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Assessment of Seawater Desalination as a Water Supply Strategy for San Diego County

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Increasing water scarcity in coastal Southern California has recently evoked interest in seawater desalination as a strategy for meeting a portion of the region's water needs. While in the past the prohibitive costs of operating desalination plants have restricted their use to extreme situations, recent technological advances in desalination technology have lowered operating costs to the point where desalination is now a viable supply option in water-stressed regions of the world. In this project we assess the implications of developing a large-scale desalination facility in northern San Diego County. We assess potential impacts of the plant in terms of resource consumption and environmental impacts. We also investigate whether a portion of the excess costs of water generated at the facility are in part recovered by benefits associated with reduced drinking water salinity and water supply reliability. In light of the desirability of water supply diversification, we conclude that desalination can be an appropriate strategy for supplementing a portion of existing supplies, however despite the benefits of salinity reduction and reliability it is still not clear that it would be cost-effective or environmentally preferable to create a regional dependence on desalinated water supplies in San Diego County.

BACKGROUND

San Diego County is located in a dry, coastal region with limited local water resources. Rapid population growth in past decades and limited local water supplies have forced the county to become heavily reliant on imported water resources from the State Water Project and the Colorado River. Threats to these resources, such as drought, claims by other rights-holders, and environmental restrictions on water flows, have driven San Diego County to pursue seawater desalination as a water provision strategy.

A 56,000 acre-feet per year (AFY) desalination plant capable of serving 8% of the county's water demand has been proposed for construction in Carlsbad, in northern San Diego County. The $270 million dollar plant, which would be located adjacent to the Encina Power Station, would produce water by reverse osmosis at a cost of approximately $900 per acre-foot, including distribution costs. This water would be more costly than imported water, which is purchased by local water agencies at $526 per acre-foot. A $250 per acre-foot subsidy provided by the Metropolitan Water District will help defray some of the cost difference. However, the desalinated water is still a more expensive water supply, when viewed from a pure cost perspective. It also presents some environmental challenges, such as the discharge of waste brine and heavy energy demands.

Encina Power Station

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PROJECT APPROACH

Although desalinated water is expensive, it possesses characteristics that differentiate it from imported water. Desalinated water produced at the Carlsbad Plant would be relatively pure compared to the imported water blend that is currently supplied to San Diego County. It would be drought-proof and locally managed, unlike imported surface water resources, which are prone to quantity fluctuations and allocation disputes. Finally, whereas imported water requires a distributed network of pumping stations that draw power from the electricity grid, the Carlsbad desalination plant would draw power from a single gas-fired power plant.

Our project approach involves performing a thorough investigation of each of these differences, in order to determine whether seawater desalination is an appropriate water provision strategy for the San Diego region. Making this assessment involves dividing the impacts of desalination plant operation into four broad categories: salinity, reliability, energy and environment.

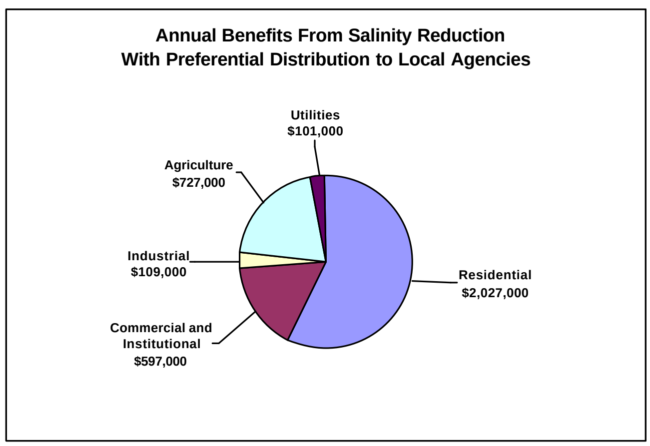
SALINITY

Excessive salinity in water supplies can have a variety of detrimental impacts, including reduced life of appliances, the need to clean mineral deposits from surfaces, and reduced agricultural yields. Salinity affects domestic water users by increasing expenditures on bottled water, water softening, soaps and detergents.

The Carlsbad Desalination Plant is expected to produce drinking water with a quality of 250-350 mg/L of Total Dissolved Solids (TDS). This will represent a substantial decrease in salinity as compared to existing supplies, which are approximately 500 mg/L. As a result, water customers may evade certain expenditures associated with damages from salinity, and experience benefits associated with the quality improvement. The distribution and magnitude of these benefits will depend on how the desalinated water is delivered to the residents of the county.

An existing econometric model was used to value the potential benefit of salinity changes due to introducing desalinated seawater into the San Diego County water supply. This model, developed by the Metropolitan Water District, generates regional approximations of the costs or benefits of changes in water supply salinity. The model divides these impacts into a set of customer classes: residential, commercial, industrial, agriculture, utilities and recycled water users.[i]

In our project, Metropolitan's model was customized to simulate inclusion of desalinated water in the San Diego County water supply under multiple distribution scenarios. Our results indicate that substitution of desalinated water for a portion of San Diego County's imported water supply will produce an annual benefit on the order of $3 million, equivalent to $60 per acre-foot of desalinated water. The maximum benefit is observed when desalinated water is preferentially delivered to the cities of Carlsbad and Oceanside, as opposed to the entire county. The total magnitude of this benefit is highest for residential customers, however the highest per-acre benefit accrues to agriculture. Significant benefits from salinity reduction are associated with avoided water softening, increased life of dishwashers, improved water efficiency in cooling towers, and increased avocado yields. Benefits to nursery crops may also be significant, however we were not able to provide an accurate estimate of this value.



In addition to the primary benefits experienced by end-use water customers, there will also be secondary, system-wide benefits that are more difficult to quantify. These include a minor decrease in overall water consumption from irrigated soil leaching and cooling tower operation. An additional benefit of salinity improvement would be improved quality of reclaimed water. Salinity reductions in reclaimed water would generally increase the value of this water for other uses, such as agricultural irrigation for crops with limited salt tolerance.

RELIABILITY

Water supply reliability entails the provision of supplies, expertise, and facilities to ensure the availability of sufficient and affordable water, both now and in the future. When supplies become threatened by service interruptions or drought, there can be severe economic and social consequences to agricultural, business and residential users. Therefore the issue of water reliability becomes an important element of any water agency's management plan.

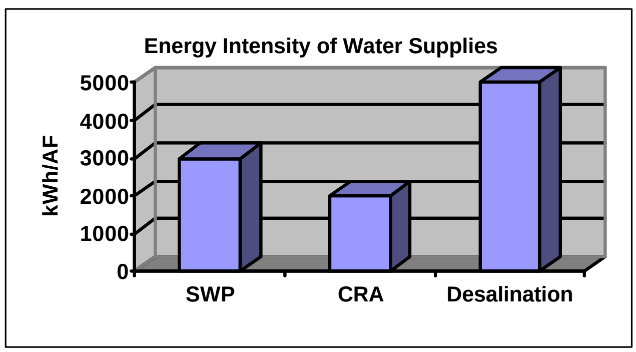
An existing contingent valuation model was used to estimate the willingness to pay (WTP) among San Diego County residential users to avoid water shortages of varying magnitude and frequency[ii]. Frequency ranged from once every 3 years to once every 30 years, with intervals at 5, 10 and 20 years. Reduction in water availability ranged from 10% to 50%, with intervals at 10, 20, 30 and 40 percent. The model then created several scenarios in which respondents were asked their willingness-to-pay to avoid a percentage reduction in water availability at different time periods.

Results for San Diego County ranged from approximately $16 per month to avoid either a 10% shortage every 10 years or a 20% shortage once every 30 years, to a high of approximately $20 per month to avoid a 50% shortage every 20 years. Given the size and number of users that desalinated water could serve, the WTP for the county amounted to over $1.7 million dollars per month, or nearly $35 an acre-foot for desalinated water, and therefore could be considered when factoring in the additional costs that desalination will place on the county.

The use and reliability of desalination as a water supply option merits consideration when viewed in terms of people's willingness to pay for water reliability. Despite the fact that current costs are still more prohibitive than imported supplies, respondents in San Diego are willing to see their water bills increase in order to ensure water reliability.

ENERGY

As designed, the desalination plant would consume approximately 3% of the adjacent Encina Power Plant's output (965 MW), with a load of 35 MW. Between 60 and 75 gallons of water would be generated per kilowatt-hour, suggesting an embedded energy of 4,700-5,400 kWh per acre-foot. Imported water supplies, which consume energy for conveyance, are also energy intensive. The bulk of San Diego's water originates from the Colorado River, requiring 2,000 kWh per acre-foot of delivered water. The State Water Project, which provides approximately 24% of San Diego's water supplies, consumes approximately 3,000kWh/AF to deliver water to Southern California. Thus, the energy requirements of desalinated water still exceed those of existing supplies.



An implication of devoting some of the County's local generating capacity to desalination is an increased need for energy imports. This desalination plant would not cause serious energy deficiencies in San Diego County if it were operated using off-peak-load power. Power plants produce electricity from fuel most efficiently at full load, however due to daily and seasonal demand fluctuations they are forced to operate at reduced loads. During these periods, fuel consumption efficiency is reduced. Therefore, if the desalination plant is operated using off-peak power, the overall efficiency of power plant operation is improved.

ENVIRONMENTAL CONSIDERATIONS

Air pollution due to electric power consumption is estimated for imported water sources using U.S. nationwide average of emissions from electric power plants by fuel and the proportion of the California energy sources. Emissions for the desalination plant are estimated using the facility's load on the power plant and average natural gas emissions. The results indicate that the Carlsbad Desalination Plant emits ten times less SOx but more NOx and CO_2 than water delivery projects on a per acre-foot basis. Also, since the desalination plant consumes existing local energy supplies it does not become a significant additional contributor of air pollution in northern San Diego County. Moreover, since the Encina Power Plant does not affect regional air quality, the small additional use of electric power by the desalination plant will not be a problem.

The separation of seawater results in a waste brine stream that requires disposal. Brine discharge to the marine environment constitutes the main environmental impact of coastal seawater desalination plants. In addition to the high concentration of salts, discharge water may also contain various chemicals used during defouling of plant equipment and pretreatment-stage of the desalination.

Diluting brine with power plant cooling water mitigates environmental impacts from brine discharge. The addition of brine to power plant thermal effluent decreases the difference in density between the combined discharge and seawater, aiding in mixing. The estimated salinity of the combined effluent would be 38,000 mg/l, as compared with 35,000 mg/L in seawater.

CONCLUSION

We have observed that a portion of the excess cost associated with desalinated water is recovered as reduced salinity in delivered water, which produces benefits in the form of avoided water softening, increased life of water-using appliances, improved water efficiency in cooling towers and increased crop yields. Consumers are willing to pay higher monthly water bills to avoid shortages, so presumably there is an excess value to desalinated water due to its reliability. However it is difficult to estimate this value due to the difficulty of converting a theoretical willingness to pay to a received benefit. In addition, desalination still requires more energy than the alternative of transporting water to the county using existing conveyance infrastructure, despite the energy savings associated with co-locating desalination plants and energy facilities. While the Carlsbad Desalination Facility would decrease San Diego County's reliance on imported water, it would in turn increase the County's reliance on imported power. Operation of desalination facilities during off-peak periods of power generation may be a preferable alternative. Progress in the membrane industry may eventually reduce the energy required to operate reverse osmosis facilities.

The merits of desalination are more evident when it is viewed as a form of supply diversification, and an emergency source of water. Operation of the Carlsbad Facility would provide San Diego County with a hedge against drought, as well as a source of dilution for the county's high salinity water imports. The addition of coastal seawater desalination plants to California's mix of water supplies aids in decentralizing the state's water infrastructure. As a result, a disruption at an individual location is mitigated by the presence of alternative sources of supply. It is recommended that agencies involved in considering development of these facilities should attempt to simulate worst-case supply interruptions, and then evaluate the optimum level of desalination capacity for providing municipal water during emergencies.

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[i] Metropolitan Water District of Southern California. 1999. Salinity Management Study Final Report. Prepared by Bookman-Edmonston Engineering, Inc.
[ii] California Urban Water Agencies. 1994. The Value of Water Supply Reliability: Results of a Contingent Valuation Survey of Residential Customers. Prepared by Barakat and Chamberlin, Inc.