WATER, SUSTAINABILITY, AND SELF-RELIANCE

To improve the quality and reliability of its water supply, the City of Oxnard, California, has developed an approach to water management that seeks to make greater use of local resources and to do so in a sustainable way. By creating facilities to treat local brackish groundwater, the city is reducing its dependence on costly and potentially unreliable sources of imported water.

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The City of Oxnard's desalter and chemical buildings each include solar photovoltaic panels, one of the many features that helped the project earn gold certification in the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System.

CITY OF OXNARD

LOCATED ALONG the Pacific coastline approximately 60 mi (97 km) northwest of Los Angeles, the growing community of Oxnard, California, requires a reliable, local supply of water to ensure its future prosperity. To meet its needs, the city of more than 170,000 residents has traditionally relied on a blend of local groundwater and imported water supplied by the Metropolitan Water District of Southern California (MWD) from the Colorado River and from sources in northern California and the Colorado River. The city has blended the lower-quality (brackish) groundwater with the higher-quality imported water to produce an economically viable supply of moderate quality.

In 2002 the city, in conjunction with Kennedy/Jenks Consultants, of San Francisco, analyzed its projected potable water demand in relation to the supplies expected to be available within the next 20 years. The findings made clear that a supplemental source would have to be developed to meet Oxnard's growing demands. However, neither of the existing sources could be expanded without detrimental consequences. If the city increased its use of local groundwater, it would face potential overdraft fees from the Fox Canyon Groundwater Management Agency (the state-created agency responsible for overseeing the county's groundwater sources) and would risk diminishing the quality of the overall blended water. The city also realized that imported water would continue to be a less reliable and increasingly costly option because of more frequent droughts and environmental concerns regarding the water supply system in the delta formed by the Sacramento and San Joaquin rivers in northern California. (See "Is California Next?" *Civil Engineering,* November 2005, pages 39–47, 84–85.)

To provide a long-term, local solution to its water conundrum, in May 2002 Oxnard carried out a planning study that led to the Groundwater Recovery and Treatment (GREAT) program, which would take a sustainable approach in managing the community's local resources within an integrated, comprehensive water supply system. Kennedy/Jenks worked with the City of Oxnard to develop the GREAT program, and the firm designed the first project within that plan, the GREAT program desalter. A complex and visionary scheme, the GREAT program links all of the water resources in the Oxnard area—including imported water, local groundwater, wastewater, recycled water, and brine wastes—and describes how each resource can be used to best advantage. Its key principle is to reduce the need for costly imported water by creating facilities that can treat local brackish groundwater resources. To implement this approach, the GREAT program also includes facilities that will protect the local groundwater basin by offsetting some of the extracted groundwater and minimizing seawater intrusion. These goals will be met by treating wastewater to recycled water standards and then returning it belowground by means of various injection wells. Moreover, brine wastes and industrial discharges are seen as potential water sources for restoring local wetlands.

In October 2008 the city completed the brackish water desalter, the first component and cornerstone of its GREAT program. Dedicated the following month, the facility includes an advanced reverse-osmosis (RO) treatment process to reliably provide the city with high-quality water from a local source. The high-quality product water is blended with local groundwater to improve overall quality and reduce the community's reliance on imported water. The GREAT program reduces the amount of imported water provided through the MWD by shifting demand to local groundwater sources through use of the desalter. Costing $25-million, this important project embodies sustainable principles and elements that have earned the facility a gold certification in the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System.

The GREAT program desalter is located at the city's water campus, which also includes the city's largest blending station (previously known as blending station 1), an administration building, and a multipurpose building used for training staff and conducting presentations and seminars. Within this location, the desalter was easily integrated into the blending station and administration building. The water campus is within walking distance of the city's historically important downtown area and such key city buildings as the library and city hall. The water campus is also located next to an existing transportation hub. Because of this, the city earned additional points in the LEED rating system for providing

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workers and visitors with an alternative form of transportation. What is more, the facility can accommodate tours in a way that is more environmentally responsible by offering a mass transit alternative.

As stated above, the blending station previously combined high-quality imported water supplied by the MWD with local groundwater of a lower quality withdrawn from on-site wells or delivered from off-site wells. The new desalter provides a high-quality replacement for the MWD water previously used at the blending station. By shifting the demand at the facility from imported water to treated water that is locally derived, the city is able to minimize its exposure to the risks of escalating costs and decreasing reliability attendant upon importing water from northern California.

The GREAT program desalter consists of several components that were designed and constructed in four stages. The following facilities, listed in order of completion, form part of the overall project:

Stage 1: A 600,000 gal (2,279 m^3) steel reservoir;

Stage 2: Three dedicated groundwater wells with a total capacity of 7,000 gpm (27 m^3/min);

Stage 3: A power and wellness center, which provides emergency power to the new supply wells and includes a recreation area and a lunch room for operations and distribution personnel;

Stage 4: The desalter building, which includes a security check-in area, a visitors' viewing gallery, and room for mechanical equipment, cartridge filters, RO units, and the clean-in-place system for the membranes. This stage also produced the chemical building, which houses the main control room, permeate booster pumps, an electrical room, a laboratory, and an area for storing antiscalant, sodium hypochlorite, and sodium hydroxide

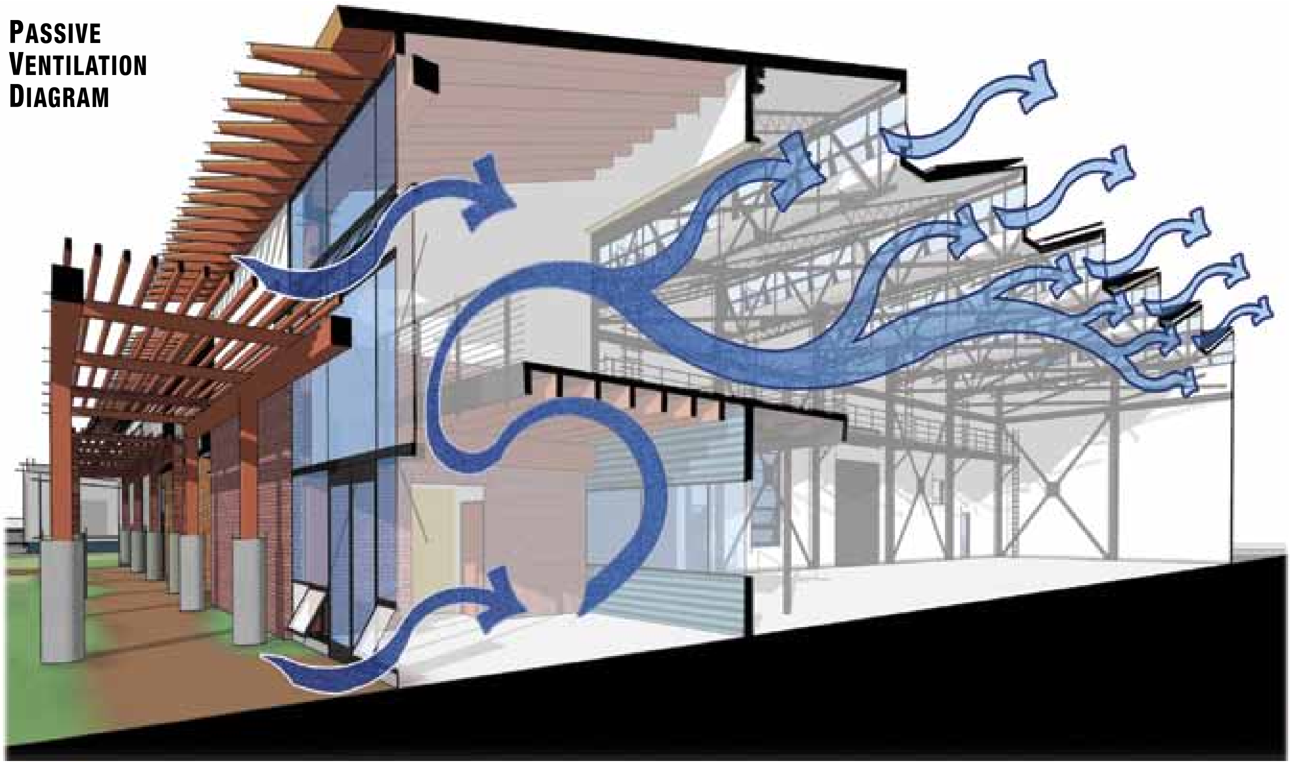
Located along the southern portion of the site, the three dedicated groundwater wells pump brackish groundwater at a pressure of approximately 130 psi (900 kPa) across the campus to the desalter building. Here the water enters four parallel stainless steel vessels, each containing 176 replaceable wound cartridge filters. The filter media within the cartridges are designed to protect the RO membranes by capturing debris larger than 5 µm. As an added measure, the raw water is dosed with antiscalant before it reaches the cartridge vessels.

Typical desalination systems include low-pressure well pumps that feed into a tank, followed by high-pressure booster pumps that feed the RO process. However, to optimize the RO process at the Oxnard desalter, Kennedy/Jenks proposed an innovative approach that the firm had used previously in designing an RO process for brackish water in the Middle East. In this approach, the high-pressure well pumps convey groundwater through the cartridge filters directly to the RO process, eliminating the need for a break tank and additional high-pressure pumps. Although this concept requires the use of larger well-head pumps and high-pressure cartridge filters, it eliminates the inefficient series pumping, reduces the footprint required for the building, and reduces noise in the facility. (See the figure on page 72.)

The membrane unit consists of three parallel process skids, each containing energy-efficient RO membrane units for brackish water capable of providing 2.5 mgd (9,500 m^3/d). However, the total plant capacity of 7.5 mgd (28,400 m^3/d) was designed to be expandable to 15 mgd (56,800 m^3/d). Each RO unit for brackish water includes two stages and an interstage turbocharger for energy recovery. This arrangement maximizes production and energy efficiency, resulting in a recovery rate of 80 percent, that is, 80 gal (0.3 m^3) of permeate produced for every 100 gal (0.4 m^3) of raw water.

The system for recovering energy transfers pressure energy from the RO brine to reduce the feed pressure required for the

Passive Ventilation Diagram



MAINSTREET ARCHITECTS + PLANNERS

Table 1 Cost Savings

Configuration	Feed (psi)	Feed flow (gpm)	Permeate flow (gpm)	Cost per acre-foot
Operation with energy recovery	114	2,163	1,728	$50
Operation without energy recovery	119	2,025	1,618	$52

system and improve the performance of the RO process. The high-pressure brine is passed through a turbine for energy recovery, that is, a turbocharger. The turbine rotor converts pressure energy to mechanical shaft energy, which drives a booster pump to add pressure to the feedwater for the second stage of the RO system. With this approach, energy that would otherwise be wasted in a pressure drop through a valve can be utilized to reduce the overall energy consumption of the facility. By reducing the system's required feed pressure, the interstage process for energy recovery reduces the cost of the treated water by approximately $2 per acre-foot. For the 7.5 mgd (28,400 m^3/d) desalter, this saving could amount to nearly $17,000 per year (see table 1).

Permeate from the RO process for brackish water is stored in the permeate tank before being pumped at 70 psi (483 kPa) to the existing blending station via three booster pumps that are controlled by variable-frequency drives and have a combined operational capacity of 5,200 gpm (20 m^3/min). The permeate is dosed with sodium hypochlorite and ammonia for disinfection and with sodium hydroxide to control pH. Table 2 illustrates the quality of the source water supplied to the RO system for brackish water and the corresponding permeate water quality.

Table 2 Typical Source Characteristics and Permeate Water Performance

Performance	Reverse-osmosis feedwater	Permeate
Manganese (μg/L)	34	Not detectable
Nitrate-NO_3 (mg/L)	62	15
Sulfate (mg/L)	700	1.8
Total dissolved solids (mg/L)	1,500	37
Hardness (mg/L)	820	14

The brine from the desalination process is discharged into the city's wastewater collection system and routed to the Oxnard Wastewater Treatment Plant. Oxnard has plans to construct a citywide brine collection system that will discharge to the Calleguas Regional Salinity Management Pipeline, which the Calleguas Municipal Water District is currently constructing, or to an existing ocean outfall located at the treatment plant. As an alternative, the brine could be used to restore local wetlands.

The imported water supply pipeline leading to the existing water campus blending station was modified to transport permeate rather than imported water from the booster pumps to the blending station. With this configuration, the city was able to utilize most of the existing equipment used for chloramination, minimize construction at the existing blending station, and limit modifications to the controls at the blending station. Aside from minor changes to the chloramination pumping equipment and blend ratio, the blending station (formerly blending station 1) operates in roughly the same manner as it did before, blending high-quality water with water of a lower quality to meet the city's water quality objectives in a cost-effective manner. The only difference in the operation of the blending station is that the source of high-quality water is now only 400 ft (122 m) away, not 400 mi (644 km) away. The figure on page 73 illustrates how the desalter was incorporated into the existing blending station.

The desalter has been operating continuously since January 2009, with operation preceded by start-up and testing of the membranes. Between January and August the desalter produced more than 2,900 acre-ft (3.6 million m^3) of permeate. Despite the fact that only two of the three available units have been operating, the desalter has successfully met the system demands, indicating that the facility is sized to meet the growing needs of the city.

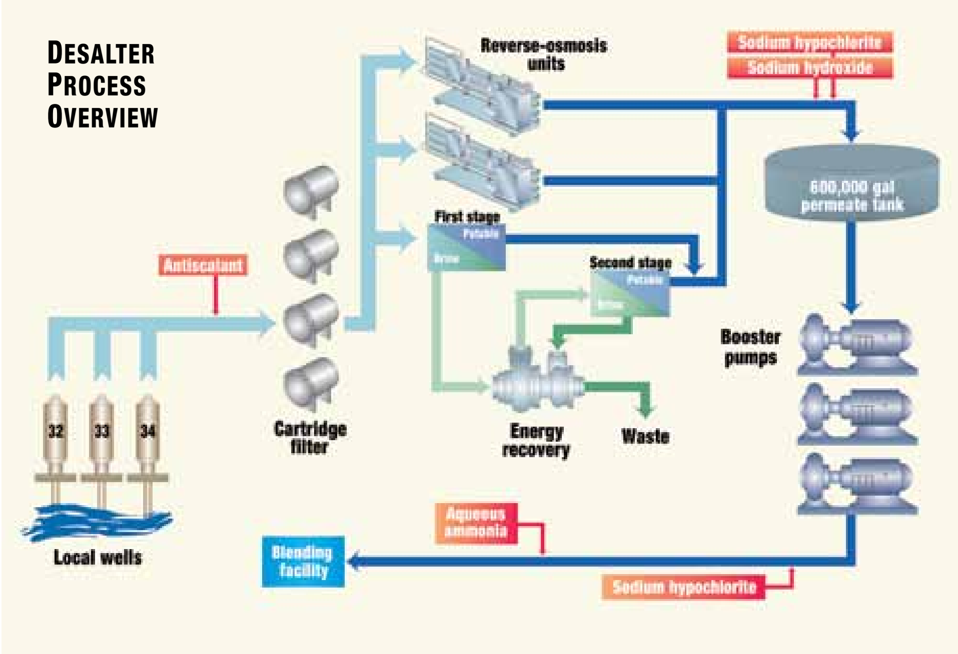
The city's GREAT program strives to provide an exceptional example of environmental stewardship, that is, to show how water resources can be used in sustainable fashion and how economic development can proceed in a way that is environmentally responsible. After construction was completed, the U.S. Green Building Council accorded the facility a gold certification. In fact, the facility earned 46 credits, just 6 short of the number needed for platinum certification.

To help inspire others and to highlight the core sustainability principles of the GREAT program, the city made its water treatment facility publicly accessible so that it would also provide an educational experience and demonstrate Oxnard's commitment to "green" building features. To help educate the public and local agencies about the system as well as about green construction techniques, the facility was designed with a tour path equipped with viewing windows and hands-on educational kiosks. Visitors can view information on every aspect of the treatment process, from raw water to the distribution system.

The visitors' entrance opens to a visually striking visitor path lined with windows that offer views of the process area. From this vantage point, visitors can see the 30 in. (750 mm) diameter stainless steel raw water piping, the cartridge filters, the clean-in-place system for the membranes, and the RO process equipment. This area also includes public restrooms equipped with low-flow fixtures.

Several design features were implemented to reduce energy costs and increase patron and operator comfort. The desalter building's south-facing wall and the north-facing sawtooth roof are lined with 156 temperature-controlled, motorized windows, while another 36 operable window units line the chemical building. The windows automatically open and close, depending upon the temperature. With this configuration, the temperate climate of this beachside community can provide natural, passive ventilation, thereby minimizing the use of the heating, ventilation, and air-conditioning system. (See the figure on page 70.)

To ensure proper ventilation, carbon dioxide monitors are located in frequently populated areas. The glass wall enclosing the south and east sides of the 800 sq ft (74 m^2) security check-in area and visitors' gallery is made of Solexia, a specially tinted glass produced by PPG Industries, of Pittsburgh. Solexia provides natural lighting to the interior while reducing heat loss in cold weather and solar heat buildup during warm weather. Patrons touring the visitors' gallery will also benefit from the motorized shades and louvers that the staff can operate to minimize glare. Certain architectural features—including the roof overhang and an exterior wood-framed trellis covered in morning glory and orange clock vine—also control glare and impart aesthetic appeal.



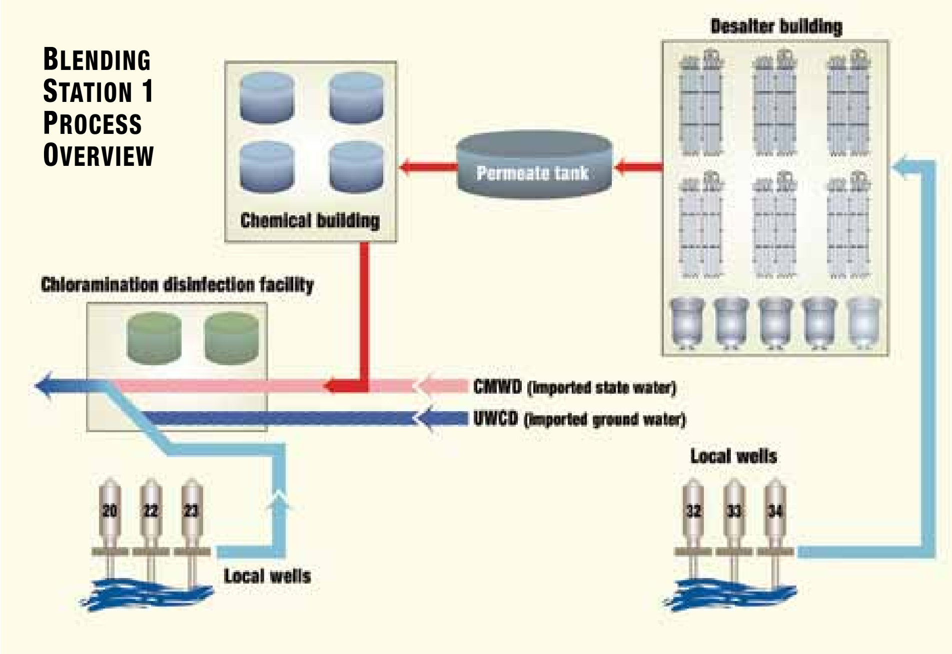
From the visitors' gallery, an elevator next to the main process viewing window is available to transport visitors to the viewing balcony, which is on the second floor and provides an unobstructed view of the membranes from a height of 12 ft (3.7 m). It also directs the attention of visitors to the sawtooth roof overhead. Tilted at an angle of 18.5 degrees due south, the roof is lined with windows to provide patrons with a clear view of the photovoltaic panels blanketing each of the five sections of the roof. The roof is designed in a sawtooth pattern with five "teeth," or sections, that provide the necessary slope for each array of solar panels while maintaining a relatively level roofline. The 5,000 sq ft (465 m^2) of 175 W monocrystalline solar modules between the roofs of the desalter and chemical buildings produce approximately 101,000 kWh per year, far exceeding the building's annual demand of 46,000 kWh. Although the solar panels supply enough energy to meet the needs associated with such normal building operations as lighting and computers, the process equipment requires additional power supplies. Located beneath and surrounding the solar panel structures is a Sarnafil G410 EnergySmart Roof, manufactured by Sika Sarnafil, a division of the Sika Corporation, of Canton, Massachusetts. This single-ply white membrane, which meets the guidelines for energy efficiency established by the U.S. Environmental Protection Agency's Energy Star program, reduces cooling costs and helps minimize the urban "heat island" effect.

Visitors familiar with standard desalination facilities will certainly notice that the process area is nearly silent, the result of the innovative approach that eliminates the need for a break tank and additional high-pressure pumps. Complementing this serene environment is a 180 sq ft (17 m^2) mural painted by a local artist that pictorially leads visitors through the history of water supplies within the Oxnard area. The mural includes an image of the elevated water tank that previously towered over the site. Furthermore, various renderings pay homage to the area's agricultural roots.

An open-air walkway on its second floor links the desalter facility with the chemical building. From the second-floor balcony of the chemical building, visitors can view the laboratory area, the permeate tank, and the grass-covered permeable parking lot. The lab area includes a sink in which several process sample streams flow continuously. These streams enable plant operators to test various stages of the brackish water RO process. Water from the sample streams is not sent to the city's sewer collection system. Instead, it is collected in a 400 gal (1.5 m^3) tank and used to irrigate the site's landscaping. By using sample water in place of recycled water, the city is able to provide a source of irrigation water that, in contrast to pumped and treated recycled water, does not require substantial energy. By using the on-site resource from the sample streams in lieu of highly treated water from the city's advanced water purification facility (AWPF), the city is able to minimize energy use and reduce the cost of on-site irrigation by 96 percent. Although not significant on its own, the savings afforded by this design provide a template for future treatment facility projects within the city as well as for outside agencies.

From the second floor of the chemical building, visitors may use one of two staircases that provide access to the ground floor. One stairway leads down to a breezeway and an area between the desalter building and the chemical building featuring nearly 2,400 sq ft (223 m^2) of permeable paver blocks. The pavers facilitate storm-water infiltration and further reduce the heat island effect. The second staircase takes visitors past the 24 in. (600 mm) diameter permeate manifold, the sample water irrigation tank, and various pumping equipment to an expanse of nearly 4,000 sq ft (372 m^2) of colored concrete that delineates the pathway for visitors. The pathway connects the public access point to the new desalter and chemical buildings as well as to the administration and multipurpose buildings.

KENNEDY/JENKS CONSULTANTS, *ABOVE LEFT AND ABOVE RIGHT*; CITY OF OXNARD, *BOTTOM RIGHT*



various catch basins throughout the site, captures large debris through a 60 in. (1,524 mm) tall buried swirl concentrator, and routes the remaining flows to a 50 by 17 by 4 ft (15 by 5.2 by 1.2 m) underground detention and retention basin. The buried structure not only provides detention time to reduce the effect of the facility's runoff on the city's storm-water collection system but also retains storm water, enabling it to recharge the groundwater table through percolation.

The GREAT program desalter was constructed through various independent contracts. Three important contracts were established with the RO system supplier, the general contractor, and a firm hired by the city to work with the general contractor during construction and start-up to ensure that the new equipment was properly programmed and seamlessly integrated into the city's existing supervisory control and data acquisition (SCADA) system. Given the three separate contracts, specifications, and drawings, challenges arose with respect to accurately assigning responsibility for overlapping tasks or gaps in scope that needed to be filled. Early on in the construction phase of the desalter, the project participants realized that they needed to facilitate a continuous dialogue with all parties to avoid delays in equipment deliveries and installation conflicts, as well as to minimize change orders.

The new and existing buildings surround a 12,400 sq ft (1,152 m²) grass-covered parking lot. The grass paving system consists of high-impact polypropylene honeycomb cells capable of withstanding loads associated with emergency vehicles and the heavy trucks used to deliver chemicals. Located underneath the grass paving south of the chemical building is the storm-water treatment system. This system combines runoff from the roof collection systems and

The desalter's membrane process employs three parallel process skids, each containing reverse-osmosis membrane technology for brackish water capable of providing 2.5 mgd (9,463 m³/d).

In its initial analysis of the GREAT program, city officials determined that using local water resources would improve self-reliance but would also cause the city to exceed its available groundwater pumping rights, or credits, as enforced by the groundwater management agency. To mitigate this situation and develop a truly sustainable approach, the GREAT program includes an AWPF that will provide a new water source to reduce demand on the groundwater basin.

A portion of the treated wastewater from the 32 mgd (121,120 m³/d) Oxnard Wastewater Treatment Plant will be delivered to the nearby AWPF for further purification in a three-step process that will involve microfiltration, RO, ultraviolet light, and hydrogen peroxide. Construction of the AWPF is scheduled to begin early next year and to conclude by late 2011, at which time the facility will have the capacity to produce 6.25 mgd (23,660 m³/d) of recycled water. Ultimately, the AWPF will have a capacity of 25 mgd (94,625 m³/d) and will provide recycled water to regional customers for nonpotable purposes, including landscape and agricultural irrigation and use in industrial processes. When irrigation needs are low, recycled water will be injected underground by means of a string of coastal wells to prevent saltwater intrusion. Like the desalter, the AWPF will have a visitors' center to support educational goals and will irrigate on-site wetlands. It will also *(Continued on Page 76)*

Biosolids Burning

(Continued from Page 59) demonstrates that this advanced technology is not just for large population centers. At present virtually all mechanical wastewater plants in the United States either use some level of land application or haul away the waste to be burned. Here, land application is eliminated and the biosolids become fuel to power the treatment process. From the perspective of Buffalo citizens and city officials, this project eliminated the need to place biosolids on farmland, lowered natural gas costs, and created a renewable energy resource.

By recycling the biosolids into a fuel source, Buffalo has reduced its natural gas consumption for drying by 80 percent. Energy savings in the first year of operation are expected to exceed $90,000. By 2027 annual savings are projected to reach $500,000, which translates to approximately $5 million in energy savings over 20 years. By reducing the volume of the remaining biosolids to approximately 5 percent of the original amount, truck hauling in and around the community has been dramatically reduced. What would have amounted to 1,000 truckloads of biosolids per year has become a mere 50 loads of ash, a definite plus in the view of residents who are spared the traffic, noise, and odor.

The Bolton & Menk team worked closely with Buffalo's forward-thinking officials to satisfy their unique goals. It became clear early on that something more than the usual tried-and-true methods would be necessary to accomplish their objectives. The initial project estimate for the entire wastewater treatment plant upgrade project was $12 million, but that did not include the incinerator. Adding that component to the process raised the price by $2.6 million. However, cost was not the determining factor in deciding which type of system to build. Buffalo was willing from the outset to embrace higher capital costs to construct a plant that would offer future savings on operating costs. Priding itself as a "green" city, the community wanted to set a benchmark for what was possible in wastewater treatment. Consequently, Buffalo adjusted its budget to $14.6 million, and the project was completed for that amount.

The city's solution to its biosolids problem has resulted in significantly reduced by-products from the process and considerable savings in fuel costs. Those savings will only increase as natural gas prices rise. The facility has turned a liability into a renewable resource, far exceeding the city's expectations and setting a new standard for treatment in the United States. The project was completed on schedule, and phased start-up was carried out last year between September and November. The plant's capacity is such that it will be able to accommodate the city's growth for the next 20 years. **CE**

Bradley C. DeWolf, P.E., M.ASCE, is a principal engineer for Bolton & Menk, Inc., which is headquartered in Mankato, Minnesota.

PROJECT CREDITS **Owner:** City of Buffalo, Minnesota **Consultant:** Bolton & Menk, Inc., Mankato, Minnesota **Equipment supplier:** Krüger, Inc., Cary, North Carolina **Structural engineering:** LS Engineers, Inc., Le Sueur, Minnesota **Electrical engineering:** Barr Engineering Company, Minneapolis **Geotechnical engineering:** Braun Intertec Corporation, Minneapolis **Air quality permitting:** Golder Associates, Inc., Roseville, Minnesota **Building design:** Architects Plus, Faribault, Minnesota **General contractor:** Rice Lake Construction Group, Deerwood, Minnesota

Water, Sustainablity, And Self Reliance

(Continued from Page 73) demonstrate the feasibility of using wetlands technology to support healthy ecosystems, polish effluent, and reduce the volume of brine to be disposed of by ocean outfall.

Given the additional management tasks necessitated by separate contracts during the construction of the desalter, the city has decided to proceed with the construction of the AWPF by first selecting the process system supplier and then carrying out the design under a subcontract to the general contract. This approach will provide one point of contact for the city during installation and start-up of the equipment. What is more, all responsibility will be shifted to one source, the general contractor, and the city will not have to participate in debates that might arise regarding such topics as points of connection or discrepancies of scope.

By using recycled water, the city will accrue groundwater pumping credits that will offset the increased extraction of groundwater required by the desalter as well as by future desalination facilities for producing potable water. For example, the city recently completed the preliminary design of a 7.5 mgd (28,400 m^3/d) RO facility that will be located at its second-largest blending station and will treat brackish groundwater. By completing this project, Oxnard will continue its efforts to secure a reliable and cost-effective supply of water in as sustainable a manner as possible. **CE**

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PROJECT CREDITS **Owner:** City of Oxnard, California **Design engineer and construction manager:** Kennedy/Jenks Consultants, San Francisco **General contractor:** Emma Corporation, Santa Monica, California **Reverse-osmosis system supplier:** Biwater-AEWT, Inc., Monrovia, California **Architect:** Mainstreet Architects and Planners, Inc., Ventura, California **Instrumentation control and system integration:** Prousys, Inc., Ventura, California **Membrane system design:** Black & Veatch Corporation, Kansas City, Missouri **Landscape architect:** CPS Landscape Architecture, Ventura, California