



MARSI A. STEIRER AND DANIELLE THORSEN

Potable reuse: Developing a new source of water for San Diego

San Diego is renowned for its sunny skies and ideal climate, but because of the region's semi-arid climate, the city has limited local water sources and imports approximately 85% of its water supply each year. The last time local water sources could supply San Diego's population was in the 1940s. Since then, the city has relied on imported water supplies to support its economy and quality of life. Unlike neighboring cities to the north, San Diego does not overlay large groundwater basins, so it has examined whether purifying recycled water and adding it to a local reservoir is a feasible option for supplementing local water supplies. In April 2013, the San Diego City Council unanimously adopted the report on the Water Purification Demonstration Project, and San Diego is now exploring the next steps toward making potable reuse a reality.

A NEED FOR WATER

San Diego provides drinking water to more than 1.3 million people. The city's actual water use in fiscal year 2012, which also included wholesale deliveries to other agencies, was 190,000 acre-ft (170 mgd on average). Actual water use varies from year to year because of climatic and economic conditions. The city meets water demands using the following supplies:

- imported water from the California Bay-Delta and the Colorado River,
- local surface water,
- recycled water.

San Diego's imported water supplies come from the California Bay-Delta and the Colorado River through a network of state, federal, and regional pipeline facilities. The cost of imported water has increased significantly and is expected to double in the next 10 years. Environmental stressors, such as ongoing drought in the Colorado River Basin, reduced snowpack and runoff in Northern California, and court-ordered pumping restrictions necessary to protect endangered species, have decreased the reliability of imported water supplies. In addition, all of the pipelines bringing imported water to San Diego cross earthquake faults, increasing the importance of meeting demand with local supplies. Imported water issues, coupled with recurring

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droughts in the San Diego region, leave the city dependent on unreliable water sources.

The city implements a wide array of water conservation measures, which are embraced by city residents and designed to reduce water demands and maximize water use efficiency. The city's conservation programs have helped reduce its dependence on imported water, saving more than 35,000 acre-ft of drinking water a year as of 2013. Nonetheless, by 2030 the city will need an additional 83,000 acre-ft of water per year to meet the needs of current and future water customers. Although conservation is important, efforts to save water must be combined with other sustainable strategies if San Diego is to have enough water to meet the needs of all of its residents and businesses.

The viability of San Diego's thriving metropolis depends on having a secure source of water. A variety of local recreational activities, periodic threats of fires, an influx of biotech companies, and a booming craft beer community all count on a reliable and safe water supply. Therefore increasing local water supplies is necessary for more than just drinking water purposes. For two decades, potable reuse (purifying recycled water so it is safe for consumption) has been considered an option to further diversify San Diego's water portfolio. The city attempted to implement potable reuse in the past, but negative public perception led the mayor and city council to stop work on an indirect potable reuse project in the late 1990s. It was not until a water reuse study was conducted in 2005 that potable reuse efforts were revived.

WATER REUSE STUDY

In 2006, the city completed a water reuse study that evaluated options to maximize the use of recycled water in San Diego. The study included analysis and research on the health effects of various reuse options and also implemented a

comprehensive public participation process. On the basis of the information presented in the study, a broad-based group of 59 San Diego residents determined that the preferred option for maximizing use of the city's recycled water supply would be to augment existing supplies in the city's San Vicente Reservoir with advanced treated recycled water. This option was referred to as "reservoir augmentation at San Vicente Reservoir."

DEMONSTRATION PHASE

On Oct. 29, 2007, the city council voted to accept the findings of the reuse study and directed the mayor and city staff to implement actions to demonstrate the feasibility of reservoir augmentation at San Vicente Reservoir. These actions, known as the water purification demonstration project, were intended to evaluate the feasibility of implementing a reservoir augmentation project at San Vicente Reservoir. It would determine whether advanced water purification technology could safely and reliably produce water that could be sent to a reservoir where it would blend with "raw" or untreated water supplies and later be treated at a drinking water treatment plant and become part of the city's drinking water. The components of the demonstration project were to

- convene an independent advisory panel;
- design, construct, operate, and test a 1-mgd demonstration-scale advanced water purification facility;
- conduct a study of San Vicente Reservoir to establish residence time and dilution of purified water in the reservoir and assess water quality changes;
- perform an energy and economic analysis;
- propose a regulatory framework for a reservoir augmentation project at San Vicente Reservoir;
- perform a pipeline alignment study; and
- conduct a public outreach and education program.

PROJECT COMPONENTS AND FINDINGS

The demonstration project established that purified water can be produced and safely added to the San Vicente Reservoir as part of a full-scale potable reuse project. The city released the Water Purification Demonstration Project Report in March 2013, detailing the following findings from each of the project components.

Independent advisory panel. The California Department of Public Health (CDPH), one of the project's regulators, requested that an independent advisory panel (IAP) be formed to provide expert peer review of the technical, scientific, and regulatory aspects of the city's potable reuse concept. An IAP, organized and managed by the National Water Research Institute, was convened in 2009 and completed its role in November 2012. The IAP was composed of 10 academics and professionals with extensive expertise in the science of water reuse and public health, including chemistry, microbiology, treatment engineering, operations engineering, water reuse regulatory criteria, limnology, research science, toxicology, and public and environmental health.

The IAP summarized its findings as follows: "It is the unanimous conclusion of the [panel] that the project as described in the [report] will be a landmark development in the acceptance and furtherance of indirect potable reuse and will contribute to the city of San Diego's water portfolio." The panel found that the purified water met or surpassed all drinking water standards, that the quality of the water was actually better than existing water stored in San Vicente Reservoir, and that city staff had conducted an extensive and well-directed public outreach program to inform San Diegans about the project. The IAP concluded that the project report and supporting documents "... are responsive to the directives set forth by the City Council."

Advanced water purification facility. The city installed, operated, and

tested a 1-mgd demonstration-scale facility, referred to as the Advanced Water Purification Facility (AWPF), for 12 months. An integral component of the demonstration project, the AWPF generated valuable information that will aid the city in understanding the quality of water that would be produced by a full-scale facility, validating process integrity monitoring methods, securing regulatory approval, selecting specific process equipment, and estimating full-scale AWPF costs.

The AWPF purified 1 mgd of tertiary-treated water using membrane filtration, reverse osmosis, and advanced oxidation with ultraviolet light and hydrogen peroxide. This purification process is being successfully used by other projects currently operating in California, including Orange County's Groundwater Replenishment System (GWRS). The purified water was not sent to San Vicente Reservoir during the demonstration project; instead the water produced at the AWPF was returned to the existing nonpotable recycled water distribution system to be used for irrigation and industrial purposes.

A formal testing and monitoring plan was designed to validate the overall performance of the water purification process in meeting regulatory requirements. The plan was also put in place to demonstrate that continuous and daily monitoring of each water purification step can ensure the integrity of the process and that only the highest-quality water is produced.

More than 9,000 laboratory tests were conducted for 342 chemical constituents, microbial constituents, and water quality parameters. The quality of the purified water was compared against regulatory limits, verifying that it met all state and federal drinking water standards. Furthermore, the comprehensive water quality testing showed that the purified water produced at the AWPF is very pure—approaching that of distilled water.

Additionally, integrity monitoring and critical control-point monitoring showed that continuous and daily monitoring of each water purification step can ensure the integrity of the purification process and that only high-quality water is produced.

The AWPF continues to operate for additional testing purposes and public tours beyond the demonstration project.

San Vicente Reservoir study. If reservoir augmentation is approved as the potable reuse option for San Diego, purified water would be added to the raw water already stored in the San Vicente Reservoir. Part of the research conducted during the demonstration project was a limnology study that examined the biological and physical features of the reservoir. Primarily, the city needed to gain a good understanding of what effect—if any—purified water would have on the other water in the reservoir.

Although water purification technology is widely recognized as capable of purifying recycled water into drinkable water, regulatory agencies currently require that purified water be retained in an “environmental buffer,” such as a groundwater basin or a surface water reservoir, before it becomes part of the drinking water supply. Adding purified water to an environmental buffer provides a public health barrier:



Operations at AWPF Continue Beyond the Demonstration Project

Although the demonstration project report is complete and has been presented to the San Diego City Council, operation of the Advanced Water Purification Facility (AWPF) is ongoing. Staff are now using the demonstration facility to test alternative treatment processes and monitoring techniques that could provide additional health and safety barrier options for direct potable reuse projects. These studies will also test treatment options that could lower the cost of full-scale water purification facilities. San Diego's AWPF is ideal for these studies because the equipment is already in place and the water produced during the testing can be returned to the recycled water system for irrigation and industrial purposes.

Operation and testing of the AWPF from August 2011 to July 2012 proved that the treatment train—microfiltration/

ultrafiltration, reverse osmosis, and advanced oxidation with ultraviolet light and hydrogen peroxide—produces purified water that meets or exceeds all state and federal drinking water standards. Follow-on operation and testing of the AWPF will evaluate additional treatment processes, including ozone and biologically activated carbon. The AWPF will also be used for another study that will draw on knowledge gained from other water purification projects in the United States, Singapore, South Africa, and Australia. Public health, water treatment, and water quality experts from around the world will convene to establish an appropriate framework for failure-response readiness in direct potable reuse. These cutting-edge studies are funded by California state grants and will advance future water purification endeavors in communities around the globe.

dilution with other water sources and retention time that allows for additional natural treatment.

San Vicente Reservoir would serve as an effective environmental buffer for a full-scale project in San Diego. The reservoir stores a large volume of water capable of providing adequate dilution and retention of the purified water and exhibits seasonal stratification, the formation of layers of water within a reservoir. A three-dimensional hydrodynamic model of the reservoir was developed by experts from a private firm and was reviewed and accepted by the demonstration project's IAP.

San Vicente Reservoir has been studied many times in the past, including tracer studies that were conducted in the 1990s. These tracer studies provided good background for the current study, which involved running the three-dimensional hydrodynamic model 18 times. The project team, with input from the IAP and regulator, selected eight modeling scenarios representing the full range of operational conditions the reservoir augmentation project could encounter. The key findings were:

- The addition of purified water to San Vicente Reservoir would not affect the natural hydrologic characteristics of the reservoir.
- Dilution and retention of purified water in San Vicente Reservoir would constitute a substantial environmental barrier, sufficient to meet regulatory requirements.
- For all anticipated reservoir operating scenarios and purified water entry locations, the reservoir would dilute the purified water by a factor of at least 200:1 at all times.
- The addition of purified water would not negatively affect any aspect of water quality in San Vicente Reservoir. Independent of the demonstration project, the San Vicente Dam has been raised to increase the storage capacity of the reservoir as part of the San Diego County Water Authority's Emergency Storage Project. In the case of an emergency, San Vicente Reservoir water could be

Tours Teach Public About Reuse

One of the most valuable outreach tools for explaining the science of water purification technology was San Diego's tour program that was part of the demonstration project. The Advanced Water Purification Facility (AWPF) provided a venue for conducting tours and educating the public about potable reuse. Since June 2011, AWPF tours have provided San Diegans with an in-person experience of the demonstration project, increased the visibility of water purification technology, corrected inaccurate perceptions about potable reuse, and solidified relationships with stakeholders.

Each tour begins with a presentation about the city's water supply situation and an explanation of the various potable reuse project components, goals, objectives, and benefits. The presentation is followed by a tour of the facility with explanations of how the many pieces of equipment work together as part of a multibarrier treatment process. At the conclusion of the tour, guests visually compare samples of recycled water, tap water, and purified water produced at the facility. Since the facility opened, more than 3,500 guests have taken the tour. Attendees have included local decision-makers, international guests, a variety of organizations, and the general public.

distributed to homes and businesses throughout San Diego County. The enlarged reservoir will hold more than 240,000 acre-ft of water (more than double its original 90,000 acre-ft), which will improve the overall water quality in the reservoir. Addition of the purified water will have no effect on these water quality improvements.

Regulatory coordination. Projects in California that incorporate water purification processes using reservoir augmentation are regulated by both the CDPH and the State Water Resources Control Board (administered by local Regional Water Quality Control Boards). Before implementation, a reservoir augmentation project at San Vicente Reservoir would require approval by CDPH and the regional board.

Although reservoir augmentation at San Vicente Reservoir would use the same water purification processes as the Orange County GWRS, its regulatory pathway is less established. CDPH has set guidelines for groundwater augmentation projects such as the Orange County GWRS

but permits reservoir augmentation projects on a case-by-case basis.

Neither CDPH nor the regional board has specific regulations in place for projects using purified water for reservoir augmentation, making the process for securing regulatory approval a challenge. A key objective of the demonstration project was to work closely with the regulatory agencies to identify appropriate requirements for a reservoir augmentation project at San Vicente. Additionally, it had to be determined whether a potable reuse project incorporating water purification technologies and San Vicente Reservoir could meet these requirements.

On the basis of the initial meetings with CDPH and the regional board, staff developed a plan to achieve regulatory conceptual approval. This plan provided the framework for regulatory activities that would ultimately lead to preliminary regulatory approval for a reservoir augmentation project at San Vicente. Both regulators issued conceptual approval of the proposed approach for reservoir augmentation. If San Diego's

indirect potable reuse project using reservoir augmentation is implemented, it would be the first reservoir augmentation project in the state and could pave the way for other reservoir augmentation projects.

Energy and cost analyses. An important consideration in implementing a potable reuse project is its cost and how it compares with the cost of other sources of water. San Diego's energy and cost analyses found that the energy use and cost of a full-scale potable reuse project would be comparable to that of imported water. To produce and convey 15 mil gal of purified water to San Vicente Reservoir would cost approximately \$2,000/acre-ft and would require about 2,500 kW·h/acre-ft.

One of the benefits of potable reuse is that it provides a new source of water, but it also reduces the amount of wastewater flows, which has both environmental and financial benefits. A full-scale purification project would lead to avoided wastewater costs by reducing the amount of flow to the Point Loma Wastewater Treatment Plant, thus reducing the extent and complexity of upgrades needed at Point Loma. Avoided wastewater costs also include those associated with the construction of a 7-mil-gal storage facility that would manage peak wet-weather flows to Point Loma. The total of these avoided costs and savings are estimated to be about \$1,000/acre-ft.

Education and outreach. In the past, adverse public opinion stifled potable reuse efforts. Although few question the "science" of water purification, the greater challenge is public perception. Potable reuse is a concept that has been attempted previously in the city's history, but because of public and political concerns, it did not have the support to move forward. To overcome misinformation and to inform the public about the science of potable reuse, the city council instructed that public outreach be included as a component of the demonstration project.

The public outreach and education program aimed to inform and educate San Diego's local leaders, stakeholders, and residents about the demonstration project. A team of outreach experts worked together to provide project information through stakeholder interviews, speakers bureau presentations, community events, a tour program, written and electronic materials, and traditional and social media.

Through all of the outreach activities implemented, thousands of San Diegans have been informed and educated about potable reuse. Research findings support the importance of these efforts. A study conducted in 2012 by San Diego State University found that after being read a description of the demonstration project, 78% of respondents supported it. Additionally, public opinion polls that studied San Diegans' opinions on recycled water use in 2004, 2011, and 2012 found a steady increase in residents favoring the use of advanced treated recycled water to diversify the city's water supply from 26% in 2004 to 73% in 2012.

Media coverage also reflects the success of the outreach program. The *San Diego Union-Tribune*, a long-standing opponent of indirect potable reuse, published an editorial in 2011 declaring that the paper had come to accept the science behind water purification technology and encouraged the rest of San Diego to do the same: "The Yuck Factor—Get Over It." On a national level, *USA Today* and the *New York Times* both featured San Diego's water purification demonstration project in front-page stories.

A similar sentiment in support of potable reuse was echoed by a coalition of local stakeholders. Recognizing the importance of local, drought-proof water supplies, nearly two dozen San Diego-based groups came together to form the Water Reliability Coalition. This group has a diverse membership that ranges from environmental organizations to business and taxpayer groups. It played an

important role by initially supporting the project and pushing to implement it as well as providing an independent voice about the safety and efficacy of potable reuse in San Diego.

Outreach efforts by the city and by supporters such as the Water Reliability Coalition are leading the way in battling misinformation and enabling a better understanding of potable reuse. But just because there has been a shift in the acceptance of potable reuse does not mean outreach activities are complete. Opinions can shift in any direction, often depending on whether it rains or not. So the city's outreach efforts, including tours and presentations, continue beyond the completion of the demonstration project.

UNANIMOUS ACCEPTANCE

In spring 2013, the project report, which includes project testing results and cost estimates, was presented before the city council's Natural Resources and Culture Committee (NR&C)—a city council subcommittee with a focus on a variety of community issues including water—and the San Diego City Council.

During the NR&C meeting, the committee expressed strong support for the demonstration project and moving forward with potable reuse in San Diego. Committee members asked that the public utilities department not only continue to explore indirect potable reuse but also explore direct potable reuse. By unanimous vote NR&C members recommended the item be moved to the city council for its consideration.

The project report was presented to the full city council April 23, 2013. Led by Councilmember David Alvarez, a long-time champion of the project, individual council members joined him in expressing their support for potable reuse as a sustainable, reliable local water supply for San Diego. When the council took public testimony, members of the IAP and the Water Reliability Coalition voiced their support for developing potable reuse in San Diego. Again, the vote

was unanimous, with all eight council members voting in favor of adopting the project report and moving toward implementation of potable reuse in San Diego. The council directed staff to complete the following tasks:

- determine a preferred implementation plan and schedule for a full-scale project,
- develop a strategy for allocating potable reuse costs among local water and wastewater funding sources,
- develop a financing plan for a full-scale project,
- monitor the development of direct potable reuse regulations in California,
- report to NR&C on the progress of each of the previous items within 90 days of the city council hearing,
- join the WateReuse Foundation's direct potable reuse initiative, and
- use remaining project funds to initiate work on the next steps.

Guided by the resolution adopted by the city council, the project team is now working on the next steps:

- continuing AWPf operations to test alternative treatment processes and monitoring techniques;
- continuing outreach efforts, including tours and speakers bureau presentations;
- determining contracting modes; and
- refining the pipeline alignment.

The unanimous support of the city council marks a major milestone for potable reuse in San Diego. Although much work lies ahead, San Diego is on the path toward developing a new, local, and reliable source of water through potable reuse. Not only will San Diego benefit from having a new source of drinking water, but the city is also blazing a trail for future potable reuse projects statewide.

For more information about the city of San Diego's Water Purification Demonstration Project, visit www.purewatersd.org, or e-mail purewatersd@sandiego.gov. The full project report is available at www.PureWaterSD.org/projectreports.

ABOUT THE AUTHOR



Marsi A. Steirer is deputy director for the city of San Diego's Public Utilities Department, 525 B St., Ste. 300, San Diego, CA

92101-4409. She can be reached at msteirer@sandiego.gov. Danielle Thorsen is an onsite community relations specialist with Katz & Associates, 4250 Executive Square, Ste. 670, San Diego, CA 92037.

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