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

Technical Appendix B. Costs of Alternative Water Supplies and Conservation in Southern California

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Introduction

One way to expand water availability in the San Joaquin Valley is to reduce the amount of water transferred from the region to other areas. Reducing water deliveries to Southern California through the State Water Project—on average, these deliveries totaled 1.45 million acre-feet per year from 2003 to 2017—is one possibility. However, the costs to replace these supplies in Southern California might limit the feasibility of this approach.

This appendix estimates the costs of alternative water supplies—recycled wastewater, urban stormwater, and desalinated seawater and brackish water—and conservation efforts in Southern California, using data on recent and proposed projects. Our goal is to shed light on which options might be most economically feasible both for Southern California utilities, and for interregional partnerships. In the first section, we share the data sources, methods, and results of our alternative urban water supply analysis. In the second section, we share the data, methods, and results of our urban water conservation analysis.

Cost of Alternative Urban Water Supplies in Southern California

Alternative water supply sources including recycled water and desalination now provide around 2.5 percent of the state's urban and farm water supply, and they are growing rapidly (McCann et al. 2018). Urban stormwater capture is another important and growing alternative supply. Much of the growth in alternative supplies is due to investments by urban water agencies, particularly in Southern California. We estimate that over the past two decades, these alternative sources have provided roughly 20 percent of southern California's water supply (see main report and Technical Appendix A).[1]

Data and Methods

Given that infrastructure projects have to adapt to local conditions, there is a significant variation in the cost per acre-foot (af) of water for different projects, even within similar categories. To account for this variation, we obtained information for as many projects as we could for each alternative, then we determined unit costs for each project, and finally we calculated the ranges and distribution of costs for each category. To facilitate comparisons, all results are in unit cost terms (dollars per acre-foot per year in 2018 dollars).

Data Selection and Sources

We used recent and proposed urban water projects located in Southern California with characteristics that make it possible to estimate the cost per acre-foot of water. For seawater and brackish water desalination, where there were fewer than three data points from the region, we included projects from other regions. The primary data source is project applications for matching funds from Proposition 1, a state water bond that voters approved in 2014. This bond made available hundreds of millions of dollars for alternative water supply projects; it is administered by the State Water Board (for water recycling and stormwater projects) and the Department of Water Resources (for desalination projects). The large number of applications with detailed cost information make this an especially valuable resource for understanding local agency opportunities in these areas. We also

[1] 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 percent) of recycling, reuse and ocean desalination in recent years. Stormwater capture adds 325 thousand acre-feet per year (7 percent); this principally is stored underground, and shows up in the data as groundwater withdrawals. McCann et al. (2018)'s statewide estimates of use include recycling, reuse and desalination; there are no statewide estimates for urban stormwater capture.

acquired information on desalination projects from local agency websites.[2] Table B1 shows the sample size and main sources for each of the categories analyzed.

Applications for the Proposition 1 matching grants likely provide a representative picture of recent costs for alternative water supply projects in Southern California. To the extent that this portfolio emphasizes the “low hanging fruit,” it is possible that future projects will come in at higher costs. But changing technologies and regulatory frameworks—for instance, with the anticipated introduction of direct potable reuse methods for recycled water—could also open up opportunities for some future projects to come in at lower costs than those shown here.

TABLE B1

Data sources for the alternative water supply projects used in this study

Project Type	Number of Projects	Primary Data Sources
Recycled water	46	SWRCB staff, Bond Accountability website
Stormwater capture	33	SWRCB FAAST Portal, Bond Accountability website
Desalination	9	Department of Water Resources (2018), individual project websites*

NOTES: *Individual project website sources include: Montecito Water District (2019); City of Santa Barbara (n.d.); San Diego County Water Authority (n.d.); San Diego County Water Authority (2012); Sweedler (2015); Municipal Water District of Orange County (2014); Rodrigo and Zimmer (2017); Jones (2015); Santa Ana Watershed Project Authority (2013); Chino Basin Desalter Authority (2018).

Methods

To obtain unit costs, we first adjusted project costs to put them in 2018 terms using *Engineering News-Record’s* Construction Cost Index. Then we annualized costs over each project’s estimated lifespan. The unit cost includes an operation and maintenance (O&M) element when available from the project grant application; when that information was not included, we used a predetermined fraction of the construction cost based on the type of the project (Table B2). These predetermined fractions were derived based on the assumptions or percentages provided for similar projects. When information was missing on the expected life of investment, we assumed life spans indicated in Table B2. We assumed an interest rate of 3.5% for all projects, in alignment with Proposition 1’s Water Storage Investment Program guidelines (California Water Commission, n.d.).

[2] For desalination projects, board reports of the agencies involved often provided the information that we needed, such as the updated construction and operation and maintenance (O&M) costs. In cases where the construction or O&M costs were not publicly available, the budgets of agencies that operate desalination facilities often included the annualized costs of the desalinated water.

TABLE B2

Operations and Maintenance costs and life of investment assumptions for different project types

Project Type	Operation & Maintenance Expenses (% of the total cost)	Life of Investment (years)
Recycled water	10%	25
Stormwater capture	6% for small scale (less than 500 af/year), 15% for large scale (more than 500 af/year)	25
Desalination	80% unless project-specific estimates were provided	50

NOTES: The O&M costs and life of investment for stormwater capture projects are based on information from available application grants, while for recycled water and desalination projects we followed the assumptions in the table above.

Results

Recycled Water

The recycled water projects analyzed here are all located in Southern California. Projects were categorized as follows: (1) new facility, (2) facility expansion, (3) facility upgrade, (4) pipeline, and (5) pipeline expansion. New facility indicates a fully new facility that provides new water supply. Facility expansion can involve capacity expansion of an existing facility or the construction of additional project phases. In some cases, facility expansion is accompanied by new pipelines, pipeline expansion, pumps, and storage. Facility upgrade can consist of additional filtration systems for potable reuse or renovation of existing facilities to accelerate treatment. Pipeline and pipeline expansion involve the construction of infrastructure to deliver already-produced recycled water to new customers. Although these projects do not directly result in new water supplies, they bolster recycled water infrastructure and improve accessibility to this alternative water source by connecting new customers to the grid.

Recycled water project costs usually include project design, labor, infrastructure and equipment capital, installation, permitting, and O&M. New facility, pipeline, and storage costs may also include land acquisition. Facility upgrade and pipeline expansion may include retrofitting of old equipment.

The cost range varies across different project types (Figure B1). The highest variability in costs is observed in the new facility and facility upgrade categories.

Stormwater capture

The cost of stormwater capture projects generally includes project design, labor, infrastructure and equipment, land acquisition if not already owned, permitting and O&M. We divided stormwater projects into two categories to show the effects of the scale in the final unit cost: (1) those with capacity less than 500 af/year, and (2) those with capacity equal to or higher than 500 af/year.[3]

When categorized according to the scale of the project, the stormwater projects with a capacity of less than 500 af/year have a cost range between $452/af and well over $10,000/af, with a median value of $6,843/af.[4] Most smaller projects are distributed facilities—for instance, recharge areas within public parks or along city streets—and their primary purpose is usually water quality and/or flood control, rather than water supply.

[3] Figure B2 shows the distribution of these projects by size and costs per acre-foot; all but two of the projects classified as "large" would produce more than 1,000 acre-feet per year.

[4] Proposition 1's award criteria noted that "projects that achieve multiple benefits shall receive special consideration", and a number of these projects likely include additional benefits beyond water supply. The projects with the highest unit costs tend to be in urban settings as part of green street and alley initiatives, and in some cases—as in the most expensive case we reported ($312,772/af)—they include the cost of land acquisition.

Projects larger than 500 af/year are generally much less expensive, with the cheapest one costing $178/af and the most expensive one costing $1,432/af, with a median value of $465/af. Figure B1 shows the difference in cost variability between the two categories and as compared to the other alternative water supply categories.

Desalination

The projects included in the desalination cost analysis are mostly in Southern California, except for a brackish water project in Antioch in the San Francisco–Bay Delta. The number of projects in this category is much smaller than in the other two categories.

The analysis shows that brackish water desalination is significantly less costly than ocean water desalination (Figure B1). Numerous factors play a role in this outcome, such as less energy intensity and lower salt concentration, which lowers operating costs.

Desalination project costs include project design, labor, infrastructure and equipment, land acquisition if not already owned, permitting, and O&M. The most significant contributor to the cost of desalination projects is the O&M cost. Projects in other categories had O&M costs not exceeding 10 percent of the total project cost, whereas for some desalination projects O&M costs were more than half of total costs. Most of the O&M cost is for electricity use.

The cost of brackish desalination varies between $658/af and $937/af, with a median cost of $784/af. Ocean desalination varies between $2,240/af and $2,647/af, with a median cost of $2,538/af.

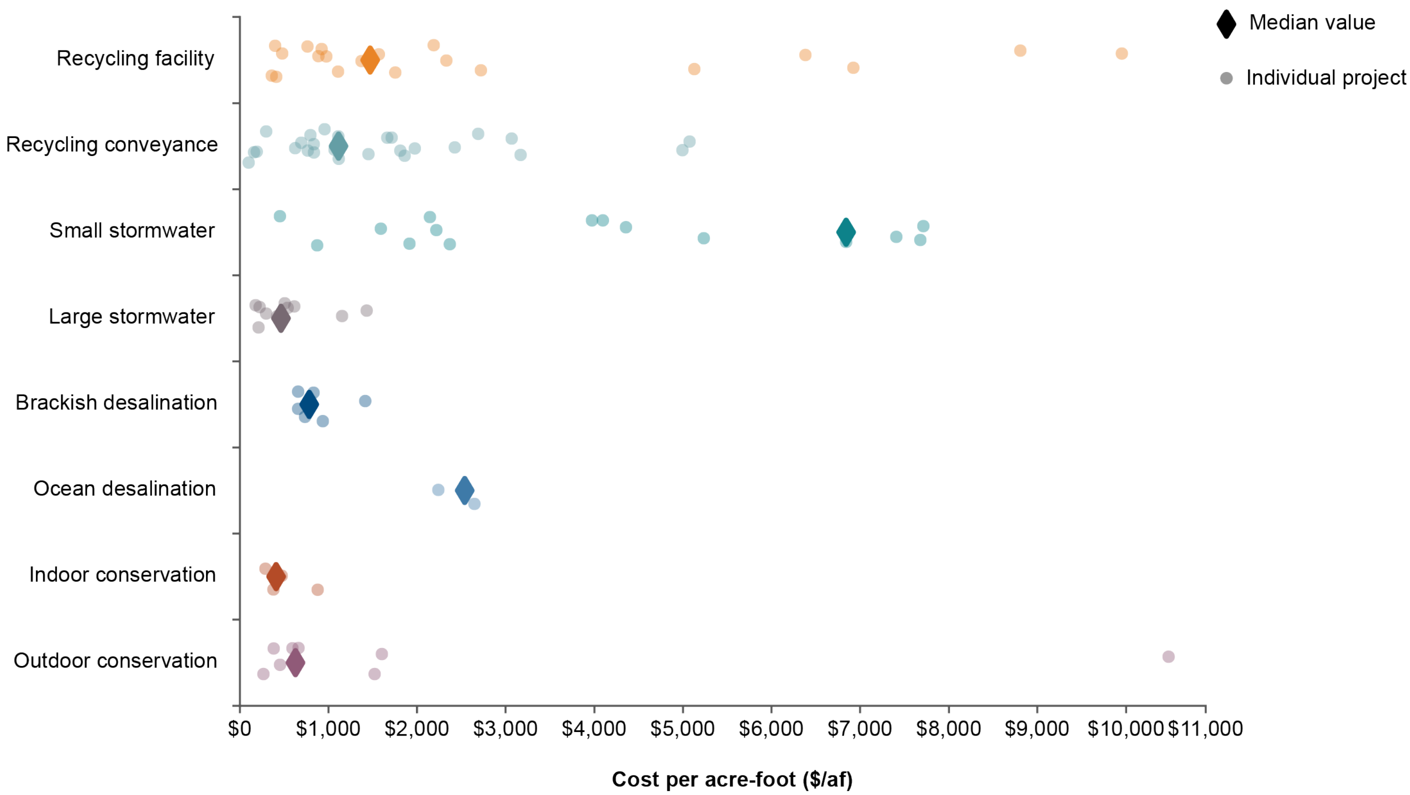
Summary of Results

Alternative water supply projects vary considerably across different project types. Figure B1 presents the total cost range for all projects and their median values, and Figure B2 shows the project costs and capacity on a logarithmic scale, highlighting the correlation between project capacity and the unit cost of the water source. The results show strong economies of scale for these water supply projects, with cost decreasing exponentially as the capacity of the project increases.

Stormwater capture has by far the greatest cost range. The cost of obtaining one acre-foot of water through stormwater retention could be as little as $178 or well over $10,000/af, with an overall median cost of $2,370 (the median cost is $6,843 for small projects, and $465 for large projects). Recycling projects have a range of $360–$9,954/af, with a median value of $1,471/af. The cost of desalination varies between $658/af and $2,647/af with a median of $922/af, with the lower-cost projects involving brackish water rather than ocean desalination.

FIGURE B1

Alternative water supply projects exhibit a wide range of unit costs

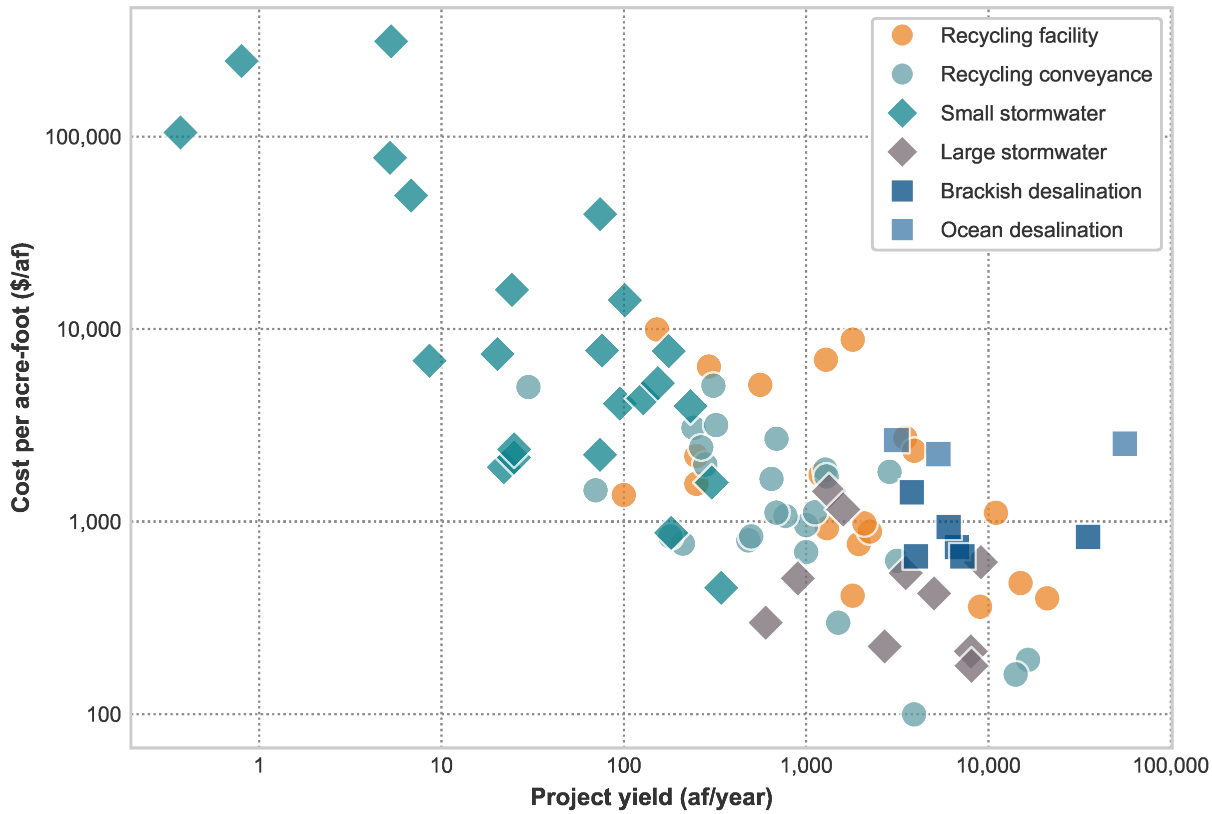


SOURCE: See "Data Sources" section and Table B1.

NOTE: Points represent the projects included in each category. The diamonds represents the median cost. Small stormwater projects yield less than 500 af/year, and large stormwater projects yield more than 500 af/year. Costs above $10,500/af (which occurred for some small stormwater projects) were excluded from the graph but were included in the calculation of the median cost (see footnote 4).

FIGURE B2

Alternative water supply projects demonstrate strong economies of scale



SOURCE: See "Data Sources" section and Table B1.

NOTE: Both axes are on the logarithmic scale. Recycling facility includes projects listed as new facility, facility expansion and facility upgrade, while recycling conveyances includes new pipeline and pipeline expansion projects.

Results Align with Other Studies

Our results are generally aligned with similar analyses on the subject. The California Public Utilities Commission (CPUC) found in 2016 that annual cost of recycling projects could vary between $396 and $5,800/af, with a median of $3,000/af (Marie 2016). For desalination projects, they calculated a cost range of between $2,367 and $5,100/af, with a median of $2,700/af (Marie and Zafar 2016). The commission did not calculate costs for stormwater capture.

CPUC collected the data from various programs across the state, whereas our analysis is restricted to projects in Southern California (with the exception of desalination). For most categories, their sample size was smaller than ours (e.g., just 5 projects in recycling and 3 projects in desalination).

The Pacific Institute also analyzed the cost of several urban water management strategies to augment local supplies and reduce demand (Cooley and Phurisamban 2016). Their calculations in the three alternative urban water supply categories use a levelized cost approach, which is similar to our method. Table B3 demonstrates the cost range similarities.

TABLE B3

Comparison of overall cost ranges by alternative supply project type across different studies

Project type	PPIC	CPUC	Pacific Institute
Recycling	\$856 – \$3,323	\$424 – \$6,206	\$606 – \$2,425
Stormwater	\$615 – \$7,714	-	\$254 – \$1,433
Ocean desalination	\$2,389 – \$2,593	\$2,533 – \$5,457	\$2,095 – \$4,520
Brackish water desalination	\$678 – \$900	-	\$926 – \$1,874

SOURCE: PPIC estimates: Data Sources section and Table B1 in this appendix; CPUC estimates: California Public Utilities Commission (2016); Pacific Institute estimates: Cooley and Phurisamban (2016).

NOTE: All units are in annual dollars per acre-foot of water supplied (in 2018 dollars). PPIC estimates show the range between the 25th and 75th percentile, while the CPUC range indicates the minimum and maximum values. The Pacific Institute study breaks down each category in "small" and "large" projects, so the figures presented here include the range from the 25th percentile of the large projects (minimum) to the 75th percentile of the small projects (maximum).

Considerations and caveats

Several considerations could affect our cost estimates. First, we calculated costs for capital expenditures and O&M using the numbers provided in grant applications submitted to the state. However, they may vary from the final cost of completed projects. Similarly, changes in electricity costs may result in fluctuations in the O&M costs, particularly for desalination and recycled water projects, which have high energy use for filtration and purification processes. Changes in interest rates may also affect annual costs (here, we used 3.5% to annualize costs). Lastly, more efficient practices in the future might lower the operations and maintenance costs, and potentially extend the life of these investments, affecting assumptions shown in Table B2.

Below we provide some additional caveats specific to each project category that are important to consider in evaluating our findings.

Recycled water. In some cases, it is challenging to pinpoint how much new water supply is created as a result of multi-faceted water recycling projects. For example, some expansion projects' costs also include infrastructure needed to deliver the additional recycled water supply, such as pumps and pipelines. Also, while pipeline projects do not directly result in additional supplies, their construction is critical for the robustness of recycled water infrastructure and the expansion of the customer base for recycled water.

Furthermore, the cost of recycled water could vary depending on the end-use of the water. For landscape irrigation, recycling to a non-potable water standard may be sufficient and cheaper than recycling for potable use in households.

Also important to consider are potential additional benefits or costs that arise from flow reductions to effluent-supported waterways. For example, treated wastewater is critical to the flow of the Los Angeles River, so diverting these flows for recycling purposes could have consequences for ecosystems and recreational uses (Chappelle et al. 2019).

Stormwater. The total cost of stormwater projects analyzed in this report demonstrates clear economies of scale, but other issues need to be considered. Large-scale projects usually have water supply augmentation as their main objective, while smaller projects often have other primary objectives. For instance, a primary purpose of many stormwater projects is to improve water quality, especially in regions close to water bodies like creeks, rivers and lakes, and coastlines. Some of these projects may also help reduce flood risks or serve as green spaces. Such benefits might be larger than the water supply benefit in small-scale projects (Diringer et al. 2020). If funding can be obtained—for instance through Los Angeles County's Measure W—these broader benefits could justify the incremental water-supply related costs of small-scale stormwater projects that would be too expensive if water supply were the main benefit.

A potential factor in determining the cost of stormwater projects is land acquisition. In urban areas high land costs can significantly increase the cost of multi-benefit stormwater projects like green spaces and parks.[5] This is one of the reasons why many stormwater capture efforts have focused on harnessing the potential from areas already owned by public agencies—such as parks and schools.

Desalination. The principal concern for our analysis of desalination costs is the small number of projects included in the dataset. However, the results are in agreement with other recent studies, and the data demonstrate that ocean desalination is significantly more costly than brackish desalination.

Costs of Urban Conservation in Southern California

Urban water conservation and efficiency has been another area of focus in Southern California, especially since the 1987–92 drought (see main report and Technical Appendix A). Water agencies have offered financial incentives to customers, and provided public education messaging, using their own resources and state and federal grants.[6]

In this section, we present the results of two analyses, using data on recent projects and programs. First, we assess the unit cost of conservation through the analysis of individual programs obtained from public sources and the literature. Then, using data from Metropolitan Water District of Southern California (MWD) conservation programs, we assess the unit costs of the largest programs in recent years.

One important caveat is that the estimated unit costs show only the costs to the utilities. The total costs may be higher, because customers typically cover a portion of the costs of replacing fixtures or appliances or changing outdoor landscaping. Our calculations also do not include potential monetary benefits customers receive from these investments (e.g., savings on water and energy bills and landscape maintenance), or other benefits that might accrue to the environment or other parties (e.g., if switching to low-water landscapes reduces chemical-laden runoff into local water bodies).

Unit Costs from Individual Programs

We obtained unit costs from two programs that received state funding. The first, Los Angeles Department of Water and Power's Institutional Water Use Efficiency Loan Program, was funded by Proposition 1's CalConserve program. This project offers zero-interest loans to institutional customers to finance water use efficiency projects with no up-front cost, with the objective of saving 285 af annually at a total cost of $5.7 million. The estimated unit cost is $1,603/af when considering operations and maintenance costs over 20 years. The second program, Municipal Water District of Orange County's Comprehensive Landscape Water Use Efficiency Runoff Reduction Rebate Program, was funded in 2013 by the SWRCB Clean Beaches Initiative, and was forecast to save 860 af per year at a unit cost of $594/af.

Finally, we also included in this category a study about turf removal in three water agencies in Southern California. Tull et al. (2016) found that 24.6 gallons of water are saved annually per square of turf removed. At $2 paid per square foot turf removed—the rebate level recently offered by MWD—that translates into a present value

[5] From our sample of 32 projects, one project (with the highest unit cost) includes land acquisition explicitly, two projects specify they own the land, two more projects exclude the land acquisition costs explicitly, and the inclusion of the land costs in the remaining projects is unknown.
[6] Significant financial aid has come from state bonds, especially since the early 2000s (Chappelle et al. 2014, Jezdimirovic and Hanak 2017). Occasionally, rebate programs have also been supported by federal funds.

of $1,521/af saved (in 2018 dollars). Even higher levels of rebates have been common, as local agencies provided additional funds. At the $3.50/ft^2 level available in several communities including Los Angeles during the recent drought, the cost of water obtained from turf removal would be $2,701/af saved.[7]

MWD Conservation Credits Program

Water conservation and efficiency efforts are widely supported within MWD's service area. Since the early 2000s, MWD and its member agencies have invested over a billion dollars (in 2018 dollars) in conservation programs, including large sums at the height of the last drought. This included offering rebates to water users who agreed to switch to water-efficient practices and products. In addition, there has been significant investment in education, outreach, and research to encourage long-term behavioral changes.

MWD rebates have been offered for the installation of high-efficiency toilets, shower heads, clothes washers and dishwashers, turf removal or replacement, high-efficiency irrigation for outdoor landscaping, rain barrels and cisterns, as well as industrial equipment including flow regulators, ice machines, and cooling towers. Some member agencies offer additional rebates.

Unit Costs for MWD Largest Conservation Programs from 2012–19

MWD provided detailed data on expenditures and estimated water savings from all their Conservation Credit Program actions from 2012–19. This dataset includes both MWD investments and member agency investments for programs administered by MWD.[8]

From 2012 to 2019, MWD and its member agencies spent $683 million in the Conservation Credits Program—$522 million from MWD budget and $161 million from member agencies—with estimated water savings of 1.5 million af over the lifetime of the investments. Programs seeking to reduce outdoor water use—mainly on residential properties, but also on commercial, industrial. or institutional (CII) properties—represented two-thirds of the total investment. Slightly over a quarter of the investment (27%) went to rebates for residential indoor appliances, while smaller amounts were used in indoor appliances for CII buildings (4%), residential rain collection (3%), and programs for education, outreach, and research (<0.2%). Figure B3 shows the investments and water savings in these categories.

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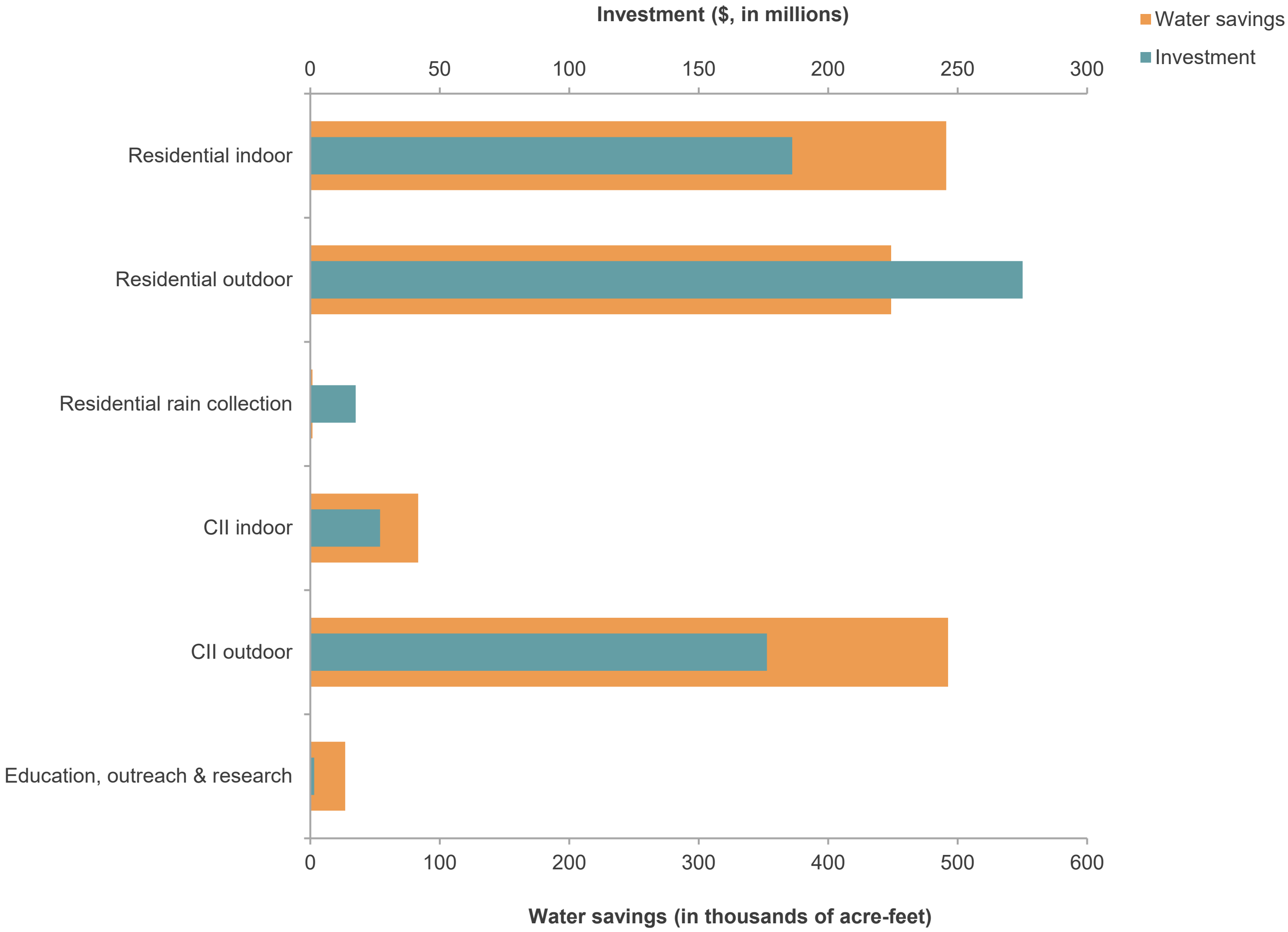
[7] Following Tull et al. (2016), these calculations assume a hyperbolic-discount rate of 5 percent over a landscape conversion lifespan of 30 years.

[8] For programs administered by MWD, MWD pays the full rebate and then gets reimbursed by the member agency for its contribution. In some cases, MWD also supports programs administered by member agencies. Our data set includes all spending in MWD-administered programs, but only the MWD spending in member agency-administered programs. For the unit costs calculations we only included the MWD-administered programs, to avoid biasing our results downward.

FIGURE B3

Outdoor programs and rebates for residential indoor fixtures and appliances represent the largest investments and water savings in MWD programs from 2012 to 2019



SOURCE: MWD Conservation Credits Program data set.

NOTE: Investments include both MWD and member agencies investments in MWD-administered programs from 2012 to 2019. Water savings are the cumulative savings over the lifetime of the investments, calculated by MWD staff.

To obtain the unit costs of the conservation programs we focused on the 10 largest programs out of the more than 60 programs included in the database. These include residential and CII turf removal, different types of high efficiency toilets and clothes washers, weather-based controllers and rotating nozzles for irrigation, and rain barrels, and they represent 92 percent of the total investment and 90 percent of the estimated water savings. The unit cost is obtained as the total investment by MWD and its member agencies, divided by the cumulative water savings over the project lifetime. The water savings are ex-ante estimates by MWD staff.[9] Table B4 shows the results of this analysis.

Three programs represent nearly 80 percent of total investments (58% for residential and CII turf removal programs, and 21% for residential high-efficiency toilets). The unit costs for indoor programs range from $397 to

[9] The details of the Metropolitan Conservation Savings Model—including savings, costs, and project lifetimes—can be found in Technical Appendix 9 of the most recent Integrated Water Resources Plan (MWD 2016).

$473/af; there is a larger dispersion in costs of outdoor programs, which range from $267/af for weather-based irrigation controllers in CII programs, to over $10,000/af for rain barrels.

TABLE B4

Unit cost and total investment for MWD's largest conservation programs (2012–19)

Indoor vs Outdoor	Program	Residential Programs	Commercial Programs
Indoor	High-efficiency toilet	$397/af *($145 million)*	$473/af *($12 million)*
	High-efficiency clothes washer	$410/af *($34 million)*	—
Outdoor	Turf removal	$662/af *($253 million)*	$454/af *($142 million)*
	Weather-based irrigation controller	$382/af *($7 million)*	$267/af *($22 million)*
	Rain barrels and cisterns	$10,482/af *($16 million)*	—

SOURCE: MWD Conservation Credits Program 2012–19 data set.

NOTE: Each cell shows the calculated cost per acre-foot and the total program investment from MWD and its member agencies, in 2018 dollars. In the original data set there were three different high-efficiency toilet programs, which we combined to ease readability.

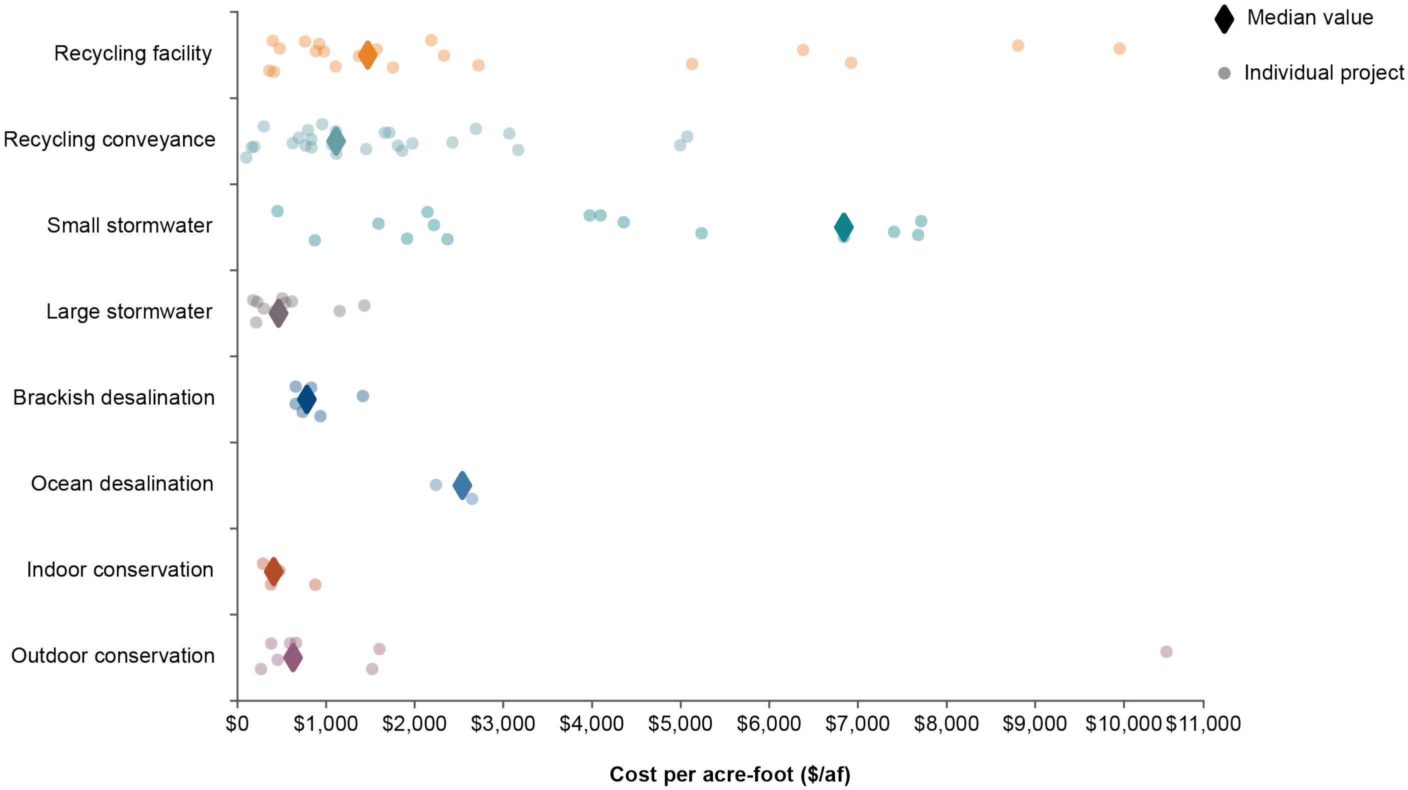
These unit costs include both MWD and member agency investments, and they come in somewhat higher than the reference point MWD uses for most of its own conservation investments ($195/af) (Metropolitan Water District of Southern California 2020). MWD takes a different approach for the more costly outdoor investments (turf replacement, rain barrel and cistern projects), aimed at larger market transformation (Metropolitan Water District of Southern California 2020). For example residential turf replacement had an estimated cost of $662/af using MWD program data (and as much as $1,521 to $2,701/af using field measurements (Tull et al. 2016)). MWD and many member agencies fund these projects to popularize voluntary turf replacement by the population at large. A recent MWD study found that for every 100 rebate-funded replacements, 13 additional replacements were made without a rebate—6 that would have happened naturally, and 7 more induced by the rebate program (MWD 2019).

Unit Costs of Alternative Water Supplies and Conservation Programs

To conclude, Figure B4 compiles all the results for the unit costs of alternative water supplies and indoor and outdoor conservation programs presented previously. Most conservation programs, large stormwater capture projects, and some recycling facilities are the most affordable supply sources in Southern California. Rain barrel rebates, small stormwater capture projects, and ocean desalination are the most expensive.

FIGURE B4

Conservation, large stormwater projects, and some recycling facilities are the most affordable supply sources



SOURCE: Author estimates.

NOTE: Points represent individual projects or programs included in each category, and the diamonds show the median cost.

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