplies from the Colorado River. Some parts of the service area only have access to SWP water, making them more vulnerable to reductions in these supplies. The City of Los Angeles—an MWD member—owns the Los Angeles Aqueduct that brings in water from the Mono Lake watershed and the Owens Valley in the southern Sierra.[15]

Despite a steady increase in population, total water use within MWD's service area peaked in the early 2000s and has been declining since, reflecting significant reductions in water use per capita (Figure 3).

The regional supply mix in MWD's service area has also been evolving (Figure 3). Local supplies have grown slightly, largely from the expanded use of recycled water. In 2015, this source—including non-potable irrigation and industrial water, and water to replenish aquifers ("indirect potable reuse")—provided about 11 percent of total regional supplies, up from 5 percent in 2000.[16] Desalination of brackish groundwater and seawater, while important for several local agencies, represents a small share of the regional supply mix. And as described below, capture of urban stormwater—which is generally stored underground—has also been on the rise.

Meanwhile, imported water supplies have been falling. Water conveyed through the Los Angeles Aqueduct has declined significantly to address environmental problems in the source region. In the early 2000s, Colorado River imports declined significantly as part of California's obligations to other states and Mexico; long-term transfers from agricultural districts in Imperial County have helped urban agencies restore some of these supplies. As noted earlier, SWP supplies increased significantly in the early 2000s, thanks to storage investments and water trading agreements. But SWP water is much less reliable during droughts, and more restrictive environmental regulations introduced in the late 2000s have also reduced its yield. The combined effect of these changes is a decrease in the share of imports in the regional portfolio. From 2006–15, imports made up 54 percent of supplies in MWD's service area, down from roughly 60 percent in the two preceding decades (Figure 3).

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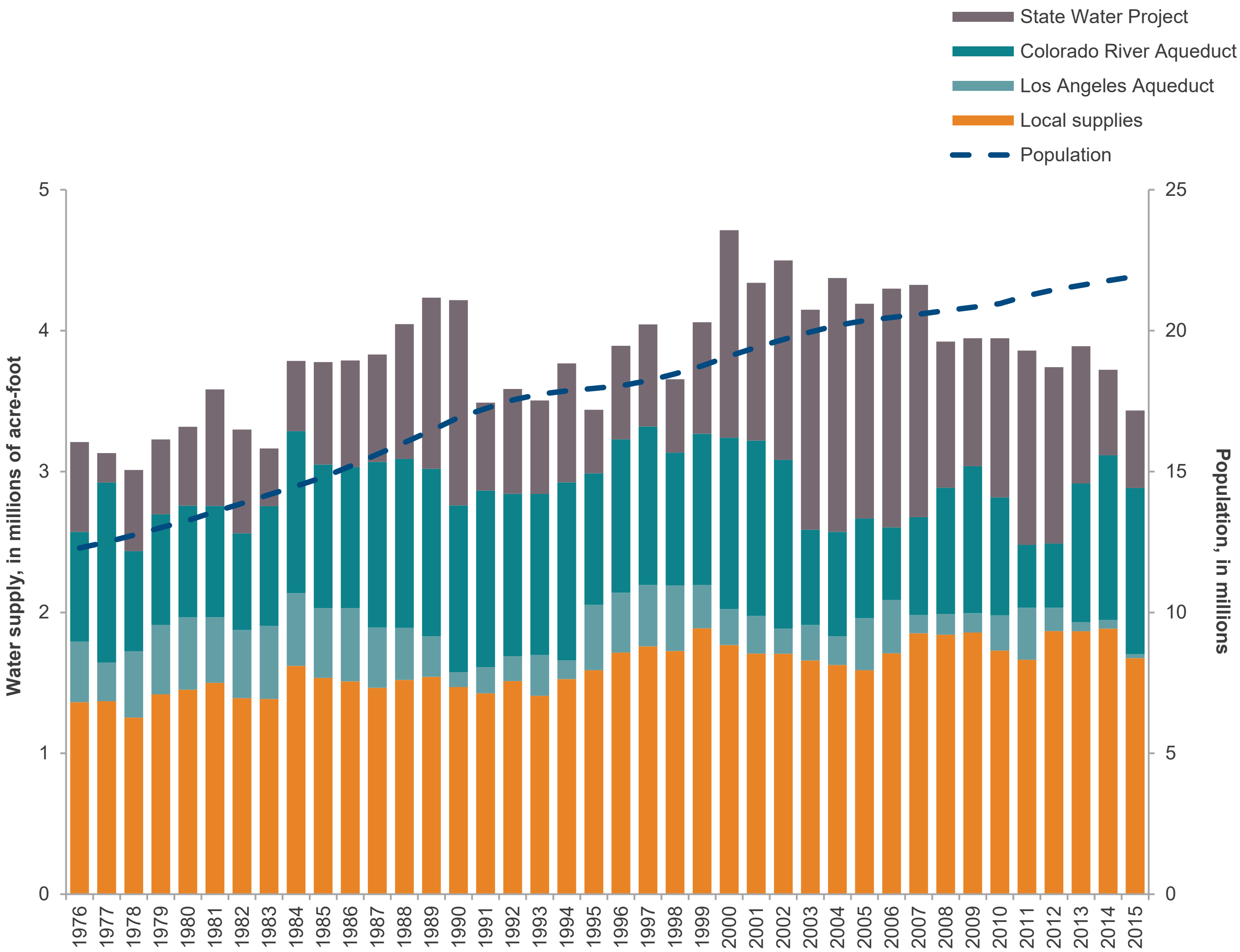
[15] In regional water planning documents, these supplies are sometimes considered "local" because they are managed directly by Los Angeles rather than by MWD, which delivers SWP and Colorado River supplies within the service area.

[16] Recycled water provided more than 450,000 af of water in Southern California in 2015, more than all other regions in the state combined (McCann et al. 2018). This represents a growth of 184,000 af since 2001, and 75,000 af since 2010 (SWRCB 2020a).

**FIGURE 3**
Supply sources have evolved, and total supplies peaked in the early 2000s, despite population growth




SOURCES: Water supplies: 2015 Urban Water Management Plan (MWD 2016a); population: Department of Finance.

NOTES: The figure shows water supplies for MWD's service area and population for the six counties served by MWD. Local sources of water include groundwater, surface water, recycled water, and desalination. Most stormwater capture is available as groundwater. Maf is million acre-feet.

## Other Hydrologic Regions

Most urban agencies in the South Lahontan hydrologic region also supplement their local supplies with SWP water, while large agencies in the Colorado River hydrologic region get water from that river (Figure 2). Like other inland areas of the state, these hydrologic regions have seen more rapid population growth than along the more developed coast, prompting several agencies to purchase additional SWP water from irrigation districts in the San Joaquin Valley (Hanak and Stryjewski 2012). Demand management has also been an important element in the portfolios of agencies in these regions—in some cases reducing total water use despite population growth.[17]

[17] The Coachella Valley Water District (CVWD) in the Colorado River hydrologic region and the Mojave Water Agency (MWA) in the South Lahontan region are two of the largest water suppliers in Southern California outside of MWD's service area. From 2000 to 2010, CVWD reduced per capita water use from 673 to 482 gallons

## Water Use Projections Are Being Revised Downward

Since the mid-1980s, urban water agencies have been required to prepare Urban Water Management Plans (UWMPs) every five years, most recently in 2015. For the MWD service area, a regional Integrated Water Resources Plan (IRP) has also been prepared several times since 1996, most recently in 2016. Work is now underway to update these plans.

To understand the changing landscape in urban water demand planning, we reviewed the latest plans for the South Coast and compared their demand projections with more recent data on water use reported to the State Water Board.[18] To ground-truth our findings, we also held workshop discussions with more than a dozen large Southern California urban agencies, including agencies within and outside of MWD's service area. The consensus is that the 2015–16 demand projections are too high, and will be revised downward.

The 2015–16 plans were prepared during the 2012–16 drought, and they did not anticipate the major structural changes in demand that the drought would bring. Although there has been some post-drought rebound, per capita water use has remained much lower than pre-drought levels. Indeed, total water use has remained below pre-drought levels in many agencies, despite population growth.[19] Workshop participants suggested that while some additional rebound is possible, per capita water use is not likely to return to pre-drought levels.

Indeed, other factors could help reduce pressure on future demands. Population growth is slowing.[20] In addition, because new houses have more efficient appliances, their water needs are usually lower than for existing homes. Finally, many urban utilities intend to continue promoting water use efficiency and landscape changes to reduce outdoor water use, and new state water conservation requirements adopted in 2018 will likely push some agencies to intensify these efforts.

Figure 4 demonstrates how actual water demand and demand projections have been shifting within the MWD service area. Actual demand has fallen sharply since its peak in 2000. Successive IRPs have revised their demand projections downward in light of these trends. The figure also shows our rough estimate of what future demand might look like given continued declines in per capita use since the last IRP. If per capita use stays at 2018 levels, water demand in 2040 will be almost 20 percent lower (850,000 af) than MWD projected in 2016. If it falls by an additional 20 percent, demand in 2040 would be even lower (35%, or 1,600,000 af).

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per capita per day (gpcd), while MWA reduced per capita use from 342 to 215 gpcd. Total water use in the CVWD went from 118 to 109 taf/year, while in the MWA it went from 181 to 152 taf/year. In 2015, when the drought conservation mandate was in effect, per capita use was reduced even further (to 383 gpcd in CVWD, and to 189 gpcd in MWA), and total use also fell (93 taf/year in CVWD and 138 taf/year in MWA).

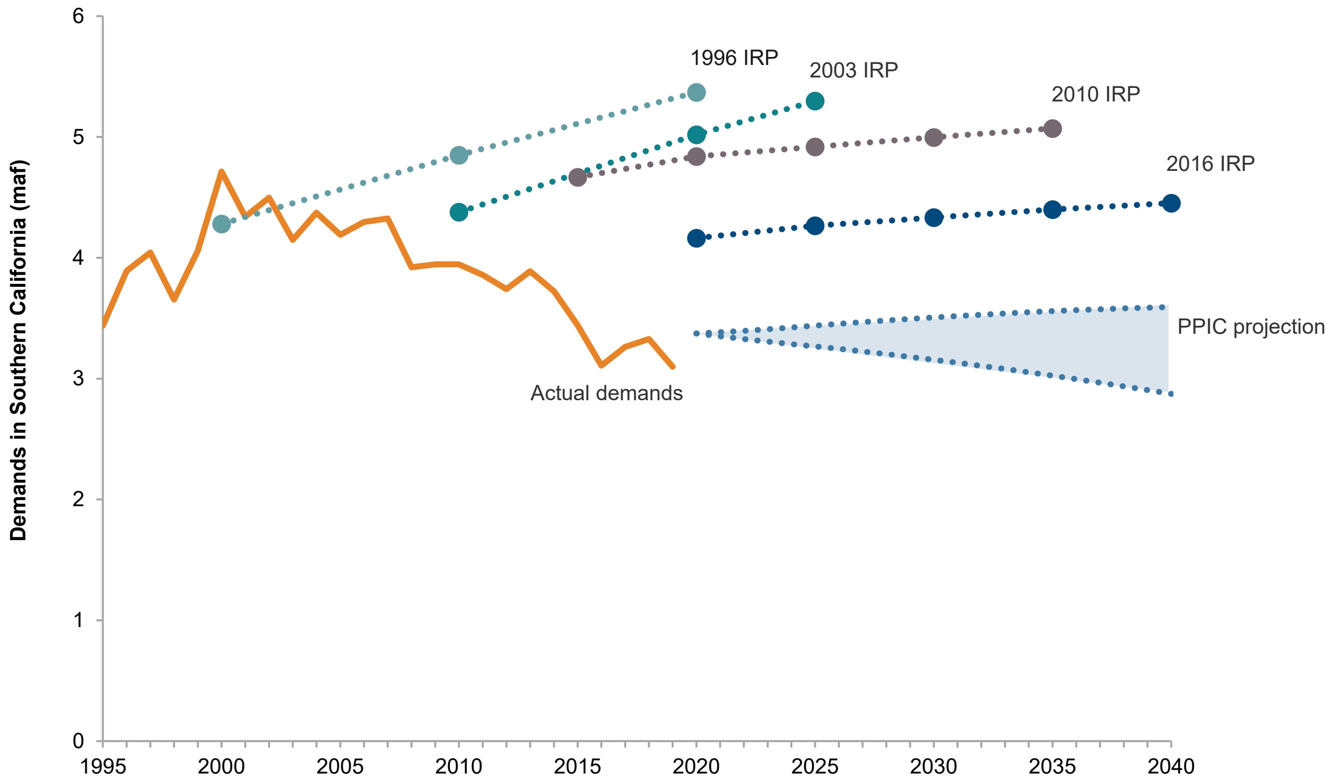
[18] For more details on this analysis, see Table A1 in Technical Appendix A.

[19] We analyzed State Water Board water use data through February 2020 and found that total water use has fully rebounded to 2013 per capita levels in only two of the 157 agencies with available data for 2018. In 2019—a wetter year requiring less outdoor water use—all agencies had lower per capita water use than in 2013 (Technical Appendix A, Figure 3).

[20] Population growth in California has slowed in recent decades (Johnson and Cuellar Mejia 2020), and the last two years have seen the lowest recorded growth rates since 1900 (California Department of Finance 2019). Accordingly, population projections have dropped from almost 44 million by 2030 (Johnson and Cuellar Mejia 2020, using Department of Finance data for 2019) to just 42.3 million (California Department of Finance 2020)

FIGURE 4

Regional water demand and demand projections have been falling over time




SOURCES: Actual demands from 1995–2015: 2015 Urban Water Management Plan (MWD 2016a); actual demands for 2016–19: State Water Board conservation reporting; demand projections: MWD Integrated Water Resources Plans (IRPs) (1996, 2003, 2010 and 2016) and author estimates.

NOTES: The figure shows actual demand and demand projections for the MWD service area. The PPIC projection spans a high-demand scenario where per capita use remains at 2018 levels (134.5 gpcd) and a low-demand scenario where use falls by 20 percent by 2040 (to 107.6 gpcd). Both scenarios are based on population growth of nearly 1.5 million by 2040 for the six counties served by MWD (Department of Finance 2020).

## Water Supply Planning: A Growing Emphasis on Reliability

This shift in demand has implications for water supply planning—potentially reducing the need to invest in new supplies. Utilities also need to consider vulnerabilities in their imported and local water supply portfolios, given changing climatic conditions and other factors (see Box 1, above). To understand this evolving landscape, we examined recent water planning documents and gathered input from urban water managers.

We also analyzed the range in costs of local water supply and conservation programs—options that could reduce Southern California's need for water imported from the Delta—as this can shed light on both the choices available for Southern California utilities and the scope for co-investment partnerships with San Joaquin Valley farmers (Figure 5). By way of comparison, the current cost of untreated water from MWD ranges from $750–$850 per acre-foot, while treated water is sold at $1,050–$1,200 per acre-foot (MWD 2020). Local groundwater supplies tend to be cheaper than imported water. The cost analysis shows that some of the new supplies are price-competitive with MWD imports, while others are more expensive than current supplies.[21]

[21] While MWD retail rates for imported water typically rise each year, project cost estimates reflect annualized costs over project lifetimes (typically 25 or more years) and are less likely to increase. This could make some of these supplies more competitive over a longer time horizon.

FIGURE 5

Costs vary widely for alternative water supplies and conservation


SOURCES: Author estimates using multiple sources. See Technical Appendix B for details.

NOTES: The figure shows utilities' annual costs per acre-foot of water, including amortized investments and ongoing maintenance and operations, for recent and proposed projects in Southern California, in 2018 dollars. The x-axis ends at $10,500 per acre-foot, but some projects (especially small stormwater projects) have higher unit costs. Diamonds show the median cost per acre-foot for each type of project: recycling facility ($1,471); recycling conveyance ($1,114), large stormwater capture ($465), small stormwater capture ($6,843), brackish desalination ($784), seawater desalination ($2,538), indoor conservation ($410), and outdoor conservation ($628). For conservation programs, consumers may incur additional costs (e.g., matching costs for landscape replacement or water-saving fixtures and appliances), and they may also benefit from savings on their water and energy bills—factors that could influence adoption.

Here are some takeaways from our analysis:

- **Managing droughts is the key regional concern.** In California's variable climate, urban water agencies need to ensure that they can meet demands during multi-year droughts. They generally use both demand- and supply-side tools. To manage demand, they promote extra conservation. And they bolster supplies by diversifying water sources and storing water. Since the early 1980s, MWD has developed more than six maf of new storage capacity within and outside of the region—a 15-fold increase (Technical Appendix A). Even so, some areas rely heavily on single sources, and are therefore more vulnerable to droughts. This includes the areas within MWD's service area that can only supplement local supplies with SWP imports, compared to agencies that have access to both SWP and Colorado River supplies (see Figure 2, above). With the prospect of more-severe droughts in California's changing climate, drought resilience is a primary concern. This makes portfolio approaches—combining multiple sources of supplies with demand management—increasingly important.
- **For imports, the focus is on safeguarding existing supplies.** Total imports have declined in recent years, and SWP and Colorado River imports are increasingly vulnerable due to climate change and other factors (Box 1). The California Department of Water Resources' proposal to improve conveyance through the Delta would avoid further reductions in SWP deliveries from sea level rise, seismic risk, and declining ecological conditions in the Delta, but the high costs of this project and regulatory and political hurdles

might hinder its development (DWR 2020a; DCA 2020). On the Colorado River, where water levels in major reservoirs have been in decline for two decades due to over-allocation, prolonged drought, and climate change, parties are working to manage growing scarcity with flexible water management tools—water trading, conservation programs, and "carryover storage" programs (allowing unused water to be stored for later use) (Hanak et al. 2018b).

- **Water recycling will be a major source of new supplies.** Southern California already recycles more wastewater than all other regions combined, and this source is expected to grow.[22] Recycled water is relatively "drought-proof," and some recycling projects are among the cheapest of new supply options. Building conveyance to move recycled water to good recharge sites and areas of demand is usually cheaper than expanding or upgrading treatment facilities (Figure 5). The prospect of "direct potable reuse"—where highly treated recycled water is directly incorporated in drinking water supplies—could lower costs by reducing the need to have extensive parallel distribution systems. Regulations to ensure public safety for such projects are expected by late 2023 (Pottinger 2016).
- **Stormwater capture is also on the rise, but climate change could lower its potential.** Over the past 30 years, an average of nearly 325,000 af/year of stormwater has been captured and recharged within MWD's service area, and there has been considerable recent growth.[23] Large stormwater projects are among the most cost-effective of all alternative supplies, whereas costs for small projects vary widely and can be very expensive per acre-foot of water produced. Most smaller projects are distributed facilities—for instance, recharge areas within public parks or along city streets—and their primary purpose is usually improving water quality or flood control rather than increasing water supply. In 2018, Los Angeles County voters approved Measure W, a parcel tax to help fund such projects. While there is increasing interest in capturing the water supply benefits from stormwater, there are also concerns that changing precipitation patterns might reduce both passive and active stormwater recharge of groundwater basins (Box 1 and MWD 2016c).[24]
- **Seawater desalination will remain limited, given its high cost.** Desalination provides highly reliable water supplies, a factor influencing San Diego County Water Authority's recent investment in a large seawater desalination plant. Similar investments are being considered by water districts in Orange County and the West Basin Municipal Water District. Yet such projects are among the most costly of all new water supplies.
- **Brackish desalination has expansion potential in some areas.** Desalination of brackish groundwater—already common in the Chino basin—is more affordable than seawater desalination, given the lower energy requirements and easier connectivity to the water distribution network. It already provides more supplies than seawater desalination, and expansion might be advantageous for some water districts with impaired groundwater.
- **Water quality poses concerns.** Salinity is an ongoing issue for some surface and groundwater supplies; it often worsens during droughts, and will be a growing threat with future sea level rise. Pollutants from agricultural and industrial processes have also been leaching into local aquifers for many decades, often requiring costly treatment. One emerging concern is a family of fluorinated organic chemicals known as PFAS, used in a variety of industrial and consumer products.[25] Given the potential for adverse health

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[22] MWD's 2016 IRP envisages more than 130,000 af/year of new supplies by 2040, including roughly 75,000 af of recycled water. Urban retailers anticipate even higher amounts of recycling (+165,000 af/year). See Technical Appendix A for details. One large regional effort under study is the Regional Recycled Water Program, a partnership between MWD and the Sanitation Districts of Los Angeles County. This program would produce up to 168,000 af/year of purified water to recharge four regional groundwater basins (MWD 2019a).

[23] This total excludes Santa Ana River base flow. The Stormwater Capture Task Force collected data on stormwater capture from 30 agencies. Of the 32 projects with complete data, 19 were operational in 2006, and the rest came online since then (Southern California Water Coalition 2018).

[24] The increased precipitation volatility expected with climate change could make it harder to capture additional flows from larger storms, unless projects are designed for larger capacity—which could increase costs. Some agencies expressed concerns that recent groundwater levels in some basins are much lower than expected, even after two very wet years (2017 and 2019).

[25] These substances have been used extensively in consumer products, including carpets, clothing, fabrics for furniture, paper packaging for food, and other materials designed to be waterproof, stain-resistant or non-stick; and in fire-retarding foam and various industrial processes.

effects, the State Water Board has ordered utilities to monitor two specific PFAS and notify customers of detections.[26] Management options include discontinuing use of affected wells or treating the water. Agencies we spoke with indicated that treatment might add $100 to $200 per acre-foot to water costs, and that it will take some years to retrofit affected wells—something that could be particularly challenging for smaller agencies. They also stressed the importance of having flexibility to tap imported surface supplies when wells must be taken offline. Stricter regulation of PFAS could also raise the costs of recycled water, since wastewater can contain high levels of these chemicals.

- **Water conservation is an essential management tool.** Since the early 2000s, MWD and its member agencies have invested more than a billion dollars (in 2018 $) in conservation programs, including large sums at the height of the latest drought. These programs appear relatively cost-effective per acre-foot, especially for indoor uses. Although outdoor programs are costlier than indoor programs per acre-foot of water saved, their overall potential for water savings is greater.[27] The latest drought may have triggered long-term behavioral changes, and recent legislation will push some utilities to increase their conservation goals. In this populous region, even small reductions in per capita water use can yield significant overall savings—making it possible to accommodate population growth without increasing overall water use.[28] However, conservation may become more difficult over time, as the easiest and cheapest investments have already been made. Conservation also involves tradeoffs that utilities need to prepare for in advance. For one, reducing non-essential uses can make demands less flexible, and hinder the effectiveness of water saving campaigns during droughts. This makes it more important to store water and make arrangements to access other supplies during dry times (Mitchell et al. 2017). Secondly, to safeguard their finances, utilities need to structure their rates to cover costs when water sales decline—for instance, by adding surcharges during droughts.
- **Trading and banking activities have improved drought resilience.** Southern California is one of the principal regional actors in the state's trading and banking activities. In the state's water market, buyers and sellers trade water through short- and long-term leases and permanent sales of their water rights. Trading adds flexibility to the state's water allocation process, and helps lessen the economic impact of shortages. Southern California cities now receive nearly 15 percent of their supplies from water trades (Hanak et al. 2019b). Water banking also helps reduce the costs of managing variable supplies. Southern California now has more than 2 maf of capacity in underground storage partnerships in the Central Valley and in Southern California (Technical Appendix Figure A7).

Southern California's success in diversifying its water portfolio and reducing demand represents important progress, but new challenges loom. What Southern California agencies worry about most going forward is their ability to supply water during a multi-year drought. What matters during droughts is the vulnerability of supplies, the ability to obtain water from storage, and the flexibility to expand supplies through exchanges or transfers, or to reduce demands with emergency actions.

All of these factors suggest that the moment may be right to expand interregional partnerships that increase water system and financial flexibility.

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[26] The board is also conducting more analyses to examine the extent of the problem, and initial reports show that Southern California is significantly affected (SWRCB 2020b). PFOA, PFOS and other PFAS chemicals have been detected in roughly half all wells sampled. Airports and landfills show a high number of detections.

[27] This is because attention has only recently focused on reducing outdoor water use, and there is considerable potential for savings with the conversion of turf and other water-intensive landscapes to plantings that require less water and more efficient irrigation systems. It is worth noting that the costs per acre-foot of water savings shown in Figure 5 are estimated, and may be too optimistic. For instance, the median cost for residential turf removal projects is $628 per acre-foot, but Tull et al. (2016) found an actual cost of $1,422 per acre-foot, because the water savings associated with rebates were lower than anticipated. On the other hand, agencies hope these programs will promote broader community change in landscaping preferences, ultimately resulting in larger savings as some customers pay the full costs of their own new landscaping. In a recent study, MWD found some evidence of this effect. For every 100 rebate-funded turf replacements, 13 additional replacements were made without a rebate—6 that would have happened naturally, and 7 more induced by the rebate program (MWD 2019c).

[28] An average 6 percent reduction of per capita water use beyond the 2018 level of 135 gpcd could provide roughly 220 taf in savings, enough water for the population increase expected by 2040. With a 9.5 percent reduction (to 123 gpcd), roughly 120 taf of additional supplies would be available, and with a 16 percent reduction (to 114 gpcd), almost 345 taf. See Technical Appendix A for details.

# The Scope for New Partnerships between Cities and Farms

There are already many examples of water supply partnerships between urban and agricultural agencies in California (Box 2). Here we describe some of the conditions that could affect efforts to form new partnerships. We then explore new partnership opportunities that could benefit both Southern California cities and San Joaquin Valley farms, assess how such partnerships would affect greenhouse gas emissions, and consider some challenges that would need to be addressed to make new partnerships succeed.

## Factors that Affect Partnerships

The following factors will affect the formation of partnerships, and also create opportunities for them:

- **The value of water varies across years and activities.** Water is much more valuable during droughts than during wet years, and shortages can be much more costly for some activities than others. This presents opportunities for water storage partnerships, such as underground storage projects in Kern County (Box 2). It also presents opportunities for additional water transfers and exchanges. Transfers typically involve monetary compensation to the party selling the water. In a form of transfer known as "unbalanced water exchanges," water becomes the currency: one party receives more water in wet years in exchange for delivering a smaller amount to the other party in dry years.
- **Agencies' needs vary over time.** Many urban agencies invest in expanding water supplies to accommodate anticipated population growth. Partnerships that make this water available to other parties until it is needed locally can help pay for these investments, while helping to address the partners' supply needs. Such partnerships are already common between cities and farms on Colorado's Front Range, and some water managers we spoke with suggested there is potential to develop similar ones in California.
- **Financial capacity varies.** Water investments are often capital-intensive. Partnerships can help reduce the financial burden and investment risk. Such partnerships can be an advantage to agriculture, which often has less access to capital than urban utilities. But they can also help keep down costs for urban utilities that are concerned about affordability.
- **Benefits can go beyond water agencies' interests.** Some water projects provide multiple benefits in addition to supplying water—such as water quality, flood control, ecosystem improvements, and recreation. Multi-agency partnerships—for instance, between stormwater and water supply agencies—can facilitate cost sharing across beneficiaries. California's Water Storage Investment Program is a partnership where the state helps fund local agency storage programs that provide public benefits, including water for ecosystems.
- **Shared water rights or service areas can ease arrangements.** Membership in the same water project or wholesale service area can reduce the legal and institutional burdens of developing partnerships. For instance, partnerships between contractors within the SWP or the CVP are easier to arrange than partnerships involving contractors across the two projects.
- **Location can be an asset.** Some agencies are well positioned for partnerships—for instance, if their service areas are located near a large conveyance facility or on an aquifer with good storage conditions. Both types of assets have been key for developing Kern County underground storage partnerships with parties in other parts of the state.
- **Infrastructure connections are important.** Another type of locational advantage is when partner agencies are connected—either directly or indirectly—through a water conveyance system or shared aquifer. Direct physical connections between partners are not always necessary for sharing water, as long as it is possible to coordinate exchanges with the assistance of other parties that are connected to both partners. California's water grid—which connects water storage and use locations across large parts of the state—facilitates water supply partnerships.

- **Accountability is essential.** As with any formal financial transaction, water trading and storage partnerships rely on trust that the parties will uphold their obligations, and the potential for recourse if they don't. This makes solid legal agreements and transparent water accounting and monitoring essential.

## Possible Models for New Partnerships

Southern California and the San Joaquin Valley benefit from shared conveyance infrastructure, one of the enabling conditions for partnerships. Their different management needs could also create opportunities, since Southern California's top concern is drought resilience, while the San Joaquin Valley needs to increase long-term supplies. Several approaches might benefit both parties (Table 1).

**TABLE 1**

Different types of partnerships would bring different benefits for Southern California and the San Joaquin Valley

| Type of partnership | Description | Benefit in Southern California | Benefit in the San Joaquin Valley | Challenges/Limitations |
|---|---|---|---|---|
| Co-investments | Farmers invest in alternative water supplies or water conservation in Southern California | - Increased water availability<br>- Financial help with local investments | - Increased water availability | - Cost of alternative supplies and water conservation often too expensive for farmers<br>- Urban agencies reserve “low-hanging fruit” for themselves |
| | Urban agencies invest in conveyance/storage infrastructure in the San Joaquin Valley | - Increased storage capacity<br>- Increased drought resilience | - Increased storage capacity<br>- Financial help with local investments | - Water supplies for recharge in the San Joaquin Valley might be too limited<br>- Storage sites would need to be connected to the California Aqueduct<br>- Groundwater contamination in the San Joaquin Valley might be an obstacle |
| Unbalanced exchanges | Water exchanges where farmers get a larger amount of water during normal/wet years in return for a lesser amount during droughts | - Increased drought resilience | - Increased water availability | - Agricultural districts must have enough water to fulfill delivery obligations in dry years<br>- Urban agencies with ample storage capacity might not be interested<br>- Storage sites in the San Joaquin Valley would need to be connected to the California Aqueduct<br>- Groundwater contamination in the San Joaquin Valley might be an obstacle<br>- SWP rules might be too rigid |
| Mixed strategies | Combination of co-investments and unbalanced exchanges | - Increased water availability/storage capacity<br>- Increased drought resilience<br>- Financial help with local investments | - Increased water availability at a price discount<br>- Financial help with local investments | - Development of complex financial and operational rules<br>- SWP rules might be too rigid |
| Opportunities related to future urban growth | Urban agencies invest in supplies to accommodate future population growth with option of near-term transfers to the agricultural sector | - Increased water availability for long-term population growth<br>- Financial help in the near-term from transfers | - Increased near-term water availability | - Urban agencies may need to opt out of these deals early if water demand grows faster than anticipated |

SOURCE: Developed by the authors.

## Co-investments in Water Supplies

One option is simple co-investments in water supplies, which parties share in proportion to the dollars invested. Co-investments in alternative supplies or conservation in Southern California are one possibility, although cost could be an obstacle. Many of these projects produce water for more than $1,000/af, while there are a number of opportunities below that price tag (Figure 5). Meanwhile, our research shows that most San Joaquin Valley farmers would be unwilling to pay more than $300–$500/af for new long-term supplies, although a few might pay as much as $900/af to avoid fallowing some very profitable lands (Hanak et al. 2019a). Conservation, recycled water conveyance, and large stormwater capture projects appear to be the most economically attractive options in

Southern California cities, and most of these would only be affordable for the most profitable agricultural activities.

Most Southern California water managers we spoke with suggested that valley farmers should not count on getting a price break for such co-investments. Agencies would want their own customers to reap the full benefits from lowest-cost options, and would be more open to partnerships for more expensive new supplies. Still, with reduced demand pressure, some agencies indicated they might welcome financial partners to help cover the costs of large investments.

Another co-investment possibility is expanding underground storage capacity in the San Joaquin Valley, which typically requires additional local conveyance infrastructure, spreading basins, and recovery wells. During very wet years (such as 2017 and 2019) limited storage capacity currently constrains SWP water deliveries south of the Delta, and these constraints could grow with warmer temperatures and more volatile precipitation anticipated as the climate changes. Some existing underground storage partnerships already operate on this model, where investment partners share the storage capacity. For partnerships with Southern California, having a physical connection between the storage facility and the California Aqueduct is a requirement. One limitation is that obtaining additional water supplies for storage will be a challenge in most years. San Joaquin Valley parties are already competing heavily for the limited supplies available from flood flows within the region (Hanak et al. 2020), and expanding access to the much more abundant high flows from the Sacramento Valley is limited by regulatory and conveyance capacity constraints on moving water through the Delta.[29] Groundwater quality issues are also a growing concern (Box 3).

### Box 3. Groundwater quality can constrain underground storage partnerships

A potential limitation for any partnership involving underground storage is the quality of water in the aquifer. Groundwater quality problems are on the rise in many regions of the state—including both the San Joaquin Valley and Southern California. This is a concern for local uses, and it can also constrain partnerships. If water pumped from a well contains high levels of chemicals considered unsafe for drinking water, it may not be pumped into the California Aqueduct. This issue recently led MWD to reject delivery of water that had high levels of 1,2,3-TCP, a newly regulated drinking water contaminant, from one of its banking partners in Kern County (Henry 2020). Water treatment is an option for addressing most contaminants, but it can substantially increase costs. For instance, urban water utilities are spending between $100 to $200 per acre-foot to remove 1,2,3-TCP from affected systems, similar to the cost of removing PFAS—an issue in many Southern California basins.

## Exchanging Long-term Water Availability for Drought Supplies

The second option is unbalanced water exchanges that take advantage of the different needs of the two regions. In this scenario, Southern California's urban agencies would exchange a larger amount of water in normal or wet years—when they need it less—in return for a lesser amount during dry years—when they need it more. These

[29] If the proposed Delta conveyance project goes forward and Southern California's demands do not grow substantially, this could increase the number of years when additional water would be available for storage south of the Delta.

exchanges would also enable San Joaquin Valley agriculture to increase average water supplies. Figure 6 shows how these agreements could work.

In some respects, existing underground storage partnerships already operate along similar principles, since there is usually a "payment" in extra water that remains at the bank for the benefit of the banking partner or the local basin.[30] Good water accounting and monitoring is a prerequisite for these projects, to keep track of water going into and out of the water bank. If the valley's new groundwater sustainability agencies develop robust groundwater accounts, they can also use their aquifers for unbalanced exchanges. [31]

Although Figure 6 depicts a case where the agricultural partner also receives SWP water allocations, other water users might also participate as long as they can receive extra surface water in normal and wet years and pay some of it back during dry years. Increasing recharge and storage potential in the valley, and having the ability to send water from the valley to the cities through the SWP during droughts, are both essential elements of such partnerships. Beyond the infrastructure requirements, solid legal assurances that water would be returned to cities in dry years are essential. Groundwater quality issues would also need to be considered.

Some Southern California managers also indicated that such unbalanced exchanges would be of limited interest to them, since their priority would be to store water for droughts in the storage facilities they have invested in since the 1990s (Technical Appendix A). But situations vary across the region, and new underground storage partnerships may be of interest to some agencies. For instance, some parts of the MWD service area do not have access to Colorado River water, including the water MWD stores in Lake Mead. With high dependence on SWP imports and limited access to storage, the benefit of unbalanced exchanges might be much higher. The same might be true for other non-MWD agencies with limited access to storage. Conveyance cost considerations could also make these partnerships attractive. Because it is considerably more expensive to bring SWP water to Southern California, some agencies might prefer to store it in the San Joaquin Valley and only bring it to Southern California if they need it.

Another consideration is the "opportunity cost" of keeping a lot of water in storage. Water stored in excess of needs during droughts might become a "stranded asset" that does not provide any benefit—and it might even be losing value from evaporation or seepage. In a situation where water demands could be lower than supplies over the long term—as could be the case in Southern California (Figure 4)—agencies may want to reconsider storage strategies, and rely more heavily on partnerships that can put more of the water to use, while having the option to call on some of it during droughts.

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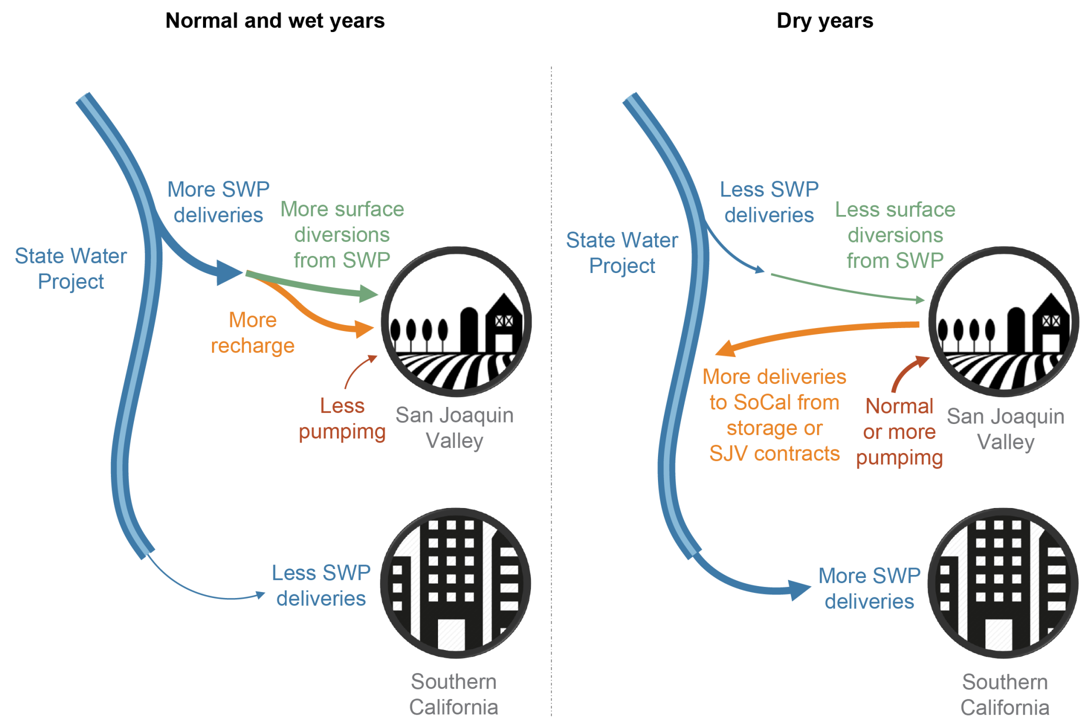
[30] Although they have begun to vary more as the region implements SGMA, the return ratios for underground storage projects typically range from 1.11:1 to 2:1. In the first case, the party receiving water in the dry year leaves behind a payment of 10 percent of the water deposited in the wetter year, and in the second case they leave behind a payment of 50 percent in the wetter year, relative to the amount received in the dry year. Unbalanced one-time exchanges of SWP Table A allocations operate along similar principles, without the use of banks. In the future, it may be useful for parties to consider more flexible return ratios, for instance with a higher payment to receive water in critically dry years than in dry or below-normal years.

[31] Even areas without good conditions for directly recharging water into the ground can use "in-lieu" recharge methods, where irrigators use extra surface water instead of pumping, thereby allowing the aquifer to recover.

FIGURE 6

SWP infrastructure can support exchanges that increase long-term supplies in the San Joaquin Valley and drought supplies in Southern California




SOURCE: Developed by the authors.

NOTES: The width of the arrows characterizes the amount of water delivered. The figure depicts how SWP operations would change relative to current operations.

## Mixed Strategies

Partnerships that combine both previous options might provide additional benefits. The price point for alternative supplies and conservation in Southern California could be a limiting factor for co-investments by farmers. And in unbalanced exchanges, farmers might want a higher return ratio—the water they receive in exchange for dry-year deliveries—than urban agencies are comfortable with. A mixed strategy might help them find middle ground.

With mixed strategies, alternative water supply or conservation projects would be developed in Southern California, and farmers could get some of this water.[32] By also engaging in unbalanced water exchanges, they could pay a lower price for their share of these co-investments. And in return, farmers would not get this water during dry years, when urban agencies need it most. Mixed strategies also help ensure that these partnerships support an overall increase in water availability, which might make this approach easier to justify to urban customers.

## Opportunities Related to Future Urban Growth

Some urban agencies are willing to engage in more near-term transfers of water to agricultural agencies. This is the case where urban agencies have SWP allocations to support future growth that they don't currently need. Such

[32] This would work through exchanges: for the farmers' share of the local supply or conservation investment project, Southern California would leave an equivalent amount of SWP water in the valley.

transfers could be very helpful in the medium term—and potentially even over the long term if water demands do not grow significantly in urban areas.

## Partnerships Have Limited Potential to Reduce Carbon Emissions

California has an energy-intensive water system, which accounts for 10 percent of the state's greenhouse gas emissions (Escriva-Bou et al. 2018a). The SWP is the largest single consumer of electricity in the state, with particularly high energy needs to pump water over the Tehachapi Mountains to Southern California (DWR 2020). We explored whether urban-agricultural partnerships that lower the volume of SWP imports into Southern California could reduce GHG emissions (Technical Appendix C). This question is of interest for understanding whether there might be climate-related incentives for these partnerships.

Some context on California climate policy is important for this assessment. Most emissions associated with water use in both the urban and agricultural sectors are regulated under California's GHG cap-and-trade program. This program establishes emissions permits for a range of activities, and allows emitters to trade these permits. For any given volume of permits (the cap), trading helps lower the cost of reducing emissions. The cap is reduced periodically in line with the state's emission targets.

Our analysis assumed that the partnerships would transfer some SWP imports from Southern California to the San Joaquin Valley, and that these imports would be replaced by local water supplies or reduced water use in Southern California. To provide an apples-to-apples comparison of water-related emissions in both regions, we also assessed the GHG emissions from increased agricultural water use in the San Joaquin Valley that these transfers would enable, and compared this with the change in emissions in Southern California cities.

Three main findings are of note:

- **The net difference in GHG emissions is only significant when partnerships are based on water conservation.** The emissions from using an acre-foot of water in a San Joaquin Valley orchard are more than 40 percent lower than using the same amount of cold water in Southern California. This comparison reflects a partnership based on cold water conservation—e.g., reduced outdoor landscaping—to transfer SWP water to the valley (Figure 7). If instead Southern California uses a new local water supply to replace the water transferred, the carbon difference is much lower, because the new supply also generates emissions. (Partnerships involving desalinated seawater actually have higher GHG emissions.) The most promising option for reducing GHG emissions through these partnerships would be by conserving water in fixtures and appliances that use heated water, which generate a large amount of carbon per unit of water.
- **The financial incentives are only significant for partnerships involving hot water conservation.** When partnerships result in lower GHG emissions, benefits could be monetized in California's cap-and-trade market. We estimated this potential financial benefit using the price of carbon in this market in February 2020 ($17.87 per metric ton). Partnerships relying on conservation of heated water could provide important financial benefits ($96 per acre-foot of water saved). Benefits are much lower for cold water conservation ($6 per acre-foot), and they are negligible for most other options (Figure 7).[33] One caveat is that the benefits associated with cap-and-trade allowances would not go directly to water project investors; instead, benefits would be received by water customers and suppliers as a reduction in their energy bills. This

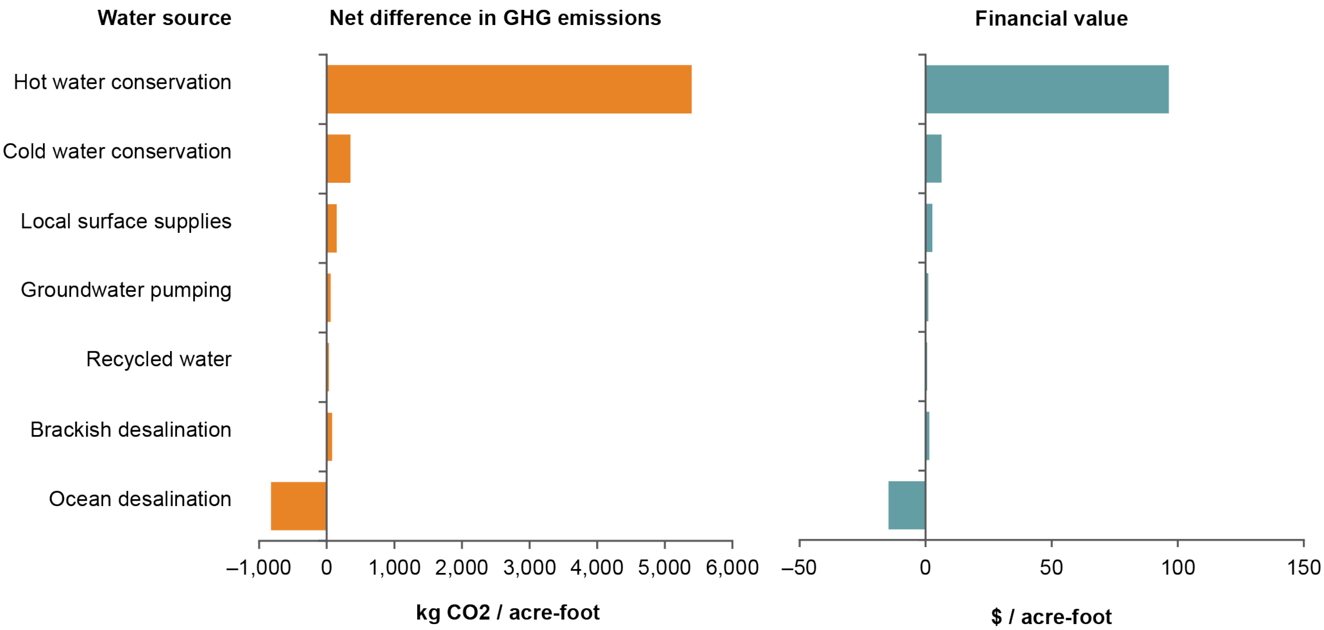
[33] These calculations only account for trade-offs in California carbon emissions; they exclude emissions from distributing California agricultural products outside the state. They also assume that any reductions in agricultural-related practices in the valley are not replaced by emissions from food production and distribution elsewhere. Such potential substitution (called "leakage" in the economics literature) would mainly generate emissions outside of California. On the other hand, the estimates do not factor in potential differences in carbon storage or loss in valley soils that are in cultivation or fallowed; fallowed lands might be expected to generate larger net carbon losses (see for instance Tautges et al. 2019 and Peterson et al. 2020). Also, these calculations assume current emission levels for energy uses. Yet investment planning would need to take into account the continued increases in the share of renewable energy sources, a trend likely to continue as California moves towards its 2045 carbon neutrality goal for electricity.

makes engaging with energy providers who could monetize these emission differences essential for incorporating the financial benefits into partnership considerations.

- **There would be no decline in net emissions for California unless the cap is lowered.** Because the emissions included in these estimates are already regulated by the state's cap-and-trade market, net emissions savings for California would not be guaranteed unless there were an accompanying reduction in emission permits—beyond the reductions that are already occurring as the state ramps down emission allowances.[34]

**FIGURE 7**

Carbon emission differences and financial value for alternative partnership scenarios




SOURCES: Author calculations. For details, see Technical Appendix C.

NOTES: The figure shows GHG differences and their potential financial value for interregional partnerships where Southern California cities make water available to San Joaquin Valley farmers using the various sources shown in the y-axis. Positive values indicate carbon emission reductions, and negative values increased emissions. Financial values are calculated at the February 2020 auction price for a metric ton of carbon in California's cap-and-trade market. Hot water conservation includes the conservation of both hot and cold water in residential end-uses that use heated water (faucet, shower, bath, clothes washer, and dishwasher). Cold water conservation is from residential end-uses that don't use heated water (toilet and outdoor uses). The comparison between scenarios only includes in-state emissions, so it excludes agricultural emissions from food distribution outside of California (those estimates are available in Technical Appendix C).

[34] Without such a reduction, savings generated through the partnership would make it possible for some other emitter regulated under the cap to emit more. This is the essence of the cap-and-trade program—one party pays another for their emissions credits.

## Overcoming Obstacles to New Water Partnerships

Interregional water supply partnerships could provide mutual benefits, but several challenges must be overcome to make them work. Many of these relate to the legal, operational, and physical constraints associated with using SWP infrastructure—the physical connection between the two regions.

- **Partnerships are constrained by SWP rules.** Current SWP rules limit the types of transfers and exchanges that can occur. For instance, it is not currently possible to develop multi-year exchanges or transfers between SWP contractors. These rules also make it hard to involve outside parties in water trading and underground storage arrangements. Some of these issues would be addressed by the proposed "water management tools" amendment of the SWP contract, which aims to facilitate trading and more flexible water use among SWP contractors (DWR 2020b).[35] Expanding the potential for partnerships with non-SWP agencies will also be essential to address growing water scarcity and make the most of state water infrastructure.
- **Place of use restrictions hinder partnerships between SWP and CVP users.** Under state law, both the SWP and CVP have a defined "place of use" where the water can be used without requesting changes to the projects' water rights. The CVP has additional restrictions on place of use for its water under federal law. SWP and CVP places of use south of the Delta are often combined on a temporary basis to increase the flexibility of operations, especially during droughts. Having a permanent joint place of use would facilitate partnerships between CVP and SWP water users and increase the water system's flexibility to manage supplies and demands. Relaxing CVP rules that limit the use of banked water outside CVP contractor's boundaries would also improve underground storage capacity—an essential tool for a more volatile climate.[36]
- **There are constraints to recharging more water in wet years.** Underground storage programs and unbalanced exchange partnerships rely on capturing surplus water in wet years for use in times of need. Infrastructure and regulatory constraints can limit the ability to move high Sacramento Valley flows through the Delta during wetter years (Gartrell et al. 2017). Recharge capacity in the San Joaquin Valley also faces infrastructure limitations, especially to convey water to the drier southern valley where demand is highest (Hanak et al. 2018a). Although SGMA is prompting many local investments in recharge basins and conveyance, capacity will be constrained without investments in regional conveyance. State assistance might be helpful to assess regional needs and potential for economically beneficial infrastructure investments.
- **Low water deliveries in dry years might constrain the ability to send extra water to Southern California.** For unbalanced exchanges to work, urban agencies need to get extra water during droughts. But surface water deliveries to San Joaquin Valley farms might not be sufficient to pay back these exchanges during dry years. In these cases, water districts in the San Joaquin Valley will generally need to supplement their surface water deliveries with groundwater from storage or other water sources to fulfill their contractual obligations. They must also be prepared to reduce their own water use in these years if groundwater withdrawals exceed sustainable pumping limits under their groundwater sustainability plans.

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[35] The proposed SWP "Water Supply Contract Amendments for Water Management" would increase the flexibility of water transfers and exchanges. The transfer provisions would facilitate water agencies' ability to: 1) transfer SWP water for multiple years without permanently relinquishing that portion of their Annual Table A amounts; 2) negotiate cost compensation and duration among the water agencies on a willing seller–willing buyer basis for water transfers; 3) obtain DWR approval of transfer packages and transfer of carryover water in San Luis Reservoir. For exchanges, the proposed amendments would: 1) establish return ratios (up to a 5:1 ratio) based on a consideration of varying hydrology and allow monetary compensation for costs of exchanges; 2) allow water agencies to exchange carryover water in San Luis Reservoir, and exchange up to 50 percent of their carryover water in a single-year transaction (however, future or multi-year commitment to exchange carryover water would still not be allowed); 3) allow water agencies to conduct water exchanges of carryover water as buyers and sellers in the same year.

[36] The US Bureau of Reclamation has determined that the water transfer provisions of the Central Valley Project Improvement Act of 1992 do not generally apply to water banking and recharge actions. Although CVP contractors are allowed to store water in 11 "acknowledged groundwater banks," there are significant restrictions on the subsequent use of that water. See the Central Valley Project Water Transfer Program Fact Sheet and the Groundwater Banking Guidelines for Central Valley Project Water for more information.

- **Legal assurances about water exchanges are key.** Beyond ensuring there is physical capacity for these exchanges, assurances about the delivery obligations of both parties will be key for building trust. A prerequisite is reliable water accounting systems in the San Joaquin Valley—something that has begun to improve under SGMA.
- **Limited financing capacity might hinder partnerships.** Even for co-investment partnerships that farmers can afford, limited access to capital markets could be a constraint. Farmers we spoke with indicated that lack of capital is already limiting investments in groundwater recharge that would otherwise pencil out, since banks are not yet confident in lending for this purpose. A lending facility modeled after the state revolving funds for urban drinking water and wastewater systems, or the California Infrastructure Economic Development Bank, might be worth exploring. And to the extent that there are public benefits from these partnerships—in terms of flood risk reduction, water quality, recreation, or others—some public funding may also be appropriate.
- **Partnerships have high transaction costs.** Entering partnerships is easier for larger agencies, which have more resources to do all the up-front work required, including screening projects and navigating permitting and regulatory hurdles. MWD might help facilitate the development of these partnerships for smaller retail agencies within its service area. And within the San Joaquin Valley, it will be hard for smaller land owners to participate unless larger agencies are willing to serve as umbrella organizations.

# Conclusion

Partnerships between Southern California cities and San Joaquin Valley farms could help alleviate groundwater overdraft in the valley, while building drought resilience in the face of growing climate risks in Southern California. To develop such partnerships, parties will need to address some legal, institutional, financial, environmental, and operational complexities. But there are promising models on which to build, including existing underground storage agreements between cities in Southern California and the Bay Area and agricultural parties in the San Joaquin Valley.

By diversifying water supplies, building connections to share water more flexibly, bringing multiple benefits, and preparing for the extreme events to come, these partnerships are examples of the type of actions underlined in Governor Newsom's Water Resilience Portfolio. And although we have focused on Southern California, urban-agricultural partnerships along these lines could be of interest for other urban communities, many of which are facing similar shifts in demand profiles and supply risks. Sharing investments is a way to reduce water supply risks, and also to share a common goal for a more resilient future.

## REFERENCES


Arizona Water Banking Authority (AWBA). 2014. *Recovery of Water Stored by the Arizona Water Banking Authority*.

Barnett, T. P. and D. W. Pierce. 2009. "Sustainable Water Deliveries from the Colorado River in a Changing Climate." *Proceedings of the National Academy of Sciences*, 106 (18): pp.7334-7338.

California Air Resources Control Board (CARB). 2017. *California's 2017 Climate Change Scoping Plan*. Accessed April 16, 2020.

California Department of Finance (DOF). 2019. *State's Population Increases by 141,300 While Rate of Growth Continues to Decline*. (December 20).

California Department of Finance. 2020. Population Projections (Baseline 2019).

California Department of Water Resources (DWR). 2018. California Water Plan Update 2018.

California Department of Water Resources (DWR). 2020a. Delta Conveyance.

California Department of Water Resources (DWR). 2020b. State Water Project Water Supply Contract Amendments for Water Management. Partially Recirculated Draft Environmental Impact Report.

CNRA, CalEPA, and CDFA 2020. *2020 Water Resilience Portfolio. In Response to the Executive Order N-10-19*. California Natural Resources Agency, California Environmental Protection Agency and California Department of Food and Agriculture.

Escriva-Bou, Alvar, Ellen Hanak, Newsha Ajami, David Jassby, Katrina Jessoe, Jay Lund, Edward Spang, Joshua Viers, and Robert Wilkinson. 2018a. "California's Water: Energy and Water." Public Policy Institute of California.

Escriva-Bou, A., J. Lund, M. Pulido-Velazquez, R. Hui, and J. Medellín-Azuara. 2018b. "Developing a Water-Energy–GHG Emissions Modeling Framework: Insights from an Application to California's Water System." *Environmental Modelling & Software*, 109, pp. 54–65.

Escriva-Bou, Alvar. 2019. "Technical Appendix A: Updated Assessment of the San Joaquin Valley's Water Balance." In *Water and the Future of the San Joaquin Valley*. Public Policy Institute of California.

Faunt, C. C., K. Belitz, R.T. Hanson. 2009. *Groundwater Availability of the Central Valley Aquifer, California. Chapter B: Groundwater Availability in California's Central Valley*, Groundwater Resources Program.

Garcetti, Eric. 2019. L.A.'s Green New Deal. Sustainable City Plan.

Garrick, D., L. De Stefano, W. Yu, I. Jorgensen, E. O'Donnell, L. Turley, I. Aguilar-Barajas, X. Dai, R. de Souza Leão, B. Punjabi, and B. Schreiner. 2019. "Rural Water for Thirsty Cities: A Systematic Review of Water Reallocation from Rural to Urban Regions." *Environmental Research Letters*, 14 (4): p. 043003.

Hall, Alex, Neil Berg, and Katharine Reich. 2018. *Los Angeles Summary Report. California's Fourth Climate Change Assessment*. Publication number SUM-CCCA4-2018-007.

Hanak, Ellen, and Elizabeth Stryjewski. 2012. *California's Water Market, By the Numbers: Update 2012*. Public Policy Institute of California

Hanak, Ellen, Jay Lund, Brad Arnold, Alvar Escriva-Bou, Brian Gray, Sarge Green, Thomas Harter, Richard Howitt, Duncan MacEwan, and Josué Medellín-Azuara. 2017. *Water Stress and a Changing San Joaquin Valley*. Public Policy Institute of California.

Hanak, Ellen, Jelena Jezdimirovic, Sarge Green, and Alvar Escriva-Bou. 2018a. *Replenishing Groundwater in the San Joaquin Valley*. Public Policy Institute of California.

Hanak, Ellen, Alvar Escriva-Bou, Brian Gray, Jelena Jezdimirovic, Jeffrey Mount, Timothy Bradley, Bonnie Colby, John Fleck, Douglas Kenney, and Kurt Schwabe. 2018b. *California's Water: The Colorado River*. Public Policy Institute of California.

Hanak, Ellen, Alvar Escriva-Bou, Brian Gray, Sarge Green, Thomas Harter, Jelena Jezdimirovic, Jay Lund, Josué Medellín-Azuara, Peter Moyle, and Nathaniel Seavy. 2019a. *Water and the Future of the San Joaquin Valley*. Public Policy Institute of California.

Hanak, Ellen, Jelena Jezdimirovic, and Gokce Sencan. 2019b. "California's Water Market." Just the Facts. Public Policy Institute of California.

Hanak, Ellen, Jelena Jezdimirovic, Alvar Escriva-Bou, and Andrew Ayres. 2020. "A Review of Groundwater Sustainability Plans in the San Joaquin Valley." Public Policy Institute of California.

Henry, Lois. 2020. "Tainted Valley Groundwater Could Stymie Banking Deals." *SJV Water*.

Hopkins, Francesca. 2018. *Inland Deserts Summary Report. California's Fourth Climate Change Assessment*. Publication number: SUM-CCCA4-2018-008.

Imperial County. 2018. Agricultural Crop and Livestock Report (2018).

Irvine Ranch Water District. 2020. Water Banking.

Jezdimirovic, Jelena, Gokce Sencan, and Ellen Hanak. 2019. "Groundwater Recharge." Just the Facts. Public Policy Institute of California.

Johnson, Hans and Marisol Cuellar Mejia. 2020. *California's Future: Population.* Public Policy Institute of California.

Joyce, B., V. Mehta, D. Purkey, L. Dale, and M. Hanemann. 2011. "Modifying Agricultural Water Management to Adapt to Climate Change in California's Central Valley." *Climatic Change,* 109 (1): pp. 299–316.

Littleworth, Arthur, and Eric Garner. 2019. *California Water*, 3d ed. Solano Press.

McCann, Henry, Alvar Escriva-Bou, and Kurt Schwabe. 2018. "Alternative Water Supplies." Just the Facts. Public Policy Institute of California.

Metropolitan Water District of Southern California (MWD). 1996. *Integrated Water Resources Plan 1996.*

Metropolitan Water District of Southern California (MWD). 2003. *Integrated Water Resources Plan 2003 Update*.

Metropolitan Water District of Southern California (MWD). 2010. *Integrated Water Resources Plan 2010 Update*.

Metropolitan Water District of Southern California (MWD). 2016a. *2015 Urban Water Management Plan.*

Metropolitan Water District of Southern California (MWD). 2016b. *Integrated Water Resources Plan 2015 Update*.

Metropolitan Water District of Southern California (MWD). 2016c. 2015 Urban Water Management Plan. Technical Appendices.

Metropolitan Water District of Southern California (MWD). 2019a. Regional Recycled Water Program Brochure.

Metropolitan Water District of Southern California (MWD). 2019b. Lower Colorado River Quality Partnership.

Metropolitan Water District of Southern California (MWD). 2019c. "Review of Water Savings from Metropolitan's Turf Removal Program." Presentation. Conservation and Local Resources Committee Item 4c. June 11.

Metropolitan Water District of Southern California (MWD). 2020. Financial Information. Water Rates and Charges.

Mitchell, David, Ellen Hanak, Ken Baerenklau, Alvar Escriva-Bou, Henry McCann, María Pérez-Urdiales, and Kurt Schwabe. 2017. *Building Drought Resilience in California's Cities and Suburbs.* Public Policy Institute of California.

Mount, Jeffrey, Brian Gray, Caitrin Chappelle, Greg Gartrell, Ted Grantham, Peter Moyle, Nathaniel Seavy, Leon Szeptycki, and Barton "Buzz" Thompson. 2017. "Technical Appendix: Eight Case Studies of Environmental Water Management During the 2012-16 Drought." In *Managing California's Freshwater Ecosystems. Lessons from the 2012-16 Drought*. Public Policy Institute of California.

Mount, Jeffrey, Ellen Hanak, Ken Baerenklau, Van Butsic, Caitrin Chappelle, Alvar Escriva-Bou, Graham Fogg, Greg Gartrell, Ted Grantham, Brian Gray, Sarge Green, Thomas Harter, David Jassby, Jelena Jezdimirovic, Yufang Jin, Jay Lund, Henry McCann, Josué Medellín-Azuara, David Mitchell, Peter Moyle, Alan Rhoades, Kurt Schwabe, Nathaniel Seavy, Scott Stephens, Daniel Swain, Leon Szeptycki, Barton "Buzz" Thompson, Paul Ullrich, Joshua Viers, and Zexuan Xu. 2018. *Managing Drought in a Changing Climate: Four Essential Reforms.* Public Policy Institute of California.

Peterson, C.A., E. Marvinney, and K. Dybala. 2020. "Multiple Benefits from Agricultural and Natural Land Covers in California's Central Valley." The Migratory Bird Conservation Partnership (Point Blue Conservation Science, The Nature Conservancy, and Audubon California).

Pottinger, Lori. 2016. "Recycled Drinking Water: The Next Frontier." *PPIC Blog*. October 17.

Purkey, D. R., B. Joyce, S. Vicuna, M. W. Hanemann, L. L. Dale, D. Yates, and J. A. Dracup. 2007. "Robust Analysis of Future Climate Change Impacts on Water for Agriculture and Other Sectors: A Case Study in the Sacramento Valley." *Climatic Change* 87 (S1): 109–22.

Rothberg, Daniel. 2019. . *Indy Environment: Water Authority Looks at Investment in Southern California Water Reuse Project – in Exchange for Colorado River*. The Nevada Independent.

Southern California Water Coalition. 2018. Stormwater Capture. Enhancing Recharge and Direct Use through Data Collection.

State Water Resources Control Board (SWRCB). 2020a. Municipal Wastewater Recycling Survey.

State Water Resources Control Board (SWRCB). 2020b. Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid (PFOS).

Swain, D., B. Langenbrunner, J. David Neelin, and A. Hall. 2018. "Increasing Precipitation Volatility in Twenty-first-century California." *Nature Climate Change* 8, 427–433.

Tautges, N. E., J. L. Chiartas, A. C. M. Gaudin, A. T. O'Geen, I. Herrera, and K. M. Scow. 2019. "Deep Soil Inventories Reveal that Impacts of Cover Crops and Compost on Soil Carbon Sequestration Differ in Surface and Subsurface Soils." *Global Change Biology*, 25(11), 3753–3766.

Tull, Christopher, Eric Schmitt, and Patrick Atwater. 2016. "How Much Water Does Turf Removal Save? Applying Bayesian Structural Time-Series to California Residential Water Demand." Presented at KDD Workshop on Data Science for Food, Energy and Water.

Wang, J., H. Yin, E. Reyes, T. Smith, and F. Chung. 2018. *Mean and Extreme Climate Change Impacts on the State Water Project. California's Fourth Climate Change Assessment*. Publication Number: CCCA4-EXT-2018-004.

Xiao, M., A. Koppa, Z. Mekonnen, B. Pagan, S. Zhan, Q. Cao, A. Aierken, H. Lee, and D. Lettenmaier. 2017. "How Much Groundwater Did California's Central Valley Lose During the 2012–2016 Drought?" *Geophysical Research Letters* 44, 4872–4879.

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