

Where Will We Get the Water?

Assessing Southern California's Future Water Strategies



Los Angeles County Economic Development Corporation

PRELIMINARY FINDINGS

DRAFT

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REVISED AUGUST 14, 2008

This is the third in a series of reports on the region's water supply prepared by the LAEDC Consulting Practice for the Southern California Leadership Council (SCLC). The LAEDC research was sponsored by the SCLC, AECOM Water, and the Eastern Municipal Water District.

The Southern California Leadership Council is a business-led-and-sponsored public policy partnership for the Southern California region. The Council provides proactive leadership for a strong economy, a vital business environment and a better quality of life for area residents. Founded in 2005 as a voice for the region's business community and like-minded individuals to focus and combine their efforts, the Leadership Council's objective is to help enable public sector officials, policy makers and other civic leaders to address and solve public policy issues critical to the region's economic vitality and quality of life. www.laedc.org/sclc

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The LAEDC would also like to acknowledge and thank the members of the SCLC Water Committee as well as the numerous water industry experts (state and local, public and private) who have generously contributed their knowledge and insight to this report.

Assessing Southern California Water Strategies

Strategy	2025 Regional Potential (TAF*)	Typical Project Characteristics							
		Timeframe (years)	Drought-Proof (Reliability)	Risk (Project Aborted)	Enviro Opinion	GHG	Initial Cap. Cost (\$millions)	Annual Oper. Cost (\$millions)	30-yr cost Treated (\$/AF)
<i>Strategies to Replace or Augment Imported Water</i>									
Urban Water Conservation	1,100+	0-2	●	●	●	●	\$0	\$0.5	\$210
Local Stormwater Capture	150+	3-5	●	●	●	●	\$40-\$63	\$1-\$3.5	\$350+
Recycling	450+	6-10	●	●	●	●	\$480	\$30	\$1,000
Ocean Desalination	150+	6-10	●	●	●	●	\$300	\$37	\$1,000+
Groundwater Desalination	TBD	6-10	●	●	●	●	\$24	\$0.7	\$750-\$1,200
<i>Strategies to Increase Imported Water</i>									
Transfers-Ag to Urban	200+	1-5	●	●	●	●	n/a	n/a	\$700+
<i>Strategies to Increase Reliability</i>									
Inter-agency Cooperation	**	0-5	●	●	●	●	low	low	n/a
Groundwater Storage	1,500+	3-5	●	●	●	●	\$68-\$135	\$13	\$580
Surface Storage	0	10+	●	●	●	●	\$2,500+	\$7.5-\$15.5	\$760-\$1,400

*TAF-Thousand Acre-Feet

** Improves reliability and efficiency of existing supplies

Source: LAEDC

● Favorable	● Neutral	● Unfavorable
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I. INTRODUCTION

California is heading toward a water crisis. The spring of 2008 was the driest in 88 years, and rivers across the state are running dangerously low. Furthermore, mountain snowpack has been subject to increased evaporation, a condition likely to be exacerbated in future years by climate change. The disaster in New Orleans has also brought attention to the aging levees in the Sacramento-San Joaquin Delta system. An earthquake or levee breach could disrupt the intricate flow of water into and out of the Bay Area; such an event would create a water disaster in all parts of the state from the East Bay to the Mexican border.

In the face of this emergency, Governor Schwarzenegger has declared a statewide drought. His declaration has brought water to the forefront of California politics, news and public opinion. It is crucial to address California's long-deferred water issues now, while the entire state is focused on the threat to water viability. The Governor and Senator Feinstein have collaborated to produce the Safe, Clean, Reliable, Drinking Water Supply Act of 2008. This act proposes spending over \$9 billion on various strategies to increase water supply, decrease the variability of supply, restore ecosystems and promote conservation and efficient water use. Speaker Pro-Tem Perata has introduced legislation that would appropriate over \$600 million in previously authorized bond funds to restore the Delta and improve water infrastructure.

In November, Californians will face one or more ballot initiatives that would authorize funds to solve the water crisis. Approving the funds, however, is merely the starting point. The state's water needs are vast (and expensive). Yet, the budget crisis and the demands for other infrastructure improvements, education and health services, and other spending priorities mean the state will always have fewer resources to address water issues than there are worthy projects. In this context, California voters, elected officials and water policy makers must carefully select the strategies to which they will commit scarce resources. To this end, the LAEDC has produced for the Southern California Leadership Council (SCLC) a report evaluating strategies for improving Southern California's water supply based on cost-effectiveness, environmental impact and overall efficacy.

This preliminary report is a work in progress and will be updated frequently. Please check for the latest version at www.laedc.org/sclc/studies.html. The LAEDC is constantly seeking new input from water agencies and experts regarding existing and proposed water sources. To contribute information on water strategies, please contact Greg Freeman, Vice President of Economic Policy and Consulting, at greg.freeman@laedc.org, or call (213) 236-4846.

We evaluate nine water strategies. Urban water conservation, stormwater capture, recycling, ocean desalination, and groundwater desalination are viable strategies to replace or augment imported water. Transfers from agricultural users to urban users increase the volume of imported water. And inter-agency cooperation, groundwater storage, and surface storage are strategies that increase overall water system reliability, particularly during dry years.

BACKGROUND

Southern California, comprised of Los Angeles, Orange, San Bernardino, San Diego, Riverside and Ventura counties, is the 10th largest economy in the world and home to almost 22 million people. The semi-arid region's development was underpinned by imported water, which accounts for 60% of supplies overall and up to 90% in areas with limited local sources. Driven by natural increase – people already here having children – population growth is expected to add 6 million more residents, 2007 to 2030. Securing reliable water supplies for the next generation (and its successors) looms as a significant challenge.

Most of Southern California's water is imported from three sources: the Colorado River, the San Francisco Bay-Delta, and, for the City of Los Angeles, the Owens River Valley. All three sources are under pressure. A significant portion of the Colorado River Basin experienced above average rainfall and run-off this year, providing some relief from a drought that has lasted eight years. Nonetheless, water levels at the two main storage facilities on the river (Lake Mead behind the Hoover Dam and Lake Powell behind the Glen Canyon Dam) remain below half of capacity. Whether the rains marked the end of the drought or are just a blip in what could be an even longer-term dry spell remains to be seen.

Supplies from the Bay-Delta and Owens River have already been reduced by restrictions on pumping operations for the protection of endangered species and habitat restoration. Until measures to restore fisheries and a long-term solution for water exports that is compatible with fishery protection are implemented, further cuts appear unavoidable. Exports from the Delta could also be cut off completely for a year or more if a temblor or flood were to breach key earthen levees. Continued population growth in California and throughout the Southwestern U.S. will place greater demands on these sources just as climate change threatens to reduce their productivity and reliability.

Water shortages or disruptions would have far-reaching and, if prolonged, dire consequences for Southern California. The region needs to undertake an urgent program to secure sufficient, reliable water supplies for the coming decades. The solution will have to incorporate a portfolio of water strategies, since no single strategy will provide a “silver bullet” solution to the region's water needs. The price of water security will not be cheap. The rate charged by MWD for Tier II treated water (currently \$695 per acre-foot) represents the baseline cost of incremental water supplies in Southern California. Many of the water strategies evaluated in this report exceed the cost of the MWD-supplied water by hundreds of dollars per acre-foot. Since the MWD rate is expected to continue to rise substantially over the coming decade, many of the more expensive strategies will look more reasonable in the future.

METHODOLOGY

The LAEDC has evaluated nine water strategies based on their *potential* (the total average annual volume of water the strategy could add to the region's water supply available to urban water users). For each strategy, representative projects were selected and evaluated based on eight criteria: *reliability* (the ability to deliver water during dry years); *timeliness* (the number of years from project conception to the start of operations); *risk* (the probability that projects undertaken as part of a strategy will ultimately be completed and deliver or store water); *environmental friendliness* (the likely reception projects can expect based on their environmental impacts); *greenhouse gases* (the impact of the project's operations and water deliveries on the state's carbon footprint); *capital cost* (the initial cost of the strategy); *operating cost* (the ongoing annual cost of the strategy); and *30-year cost* (the all-in cost per acre-foot for water sourced from the project, including initial capital costs plus operating costs, interest payments, and, where applicable, the cost of transporting the water to Southern California).

In selecting representative water projects for each strategy, we gave preference to those that are large, already in operation, or likely to come to fruition. Some projects have little in common. Our objective has been to create an apples-to-apples comparison, particularly for the cost of the projects typical of each strategy, which we have estimated on a per acre-foot basis. Our data and calculations are based on the best available public information. Some data were unavailable and have been estimated by extrapolation. Throughout the process, we always erred on the side of understating a project's yield (amount of water supplied), therefore overstating the unit cost of its water, but we also used low estimates of the project's costs, therefore potentially understating the price of its water. These effects should be roughly offsetting in the final price of water per acre-foot.

Three numbers go into the calculation of each project's overall cost per acre-foot of treated water ready for delivery in Southern California: capital cost, operating cost, and yield. The capital cost is the initial cost of building or implementing a project. The operating cost is the yearly cost of keeping the project running. We assume the project's capital cost is funded by issuing debt, which is amortized over a 30-year period at a rate of 5.00%. The annual debt payments are added to the operating cost to determine the total cost per year. This number is then divided by the project's yield per year to determine the cost per acre-foot of water over the next 30 years. Many of the projects will have useful lives that exceed 30 years, which at first glance implies a lower cost per acre-foot once the debt has been repaid. However, most projects likely will experience rising maintenance costs after 30 years, as old capital facilities need to be repaired or replaced. To be conservative, therefore, we assume projects will face constant costs over their lifespan, and thus they will provide water at a constant price.

Two additional costs may also be included in the final price of water. Where applicable, the cost of transporting the water to Southern California has been included. For surface storage in Northern California, we used DWR's rates per acre-foot from the Delta to Castaic Lake (\$212) and Lake Perris (\$391). For non-local ag-to-urban transfers, we included MWD wheeling charges, and for groundwater recharge, we used the MWD rate for surplus (imported) replenishment water. We have also included treatment costs to make for a fair comparison with desalination projects, which produce water requiring little treatment. We used the \$155 difference between the cost MWD charges for treated and untreated water.

II. STRATEGIES TO REPLACE OR AUGMENT IMPORTED WATER

Southern California's traditional sources of imported water are under increasing pressure. Recognition of the environmental consequences of diverting water has led to court-ordered curtailment of water exports from the Bay-Delta and the Owens River. An ongoing eight-year drought in the Colorado River Basin has depleted stored supplies. Moreover, water agencies throughout the Southwest have belatedly realized the Colorado River is oversubscribed due to annual allocations that were based on the average flows during an exceptionally wet period. Continued population growth will increase the potential demand on the sources of Southern California's imported supplies. Simultaneously, climate change, and in particular the likely decrease in the winter snowpack in the Sierra Nevada Mountains that acts as a giant natural reservoir, threatens the reliability of supplies imported from Northern California. Finally, the fragility, vulnerability and unsustainability of the Delta as a transfer point for water exported to Southern California also results in reduced reliability of water necessary to sustain our economy and our lifestyle.

Faced with these challenges and constraints on imported supplies, Southern California must embark on a concerted self-help program that replaces or augments imported water with locally sourced supplies. In this section, we examine five strategies that could supplement or even offset current imports: urban water conservation, stormwater capture, recycling, ocean desalination, and groundwater desalination.

URBAN WATER CONSERVATION

Southern California needs to increase its water supplies to meet the needs of a growing population and to protect against inevitable interruptions to imported sources. Such interruptions may occur due to environmental mitigation; drought; natural disaster; and climate change. Using water more efficiently reduces demand, which has the same effect as adding water to the system. Conservation is a simple, reliable and environmentally friendly strategy that has already paid dividends within the region.

There are three primary strategies for encouraging water conservation: price increases, regulations, and rebates. Since much (indoor) water use is inherent to living in modern society, pricing has a limited effect on demand, a phenomenon for all commodities known to economists as price elasticity. Tiered pricing structures, in which the price of water increases steeply after predetermined usage thresholds, target water users who are particularly wasteful and who are in the best position to reduce their water use. Tiered pricing has shown some efficacy in curbing demand, particularly with irrigation uses, and many Southern California water agencies are exploring tiered pricing structures.

Regulatory measures include restrictions on landscaping and hosing off hard surfaces, as well as building code requirements for low-flow toilets and showers in new homes. Rebate programs reduce the price of low flow toilets, showers and other water-efficient appliances, in particular dishwashers and washing machines. Regulatory measures and rebates aimed at curbing indoor water use have helped hold water consumption at roughly the same level in the City of Los Angeles over the past 10 years, despite a growing population.

Here we focus on the City of Santa Monica, considered a regional leader in water conservation, which has enacted a water conservation effort as part of its Sustainable City Plan. The plan aims to reduce water consumption by 20% of 2001 levels by the year 2010. (As of 2008, citywide water use has fallen by 6% while the number of residents and businesses has increased.) Santa Monica's conservation program makes use of regulations and rebates, and additionally seeks to convince residents and businesses to reduce water consumption as a civic responsibility. The "20-Gallon Challenge" campaign provides residents and businesses with a list of easy ways to save water. The city offers residents free education on sustainable landscaping. Businesses, plumbers and landscapers can obtain certifications to prove they use water-efficient practices.

The city also makes conservation appealing to the wallet. Santa Monica residents and businesses can obtain rebates on high-efficiency bathroom and kitchen fixtures, laundry machines, and irrigation controls. The city will also help fund synthetic turf installment and sustainable landscaping that involves climate-appropriate plants.

While water conservation measures are currently optional, Santa Monica has also taken regulatory steps to ensure these plans are eventually adopted by everyone. By city ordinance, all transferred or sold properties must be equipped with low-flow toilets, showers and faucets. Larger fixtures in new or remodeled buildings must meet Energy Star standards. Similarly, new and remodeled landscapes must have water-efficient irrigation. Another ordinance prohibits creating waste water runoff from excessive irrigation and hosing down hardscapes. The city employs officials to patrol the city and enforce these ordinances.

Conservation alone will not solve Southern California water needs, but it is a hugely important strategy – the cheapest, easiest and most environmentally-friendly means of improving reliability. In addition to expanding existing supplies, an aggressive regional conservation effort could make negotiations with the rest of the state on other water strategies less contentious. Building support for a solution in the Bay-Delta that combines environmental restoration and secure supplies for Southern California will be easier, for example, if Southern California is seen to be treating water as a precious resource by implementing aggressive conservation strategies. Many other cities also have aggressive conservation programs, but conservation commitment is not uniform.

Potential: Urban water conservation could have an impact equivalent to adding more than 1 million acre-feet of water to the regional supply (about 25% of current annual use). Southern California has already taken significant strides with indoor conservation measures. Outdoor conservation offers the opportunity for additional savings. The amount of water conserved will depend on how many people participate, and how aggressively they conserve. Both factors will be heavily influenced by the nature and extent of water agency conservation programs. Even without the drastic measures taken in Southern Nevada – where new homes cannot install lawns in the front yard – there is enormous potential to decrease demand on the water supply in Southern California through greater water efficiency and conservation.

Individual water conservation and efficiency projects do not, by themselves, yield a lot of water (as shown below). Yet, the aggregate impact of hundreds of thousands of small projects and millions of people changing their behavior could be equivalent to adding a new source on par with (or greater than) MWD's share of water from the Colorado River.

- Running the dishwasher only when full (2.5 gallons per load)
- Washing only full loads of clothes (15-50 gallons per load)
- Replacing high-volume flushing toilets with low flow models (2-4 gallons per flush)
- Watering at night to reduce evaporation (20-25 gallons per day)
- Reducing each irrigation cycle by 1-3 minutes (20-25 gallons per day)
- Repairing leaks and broken sprinkler heads (20 gallons per day per leak)
- Replacing water-hungry lawns and gardens with climate-appropriate plants (10+ gallons per square foot per year)

Reliability: In general, reducing demand through conservation that is accomplished through technology or permanent end-use changes, vs. behavior alteration, is one of the most reliable sources of water, since the efficiency gains are not subject to interruption by drought or competing environmental restoration needs.

Timeliness: Conservation efforts can begin immediately (and are already underway throughout the region). Gains from demand reduction accumulate gradually, one water-efficient washing machine or reduced irrigation cycle at a time. In an emergency such as complete loss of imported water from the Bay-Delta following an earthquake, rationing (the most extreme form of conservation) could yield overnight gains from drastic measures such as severely curtailing outdoor water use.

Risk: Water conservation accomplished through technology change carries almost no risk. To the extent that conserved water relies on changes in behavior, the strategy’s continued success will depend on the persistence of residents in their conservation efforts. Many of the efficiency measures, such as low-flow toilets and drought-resistant landscapes, are likely to remain in place once installed. However, once conservation measures have been adopted the remaining demand is more fixed, or “hardened”, requiring remaining supplies to be highly reliable.

Environmental Considerations: Conservation is perhaps the ultimate in environmentally friendly sources of water. Individual strategies seldom require an environmental impact report. [Projects to line canals to save seepage have run into environmental obstacles as other water users (as well as the environment itself) have come to rely on seeped water. Additionally, return flow and run-off reductions often deplete “fresh” water supplies to coastal and other wetlands.] To the extent that conservation reduces the need for alternative sources of water (and the associated environmental impacts), it lessens the overall environmental cost of meeting the region’s water needs. Also, some conservation strategies are nature-friendly: replacing lawns with native plants tends to support local wildlife and requires less maintenance from gasoline-powered tools. Furthermore, conservation efforts aimed at the general public may encourage Southern Californians to adopt more sustainable lifestyles in general and improve the region’s image.

Greenhouse Gases: Transporting and purifying drinking water is energy-intensive, and sometimes requires fossil fuels. Conservation reduces the carbon footprint associated with the region’s water supply to the extent that it displaces the need for electricity from fossil fuels to produce, transport and purify imported water.

Costs: Most conservation measures are relatively inexpensive, and many are free, at least to residents. Nominally ‘free’ programs, such as reduced watering, require education and outreach efforts that will likely be paid for by water users through their utility rates. Santa Monica’s Sustainable City Plan spends \$500,000 annually on education, outreach, rebates and incentives. The City expects to continue this expenditure indefinitely to ensure the conservation methods it advocates remain habitual. Compared to any other source of water, however, such efforts are inexpensive. In fact, conservation is the most cost-effective way to alleviate California’s water problem. Table 1 shows an estimate of the cost per acre-foot of Santa Monica’s Sustainable City Plan.

Table 1 Urban Water Conservation	
Initial Capital Cost	\$0
Ongoing Operating Cost	\$500,000
Production Capacity in Acre-Feet	3,000
Estimated Cost Per Acre-Foot	\$210

Sources: LAEDC, City of Santa Monica

The Sustainable City Plan's stated goal is to reduce annual water consumption to 80% of 2000 consumption by 2010 (thus saving about 3,000 acre-feet per year based on the 14,800 acre-feet consumed in 2000). Citywide consumption would remain at this level indefinitely. To spur conservation, the city plans to spend an inflation-adjusted \$500,000 every year. Less water would be saved while the plan is being implemented, and more would be saved after the goal is reached. Thus water savings would be more expensive in the early years of the plan and less expensive after the city's goal is met. For our purposes, we have modeled these water savings over a 30-year period. We estimate that over 30 years, the average cost per acre-foot saved would be \$203.

However, Santa Monica is currently not on track to reach a 20% reduction in water use by 2010. As of 2008, the city has reduced consumption by 6% of 2000 levels (though the population has grown over that period). We believe Santa Monica may not reach its goal until 2015. If the city takes 15 years to meet its target, and consumption remains flat after that, then the average cost of water over 30 years would be \$225 per acre-foot. If the city reaches this goal in 15 years and water use declines by an additional 5% over the next 15 years, the average cost per acre-foot would drop to \$208. The additional 5% savings seems reasonable since the city will continue to spend money on conservation efforts after its goal is attained in 2015. It also reflects the declining returns to scale of such expenditures. (Early spending will target the cheapest and easiest ways to reduce consumption, so additional spending will be less effective because the best opportunities have already been realized.) Keeping all of these possibilities in mind, we estimate Santa Monica's annual water savings will cost approximately \$210 per acre-foot over 30 years.

Some homeowners can probably be encouraged to modify their yards without a subsidy. Yet, what would the cost be if Southern California agencies were to follow the lead of their counterparts in Southern Nevada and pay for turf removal? The Southern Nevada Water Authority pays local residents \$1.50 per acre-foot of turf removed. At this rate, the SNWA pays nearly \$9,000 per acre-foot of water saved per year. This may seem high, but over a 30-year period the cost amounts to \$578 per acre-foot, which is very reasonable when compared to other water strategies or MWD Tier II treated water, which is supplied to retail water agencies for \$695 per acre-foot.

This shows that even the most extreme conservation efforts can be cost competitive under the right circumstances. The cost per acre-foot of \$578 above would not apply to turf removal in Southern California – lawns in Southern Nevada use 1/3 more water than those in Southern California due to climatic differences. The potential savings from turf removal in the Inland Empire would be less than in Southern Nevada, and dramatically less along the coast. Drought-resistant landscapes in California typically use 1.0 to 1.5 acre-feet per acre every year, while lawns use 4 to 5 acre-feet per acre. If Southern Californians were paid \$1 per square foot of turf removed, this would produce water at a cost of \$945 per acre-foot over a thirty year period.

STORMWATER CAPTURE

On the rare occasions when it does rain in Southern California, it tends to pour. A winter storm can dump an inch or more of water on the region in just hours. Most of the deluge is directed into storm drains, culverts, channels and concrete-lined rivers on its way to the ocean. The volume of water rushing through the storm channels can be remarkable, even terrifying, as anyone who has seen the heroics of the LA County Fire Department's swift water rescue team can attest. That storms should generate flash floods is hardly a surprise. Yet, the volume of water flowing directly to the ocean has increased substantially over the past 100 years as urban development has covered vast swathes of Southern California with impermeable surfaces. Roads, freeways, parking lots, and buildings prevent water from soaking into the ground and thereby naturally replenishing the underlying aquifers. Furthermore, urban hard surfaces speed the flow of runoff. Urban stormwater flows in higher volume and for shorter periods than rural stormwater, which makes it more difficult to capture.

The amount of water percolating into the ground matters in Southern California. Roughly 40 percent of the region's water is sourced locally from groundwater. Growing urban development has diminished the natural rate of replenishment of the aquifers. While replenishment has been augmented from imported supplies for many years, the reduced availability of such imports suggests that we should find other ways to make up the losses to urbanization. One mitigation strategy is capturing stormwater and then allowing it to filter into the ground or injecting it directly into the aquifers. (This strategy is sometimes referred to as "water harvesting", reflecting the fact that the water is free for the taking.) Indeed, captured stormwater can replenish underground water supplies at a much higher rate than would occur naturally.

Stormwater refers to all runoff produced by rainfall events. Here we consider relatively clean runoff that can be captured and allowed to percolate into the groundwater or injected directly without the need for treatment. Unless the water is captured in one location and sent underground in another (which may incur transportation costs), the water is free. Some urban runoff is sufficiently contaminated that it would require treatment before being delivered underground. This water can be dealt with in two ways. A method called "first flush" involves diverting an initial portion of rainfall into normal runoff channels to the ocean; this first water carries off most of the contaminants from streets and other dirty surfaces. After these contaminants have been flushed away, subsequent runoff is diverted to ponds for percolation. Alternatively, all stormwater can be treated and stored, including the "first flush" water. Reducing the flow of contaminated runoff that reaches the ocean would have obvious environmental benefits. Treating the water puts the stormwater in the same category as wastewater for our analytical purposes (though we realize they are subject to different regulations). To keep our comparisons consistent, we consider treated stormwater under the strategy of water recycling.

Stormwater capture is an attractive water strategy for Southern California because every acre-foot of water sourced locally reduces the need to import water from outside the region.

Potential: Hundreds of thousands of acre-feet. Individual groundwater recharge projects vary in potential based on local hydrology and scale. Small projects may take the form of low-

impact best management practices that capture runoff from a specific development site. Large projects are designed to capture up to 40,000 acre-feet of water per year. Sample projects include the Inland Empire Utility Agency's water recharge project that will capture 15,000 to 20,000 acre-feet per year and the Coachella Valley Water District's project in La Quinta that will capture 40,000 acre-feet per year via 39 recharge basins on 165 acres.

Reliability: Stormwater capture is only as reliable as the rains, which makes for considerable short-term variability. Climate change could increase the variability. As long as there is at least some rain, however, these projects should be successful. Stormwater capture should increase the overall reliability of the water system by adding another (local) source of supply, thereby lessening the region's reliance on imported supplies. In addition, water does not evaporate while it is being stored, in contrast with surface storage.

Timeliness: The key challenge for a regional stormwater capture project is finding a suitable site and conducting the environmental review. Some projects are already underway; new projects would probably require 3 to 5 years to implement.

Risk: There is minimal risk to completion for stormwater capture projects. Small, local stormwater projects require little infrastructure to send stormwater into the ground, but large projects may require significant infrastructure to collect and convey the water to appropriate recharge areas. Additionally, there may be difficulties if diverting "in-stream" water requires diversion rights. Such rights for groundwater recharge are rare in California. (Typically, diversion rights are reserved for consumption and irrigation purposes.)

Environmental Considerations: Even an aggressive stormwater capture program would divert only a portion of the runoff to aquifers (at least some of the lost water would have ended up underground but for the hundreds of square miles of impermeable surfaces related to urban development). Current projects that capture runoff in the mountains and direct it to high-percolation areas have minimal adverse environmental impact. In fact, projects such as the spreading grounds preserved by the Pomona Valley Protective Association have operated successfully for almost a century. Going forward in urbanized areas, there is an opportunity to improve the environment by removing contaminants from urban stormwater runoff. Water flowing off city streets collects everything from trash to motor oil and metals (from the roads) to sewage spills. This water would have to be cleaned before being directed underground. Keeping contaminated water from flowing into the ocean should be a net positive for the environment.

Greenhouse Gases: Transporting and purifying drinking water is energy intensive, and sometimes requires fossil fuels. Capturing stormwater locally reduces the carbon footprint associated with the region's water supply to the extent that it displaces a portion of the need for electricity from fossil fuels to produce, transport and purify additional imported water. However, if the stormwater requires treatment prior to recharge, the greenhouse gas benefit may be reduced.

Costs: A stormwater capture project incurs large initial costs. First, a suitable aquifer must be found. Then, its boundaries must be established to protect against contamination; exclusive rights to the groundwater must be obtained; and the pumps, pipes and other

facilities necessary to efficiently use the water must be installed. After the facility is constructed, the operating costs vary depending on the type of facility. Maintenance costs are often low because gravity feeds excess water into the ground until it is needed, whereupon it is simply pumped out again. Costs may be higher at some facilities; for example, a spreading basin can require significant maintenance to optimize the permeability of the soil.

Table 2 Stormwater Capture	
Initial Capital Cost	\$40-63 million
Ongoing Operating Cost	\$1-3.5 million
Production Capacity in Acre-Foot	17,500-40,000
Estimated Cost Per Acre-Foot	\$350+

Sources: LAEDC; Inland Empire Utility Agencies; Coachella Valley Water District

We estimated the cost of stormwater in Table 2 based on projects planned and operated by the Inland Empire Utility Agencies (IEUA) and the Coachella Valley Water District. These numbers are site-specific; individual project costs will vary widely based on local hydrology. Stormwater from these facilities typically costs from \$300 to \$400 per acre-foot, which includes \$155 per acre-foot in treatment costs. The rest covers interest on capital costs plus the cost of the pumps that extract the water for use.

Stormwater sites in Southern California have been in operation for many decades (such as Grant Ponds in the Eastern Municipal Water District). In these cases capital costs are no longer an issue. We have selected stormwater capture projects that are large and new to illustrate the incremental cost of additional capacity. Smaller projects that can be incorporated into new developments may end up being more common. (For example, impermeable parking lots may be designed with plant beds instead of concrete dividers. The asphalt could be sloped to channel runoff into these islands, which would allow water to percolate locally. Permeable paving, which allows water to pass through into the soil instead of running off, is increasing significantly in use. Stormwater retention basins could be incorporated into urban landscapes as is common in other arid states.)

RECYCLING

Southern California, an area with limited local water supplies to meet the needs of a growing population, consistently sends small rivers of comparatively fresh water into the ocean in the form of treated wastewater. The wastewater could be cleaned up to the same standards as drinking water and returned to the local water supply. Recycled water is fully regulated under Title 22 of the California Code of Regulations, the same title that regulates drinking water standards. Yet, many people are put off by a process that has been described by detractors as “toilet to tap”. Thus, water recycling has been largely confined to reclamation for non-potable uses such as landscape irrigation. Attitudes are changing, however. Southern California water agencies have developed several recycling projects with the intent of tapping the large, reliable, local source offered by treated wastewater.

The “ick” factor is one of the biggest obstacles to greater investment in recycling wastewater. Many Southern Californians seem to imagine that their drinking water is transported directly from some pristine source (snow or rain, or perhaps an underground spring) to a water treatment facility and then on to their homes. This is true for some, but not all, of the region’s water. The Colorado River is one of the main sources of water in Southern California, and it contains a lot of heavily treated wastewater from cities upstream. (In this context, what happens in Las Vegas doesn’t stay in Las Vegas; water drawn from the Colorado River is used in Las Vegas, collected as wastewater, treated and then discharged into the Colorado River from which it is then re-diverted for reuse in California.)

The presence of treated wastewater in the water supply should not be cause for alarm. Recycled water is monitored at the recycling treatment plant, at the recharge basin, and in the groundwater before it is withdrawn for further treatment to ensure that it meets state and national standards for drinking water. There are several processes that could be used to produce recycled water. For example, at a plant in Orange County the water is cleaned in four stages including microfiltration, reverse osmosis, ultraviolet light, and oxidation. This process is so effective that the West Basin Municipal Water District has been selling the recycled water to customers who need ultra-pure water.

Given the advanced treatment processes available, the shift to viewing wastewater as something too valuable to be thrown away is long overdue; the astronauts on the international space station have been drinking recycled water for years. In Southern California, there is more separation between the source and re-use; most recycling projects use the water to recharge underground storage, where it is filtered through sand, gravel and clay before returning to the regional supply. Some Southern California water agencies avoid the issue entirely by sending recycled water into a separate system for outdoor use, primarily for irrigation.

A key advantage of recycled water is its reliability; recycled water is drought-proof because the wastewater treatment facilities produce a steady supply of water even in dry years. In addition, the recycled water is a local source, which lessens reliance on imported water from the Colorado River and the Bay-Delta. One limitation is created by the dissolved salts in recycled water. To reduce the salt content, recycled water typically has to be used in conjunction with a desalting operation or blended with captured stormwater or imported water.

Potential: The *Southern California Comprehensive Water Reclamation and Reuse Study* identifies more than 30 recycling projects in Los Angeles, Orange County, San Diego and the Inland Empire with the potential of yielding more than 450,000 acre-feet of water within five years. There is a lot of variation in size among the projects.

Reliability: Recycled water is among the most reliable sources of water since the source (treated wastewater) flows consistently, even in dry years.

Timeliness: Allowing for planning and the environmental review, projects can be developed in 6 to 10 years.

Risk: The risk to recycling projects comes from public opposition. San Diego built a water recycling facility, but had to release the water into the ocean after local voters rejected “toilet to tap” following an ill-informed and irresponsible scare campaign in the local media.

Environmental Considerations: Water must be removed from the environment for human consumption. Any method of removing it involves at least the possibility of environmental damage through habitat destruction and fossil fuel combustion. Reusing water reduces the need to remove more water from the environment. While the recycling process requires some use of energy, its incremental impact is far less than that of most other strategies.

Greenhouse Gases: All water is treated before use and the treatment process requires power; any increase in water use will require more electricity. If the electricity is sourced from fossil fuels, the state’s carbon footprint will be impacted. Transporting water also uses a lot of electricity, in particular for the pumps used to lift water over mountains. Locally sourced recycled water does not have to be transported as far as imported supplies. If recycled water is used, the carbon footprint of the region’s water supply will be affected by treating recycled water, but by less than with avoided imports. The region’s carbon footprint could conceivably fall if recycled water displaces some of the current imports.

Costs: Water recycling projects require a significant amount of initial capital because expensive treatment and distribution facilities must be constructed and winter storage is required to fully utilize available wastewater. The operating costs pay for the various stages of treating water as it passes through the facility. Orange County made headlines recently with its new water recycling plant, investing \$480 million to produce 72,000 acre-feet of water per year.

Table 3 Water Recycling	
Initial Capital Cost	\$480 million
Ongoing Operating Cost	\$30 million
Production Capacity in Acre-Feet	72,000
Estimated Cost Per Acre-Foot	\$1,000

Sources: LAEDC; Orange County Water District

We estimate the all-in cost of water from the OCWD plant at \$1,000 per acre-foot, including capital and operating costs (before recharging underground storage) and treatment (after the water is pumped back up to the surface). For comparison, the Eastern Municipal Water District has a smaller recycling operation that produces 13,700 acre-feet per year. The water is diverted to a separate system for outdoor use at a cost of about \$350 per acre-foot. The cost is lower in part because it is not treated to drinking standards. The EMWD's recycled water is also cheaper because their facility only cost \$49 million to build, a tenth of the OCWD's capital cost, while it produces a fifth of the water that the OCWD plant produces. Moreover, the EMWD's price per acre-foot does not reflect the fact that their recycled water would not be available without the concurrent operation of a groundwater desalter at considerable cost.

OCEAN DESALINATION

For decades, the desalination of ocean water has been the holy grail of water supply. So much water, so tantalizingly close! Desalination promises an extremely reliable (drought-proof) water supply that is limited only by the cost of removing the salt and the energy required to do so. The price of desalination has been falling with technological advances, particularly improvements to the semi-permeable membranes used in the reverse osmosis process. Nonetheless, the cost remains high at an estimated \$1,000 per acre-foot before subsidies.

Desalination plants require large amounts of electricity. For most plants, power is used to force seawater at high pressure through membranes to separate salts from fresh water. Desalination plants often co-locate with power plants along the coast for easy access to electricity and seawater. Clearly, desalination makes the most sense when power and seawater are plentiful and fresh water is scarce. For this reason, most existing desalination plants are in the Middle East, where fossil fuels are cheap. Nuclear aircraft carriers and submarines also utilize desalination technology because nuclear reactors produce abundant energy.

As demand for fresh water rises and technology improves, desalination could become a more attractive option. One remaining barrier is price, since desalination is currently one of the most expensive strategies for augmenting the water supply. Rising energy costs could counteract any potential savings from more efficient technology. A second barrier to desalination implementation is plant siting. Poseidon Inc. has been attempting to build a plant in Carlsbad for over seven years and still has not received all regulatory permits for construction.

Potential: MWD, which offers subsidies for water produced by desalination plants, estimates the regional potential for such facilities to be 150,000 acre-feet per year. The proposed Poseidon project in Carlsbad will deliver 56,000 acre-feet per year. The plant has obtained many, but not all, of the requisite state permits (it still lacks a coastal permit).

Reliability: Ocean desalination is the ultimate drought-proof source. At a sufficiently high price (and with an adequate source of power), desalination can provide almost limitless supplies of water, on demand.

Timeliness: 6-10 years, based on the experience of Poseidon with its proposed Carlsbad plant in San Diego County.

Risk: High, due to the difficulty of finding a suitable location for the plant, high energy demand, environmental opposition, potential problems with water intake and brine disposal, and the relatively high cost of the resulting water.

Environmental Considerations: Ocean desalination plants need to be located near the ocean, which limits the potential sites due to NIMBY objections from coastal property owners. Some environmental groups object to the large seawater intake facilities of desalination plants due to concerns about aquatic life being taken in along with the seawater. This may prevent the co-location of desalination plants with power plants, as the latter also take in a

large amount of seawater. Co-location would otherwise be an attractive strategy, as a power plant would provide a desalination plant with electricity and warm seawater with which to dilute brine, the desalination plant's byproduct. The brine is much saltier than ocean water, and some environmental groups claim the impact of the brine is detrimental, or at the very least unknown.

Greenhouse Gases: Desalination is an energy-intensive process. If the energy is supplied by a fossil-fuel powered source, then desalination could be a significant source of greenhouse gas emissions. This impact can be mitigated or avoided. A desalination plant in Western Australia, for example, draws most of its power from wind turbines.

Costs: Desalination facilities are expensive to build, and they must be located near a large source of salty water like the ocean. A large amount of energy is required in the reverse osmosis process to push salty water at high pressure through a membrane. Because of this, desalination plants will not be economically viable without subsidies unless the price of competing sources go up. However, if the price of alternative water sources rises sufficiently (or sufficient subsidies are available), then desalination offers an essentially limitless and extremely reliable supply of water.

Table 4 Ocean Desalination	
Initial Capital Cost	\$300 million
Ongoing Operating Cost	\$37 million
Production Capacity in Acre-Feet	56,000
Estimated Cost Per Acre-Foot	\$1,000+

Sources: LAEDC; Poseidon

The data in Table 4 are from Poseidon Resources, a company that is completing the permit process to construct and operate a desalination plant in Carlsbad. Poseidon hopes to take advantage of a \$250 per acre-foot subsidy from MWD, which would allow them to sell water to various agencies at approximately \$800 per acre-foot. Desalination plants purify water, so unlike other water sources, no additional water treatment (nor associated cost) is required.

One risk that could significantly increase the estimated cost per acre-foot is the amount of water actually delivered. Over half the revenue generated per acre-foot will be used to amortize the debt incurred in constructing the \$300 million plant. If the plant operates significantly below capacity, the debt payments will be spread over fewer acre-feet, so the price per acre-foot will rise. This is a real concern—Poseidon developed a plant in Florida that has consistently produced less water than its forecast production capacity.

GROUNDWATER DESALINATION

Ocean desalination is not an option for inland water districts if water cannot be pumped from the coast. However, inland areas can also take advantage of desalination technology by tapping brackish groundwater. The primary difference between seawater and brackish water is the concentration of salt in the water that is being purified. There is less salt to remove from brackish groundwater so it uses less energy in the reverse osmosis process. However, brackish bodies of water are relatively small compared to the endless supply of ocean water.

Potential: The regional potential is yet to be determined. Desalination can be used to tap otherwise unusable groundwater (as in San Diego County); it can be used to remove salts added from agricultural operations (as in the Inland Empire Utility Agency); and it can be used in conjunction with recycled water recharge of underground aquifers (as in IEUA and EMWD). Brine disposal is the limiting factor for groundwater desalination projects in the region. Without effective brine mitigation strategies, inland desalination plants cannot be built. Examples of waste stream management methods include building a “brine line” to the ocean, zero liquid discharge, and deep aquifer injection.

Reliability: High.

Timeliness: 3-5 years, to allow plenty of time for an environmental review.

Risk: Moderate, based solely on the high cost of building and operating these facilities.

Environmental Considerations: Groundwater desalination appears to be below the radar of most environmental organizations.

Greenhouse Gases: The desalination of brackish groundwater requires less energy than ocean desalination since the incoming water is not as salty. This type of process will therefore contribute less greenhouse gas emissions than an ocean desalination facility drawing power from the same source. Even if the groundwater desalter is powered by energy from fossil fuels, it will have a smaller carbon footprint than water imported from Northern California.

Costs: High. The costs in Table 5 are based on the existing Menifee Desalter in Riverside County.

Table 5 Groundwater Desalination	
Initial Capital Cost	\$24 million
Ongoing Operating Cost	\$700,000
Production Capacity in Acre-Feet	2,500
Estimated Cost Per Acre-Foot	\$750-\$1,200

Sources: LAEDC; Eastern Municipal Water District

The EMWD desalter represents the high end of costs for groundwater desalination. The facility itself operates at normal cost levels, but since it is located in the Inland Empire it must pump salty brine all the way to the ocean for disposal. First, EMWD sends the brine to Orange County via a 63-mile series of “brine line” pipes. Then the brine is ‘treated’ (diluted with treated wastewater) at the wastewater treatment plant and discharged to the ocean. The cost of brine line, when added to the initial capital costs of the desalter, adds considerably to the cost per acre-foot. Charges for the disposal of the brine accounted for \$310,000 of the \$693,000 in annual operating costs. The large costs incurred by EMWD illustrate the importance of brine disposal for all groundwater desalination projects.

EMWD’s desalter may also be a high cost example because the water being desalted is saltier than other brackish water in the region. The Menifee plant reduces dissolved salts from 2,000 parts per million to 330 parts per million. Other facilities in the region start with water that may have a concentration of salts of 800 to 900 parts per million or less. Saltier water can require different membranes and higher pressure, both of which add to the cost.

Finally, the costs in Table 5 are based on actual production (which varies from roughly 1,500 acre-feet per year to 3,360 acre-feet per year), not theoretical capacity. We estimate the facility produces 2,500 acre-feet on average. If the facility operated closer to maximum capacity, the final cost per acre-foot would drop significantly.

The cost per acre-foot in Table 5 represents the final cost of water delivered to the distribution system. Water from the desalter comes out at drinking standards, so we have not added a treatment cost to the water.

As mentioned above, the EMWD desalter’s brine line adds considerably to the cost per acre-foot of its water. In comparison, the Richard A. Reynolds Groundwater Desalination Facility in Chula Vista, San Diego County operates very close to the ocean. According to the Sweetwater Authority, the plant, which has a maximum capacity of 3,500 acre-feet per year, produces water at a cost of \$750 per acre-foot. This cost includes capital costs (\$430 per acre-foot) and operating costs (\$320 per acre-foot). [The cost to the Authority is actually \$540 per acre-foot, as MWD subsidizes the water at a rate of \$210 per acre-foot.]

Another example of a groundwater desalination facility near the ocean is the desalter in Oxnard, Ventura County. This facility will collect groundwater from agricultural areas in the Oxnard plain and deliver the treated water to the City of Oxnard’s distribution system. This plant is still under construction and should begin producing water in September 2008. Under ideal conditions, the plant will produce about 5,600 acre-feet per year at a cost of \$634 per acre-foot. The cost could be higher if the facility does not produce at full capacity.

III. STRATEGIES TO INCREASE IMPORTED WATER

To meet the needs of its growing population, Southern California will need more water. Since importing water worked so well in the past, it is natural to consider a similar approach to meet future demand. There are three possibilities for imports: develop new sources; draw more water from existing sources; and seek transfers from agricultural users in other regions. Only the last possibility is feasible.

Developing new sources of imported water is controversial.

- The first limitation is financial. The existing water infrastructure – the canals, aqueducts, pumps, dams, reservoirs and hydroelectric plants that make it possible to transport water hundreds of miles across the state – was enormously expensive, even before the hidden costs of environmental mitigation are taken into account. Building a new aqueduct to connect Southern California with a source over two hundred miles away would cost billions of dollars. (For comparison, the San Diego County Water Authority explored the possibility of building a new aqueduct to import water from the Imperial Irrigation District, but found the projected \$2 billion cost prohibitive.)
- The second limitation on new sources is environmental. California's water infrastructure was designed and largely built in an era before environmental impact reports. The existing water export operations have been the subject of decades of litigation. Environmentalists have successfully persuaded the courts to curtail exports from the Owens River (for habitat restoration) and from the Bay-Delta (to protect endangered species). Any significant new water diversion or storage project would be subject to a vigorous CEQA challenge. Even if it were ultimately approved, which is far from certain, lawsuits would delay the project for years.

Drawing more water from existing sources is another non-starter.

- The Colorado River is in the midst of a multi-year drought, and the main reservoirs on the river are below 50% of capacity. Worse, the eventual end of the drought may not bring much relief. California's annual allotment of Colorado River water is 4.4 million acre-feet, all of which is already allocated. Indeed, California has had to cut back in recent years to remain within its allotment, which it had routinely exceeded. Because the historical division of water among the Colorado River Basin states was based on flows during an unusually wet period, the total allocation of water (plus treaty obligations to Mexico) appears to exceed the long-term average flow. Some states' annual allotments have gone unused, but no longer. For example, increased water demand based on population growth is driving Utah to spend \$500 million for a 158-mile pipeline to claim its share of Colorado River water.

- The Bay-Delta is in crisis. The area's current mix of urban development, agriculture, and water exports is not environmentally sustainable. Pumping water from the Delta has been curtailed to protect endangered species of fish, pending the development of a long-term habitat restoration strategy. There is no practical possibility of increased water deliveries from the Delta. Rather, Southern California's priority should be the implementation of a long-term fix that both protects the Delta as an ecosystem and tidal estuary and maintains exports as close to the pre-curtailed levels as is sustainable. [Quite apart from the environmental considerations, it is probably not in Southern California's interest to increase dependence on a water source that could be disrupted for a year or more if an earthquake or flood were to destroy levees in the Delta.]
- The City of Los Angeles imports water from the Owens River via two aqueducts. Because of necessary environmental mitigation, there is no possibility of increasing the amount of water imported from the Owens River. On the contrary, the LADWP has had to reduce its imports under a court order requiring that water be provided for environmental mitigation (around Mono Lake) and habitat restoration (restoring flows along part of the Owens River).

To increase water imports, therefore, Southern California will have to seek transfers via the existing infrastructure from other existing users outside of the region. In practice, this means negotiating with agricultural users, who account for 75% of the state's developed water supply.

The subject of water transfers from agricultural users requires a light touch and considerable diplomacy. Signs in the San Joaquin Valley remind urbanites passing through on the freeway that "Food Grows Where Water Flows." Rhetorical flourishes aside, there is no danger that urban users will "steal" agricultural water. Many irrigation districts have senior water rights, including priority claims on Colorado River water as well as water delivered under long-term contracts through the federal Central Valley Project and/or the State Water Project. Their water rights are firmly backed by state and federal law. The underlying fear of a functioning water market is that farmers, who pay hundreds of dollars per acre-foot less than urban water agencies, will be outbid for the water, thus jeopardizing not only farm economics but the nation's supplies of food and fiber.

Agriculture is an important economic engine in California and water should not be transferred if it would imperil the industry or the nation's food security. On the margins, however, there is scope for beneficial water transfers, particularly when the agricultural water is being used for low-value, water-intensive crops such as hay and alfalfa. And just a few transfers could make an enormous difference for urban water supplies. Shifting just 5% of the state's water use from agricultural to urban users would increase the amount of urban water available by 25%—and would enhance agricultural area economies, if properly priced and managed.

TRANSFERS FROM AGRICULTURAL TO URBAN USERS

There are three strategies for freeing up water for transfer from agricultural to urban users: groundwater substitution; crop substitution (or, in rare instances, fallowing); and agricultural conservation.

In transfers based on groundwater substitution, an agricultural user sells his right to divert and use surface water to an urban user and makes up the difference by pumping more locally sourced groundwater. Farmers continue to use the same amount of water as before. Such transfers, based on the farmer's ability to temporarily switch to the use of groundwater, are very effective in meeting urban demand caused by drought or other short-term supply interruptions. Whether such transfers are sustainable depends on the local water basins in the agricultural area. If the substitution groundwater is extracted faster than it is replenished (a practice known as water mining), then it will eventually be depleted. Water-mining projects are unlikely to be approved as state law prohibits exports from overdrafted basins. In many cases, the aquifer will either recharge naturally during winter periods when water is in surplus, or the groundwater can be artificially recharged through spreading surface water in settling basins or by direct injection. The practice of using rights to surface water and extraction of local groundwater alternatively based on weather, hydrology and market forces is often called "conjunctive use".

In transfers based on crop shifting, agricultural users free up water by changing their crop mix to substitute low-water-use plants for more water-intensive crops. For example, a farmer might substitute winter wheat for rice in a particular year and transfer the difference in water use to an urban use. In some situations, farmers might even choose to take marginally productive land out of production in a year where the value of water was high enough to make that a prudent economic decision. This can only work for specific crops; while annual row crops can be fallowed, permanent crops such as fruit trees need uninterrupted water throughout the year. Fallowing can hurt the local economy if it reduces demand for goods and services from the businesses that supply the farmers. This makes long-term transfers based on idling farmland particularly unpopular. MWD has pursued a strategy based on short-term fallowing as a form of drought protection. MWD makes annual payments to farmers along the Colorado River who continue to farm as usual. In exchange, the farmers agree to leave a specified portion of their fields fallow and transfer their right to divert and use Colorado River water to MWD during dry years. The combination of normal cropping patterns punctuated by reduced planting in dry years and predictable payments for the urban call on surface rights improves the position of both parties. Farmers are compensated for managing their water use on a variable basis, while urban users get augmented reliability of supply at a predictable price.

Transfers based on agricultural conservation also seem to offer advantages for both parties. Farmers can free up water by using water more efficiently, often through capital investment or improved agricultural practices. The disparity between urban and agricultural prices for water suggests it might be worthwhile for urban users to subsidize the cost of water-saving devices, like drip irrigation systems, that might not otherwise be a cost-effective choice for farmers. Only reductions in consumptive use are allowable as transfers. Permanent changes are usually required to create a transferrable supply, which is generally only temporarily needed. Thus they are fairly rare.

Potential: Probably less than 500,000 acre-feet per year. Meeting even this modest target will require overcoming rural doubts about urban ‘water grabs’. Climate change might make the certainty of payments for water transfers more attractive, or it might make rural areas more inclined to retain their water ‘just in case’. Rapid urban development in the San Joaquin Valley could alter the water calculus, particularly if new residents decide they’d prefer to keep the water for regional development—as seems to be the case already among Sacramento Valley residents north of the Delta. Based on current transfer agreements, individual projects may supply 25,000-110,000 acre-feet per year.

Reliability: Moderate. The water is subject to the same risks as current imported supplies (such as climate change, drought, environmental considerations and conveyance limitations), but in most cases the irrigation districts have priority water rights, meaning that their senior rights to the water will be the last ones cut.

Timeliness: 1 year with short-term, one-year agreements. Up to 5 years for long-term agreements, mostly to allow for protracted negotiations, an environmental review and court challenges.

Risk: Moderate. The risk is less about completing the project than about securing a mutually beneficial agreement between a willing seller and a willing buyer. However, recent agreements for transfers from the Sacramento Valley have been subject to environmental litigation.

Environmental Considerations: Water transfers from rural to urban areas can have unintended consequences for the environment. One of the key sticking points in the transfer agreement between the San Diego County Water Authority and the Imperial Irrigation District was the fate of the Salton Sea. This inland water body, which is sustained only by the runoff from farm irrigation, is an important habitat for migratory birds. Conserving water for transfer to San Diego would necessarily mean less water draining into the Salton Sea as tailwater from surrounding agricultural irrigation. Similarly, significant water transfers from the northern Sacramento Valley could mean reduced habitat for a variety of endangered species (not to mention the uncertainty of conveying the water through the Delta). Each transfer, therefore, requires a careful evaluation and mitigation of its environmental impacts.

Greenhouse Gases: Higher. Greenhouse gas emissions will be the same as those generated by the energy-intensive transport of current imports. All else equal, increasing imports will add to the state’s carbon footprint. The amount of greenhouse gas emissions will depend on where the agricultural water is transferred from. For example, transporting water from the Central Valley will have a larger carbon footprint than transporting water from areas east of LA (which use Colorado River water). Transferring imported water from agricultural users within the region would have no or little net impact on emissions since the water is already being transported to the region. The transfer of locally sourced groundwater, on the other hand, would increase emissions to the extent that power is needed to move the water to urban users. However, some transfers (those which result in reduced agricultural production) could produce some carbon offset on the farm.

Costs: IID agreed to sell SDCWA water for \$300 per acre-foot.

Table 6 Water Transfers from Agriculture to Urban	
Initial Capital Cost	n/a
Ongoing Operating Cost	n/a
Production Capacity in Acre-Feet	25,000-200,000
Estimated Cost Per Acre-Foot	\$700+

Source: LAEDC; SDCWA

Water from the SDCWA-IID deal is transported to San Diego via existing MWD infrastructure. (MWD wheeling charges bring SDCWA's cost for the water up to \$578 per acre-foot.) Since the water is paid for on an ongoing basis, there are no additional debt-service charges. Treatment costs add \$155 per acre-foot.

Water treatment and transportation costs compose more than half of the final price per acre-foot, and the rest reflects the cost of convincing farmers to sell some of their water. Treatment and transportation costs are fixed, so the farmers' variable willingness to sell will determine the final price of transferred water. They may demand a high premium for their water rights; this is understandable, as their livelihoods depend on water.

IV. STRATEGIES TO INCREASE WATER SYSTEM RELIABILITY

Southern California's water agencies have a long and distinguished history of consistently meeting the region's water needs. Delivering reliable water supplies in the future will be harder – and more expensive – than it has been in the past. The problem is not solely a lack of water, though the twin needs of habitat restoration and endangered species protection will constrain import volumes. Rather, population growth ensures demand will be steady or rising, even with conservation efforts, while the water supply is more consistently constrained and always variable. The amount of water available varies seasonally (wet winters followed by dry summers) and annually. Water system operators smooth out this variability by storing enough surplus water in the winter and wet years to last through the summer and periodic droughts. They rely on a portfolio approach to supplies (on the theory that sufficiently diverse sources are unlikely simultaneously to experience a shortfall) and abundant storage.

Climate change may increase the seasonal and annual variability. And the region's growing population dilutes the protection offered by current storage facilities, because there will be less water available per capita (when the storage is full) to draw on during supply shocks. Moreover, the expected decline in snowfall in California mountain ranges, particularly the Sierra Nevadas, will reduce storage outside Southern California. Mountain snowpack acts as a vast reservoir that conveniently stores water in the winter, when it is abundant, and releases it in the summer, when it is needed most. If more precipitation falls as rain instead of snow, the storage capacity of this natural reservoir will be diminished.

To maintain water system reliability in the face of these challenges, therefore, water agencies will need to maximize their ability to store water when it is available. Three strategies for doing so are inter-agency cooperation (which has many of the same effects as increased storage), groundwater storage, and surface storage.

INTER-AGENCY COOPERATION

There are 26 member agencies of the Metropolitan Water District, each dedicated to providing secure, reliable water supplies within its service territory. Relying on these member agencies, roughly 300 retail water purveyors (water districts, investor-owned water utilities, and city water departments) actually serve water to homes and businesses throughout the region. These entities have undertaken a variety of projects that add water, such as desalination (primarily of brackish groundwater), recycling, stormwater capture, and urban water conservation.

In principle, locally sourced water helps everyone in Southern California since it reduces the pressure to increase imports. In times of shortage, drought-proof local supplies provide more scope for sharing cuts in imported water across the region. In practice, the benefits from local projects remain local, making them less likely to attract funding because potential beneficiaries and coalition partners outside the area are unable to participate.

With the exception of imported water, the various strategies discussed in this report provide benefits that are artificially limited to the service territory of the participating entity. And need, storage and cost-effective opportunities do not always coincide within the territories of individual water agencies. (For example, one utility may have a prime location for stormwater capture, but lack suitable storage capacity.) Absent cooperation among the various water utilities and their wholesalers and regulators, many promising opportunities may be missed.

In an integrated system where utilities could trade routinely among themselves, there would be a way for multiple parties to enter into mutually beneficial project agreements. Such a system would not add volume to the regional water system, but would improve reliability and efficiency by addressing short-term supply/demand/facility imbalances.

There are three paths to system integration: (1) through use of existing facilities (exchanges, wheeling, conveyance); (2) through the construction of integrating pipelines that interconnect Southern California's groundwater basins as storage reservoirs; and (3) off the shared MWD supply and distribution system. The first two paths are self-explanatory. The third is based on the concept of augmentation/conservation credits. Instead of physically moving water, water agencies could trade credits based on their MWD entitlements. This would open up the possibility of one water agency making an investment in retail and system conservation within another party's service area.

The conservation credit concept would require the identification of qualifying long-term conservation projects, independent audits and a registry. The novel aspect of such a system, at least for Southern California, is the ability to trade credits across agency boundaries using the one thing they share in common: their MWD water. For example, a new industry in Orange County should be able to make investments in Compton to reduce system inefficiencies. Otherwise, each entity is limited by its own internal opportunities. The older water distribution systems offer substantial opportunities for efficiency improvements, yet lack the growth necessary to fund such investments.

The conservation credit concept does not need to be limited strictly to conservation. Supply augmentation – properly qualified, audited and consistent with project parameters – could help the groundwater basins within Southern California receive more recycled water for replenishment and re-use. Similarly, desalination may otherwise be limited to a handful of Coastal communities.

Potential: The strategy does not add new water to the system, but would allow the region to make better use of current supplies. There is considerable scope for improvements that could be realized for a relatively modest investment. A market in water credits, in particular, would allow (and incentivize) agencies to seek out the most cost-effective water projects across Southern California, not just within their own districts.

Reliability: A more efficient system would strengthen overall reliability and improve efficiency.

Timeliness: 0-5 years. In theory, interagency cooperation—which already occurs—could be enhanced immediately, but developing a predictable legal and accounting framework for routine trading would take several years so that experimentation and experience can be integrated into a trading regime with adequate protections and low transactional friction.

Risk: High initially, due to the uncertainty surrounding the outcome. Particularly with leadership and cooperation from MWD, such uncertainty could be reduced or significantly mitigated. (For example, the risk of trading water supplies over time could be ameliorated if the trade were “registered” or “administered” by MWD and back-stopped by a pledge of the water-debtor-entity’s right to imported supplies.) Once a framework is in place, the risk of interagency cooperation falls substantially.

Environmental Considerations: Positive. Makes more efficient use of the water we already have; reduces the need for imports, reduces pressure on storage.

Greenhouse Gases: Neutral, because trading within the region does not augment supply and, just as with use of stored water, replacing the supply made available through storage will ultimately depend on importing, conserving, re-using or capturing other water.

Costs: TBD. The program itself should be relatively inexpensive to administer. Encouraging the development of the most cost-effective projects at the front end should restrain the overall cost of developing reliable frameworks for cooperation.

Table 7 Inter-agency Cooperation	
Initial Capital Cost	Low
Ongoing Operating Cost	Low
Production Capacity in Acre-Feet	n/a
Estimated Cost Per Acre-Foot	n/a

Sources: LAEDC

There may be some relatively low investment and operational costs. For example, it may be necessary to add pipes to interconnect adjacent water agencies. Initial and operating costs will vary based on the scope and details of each project. Inter-agency cooperation is a strategy for improving the efficiency and reliability of existing supplies, not increasing supplies, so the production capacity and estimated cost per acre-foot estimates are not applicable. More than money, this strategy requires institutional reform and creativity to implement.

GROUNDWATER STORAGE

Groundwater storage basins are an underdeveloped resource that could significantly improve the overall reliability of water supplies in Southern California. For Southern California, locally stored water is preferable to water reserves behind dams in Northern California. The ability to draw down reserves immediately when needed makes it easier to ride out dry periods and lessens the region's vulnerability to sudden disruptions of imported supplies.

Vast quantities of water can be stored cheaply underground. Statewide, the California Groundwater Coalition argues that there is room to store at least 9 million acre-feet underground. The Metropolitan Water District estimates there are 3.2 million acre-feet of unused storage capacity in Southern California alone. The cost of developing underground storage is attractive, since the construction of dams and other expensive infrastructure is not required.

While dams create recreational opportunities and offer the visual reassurance that the stored water is really there, reservoirs flood large areas and may negatively impact the local ecosystem. In contrast, the land directly above underground "lakes" can be developed like normal real estate. Furthermore, underground storage is perceived as an eco-friendly water management practice, in contrast with most other water strategies.

Currently, groundwater contributes 1.5 million acre-feet per year to the Southern California water supply, or 40% of overall supply. About half of this is replaced by artificially recharging underground aquifers, and most of the rest is refilled by natural sources. However, on average Southern California has tended to withdraw more water each year than gets replaced; this is unsustainable in the long-run. (However, it is precisely this "overdrafting" of the region's aquifers that has created the vacant storage capacity that this strategy seeks to exploit for regional benefit.) Surplus surface water supplies periodically exist, but there is not always capacity available to convey it to groundwater storage locations.

Underground storage, also called water banking, does have its challenges. The most serious issue revolves around water rights in the aquifer or basin, since water utilities will not pump water into the ground without a secure right to pump it out again when it is needed. The water rights picture can get fuzzy if there is also surface water present, and potentially even more indecipherable when the groundwater and surface water interact such that drawing from one affects the other. The presence of multiple parties with claims to the underground water, or a shared aquifer that lies beneath multiple jurisdictions, can also delay or derail underground storage projects. As a consequence of the need for legal certainty when storing water underground, over 90% of the groundwater used in Southern California today is drawn from basins that are adjudicated or formally managed. The ability to use an adjudicated or managed basin to store non-native water is thus more clear.

Issues may also arise regarding the physical characteristics of underground aquifers. Structure and capacity, flow (if any) of underground water, quality of the existing water, and any pollutants (including natural ones such as arsenic) that may be present and may be affected by the introduction of non-native water will affect the development potential of a given groundwater basin.

Groundwater storage will not, by itself, produce incremental water supplies for Southern California. (All water that is currently in the ground has already been claimed, even if it cannot be accessed yet.) To take advantage of storage, a source of water is first required. Better use of available groundwater storage capacity simply allows water to be saved in wet times to be made available in dry times. Assessing groundwater strategies, therefore, involves analyzing the original source of stored water. Here, we consider three sources: stormwater runoff, recycled water, and imports.

Potential: 3,200,000 acre-feet of underground storage is available in Southern California. Individual basins in Southern California currently yield 20,000 to 294,000 acre-feet per year; the yield of any new projects will depend on local hydrology and the water available for recharge.

Reliability: Moderate. Groundwater storage is considered highly reliable once an aquifer has been charged with water. Pollution can be avoided through diligent management, but contaminants may still enter groundwater from time to time. Contaminated groundwater can be recovered by treating it before it is used. Groundwater reliability also depends on the source of the water; reliability will rise by diversifying replenishment water sources. Many existing and proposed projects use recycled water, one of the most reliable sources. Stormwater capture, on the other hand, is unpredictable and episodic; under current transfer capacity limitations, surplus imported water is only available in particularly wet years. Like any storage scheme, however, long-term reliability depends on periodic refills from water that is surplus to current demand. Thus, efficient use of groundwater storage goes hand-in-glove with water conservation, recycling, and import supply strategies.

Timelines: 3-5 years. Assuming water is available to be stored, installing pumps and preparing the site for water spreading (for infiltration) is a comparatively quick process. How long it takes to bring a project online will depend on the length of time required to study the local geology and hydrology, to evaluate and resolve any environmental impacts, and to resolve any legal issues over rights to pump water from the basin. While a groundwater facility can be completed in 3-5 years, it must also be filled with water in order to be useful. This can take considerable time depending on the availability of excess water to send to storage.

Risk: Moderate, depending primarily on legal issues and secondarily on physical operating arrangements.

Environmental Considerations: Variable. Groundwater storage is generally considered an environmentally friendly way to store water—particularly insofar as it eliminates or defers the need for new surface storage reservoirs and dams—but it depends on the source of the stored water and local water quality issues.

Greenhouse Gases: Moderate. The operation of underground storage facilities will require some electricity to pump water out of the ground and inject water into the ground (if that is the method for recharging). If the electricity is derived from fossil fuels, then the activity will generate greenhouse gases. The overall environmental footprint of the project also will depend on the source of the stored water: almost no extra emissions for stormwater capture, but some emissions for recycled water and imports.

Costs: Groundwater storage facilities require a varying range of initial capital costs depending on the location, hydrology and geology. At a given site, the boundaries of underground aquifers must be explored and any gaps must be identified. If the aquifer abuts a source of contamination, such as saltwater or leached pollutants, then care must be taken to buffer stored water from the potential contamination. It costs money to assess and monitor the conditions underground, so some groundwater storage locations will be more costly than others. Furthermore, if water sources that replenish the groundwater do not naturally flow near the site, then refill water must be pumped to the aquifer at additional cost.

Table 8 Groundwater Storage	
Initial Capital Cost	\$68-135 million
Ongoing Operating Cost	\$13 million
Production Capacity in Acre-Feet	150,000
Estimated Cost Per Acre-Foot	\$580

Sources: LAEDC

Table 8 indicates the differences in costs faced by groundwater storage facilities. The Metropolitan Water District’s facility in Hayfield would rely on water from the Colorado River, which would be inexpensive (for MWD) but may be available only episodically due to reduced flow and limited allocation. The San Gabriel/Montebello storage facility is typical in that it draws water from several sources, including recycled water, storm runoff and imported water. The recycled water must be treated and the imported water must be transported, so the water stored in this aquifer is more expensive. Native water captured and infiltrated in the spreading grounds operated by the Pomona Valley Protective Association provides the primary replenishment source for the adjudicated Six Basins underlying eastern Los Angeles and western San Bernardino counties.

Water from groundwater storage will vary widely in price due to numerous factors. We estimate the capital and operating costs of a large groundwater facility would typically amount to \$131 per acre-foot. This includes pumping costs of \$88 per acre-foot, based on the weighted average among existing groundwater basins in Southern California. This water would also need to be treated at a cost of \$155 per acre-foot. This sums to a baseline price of \$286 per acre-foot for water in groundwater storage. Water in storage has to come from somewhere, so there may also be an acquisition cost attached to the water. This can range from \$0 for captured runoff water (as with PVPA) up to \$1,000 for the most expensive recycled water (as with injection barriers to saltwater intrusion along the coast). As a result, we estimate the cost per acre-foot of groundwater will range from \$286-1,286. The figures in Table 8 reflect an acquisition cost of \$294 per acre-foot for surplus water from MWD. Choosing the MWD surplus water price makes groundwater storage easily comparable to surface storage, which we describe in the next section.

SURFACE STORAGE

There are generally two types of surface storage in Southern California: on-stream storage that captures local runoff and off-stream storage used to store imported water. Surface storage has played a vital role in helping Southern California cope with the court-ordered reduction in water exports from the Delta. The Diamond Valley Reservoir (DVR), an off-stream storage reservoir, built in Riverside County at great expense, has allowed MWD to draw down reserves and generally insulate the public from recent and on-going supply disruption, notwithstanding interruption and reductions in imports from both the Colorado River and from Northern California.

The utility of reservoirs is high, but their usefulness is matched by their cost. The capital costs are high because the projects tend to be enormous, capable of storing one million acre-feet or more. The marginal cost of water supplied from surface storage is driven up by the debt service or other capital costs required to finance the construction cost. Surface storage projects also face considerable opposition based on their environmental impacts (described below).

We do not expect any new major surface storage projects to be approved in Southern California as available local yield is already developed and new off-stream storage is limited due to export supply constraints. However, the San Diego County Water Authority is expanding San Vicente Reservoir to create local storage capacity for emergency reserves of imported water. Two surface storage projects have been proposed for Northern California: the Sites Reservoir and Temperance Flat Reservoir. These projects are described and evaluated below.

Potential: No new major surface storage projects are likely to be approved in Southern California, due to the high initial cost, the presence of more cost-effective alternatives, and probable environmental impacts. Outside the region, the Sites Reservoir will have a capacity of almost 2 million acre-feet and will yield 470,000 to 640,000 acre-feet of water annually, on average. The comparable figures for Temperance Flat are 1.2 million acre-feet and 183,000 to 208,000 acre-feet. It is expected much of this yield would be dedicated to environmental needs in the Delta and upstream.

Reliability: Surface storage can be crucial for weathering extended dry spells. The long-term reliability of a reservoir depends on the source of the water used to fill it. On-stream projects that are also used for flood control face additional risks due to climate change. The reservoir must be left low during winter in order to maintain its capacity to capture (and thus moderate) the runoff from major storms. As the danger of flooding recedes late in the season, the reservoir can be refilled, storing water for use in the summer and fall. If climate change shifts the peak runoff to earlier in the year, it would pose a dilemma for dam operators: refill the reservoir too soon and risk a devastating flood; or keep the reservoir low too long and miss the opportunity to capture water.

From a Southern California perspective, dams in the northern part of the state have to be considered unreliable. To reach Southern California, water from Sites Reservoir would have to pass through the Delta. Temperance Flat water, although originating on the San Joaquin River south of the Delta, also faces a legally and environmentally tortuous path to Southern

California. Pending a comprehensive solution in the Delta, water from these reservoirs will be subject to interruption.

Timeliness: 10 to 20 years. The permitting process may require several years to complete before the lengthy construction phase can get underway.

Risk: High. A proposed surface storage project may be abandoned or substantially modified before completion due to political pressure, funding constraints or environmental litigation.

Environmental Considerations: Environmental groups oppose surface storage projects because they divert water from ecosystem uses. On-stream projects draw particular ire because they impede fish migrating upstream to spawn.

Greenhouse Gases: The Sites Reservoir is off-stream and would require energy to pump water into the reservoir (more energy than is produced by its power plant). If the additional power is derived from fossil fuels, it will add to the state’s carbon emissions. (This does not apply to Temperance Flat, which is on-stream). From a Southern California perspective, transporting the water from either of these projects (if feasible) would require additional energy, particularly for the pumps that would lift the water over the Tehachapi Mountains.

Cost: Constructing a surface storage reservoir is a massive undertaking. Land must be obtained, experts hired, a dam and power plant built, and water sources diverted. Projects this large cannot be completed without significant government intervention. Identifying beneficiaries of these projects is key. If water yield is used for environmental purposes, public funding is justifiable. If the yield goes to water users, they will be expected to pay for the project. Benefits can be divided, but environmentalists are generally opposed regardless of the benefits. Government subsidies and public debt issues pay for the initial capital, meaning the taxpayers eventually foot the bill. On the other hand, reservoirs have long useful lives, supplying reliable water and electricity at a relatively low price for decades.

Table 9 Surface Water Storage	
Initial Capital Cost	\$2.50-2.75 billion
Ongoing Operating Cost	\$7.5-15.5 million
Production Capacity in Acre-Feet	200,000-500,000
Estimated Cost Per Acre-Foot	\$760-1,400

Sources: LAEDC; Department of Water Resources

Table 9, based on the proposed Sites and Temperance Flat reservoirs, reveals the large initial outlay required to build surface storage. These costs would be paid off over decades by a combination of taxpayer dollars backing general obligation bonds issued by the state and consumer dollars backing project revenue bonds issued by water agencies. Combining debt repayments with the operating costs yields a total cost per acre-foot over the next 30 years of \$389 (Sites) to \$851 (Temperance Flat). This would be the price of the water at reservoir.

The California Department of Water Resources *Bulletin 132-05* (on the management of the State Water Project) reports that transporting water to Southern California from the Delta to Castaic Lake costs \$212 per acre-foot. From the Delta to Lake Perris costs \$391 per acre-foot. Treatment costs add a further \$155 per acre-foot. Thus, water sourced from the proposed Northern California reservoirs would cost \$760-1,400 per acre-foot, delivered to a retail agency in Southern California after treatment. If the reservoirs yield less water annually than projected, the costs would be higher still.