Innovative Applications in Water Reuse and Desalination

Case Studies 2




Innovative Applications in Water Reuse and Desalination

Case Studies 2

ABOUT THE WATEREUSE ASSOCIATION

THE WATEREUSE ASSOCIATION is a non-profit organization whose mission is to advance the beneficial and efficient use of water resources through education, sound science, and technology using reclamation, recycling, reuse, and desalination for the benefit of our members, the public, and the environment. Across the United States and the world, communities face water supply challenges due to increasing demand, drought, depletion and contamination of groundwater, and dependence on single sources of supply.

WateReuse addresses these challenges by working with local agencies to implement water reuse and desalination projects that resolve water resource issues and create value for communities. The vision of WateReuse is to be the leading voice for reclamation, recycling, reuse, and desalination in the development and utilization of new sources of high quality water.

ABOUT THE AUTHOR

DR. JAMES CROOK is an environmental engineering consultant specializing in water reclamation and reuse. He has more than 35 years of experience in state government and consulting engineering serving public and private sectors in the United States and abroad. Dr. Crook has been involved in numerous projects, studies, and research activities involving public health, regulatory and permitting issues, water quality, risk assessment, and treatment technology. He has authored more than 100 publications and is an internationally recognized expert in the area of water reuse.

Innovative Applications in Water Reuse and Desalination

Case Studies 2

James Crook, Ph.D., P.E.

WateReuse Association

Alexandria, VA

For more information, contact:

WateReuse Association
1199 North Fairfax Street, Suite 410
Alexandria, VA 22314
(703) 548-0880
Fax: (703) 548-5085
Information@WateReuse.org
www.WateReuse.org

Printed in the United States of America

CONTENTS

FOREWORD

ALTHOUGH OUR PLANET IS MOSTLY WATER, approximately 97.2% of this precious resource is saline and only about 2.5% of it is classified as fresh water. Approximately 70% of the fresh water is locked up in the form of polar icecaps and glaciers. The remaining groundwater or surface water (0.7% of the world's water) often does not meet the needs of local populations. Under pressure from such factors as population growth, climate change, depletion of groundwater resources, and impacts from salt, many communities are struggling to find enough water to meet their needs. This report profiles 10 communities which have faced such problems to varying extents and found innovative solutions that combine conservation, water reuse, and sometimes desalination.

The WateReuse Association released the first *Case Studies* report in 2004 to document the success of 10 diverse water reuse projects in the United States. Today, there are more than 1,200 known water reuse projects in 20 states. This edition of the *Case Studies* report shows how communities have found success by looking at a menu of options for alternative water supplies. The El Paso Water Utilities and the Inland Empire Utilities Agency, for example, are using both water reuse and brackish groundwater desalination in novel ways to achieve a sustainable water supply. This publication also offers an international perspective through a review of the Singapore NEWater project, which provides reclaimed water for both nonpotable and indirect potable reuse.

The 10 successful projects profiled in this report are as diverse as the communities that championed them. Each project faced obstacles ranging from varying seasonal water needs to water supply rights that could be negatively impacted by effluent that is reused instead of discharged. Every community needs to find their unique solution, but these case studies provide examples that can be beneficial to any community that is thinking about launching a new project. Even with the diverse and novel approaches, there are some common themes in these successful projects. The utilities involved spent time informing and educating the public about water needs and the safety and efficacy of the proposed projects. These successful projects also included thorough planning and design stages often combined with pilot plants and research to ensure project success.

In the 21st Century, more and more communities will find that they cannot rely on a single source of water supply. The WateReuse Association supports water projects that produce high-quality water supplies from treated municipal and industrial effluents, stormwater, agricultural drainage, and sources with high salinity such as seawater and brackish water. The first *Case Studies* report demonstrated that sharing information on successful projects is vital for communities which are striving to find alternative sources of supply. The 10 new case studies represent some of the most innovative approaches and will no doubt educate and inspire new ideas.

The Association is grateful to Dr. Jim Crook who has once again authored an easy to read and informative set of case studies. The Association also acknowledges the participation and support of the water utilities and agencies discussed in this publication. Their willingness to share information and review the case studies have helped make this a quality publication. The Association hopes that their experiences will enlighten, motivate, and inspire.

G. Wade Miller
Executive Director
WateReuse Association

CARY, NORTH CAROLINA

Background

THE TOWN OF CARY is located in the Triangle area of North Carolina between Raleigh and Research Triangle Park and had a population of about 121,500 in mid-2007. Rapid population growth in the Research Triangle region in the 1980s and 1990s began to put a strain on the water resources in the region. In response to the need to develop an integrated water management system to help meet future water needs, Cary initiated a water reuse feasibility study in 1997, followed by the design, construction, and ultimately, implementation of a water reclamation and reuse system in 2001. The total project construction cost of the two water reclamation facilities that were built was about $11 million. The project was funded through the capital improvement budget of the Town. Revenue from the sale of reclaimed water helped offset the cost of construction.

The primary goals of developing the reclaimed water system were to provide demand management of the potable water system, safely and cost-effectively use reclaimed water as a valuable resource, satisfy a commitment made to the Neuse River Foundation in 1995, and satisfy a Town Directive to reduce per capita water consumption by 20% by 2015. Through water conservation measures and the use of reclaimed water, the Town has reduced its water consumption by 1% per year since that commitment was made.

Reclaimed Water Facilities

The Town of Cary treats wastewater for Cary, Morrisville, the Raleigh–Durham International Airport, and the Wake County portion of the Research Triangle Park. The reclaimed water system includes the North Cary Water Reclamation Facility (WRF) and the South Cary WRF, their related reclaimed water distribution systems, and bulk reclaimed water distribution centers located at each of the treatment plants. The treatment plants are located at opposite ends of the Town.

The permitted reclaimed water diversion limit from both plants is slightly more than 5.1 mgd; about 4.3 mgd from the North Cary WRF and 0.86 mgd from the South Cary WRF. The available supply of reclaimed water is much larger than the current demand in the service area, and on a peak day Cary uses a total of approximately 1.2 mgd of reclaimed water for nonpotable water reuse at just shy of 500 sites, including residential property. As much as 20 million gallons of reclaimed water are used per month in the summer, and more than 85% of the annual reclaimed usage typically occurs in May through October. In 2006, there were about 16 miles of distribution pipelines, with another six miles scheduled for installation in 2007–2008.

IRRIGATION AT MIDDLE CREEK SOFTBALL COMPLEX

There are no plans to serve the entire town with reclaimed water, and only areas with the highest potential demand are targeted for reclaimed water service. Reclaimed water applications include irrigation (residential lawns, parks, school grounds, highway medians, etc.), manufacturing processes, industrial cooling, street sweeping, and dust control at construction sites. State regulations prohibit uses of reclaimed water that discharge directly into a storm drain, but residential customers can use reclaimed water for such nonirrigation uses as making concrete and cleaning tools if the spent wash water is not discharged to the street or a storm drain.

North Cary WRF—The capacity of the North Cary WRF was increased from 10 to 12 mgd in 2005. The average flow in 2006 was 6.5 mgd. On average, about 58 million gallons of reclaimed water are used per year; the rest of the treated wastewater is discharged to Crabtree Creek, a tributary of the Neuse River. Treatment processes included the following:

- Preliminary treatment (screening, grit and grease removal);
- Activated sludge secondary treatment via oxidation ditches, including biological nutrient removal;

- Secondary clarification;
- Filtration with continuous backwash upflow sand filters;
- UV disinfection with medium pressure lamps; and
- Post aeration using a cascade aerator.

Sodium hypochlorite is added to the water before it enters a one million gallon storage tank to provide a target chlorine residual of 0.5 mg/L. The tank is needed to equalize differences between peak morning irrigation demands and concurrent low influent flow to the WRF.

In 2005–06, the ranges of the monthly averages of various water quality parameters were as follows: 1 to 3 fecal coli/100 mL; 0 to 0.6 mg/L CBOD; 0.1 to 1.4 mg/L TSS; 0.01 to 0.33 mg/L NH_3; 2.5 to 4.5 mg/L total nitrogen; and 0.2 to 1.1 mg/L total phosphorus.

South Cary WRF—The capacity of the South Cary WRF is 12.6 mgd. The average flow in 2006 was 4.9 mgd. About 6.5 million gallons of reclaimed water are used per year; the rest of the treated wastewater is discharged to Middle Creek, a tributary of the Neuse River. Treatment processes include the following:

- Preliminary treatment (screening, grit removal);
- Activated sludge secondary treatment with biological nutrient removal;
- Magnesium hydroxide addition for alkalinity addition;
- Secondary clarification;
- filtration via deep-bed multimedia filters with methanol addition for denitrification;
- UV disinfection with medium pressure lamps; and
- Post aeration using a cascade aerator.

There are no reclaimed water storage facilities at this WRF. Sodium hypochlorite is added to the reclaimed water to maintain a target chlorine residual of 0.5 mg/L in the distribution pipelines.

In 2005–06, the ranges of the monthly averages of various water quality parameters were as follows: 1 to 9 fecal coli/100 mL; 0 to 0.2 mg/L CBOD; 0.8 to 2.1 mg/L TSS; 0 to 0.8 mg/L NH_3; 1.8 to 3.6 mg/L total nitrogen; and 0.4 to 2.1 mg/L total phosphorus.

State Reclaimed Water Quality Criteria

The North Carolina Department of the Environment and Natural Resources (DENR) water reuse criteria for Cary's reclaimed water applications require that the water receive tertiary treatment (i.e., that it be filtered or receive equivalent treatment). The reclaimed water quality from both of the WRFs readily meets all regulatory requirements The DENR reclaimed water quality requirements are provided in the table below.

Reclaimed Water Quality Requirements

Parameter	Monthly Average	Daily Maximum
Fecal coliform	14/100 mL	25/100 mL
TSS	5 mg/L	10 mg/L
CBOD	10 mg/L	15 mg/L
Turbidity	--	10 NTU*
NH_3	4 mg/L	6 mg/L

** Continuous online monitoring*

Benefits

The use of reclaimed water, in conjunction with a comprehensive water conservation program, reduces the use of potable water and extends the life of Cary's current potable water treatment system, which translates into a substantial cost savings. Other benefits are that wastewater discharges to tributaries of the Neuse River—an environmentally sensitive watercourse—are reduced, and residential reclaimed water users are not subject to watering restrictions placed on potable water users. Customers who use potable water for irrigation via automatic watering devices are allowed to irrigate only on alternate days, with the exception that no watering is allowed on Mondays. Hand watering with cans, wands, or hand-held devices is allowed any day of the week. Residential reclaimed water customers are exempt from the alternate day watering ordinance and outdoor water use is not restricted during dry periods.

Bulk Reclaimed Water Program

The Town's bulk reclaimed water program was initiated at the North Cary WRF in 1999 and at the South Cary WRF in 2001 and allows tank trucks to fill up with reclaimed water at the WRFs for offsite applications of the water. Cary is permitted by DENR to disperse up to 100,000 gallons per day from each of the two bulk reclaimed water filling stations. Bulk reclaimed water uses include road construction, dust control, sewer flushing, and street sweeping. Reclaimed water is made available at no charge to contractors, landscapers, and other approved users for roadbed preparation, dust control, sewer flushing, street sweeping, and landscape irrigation. The minimum fill-up amount is 250 gallons. Only customers that have completed required training may obtain permits for bulk reclaimed water from the North Cary or South Cary WRFs. The bulk water reuse filling stations include a concrete spill containment pad, reclaimed water piping, valves and appurtenances, meter vault, hose connections, and other miscellaneous equipment.

Reclaimed Water Rate

The reclaimed water rate is equal to the Town's Tier 1 (0 to 5,000 gallons) single family residential inside water rate of $3.28/1,000 gallons. The reclaimed water rate is the same for all users regardless of amount used. The reclaimed water rate is based on a number of factors, including a desire to keep the rates less than those for potable water while recovering a substantial part of the capital and operating costs of the reclaimed water system. As demand can double during the summer months, the Town recommends that customers water lawns no more than one inch per week—including rainfall.

Public Information Program

During construction of the water reclamation and reuse facilities, the Town of Cary established an extensive public information program. Salient information on the reclaimed water system was provided to residents and all reclaimed water customers through a variety of sources, including newspaper articles, television programs, brochures, newsletters, and public meetings. A hotline was created for telephone inquiries regarding the reclaimed water program. The Town's website was used to provide general program information, as well as construction progress information. Direct mailings were sent to customers within the reclaimed water service area, both 30 days and 14 days prior to construction of pipelines on a particular street. The Town continues to educate and inform the public on its reclaimed water program mainly through its website, which contains a plethora of both general and specific information on the reclaimed water program.

Reclaimed Water Ordinance

Reclaimed water rules have been integrated into the Town's existing water use ordinance. All water conservation provisions restricting customers from wasting water also apply to

BULK RECLAIMED WATER FILLING STATION

the reclaimed water system. This includes requirements for installation of rain sensors on irrigation systems to restrict usage during wet weather. In addition, the Town takes enforcement actions against poorly maintained irrigation systems that discharge into the stormwater drainage system.

The ordinance requires that all dedicated in-ground irrigation systems within the reclaimed water service area be connected to the reclaimed water system. These users are provided a separate reclaimed water meter. A special reclaimed water hose bib is available for customers to install who want to connect an above-ground sprinkler to the reclaimed water system. Users are not charged any sewer fees on reclaimed water that may be returned to the Town's sewer system, such as cooling water blow-down.

Future Projects

One future project involves obtaining reclaimed water from the Durham County Triangle Wastewater Treatment Plant for irrigation at the Thomas Brooks Park in Cary as part of a joint effort between Durham County, Wake County, and the Town of Cary. The project has been approved for grant funding through the U.S. Environmental Protection Agency. This project will involve construction of almost seven miles of pipelines by the Town at an anticipated cost of about $5.7 million. In addition to this project, the Town is exploring the possibility of using reclaimed water for toilet and urinal flushing through a dual plumbing system in commercial and other buildings.

For further information, contact: Robert Bonne, Utilities Director, Town of Cary, Public Works and Utilities Department, 400 James Jackson Avenue, Cary, NC 27512

DENVER WATER RECYCLING PROJECT

Background

THE POPULATION OF DENVER—Colorado's largest city—has grown about 20% in the last 15 years and continues to grow at a significant rate, thus stressing the region's water resources. The City of Denver's water department (Denver Water) supplies drinking water to approximately 1.1 million customers within Denver proper and in some of the surrounding suburbs. The raw water infrastructure includes seven mountain storage reservoirs that hold water for treatment and consumption and two reservoirs that are used for exchange purposes to satisfy water rights. The reservoirs are filled primarily with snowmelt following spring runoff. The watershed covers about 3,100 square miles on both sides of the continental divide.

Denver's history of water reuse dates back to the Blue River Decree of 1955. In that court ruling, which was issued in conjunction with the permitting of Dillon Reservoir, Denver Water was allowed unlimited reuse of water transported to the east side of the continental divide from Dillon Reservoir. The reservoir is located in the Rocky Mountains on the west side of the continental divide. The Blue River Decree mandates that the utility maximize its use of this transported, or trans-basin, water to minimize or defer new imports of water from the western slope. To help meet the water needs of Denver's burgeoning population, Denver Water has been investigating methods of reusing treated wastewater since that time.

Denver first initiated water reuse studies in the late 1960s with a study dubbed the "Successive Use Project." In the 1980s and 1990s, Denver's Direct Potable Water Reuse Demonstration Project, a larger scale study, sought to establish the relative safety of using highly treated reclaimed wastewater as a potable supply. However, Denver Water chose not to pursue direct potable reuse because of high costs, customer perceptions, and regulatory constraints. An Integrated Resource Planning study, conducted from 1994 to 1997, deemed that nonpotable reuse of effluent originating as trans-basin water and water conservation were preferable in the short-term.

Project Description

Source water for the Denver Recycling Plant is secondary effluent from the adjacent Metro Wastewater Reclamation District Plant. The Recycling Plant, commissioned in 2004, has a capacity of 30 mgd and in 2006 had an average daily flow of 5.1 mgd. The plant is designed for expansion to 45 mgd, which currently is planned for 2012. Treated water storage is provided in an 11 million gallon tank on the treatment plant site. An additional six million gallon storage tank in the distribution system is scheduled to go online in 2007. Treatment at the facility includes:

- Nitrification with biologically aerated filters (BAFs);
- Chemical precipitation with ferric sulfate or aluminum sulfate for phosphorus reduction;
- Flocculation and high rate sedimentation;
- Filtration with deep-bed anthracite filters; and
- Chlorine disinfection with either free chlorine or chloramines depending on season and need.

BIOLOGICALLY AERATED FILTERS

At the time the Denver Recycling Plant was designed, there were no regulations in Colorado governing water reuse. The decision was made to design the facility so that it would be capable of meeting California's Water Recycling Criteria. Colorado subsequently adopted reclaimed water regulations for various nonpotable reuse applications. The treatment and quality standards applicable to the current uses of reclaimed water from the Recycling Plant are as follows:

- Minimum of secondary treatment, filtration, and disinfection;
- No detectable *E. coli*/100 mL in at least 75% of samples in a calendar month and a single sample maximum of 126 *E. coli*/100 mL;

- Monthly average turbidity ≤3 NTU; cannot exceed 5 NTU in more than 5% of the samples in any calendar month.

The Recycling Plant was designed to produce highly treated tertiary effluent and easily meets the reclaimed water limits specified in the Colorado regulations. Average values for selected reclaimed water constituents/parameters are as follows:

- Ammonia: <0.2 mg/L
- Nitrate + nitrite: 15 mg/L
- Phosphorus: 0.17 mg/L
- pH: 7.1
- Total dissolved solids: 570 mg/L
- Turbidity: 0.5 NTU
- *E. coli*: <1/100 mL

Reclaimed water is used for landscape irrigation at City parks and school grounds, golf course irrigation, landscape irrigation and animal-pen washdown at the Denver Zoo, and in cooling towers at a power plant. Approximately 1.8 billion gallons of reclaimed water are used per year, most of which is used during the irrigation season, although the power plant uses up to 10 mgd on a year-round basis.

The reclaimed water distribution system is undergoing continual expansion, and several large areas, including the redevelopment of Stapleton International Airport and Lowry Air Force Base, are slated to receive reclaimed water in the next few years, primarily for nonresidential landscape irrigation. The area in and around Denver International Airport (DIA) was developed with a dual distribution system that will be served with reclaimed water when transmission lines are extended to the area. Uses at DIA will include landscape irrigation, car washing at rental agencies, and water for use in cooling towers. At build-out, the project will provide approximately 6.2 billion gallons per year of reclaimed water for nonpotable uses.

Alternatives to the Project

The Recycling Project is only one component of a larger program designed to ensure a sustainable water supply for Denver and its suburban customers. Since the 1960s, several water supply alternatives involving water conservation

LANDSCAPE IRRIGATION AT PARK

and development of new water sources have been considered in addition to water reuse. Alternatives implemented to date include the following:

- Universal metering and an associated inclining block water rate structure that promotes conservation;
- Conservation programs that include audits of large water users;
- Rebates for the purchase of low water use plumbing fixtures;
- Education about conservation and xeriscape;
- System refinements such as ditch lining projects that minimize evaporation and transmission losses; and
- Small scale raw water supply projects.

Costs and Funding

The entire Recycling Project was cash financed by Denver Water. However, water revenue bonds were subsequently issued to reimburse a portion of the cash spent on the project. Since the Recycling Project is a new source of supply for Denver Water's customers, the component of the cost associated with raw water supply is borne by the entire customer base. The remaining costs, associated directly with treatment and distribution of reclaimed water, are allocated on a cost-of-service basis to reclaimed water customers.

Capital costs for construction of the treatment plant were approximately $80 million, and distribution facilities have cost about $40 million to date. The total O&M cost for all facilities was approximately $2.3 million in 2006. Reclaimed water rates are based on the system's O&M costs for the area served. In 2006, the reclaimed water rates in areas classified as "City and County," "Inside City," and "Outside" were $0.51/1,000 gallons, $0.69/1,000 gallons, and $0.71/1,000 gallons, respectively.

Problems Encountered

The only significant problem related to the Recycling Project was a direct cross connection between the potable and nonpotable plumbing systems in an animal care building at the Denver Zoo. The problem occurred when a zoo contractor installed a temporary line to accommodate construction. Denver Water discovered the error and assisted the zoo with correcting the problem and flushing the potable system in the area of the cross connection. The potable water distribution system outside of the zoo property was protected by backflow prevention devices on the zoo's potable water service lines. State regulators were contacted and consulted throughout the investigation and were satisfied with the corrective actions taken to mitigate the problem. The investigation determined that no zoo guests were exposed to the nonpotable water.

One barrier to water reuse in Colorado is the state's water laws which stipulate that only certain types of water can be reused. In the case of Denver, most of its reusable water is water imported from watersheds west of the continental divide. At times, the amount of reusable water (and, ultimately, wastewater) may be limited, such as when a trans-basin water tunnel is out of service. When nonreusable wastewater is treated at the recycling plant and sent to Denver's recycle customers, it must be augmented on a one-for-one basis with water from another source. Denver Water currently is purchasing and developing gravel pits adjacent to the South Platte River downstream of the wastewater plant to store augmentation water for the recycling plant.

Benefits

The goal of Denver Water's Recycling Project is to conserve potable water. Although the plant production rates currently are low, pending completion of the distribution system, the system has functioned as intended. As additional customers are added to the reclaimed water system, the amount of potable water saved is expected to reach approximately 10% of the current peak day demand.

The plant supervisors and some of the plant's lead operators were hired at the beginning of the construction phase of the project. In addition to their involvement in final design, these key staff members were able to observe construction, allowing them to become familiar with the facility prior to the critical start-up date. In addition, they developed standard operating procedures, computerized operation and maintenance manuals, and a detailed startup plan that led to a smooth commissioning.

Prior to start-up, Denver Water petitioned the Colorado Department of Public Health and Environment (CDPHE) to allow the plant to be operated by water treatment plant operators instead of wastewater treatment plant operators. The request was made because the treatment train at the reuse plant is essentially the same as conventional water treatment with the exception of the BAFs. CDPHE granted the request and the plant is operated by Class A water treatment plant operators.

Prior to and immediately after system start-up, an effort was made to educate reclaimed water users as well as the general public. Outreach included meetings with users and a media campaign. These efforts resulted in positive feedback from all stakeholders and a community-wide acceptance of the nonpotable reuse applications.

For further information, contact: Kenneth Pollock, Superintendent of Water Treatment, Denver Water, 1600 West 12th Avenue, Denver, CO 80204-3412

DUNEDIN, FLORIDA

Background

THE CITY OF DUNEDIN is a well-established residential community of 40,000 residents located on the west coast of Florida in northern Pinellas County and borders the Gulf of Mexico. The City relies on its own groundwater supply to meet all of its potable water demands. The aquifer underlying the City contains a limited amount of fresh water having a chloride level of less than 250 mg/L. In 1992, reverse osmosis (RO) was incorporated into the water treatment scheme to address relatively high groundwater TDS levels of up to 600 mg/L. All of the well water receives pretreatment (principally to remove iron and hydrogen sulfide), and 73.5% receives further treatment via RO. Water not receiving RO treatment is blended with RO-treated water prior to distribution. In 2006, an average of 3.5 mgd of potable water was produced.

Legislation passed by the State of Florida in 1987 mandated advanced wastewater treatment (AWT) with nutrient removal for wastewater discharges to the Gulf of Mexico. The City upgraded its wastewater treatment plant (WWTP) from secondary treatment to AWT in 1991 and began construction of a reclaimed water distribution system. The reclaimed water system went into operation in 1992.

Need for Reclaimed Water

In the 1980s, the City recognized that it needed a water management program for the local groundwater sources to maintain adequate potable water supply quality and quantity and sustain the groundwater resource for the long term. Although well field expansion and water conservation measures were implemented, it became clear that these measures alone would not ensure adequate water supplies in the future. Further, there was concern that increased pumping of groundwater would increase the potential for saltwater intrusion into the potable water supply aquifer. Thus, it was necessary to find an additional source of supply to help meet the City's water needs. Reclaimed water was the obvious choice.

Benefits

The use of reclaimed water for irrigation purposes has reduced the quantity of water pumped from the City's well field, thus reducing the potential effects of local aquifer stress and saltwater intrusion. Daily peak demand on the potable water system has been reduced from 8 mgd to 5 mgd. The annual average daily demand of potable water has decreased by about 1 mgd from 1990 to 2007. In addition, the use of reclaimed water has reduced the volume of wastewater discharged to the Gulf of Mexico by 70%.

RESIDENTIAL IRRIGATION WITH RECLAIMED WATER

Water Reclamation Facility

The WWTP provides biological nutrient removal to reduce nitrogen and phosphorus levels in the water. The current treatment processes are as follows:

- Preliminary treatment (screening and grit removal);
- Flow equalization tank;
- Activated sludge secondary treatment, including biological nutrient removal via the anaerobic/anoxic/oxic mode of operation;
- Secondary clarification with coagulant addition (sodium aluminate);
- Filtration with methanol addition prior to deep-bed sand and gravel nitrification filters;
- Disinfection with chlorine gas to maintain a residual of at least 1.8 mg/L; and
- Dechlorination of effluent discharged to St. Joseph's Sound.

The plant is designed to treat an average of 6 mgd with a peak flow of 12.6 mgd. The average daily flow in 2006 was slightly more than 4.4 mgd—3.3 mgd of which was reused for irrigation and industrial purposes. Although about 1 mgd of RO reject water from the water treatment facility is added to the WWTP influent, the chloride level in the product water is less than 300 mg/L.

The WWTP effluent meets the Florida Department of Environmental Protection (DEP) discharge permit limits of 5 mg/L CBOD, 5 mg/L TSS, 3 mg/L total nitrogen, and 1 mg/L total phosphorus. Although the nitrogen and phosphorus limits are imposed due to discharge to St. Joseph's Sound, which is a saltwater body adjacent to the Gulf of Mexico, these limits also are met during the dry season when all of the wastewater produced is reclaimed for irrigation. The reclaimed water meets all DEP criteria for irrigation of public access areas. Typical reclaimed water quality is as follows:

- No detectable fecal coliforms/100 mL
- CBOD $<$2 mg/L
- TSS $<$1 mg/L
- Turbidity $<$0.7 NTU
- Total nitrogen $<$2 mg/L
- Phosphorus $<$0.2 mg/L
- Cl_2 residual $\approx$ 2 mg/L

Distribution System—The reclaimed water distribution system consists of about 66 miles of transmission mains. There are four storage tanks located on the system ranging from 0.5 to 2 million gallons in capacity that provide 5.5 million gallons of storage. There are no storage facilities at the WWTP. Reclaimed water is used for landscape irrigation at individual residential property, golf courses, parks, recreational fields, apartment complexes, and commercial businesses as well as for industrial processes and cooling towers. More than 3,000 of the approximately 3,100 reclaimed water customers use the water for residential landscape irrigation.

Water Use Restrictions

Reclaimed water customers are encouraged to irrigate no more than three days per week, whereas customers using potable water or private wells for irrigation are allowed to water only once per week. A City ordinance prohibits shallow irrigation well drilling and new potable water irrigation meters to reduce withdrawals from the fresh water aquifer. Furthermore, the City adopted an ordinance which prohibits all irrigation wells in areas where reclaimed water is available. The ordinance requires reclaimed water pipeline installation in new land development areas where other utilities are being installed.

Reclaimed Water Rates and Metering

All reclaimed water usage in Dunedin is metered, based in part on studies conducted by the Southwest Florida Water Management District (SWFWMD) indicating that, on average, flat-rate residential customers in the area use almost twice as much reclaimed water as metered-rate reclaimed water customers. A double check valve backflow prevention device is installed on the potable water service connections to all residences within a subdivision that has reclaimed water service. Commercial customers are required to have a reduced pressure principle backflow prevention device at their potable water connections.

A quantity-based reclaimed water rate structure has enabled Dunedin to set up the reclaimed water program as an independent enterprise fund. In recent years, reclaimed water revenues have met O&M expenses. Reclaimed water rates are provided in the following table:

Gallons Used/Month	Rate/1,000 Gallons
0–15,000	$0.50 (base rate)
15,001–125,000	$0.25 (primarily commercial)
Over 125,000	$0.10 (golf courses, parks, etc.)

The City has determined that, based on local soils, an irrigation rate of 0.8 inches/week is adequate to maintain lawn irrigation. Residential customers who exceed this rate during the dry season (February 1 through June 30) are charged $2.00 per 1,000 gallons of reclaimed water used above their allocated amount. Each customer's allocated amount is determined based on their individual irrigable acreage.

Computer-Controlled Control Valves

The original design of the reclaimed water distribution system made it difficult to fill the storage tanks during high demand periods since they are served by the same reclaimed water transmission mains that provide irrigation water to customers. The solution was to install telemetry-controlled fill valves at the storage tanks and 13 butterfly valves at various locations on the reclaimed water distribution network to limit the effect of distribution demands between the WWTP and storage tanks. The control valves provide a means to divide the reclaimed distribution system into eight discrete zones of operation and limit irrigation during tank filling.

The control valve project allows storage tank replenishment by decreasing water pressure with City-controlled valves in selected parts of the transmission system. This decrease in water pressure occurs all day on Wednesdays

SOLAR-POWERED RECLAIMED WATER CONTROL VALVE

and during nonwatering times on other days. During watering times, water pressure resumes to normal operating pressures with the control valves. Utilizing the control valves allows the reclaimed water system time to recover from high demand and insure reclaimed water is available during the critical dry season. The project was partially funded through a SWFWMD grant.

Problems and Solutions

The major problems encountered by the Dunedin reclaimed water program are related to seasonal rainfall, low pressure, and maintenance of storage tank levels. Typical Florida precipitation consists of a relatively dry season extending from mid-October through mid-June, with the most critical time period being from mid-April through mid-June. Since most reclaimed water is used for irrigation, demand fluctuates seasonally. During the wet season, more reclaimed water is produced than can be used, whereas during the dry season not enough reclaimed water is available to meet demand. Steps taken to alleviate this problem are described below.

- In 2005, SWFWMD allowed the City to use groundwater to augment the reclaimed water supply by up to 1 mgd during the dry season for a cumulative total of 14 million gallons. In addition to solving the problem of the dry season water deficit, the additional water helps maintain pressure in the reclaimed water lines and fill reclaimed water storage tanks. It also provides enough reclaimed water for an additional 800 customers and results in less potable water use for irrigation during the wet season. This will enable the City to increase its reclaimed water use from 74% to about 90% of the total amount of wastewater produced.
- The addition of control valves placed in strategic areas throughout Dunedin allows the City to limit irrigation during the filling of system storage tanks and provides greater flexibility and more options during the dry season.
- Reclaimed water customers are strongly encouraged through public awareness programs to voluntarily conserve water to help maintain pressures and storage tank levels.

Public Acceptance

Reclaimed water has been very well accepted in the City of Dunedin. With more than 3,100 customers currently served and the potential for an additional 800 customers, the only limiting factor is the availability of the water. The City has an extensive public education program via brochures, videos, workshops, tours, local television, and other means which has resulted in community and regulatory acceptance of water reuse as an environmentally sound method of utilizing limited water resources.

Costs and Revenues

Upgrading the WWTP from secondary treatment to advanced wastewater treatment cost the City $14.4 million. Funding for the upgrade was provided through municipal bonds and a trust fund grant of $866,000. SWFWMD has budgeted more than $6 million in matching grant funds for the $13 million in storage, pumping, transmission, and distribution components of Dunedin's reclaimed water system. SWFWMD funded 50% of reclaimed water project costs.

Future Upgrades—Dunedin is currently working to expand the reclaimed water distribution mains to include seven new subdivisions, adding 350 customers. SWFWMD will provide funding for 50% of the cost of this planned expansion. The addition of new customers will allow the City to continue its efforts to lower withdrawals from its potable water supply wells and reduce the discharge of wastewater to St. Joseph's Sound during the wet season. As a result of the planning and implementation by Dunedin, SWFWMD uses the City as a model of integrated water resources planning that other entities should emulate.

For further information, contact: Thomas Burke, City Engineer, P.O. Box 1348, Dunedin, FL, 34697-1348

EL PASO, TEXAS

Background

THE CITY OF EL PASO is located on the Chihuahua Desert in western Texas and has a 2007 population of almost 625,000. Water is scarce, with an average rainfall of eight inches per year and an average evaporation rate of 80 inches per year. El Paso shares groundwater from the Hueco Bolson and the Mesilla Bolson aquifers and surface water from the Rio Grande River with communities in New Mexico and Ciudad Juarez, Mexico. Water from the Rio Grande is available only during the spring, summer, and early fall months and is further limited in years of drought. As a result of long term pumping that began in the early 20th Century to sustain increasing growth, groundwater pumping, which accounts for about 50% of El Paso's water supply, has exceeded the recharge rate and groundwater levels have declined in the Hueco Bolson aquifer. The groundwater drawdown has approached 200 feet in some areas of Ciudad Juarez and El Paso within the Hueco Bolson aquifer.

The El Paso Water Utilities (EPWU) implemented several water management strategies in the early 1990s to slow down depletion of the fresh water in the Hueco Bolson, including the following: promoted water conservation measures through various incentive programs; adopted a rate structure that increases the cost of water for high usage; increased the use of Rio Grande River water; and increased the use of reclaimed water. Total water demand has been declining since the late 1990s due to conservation and pricing strategies. The current demand in the EPWU service area is about 109,000 acre-feet (ac-ft)/yr, and the per capita demand was reduced from 225 gallons/capita/day (gpcd) in the 1970s to about 136 gpcd in 2006. One element of the City's strategic plan is to increase the volume of reclaimed water used from just over 9% of the annual wastewater treated in 2005 to 15% by 2015.

EPWU is in charge of the operation and management of the City's water and wastewater systems. EPWU operates two surface water treatment plants, four groundwater arsenic treatment plants, multiple wells, booster stations and reservoirs, and four wastewater treatment plants that produce reclaimed water for a variety of uses. A brackish groundwater desalination plant has been constructed and became operational in mid-2007.

Reclaimed Water Program

El Paso began delivering reclaimed water to customers for nonpotable reuse applications in 1963. Since that time, its reuse program has been greatly expanded, and about 5 mgd of reclaimed water from four treatment plants (Northwest, Haskell Street, and Roberto Bustamante Wastewater Treatment Plants and the Fred Hervey Water Reclamation Plant) currently is used for nonpotable reuse (industrial uses, landscape irrigation at parks, school grounds, golf courses, cemeteries, and other green spaces). In addition, 2.5 mgd is used for in-plant uses and potable reuse via groundwater recharge. The almost 7.5 mgd of reclaimed water used in 2006 was distributed as follows:

- 6% for in-plant uses;
- 34% for industrial uses;
- 30% for irrigation;
- 30% for groundwater recharge (injection and percolation); and
- $<$1% for construction and other purposes.

All of the plants provide a minimum of tertiary treatment and produced reclaimed water meeting state requirements for Type I reclaimed water use, which is defined as the use of reclaimed water where contact between reclaimed water and humans is likely. Type I requirements include the following water quality limits, which are based on a 30-day average:

- BOD: 5 mg/L
- Turbidity: 3 NTU
- Fecal coli: 20 CFU/100 mL (geometric mean)
- Fecal coli not to exceed 75 CFU/100 mL (grab sample)

The concept of water reuse in El Paso was developed in response to two factors. First, studies conducted by the U.S. Geological Survey determined that the Hueco Bolson aquifer was being depleted at rates that could result in depletion of the aquifer's water supply by early in the 21st Century, and, second, there was a need to upgrade and expand the wastewater treatment facility that served the northeast area of El Paso. Studies indicated that groundwater recharge using reclaimed water was the most economic alternative for increasing El Paso's water supply. These studies were followed by development of the Hueco Bolson Recharge Project. An important consideration in the selection of a water reuse scheme was that the municipal wastewater in the northeast area of El Paso is mostly of domestic origin and contains less than 0.1% industrial wastes.

Fred Hervey Water Reclamation Plant

The Fred Hervey Water Reclamation Plant (WRP) was put into service in 1985. The WRP has a design capacity of 10 mgd and produces reclaimed water for multiple uses—primarily golf course irrigation, industrial cooling water, and groundwater recharge into a potable water supply aquifer. The recharge part of the operation is called the Hueco Bolson Recharge Project. The total capital cost was approximately $33 million; funding was provided, in part, by a 65% grant from the U.S. Environmental Protection Agency (USEPA). The remainder of the cost was provided through wastewater user rates. Unless otherwise specified in contractual arrangements, the reclaimed water rate in El Paso currently is $1.14/1,000 gallons, which is 70% of the potable Block 1 rate. The WRP includes the following treatment processes:

- Primary treatment: screening, degritting, and primary clarification;
- Flow equalization;
- Secondary treatment—combines conventional biological treatment with the use of powdered activated carbon with a patented two-stage PACT™ system process. This phase of the treatment process provides organics removal, nitrification, and denitrification; methanol is added to the second stage as a carbon source for the denitrifiers;
- High lime treatment (coagulation and clarification) to remove phosphorus and some heavy metals. A pH of at least 11 is achieved to destroy viruses;
- Recarbonation to pH 7.5 by addition of CO_2;
- Sand filtration with traveling-bridge, automatic backwash filters for turbidity and parasite removal;
- Disinfection using ozone;
- GAC filtration with traveling-bridge, automatic backwash filters as a polishing process for removal of residual organic compounds and improvement of taste, odor and color; and
- Chlorination to produce a residual of 0.25 mg/L to prevent biological growths during storage and recharge.

The powdered activated carbon used in the PACT™ process originally was regenerated via a wet-air oxidation unit that converted the activated sludge biomass to ash and recovered the carbon. The regeneration process proved to be expensive and has been discontinued in favor of feeding virgin powdered activated carbon to the bio-physical process.

AUTOMATIC BACKWASH FILTERS

Hueco Bolson Recharge Project

In 2006, the Fred Hervey WRP produced about 5.2 mgd of reclaimed water. Of that total, approximately 1.7 mgd was sent to 10 injection wells, 0.5 mgd to an infiltration basin for groundwater recharge, and about 3 mgd was reused for nonpotable reuse—principally golf course irrigation and industrial cooling water. The surface spreading basin was constructed as a pilot facility in 2000 and has been in operation since 2001 to augment the recharge. Additional

OZONE GENERATOR FOR DISINFECTION

future recharge facilities in El Paso will likely use surface spreading basins as the preferred method of recharge.

The reclaimed water, which meets both USEPA primary drinking water standards and Texas Commission on Environmental Quality standards prior to injection, is recharged into the fresh water zone of the aquifer. Well screens are placed between 350 and 880 feet below land surface. The injection wells are located from ½ to ¾ of a mile upgradient from the nearest existing drinking water supply well. This was done to ensure a minimum two-year residence time for the reclaimed water before its withdrawal by any potable water supply wells. The two-year retention time was required by the Texas Department of Health to assure inactivation of viruses prior to extraction of the reclaimed water. The actual retention time underground has been calculated to be more than five years based on simulated groundwater velocity. The extracted groundwater is commingled with other well water and chlorinated prior to distribution as potable water.

Problem Encountered

The injection wells have been subject to corrosion of steel well casings and screens in the past. Four of the original 10 wells have been replaced with PVC casings and screens to avoid this problem.

Desalination Plant

The Hueco Bolson aquifer has about 25 million ac-ft of brackish water that can be used as a potable supply after desalination using reverse osmosis (RO) treatment. EPWU and Fort Bliss formed a partnership to build the largest inland desalination plant for municipal drinking water use in the U.S. The Joint Desalination Facility became operational in mid-2007.

The capital cost of the project is $95 million, which includes the supply wells, blending wells, well collector and transmission lines, concentrate pipeline, desalination treatment facility, surface injection facilities, injection wells for concentrate disposal, and a technology/education center. Operational costs will be about $4.8 million per year. The Texas Water Development Board provided a $1 million no interest loan for the planning and preliminary design of the project, and the USEPA contributed $26 million for the project. Fort Bliss contributed $3 million for the Environmental Impact Statement and the land for the plant site, blend wells, and injection wells.

The project includes: rehabilitation or replacement of 17 existing wells to supply water to the desalination plant; a desalination plant producing 15.5 mgd of permeate; 16 new blend water wells producing 12 mgd; pipelines for collection, transmission, and concentrate disposal; and concentrate disposal facilities for 3 mgd of concentrate. The permeate will be blended with water from new wells, and the blended water will receive pH adjustment and be disinfected before being discharged to the distribution system.

The Joint Desalination Facility will produce 27.5 mgd of drinking water and, when in full production, will increase the City's water supply by about 25% of the current annual demand. The concentrate will be piped about 22 miles northeast of the City and injected into groundwater that already has a high concentration of dissolved solids. The Texas Commission on Environmental Quality has authorized up to five Class V injection wells, constructed to a depth of between 3,700 and 4,400 feet deep. The TDS in the concentrate is about 8,000 mg/L, and the TDS in the native groundwater in the injection zone is similar. The selected site will confine the concentrate to prevent migration to fresh water.

While initial concentrate disposal studies were positive, concerns have been raised regarding the potential for mineral precipitation. Laboratory studies and geochemical modeling are underway to better understand the potential for mineral precipitation and effective mitigation measures. It is not certain that any mitigation is needed; if needed, acid addition to the concentrate line is the initial alternative that will be used.

A pilot study evaluating the effectiveness of lime treatment to reduce the volume of the concentrate and increase product water recovery has recently been completed. While results were positive, additional studies are slated to evaluate the concept more fully.

For further information, contact: Ed Archuleta, General Manager, El Paso Water Utilities Public Service Board, 1154 Hawkins Blvd., P.O. Box 511, El Paso, TX 79961-0001

INLAND EMPIRE UTILITIES AGENCY

Background

THE INLAND EMPIRE UTILITIES AGENCY (IEUA) is located east of Los Angeles in southwestern San Bernardino County, California. Formed in 1950 and formerly known as the Chino Basin Municipal Water District, IEUA is a member agency of the Metropolitan Water District of Southern California (MWD) for the purpose of importing supplemental water from the Colorado River and northern California to augment local water supplies. IEUA's service area is located within the desert climate zone of Southern California and receives an average annual rainfall of about 13 inches.

IEUA serves the cities of Chino, Chino Hills, Fontana, Montclair, Ontario, and Upland, as well as the Monte Vista Water District and Cucamonga Valley Water District (City of Rancho Cucamonga). The population of about 780,000 within the 242-square mile IEUA service area is expected to grow to 1.2 million by 2025. Services include: imported water service; wastewater collection, treatment, and disposal; production and distribution of reclaimed water for a variety of uses; brackish groundwater recovery using desalination treatment technology; digestion and composting of manure and municipal biosolids into soil amendment products; renewable energy generation; and regional disposal of nonreclaimable industrial wastewater and brine flows.

The Superior Court of the State of California rendered a judgment in 1978 that the Chino Groundwater Basin be adjudicated and operated under a court-appointed watermaster, thus establishing the Chino Basin Watermaster (CBWM). The judgment mandated that the CBWM develop a management plan for the Chino Groundwater Basin that meets water quality and water quantity objectives for the region. This resulted in the development of an Optimum Basin Management Plan (OBMP) in 1998. Since that time, the CBWM developed the Chino Basin Recharge Master Plan to identify and prioritize groundwater recharge opportunities within the Basin, and IEUA subsequently developed a Recycled Water Feasibility Study and Implementation Plan to fully integrate its reclaimed water program into the CBWM's goals and objectives for the OBMP and Chino Basin Recharge Master Plan.

Both local and imported water are used within IEUA's service area. Local sources include surface water, groundwater, and reclaimed water. Imported water purchased from MWD for redistribution to local retail agencies is exclusively State Water Project water. Local sources account for about 60% of water use in IEUA's service area, with the bulk of that being groundwater. While the adjudicated safe yield of the Chino Basin has been set at 145,000 acre-feet/year (ac-ft/yr) (1 ac-ft = 0.326 million gallons), more than 180,000 ac-ft/yr have been pumped from the Basin in recent years.

Under the 1978 judgment, over-pumping is allowed if artificial recharge is implemented to assure long-term basin management. As a result of $40 million in new recharge basin improvements from 2002 through 2006, new stormwater capture, imported water replenishment from the State Water Project, and recharge of reclaimed water have increased significantly. In 2006, more than 50,000 ac-ft of recharge was managed by IEUA in coordination with the CBWM and the San Bernardino Flood Control District. The goal is to increase recharge to more than 100,000 ac-ft annually to allow for greater production in the Chino Basin.

Water Reclamation Plants

Reclaimed water is produced at four facilities—Regional Plant Nos. 1, 4, and 5 (RP-1, RP-4, and RP-5), and the Carbon Canyon Water Reclamation Facility (CCWRF). All of these plants provide tertiary treatment that includes the following:

- Primary treatment;
- Secondary treatment (activated sludge) including nitrification and denitrification;
- Coagulant addition (as needed) with alum and polymer;
- Filtration; and
- Disinfection using sodium hypochlorite.

The treatment plant capacities and current flows are provided below.

Name of Facility	Capacity (mgd)	Average Flow in 2006 (mgd)
RP-1	44	37
RP-4	7*	7
RP-5	15	10
CCWRF	11.4	9
Total	77.4	63

**Expansion to 14 mgd effective July 2007*

All of the treatment plants produce reclaimed water treated to tertiary standards specified in the California Department of Health Services (DHS) Water Recycling Criteria for high level nonpotable uses. Treated wastewater that is not reused is dechlorinated prior to surface water discharge. A 1969 Court Judgment requires that IEUA discharge 17,000 ac-ft/yr (an average of 15 mgd) to the Santa Ana River. In general, all of the Santa Ana River base flow of reclaimed water is recharged into the Orange County groundwater basin except during wet periods.

As part of IEUA's source control program, industrial wastewater is segregated from domestic wastewater in a nonreclaimable wastewater collection and conveyance system and discharged to the Santa Ana River Interceptor (SARI) system, which is a regional brine line that conveys saline waters to the Orange County Sanitation District for treatment and disposal to the Pacific Ocean.

Nonpotable Reuse Applications

Reclaimed water was first used in the 1970s for golf course and park irrigation by four customers. In 2006, about 8,000 ac-ft/yr (7.2 mgd if calculated as a daily average) of reclaimed water was supplied to more than 100 customers for nonpotable applications. Uses include agricultural crop irrigation, various types of landscape irrigation (e.g., parks, golf courses, and highway medians), industrial process water, and power plant cooling water. Landscape irrigation accounts for more than half of the reclaimed water used within the IEUA service area. The existing system serves recycled water to customers in the cities of Chino, Chino Hills, Ontario, and Rancho Cucamonga from the CCWRF, RP-1, RP-4, and RP-5 plants through 35 miles of reclaimed water transmission pipelines. Nonpotable reuse is expected to increase to 12,000 ac-ft/yr in 2007.

Indirect Potable Reuse

To reduce dependence on imported water that may not be available in the future, IEUA uses reclaimed water for indirect potable reuse by recharging groundwater aquifers via surface spreading basins. Recharge of reclaimed water began in 1997 at a rate of 500 ac-ft/yr at Ely Basin in Ontario. Since then, CBWM and IEUA have embarked on a phased program to increase groundwater recharge to replace water that is overproduced from the Chino Basin. IEUA supplies a portion of the replenishment obligation with reclaimed water.

INFLOW TO LOWER DAY RECHARGE BASIN

Phase I—IEUA expanded its recharge program in 2005 to include seven additional basins with a total effective recharge area of almost 80 acres. They have a total recharge capacity of about 44,000 ac-ft/yr. The amount of reclaimed water recharged does not exceed 8,700 ac-ft/yr as a long term average to comply with the DHS draft groundwater recharge regulations. DHS specified that reclaimed water initially can account for no more than 20% of the total water recharged (diluent waters are imported water and stormwater) in Phase I. The allowable long term percentage of reclaimed water is based on the reclaimed water total organic carbon (TOC) concentration that reaches the groundwater table. The reclaimed water is treated at RP-1 and RP-4 prior to recharge.

The reclaimed water must meet all requirements in the DHS draft groundwater recharge regulations, which include source control requirements, treatment process requirements, water quality limits, monitoring requirements, a minimum separation distance of 500 feet between spreading areas and potable water extraction wells, and a retention time underground of at least six months. The recharged water must meet California DHS drinking water standards prior to reaching the groundwater table and be monitored for additional unregulated chemicals, including perchlorate, 1,4-dioxane, and N-nitrosodimethylamine (NDMA). The water quality requirements specified in the DHS draft regulations can be met after percolation through the vadose zone, which provides additional treatment. TOC in the reclaimed water cannot exceed 0.5 mg/L divided by the maximum reclaimed water contribution. Thus, for Phase I, the reclaimed water TOC concentration after soil aquifer treatment cannot exceed an average of 2.5 mg/L with a 20% reclaimed water contribution.

The depth to groundwater in the vicinity of the recharge basins ranges from about 145 feet to 400 feet. A unique feature of this project is the use of lysimeters to sample the percolated water during treatment through the vadose zone. Lysimeters are located at depths ranging from 5 to 25 feet below the bottom of the recharge basins and have been shown to be an effective monitoring tool.

Phase II—The Phase II project has been approved by DHS and is expected to receive approval by the Santa Ana Regional Water Quality Control Board in 2007. This phase will involve recharge at Ely Basin, which has been expanded to a capacity of 2,300 ac-ft/yr, and six additional surface spreading sites, some of which include multiple basins. The total effective recharge area of the Phase II recharge basins is about 240 acres. These facilities are capable of providing an additional 90,000 ac-ft/yr of water for recharge, including 13,000 ac-ft/yr of reclaimed water. This will increase the total recharge capacity of reclaimed water by IEUA to approximately 22,000 ac-ft/yr. It will be several years before the amount of reclaimed water recharged reaches the anticipated capacity levels at all of the recharge sites.

Chino Desalters

Nearly 100 years of agricultural operations combined with more recent dairy operations in the lower Chino Groundwater Basin area have caused the groundwater to have high TDS and nitrate concentrations. The groundwater often exceeds 1,000 mg/L TDS and 10 mg/L nitrate. To address this situation, the Chino Basin Desalter Authority (CDA) was formed under a Joint Exercise of Powers Agreement in 2001. The Jurupa Community Services District (JCSD), the Santa Ana River Water Company (SARWC), IEUA, and the Cities of Chino, Chino Hills, Norco, and Ontario are members of the CDA.

CHINO DESALTER REVERSE OSMOSIS MEMBRANES

The CDA owns two groundwater treatment desalination systems known as the Chino I and II Desalters. Both of these facilities include groundwater extraction wells and appurtenances that pump brackish groundwater from the lower Chino Basin to advanced treatment facilities. Treatment processes include pretreatment, filtration, air stripping of volatile organic compounds (VOCs), ion exchange for removal of nitrates, and reverse osmosis (RO) for removal of salts. The treated water is then blended and disinfected to produce high quality drinking water that is delivered to its member agencies by a system of pipelines, pumps, and reservoirs.

The Chino I Desalter began operating with 11 extraction wells in 2000 and was expanded in 2005. Expansion included addition of stripping towers to treat VOCs in the low TDS blend water and three more extraction wells to increase the extraction capacity. Water from the new wells receives ion exchange treatment. The desalter produces 14 mgd of product water, 5 mgd of which are treated with ion exchange. RO-treated water is decarbonated and pH-adjusted prior to blending with other extracted water, and all of the extracted water is disinfected with chlorine prior to pumping to potable water distribution systems.

The Chino II Desalter became operational in 2006. It has eight extraction wells and produces 10 mgd of drinking water through treatment similar to that at the Chino I Desalter. As with the Chino I Desalter, not all of the water receives RO treatment; 6 mgd receives RO treatment and 4 mgd is treated via ion exchange. Brine from both desalters is discharged to the SARI line.

The projected ultimate development of the Chino Basin Desalter Program will produce 52,000 ac-ft/yr of potable water and extract an estimated 54,000 tons of salt from the Chino Basin aquifers annually.

Energy Savings

In concert with the California Energy Commission determination that reclaimed water represents one of the most energy efficient sources of water, a major objective of IEUA's integrated water management strategy is to reduce energy and greenhouse gas emissions through water conservation and reuse. Energy requirements are estimated to be 400 kilowatt-hours/acre-foot (kwh/ac-ft) for reclaimed water, 950 kwh/ac-ft for groundwater pumping, and 1,700 kwh/ac-ft for water produced from the Chino Desalter. In contrast, the energy requirement for imported State Water Project water ranges from 2,500 to 3,200 kwh/ac-ft.

The energy savings attributed to local development and use of reclaimed water within IEUA's service area is equivalent to about 34 megawatts/year. These energy savings result in greenhouse gas emission reductions of about 100,000 tons of CO^2 equivalents per year.

Funding and Costs

IEUA sells reclaimed water for $63/ac-ft to its member agencies, which retail the water at between 50% and 80% of the member agency potable rate. Generally, the $63/ac-ft IEUA charge pays for O&M costs of the IEUA wholesale distribution system. Capital costs are funded by state and federal grants and low interest State Revolving Fund loans heavily subsidized by MWD. Similarly, the groundwater recharge program is funded through a combination of state and federal grants; local contributions are jointly provided by IEUA and the CBWM.

For further information, contact: Richard W. Atwater, General Manager, Inland Empire Utilities Agency, 6075 Kimball Avenue, Chino, CA 91710

LAS VEGAS, NEVADA

Background

THE LAS VEGAS VALLEY (VALLEY) is located in Clark County, the southernmost county in Nevada. The major cities in the Valley are Las Vegas, North Las Vegas, and Henderson. The region is one of the fastest growing metropolitan areas in the United States, and the burgeoning population growth, coupled with an annual precipitation of only four inches and an evapotranspiration rate of about 96 inches, has put a severe burden on the region's water resources. The current population of Clark County is about 1.9 million, with about a third of that total residing in the City of Las Vegas.

The Las Vegas Valley Water District (LVVWD) is the operating agency for the Southern Nevada Water Authority (SNWA), a regional organization of seven water and wastewater purveyors in Southern Nevada that works to secure water resources for the area. LVVWD distributes potable water to the City of Las Vegas and all of Clark County within the Valley except for the City of Henderson and the City of North Las Vegas, who distribute water to their own respective customers. Potable sources of supply are groundwater and Colorado River water from Lake Mead. The City of Las Vegas, City of Henderson, and the Clark County Water Reclamation District collect and treat wastewater in the Valley, some of which is reclaimed for nonpotable purposes. All treated wastewater in the Valley that is not reused is discharged to the Las Vegas Wash, which flows into Lake Mead for return flow credits.

Return Flow Credits

Nevada's right to Colorado River water is based on consumptive allocation. That is, for every gallon of treated wastewater that is returned to Lake Mead—the principal source of potable water supply—an equal quantity of water above the basic allotment can be withdrawn and treated for potable use. Water that is not returned to Lake Mead is charged against Nevada's allocation. Although reclaimed water was used to irrigate a ranch as far back as 1931 and began to be used for power plant cooling water in 1946, extensive water reuse was deterred by the concept of "return flow credits." Since the full volume of treated wastewater can be credited toward additional potable water, no additional water resource is gained by using reclaimed water for irrigation.

Two exceptions to the return flow credits philosophy led to the beginning of large scale reuse in the Valley. First, several golf courses were constructed (beginning in the 1960s) in close proximity to the City of Las Vegas and Clark County Water Reclamation District wastewater treatment plants, making it cost effective to use reclaimed water for golf course irrigation. Second, the City of Henderson had no discharge permit to discharge its wastewater to the Las Vegas Wash and had to use rapid infiltration basins for wastewater disposal. Recognizing the value of reusing treated wastewater, the City of Henderson enacted a policy in the late 1980s requiring golf courses to use reclaimed water from the City's Water Reclamation Facility.

City of Las Vegas

The City of Las Vegas operates three wastewater treatment facilities, all of which provide tertiary treatment (i.e., biological secondary treatment, filtration, and disinfection).

Water Pollution Control Facility (WPCF)—This is the main wastewater treatment plant in the City, treating wastewater generated by more than 650,000 residents and businesses in Las Vegas and North Las Vegas. It has a capacity of 91 mgd and treated an average of 63 mgd in 2006. Treatment includes biological nutrient removal, coagulant (alum) addition prior to filtration, and sodium hypochlorite for disinfection. Most of the water is discharged to the Las Vegas Wash, which flows into Lake Mead, although a small portion, typically about 2 to 4 mgd during the summer months and 0.5 to 1.5 mgd during the winter months, is used to irrigate two golf courses and for cooling water at an adjacent power generating plant.

ANGEL PARK GOLF COURSE, LAS VEGAS

Durango Hills Water Resource Center (DHWRC)—The DHWRC, located in the northwest section of Las Vegas, is a satellite treatment plant with a design capacity of 10 mgd. The facility began operation in 2001 and had an average inflow of about 5 mgd in 2006. Treatment includes equalization basins, biological nutrient removal, clarification, filtration, ultraviolet (UV) radiation for disinfection, and a two million gallon storage reservoir. While only about 5 mgd of reclaimed water is needed for irrigation in the winter months, fully developed summer demand can exceed 18 mgd. An aquifer storage and recovery (ASR) system was constructed to recharge potable water in the winter period and extract the water during the summer months to supplement reclaimed water for irrigation. There are four recharge/recovery wells. Potable water is used for the ASR system because Nevada law prohibited the use of reclaimed water for such recharge at the time of development.

There are approximately 17 miles of distribution pipelines that currently provide reclaimed water to 11 golf courses. Full development will include parks and schools. The total project cost for all facilities, including three pump stations, was about $63 million. A Cooperative Agreement approved in 1998 specified that LVVWD would design, construct, operate, and maintain the reclaimed water distribution system, and the City would design, construct, operate, and maintain the DHWRC.

Bonanza Mojave Water Resource Center (BMWRC)—This 1 mgd satellite facility and its distribution system are operated by the City of Las Vegas. In operation since 1999, the BMWRC supplies reclaimed water to a nearby golf course. Treatment includes biological secondary treatment (oxidation ditch), filtration, UV disinfection, and chlorination to maintain a residual in the transmission pipeline to the golf course.

Clark County

Clark County operates two water reclamation facilities.

Clark County Water Reclamation District—The treatment facility has a capacity of 110 mgd and had an average flow of 98 mgd in 2006, of which 8 mgd was reclaimed for cooling water at one power plant and for irrigation at a golf course, a soccer park, and a common area at a housing development. The treatment train includes primary treatment, activated sludge secondary treatment with biological phosphorus removal, alum addition, dual media filtration, and disinfection with sodium hypochlorite.

Desert Breeze Water Resource Center (DBWRC)—The Clark County Water Reclamation District's DBWRC is a satellite plant that went into operation in 2003. This tertiary treatment facility includes influent flow equalization, activated sludge secondary treatment, filtration, UV disinfection, and a 1.25 million gallon reclaimed water storage reservoir. Sodium hypochlorite is added to the water as it enters the storage reservoir to provide residual disinfection.

Located on the west side of the Valley, the DBWRC has a design capacity of 5 mgd with an ability to expand to 10 mgd. In 2006, the plant provided 5 mgd of reclaimed water for irrigation at four golf courses through approximately 16 miles of distribution pipelines. The reclaimed water distribution system was built and is operated and maintained by LVVWD. A Frisbee golf park has been designed but not yet constructed.

City of Henderson

The City of Henderson's Kurt R. Segler Water Reclamation Facility has a capacity of 27 mgd, which will be expanded to 32 mgd in 2008. In 2006, the average daily flow was about 21 mgd. Of that total, 7 mgd (if calculated as a daily average; the peak day demand was almost 16 mgd) was reclaimed and the remainder was discharged to Lake Mead. Treatment processes include biological secondary treatment using oxidation ditches, secondary sedimentation, chemical coagulation using alum and polymer, clarification, filtration, and disinfection with sodium hypochlorite. Reclaimed water is used to irrigate nine golf courses, a cemetery, and highway medians. Reclaimed water also is used for dust control and soil compaction at construction sites and is supplied to nine ponds that support the Henderson Bird Viewing Preserve.

Construction of a new 8 mgd treatment plant (Southwest Water Reclamation Facility) began in mid-2007 and is scheduled to begin operation in 2010. The facility will use membrane bioreactors as one of the treatment processes and will process liquids only; solids will be sent to the main plant for processing.

Reclaimed Water Requirements

Reclaimed water in Nevada must comply with "Use of Treated Effluent" requirements developed by the Nevada Division of Environmental Protection and adopted by the State Environmental Commission (Sections 445A.274 to 445A.280 of the Nevada Administrative Code). All of the water reuse facilities in the Las Vegas Valley provide reclaimed water that meets either Reuse Category A or Category B requirements.

Reuse Category A Requirements—Reuse Category A requirements must be met where human contact with the water can be expected to occur and is applicable to spray irrigation of land used as a cemetery, commercial lawn, golf course, greenbelt, or park where public access to the area of use is not controlled. No buffer zone is required for reclaimed water meeting Category A requirements. The requirements are:

- Secondary treatment (BOD $\leqslant$30 mg/L; TSS $\leqslant$30 mg/L; pH = 6.0 to 9.0)
- $\leqslant$2.2 total coli/100 mL (30-day geometric mean)
- $\leqslant$23 total coli/100 mL (maximum)

Reuse Category B Requirements—Reuse Category B requirements apply to reclaimed water used for spray irrigation of land used as a cemetery, golf course, or greenbelt where public access to the area of use is controlled, and human contact with the water does not occur. A buffer zone of at least 100 feet is required. Industrial cooling water is subject to Category B requirements. The requirements are:

- Secondary treatment (BOD $\leqslant$30 mg/L; TSS $\leqslant$30 mg/L; pH = 6.0 to 9.0)
- $\leqslant$2.2 fecal coli/100 mL (30-day geometric mean)
- $\leqslant$23 total coli/100 mL (maximum)
- Buffer zone $\geqslant$100 feet

Reclaimed Water Rates

The LVVWD distributes reclaimed water from the DHWRC and the DBWRC through two independent systems. LVVWD has a tiered rate structure for potable water to encourage conservation and a flat rate of $2.33/1,000 gallons for reclaimed water supplied to golf courses. Golf courses are also on a water budget of 6.3 acre-feet/acre/year (an average of 1.5 inches/week) with severe monetary penalties for exceeding the budget. For budgeted golf courses still on potable water, their rate is capped at the 3rd tier, which currently is $2.62 per 1000 gallons. The other reclaimed water providers have lower rates, the lowest being the City of Las Vegas' rate of $0.23/1,000 gallons for golf course irrigation. As an inducement to conserve water, a SNWA "cash for grass" program will pay a user $2/ft^2 for the first 1,500 ft^2 of turf area that is replaced with irrigated xeriscape and $1 for each additional square foot.

System Problems and Solutions

One of the major challenges in the past had been lack of coordination among the various entities in the Valley to develop a unified system to collect, treat, and deliver reclaimed water to customers. This problem was rectified in 1999 when four agencies in the Valley entered into an interlocal agreement to do preliminary planning on an area-wide basis without respect to political boundaries.

The most significant water quality-related problem is due to high total dissolved solids (TDS) in the water, which can be detrimental to plants and turf. This represents a particular concern to golf course operators. Most of the drinking water in the Valley comes from Lake Mead and has a TDS concentration in the range of 600 to 700 mg/L. The TDS level in the wastewater is 1,100 mg/L or greater in some areas. It was determined that chloride levels and corresponding peaks in conductivity were highest during the early morning hours, due to discharge of brine wastes from water softeners. The solution to this problem was to install conductivity probes in the influent channels at the satellite water reclamation plants and couple the signals from the probes to electronically-operated flow control gates. The system was programmed to bypass flow around the plants when there are high conductivity readings for a specified time period. The gates can be operated on a timer once the conductivity pattern has been established. This design was incorporated at all three satellite plants.

Public Participation

Public education and participation has been crucial to the successful implementation of water reuse in the Valley at both the DHWRC and the DBWRC. As an example, the decision to proceed with the construction of the DBWRC was due, in part, to the Clark County Water Reclamation District's close association with a Water Quality Citizens Advisory Committee and other outreach efforts that included citizen surveys, public meetings, and one-on-one contacts with local businesses. The Clark County Water Reclamation District involved the public early in the planning process, and feedback influenced the design and construction of the water reuse facility and diffused opposition to the project. Public outreach is a continuing activity and includes a newsletter entitled *Good Neighbor Update*, which summarizes the Desert Breeze project and the high level of public participation in every phase of the process.

For further information, contact: Gary K. Grinnell, Las Vegas Valley Water District, 1001 South Valley Boulevard, Las Vegas, Nevada 89153

LONG BEACH, CALIFORNIA

Background

THE CITY OF LONG BEACH, with a population of about 460,000, is located 22 miles south of downtown Los Angeles. It borders the Pacific Ocean and is home to a number of large industrial activities, including oil refining, power generation operations, and the Port of Long Beach. The City's current water demand of approximately 75,000 acre-feet per year (ac-ft/yr) (1 ac-ft $\approx$ 0.326 million gallons) is obtained from the following sources: treated surface water provided by the Metropolitan Water District of Southern California (MWD) (49%); treated groundwater (44%); and reclaimed water (7%).

The Long Beach Water Department (LBWD) has been providing reclaimed water to customers in its service area since the early 1980s. LBWD's service area, characterized by a mix of residential, commercial, and industrial customers, is considered to be fully developed. Originally serving just one City park, the reclaimed water system has expanded through the years to include other public and private irrigation customers, such as parks, schools, golf courses, cemeteries, and garden nurseries. One unique reclaimed water customer is a consortium of oil companies known as the Texaco, Humble, Union, Mobile, and Shell (THUMS) Long Beach Company, which operates offshore drilling platforms in the Long Beach Harbor. As part of their operations, the THUMS Company uses approximately 1,100 ac-ft/yr of reclaimed water to repressurize offshore oil-bearing strata in order to mitigate any environmental impacts from the oil drilling activities.

Existing Facilities

Reclaimed water is produced at the Long Beach Water Reclamation Plant (LBWRP), which is located in the eastern portion of the City and is owned and operated by the County Sanitation Districts of Los Angeles County. LBWRP treats 18 mgd of wastewater to meet the California Department of Health Services Water Recycling Criteria for high level nonpotable applications. Treatment processes include primary sedimentation, activated sludge secondary treatment, secondary sedimentation, chemical coagulation, dual media filtration, and disinfection using chlorination. The treated water is separated into two streams—an effluent stream that is dechlorinated and discharged to the Pacific Ocean via the San Gabriel River and a reclaimed water stream that is distributed to LBWD customers.

In 2006, LBWD delivered more than 6,000 ac-ft/yr (an average of 5.4 mgd) of reclaimed water to existing customers; the 2007 demand is expected to increase to 7,500 ac-ft/yr.

The existing reclaimed water system consists of:

- 30 miles of pipeline ranging from six to 36 inches in diameter;
- Two open water storage reservoirs with a total storage capacity of seven million gallons;
- Three above-ground enclosed 3.3 million gallon steel storage tanks;
- Two pump stations; and
- Two groundwater wells to supplement the reclaimed water supply with untreated groundwater during interruptions in reclaimed water service (e.g., plant maintenance).

Expansion Project

LBWD is committed to developing alternative sources of water versus using imported potable water to meet customer water demands, particularly those using potable water primarily for industrial and irrigation operations. Periodic droughts, water shortages, redevelopment projects, new activities planned at the Port area, and potential reallocations of potable water sources of supply were all factors in the City's decision to consider expansion of its reclaimed water system, seawater desalination, development of conjunctive use programs, and protection of its existing groundwater supply through the Alamitos Barrier Recycled Water Project (ABRWP).

LBWD's Recycled Water System Expansion Program consists of four phases (Phases 1, 2, 3, and 4) intended to connect the reclaimed water system to new customers and to increase the reliability of the distribution system through the completion of looped transmission corridors. The elements of the program include pipelines, pump stations, augmentation of system storage, and completion of new service connections. The planned projects will support the increase in reclaimed water delivery to THUMS, provide the ABWRP with reclaimed water, and increase conveyance capacity in the southeastern portion of the existing system. Phase 1 is complete, while Phases 2, 3, and 4 are in planning stages.

Phase 1—Phase 1 projects have been completed and included pipeline construction, conversion of two existing potable water reservoir to a reclaimed water storage tank, and the construction of a pump station to supply the ABRWP with reclaimed water.

Phase 2—LBWD is in the final design stage of Phase 2, consisting of the upgrades and main extensions for the reclaimed water system. Phase 2 will include construction of facilities, including 55,000 feet of 12- and 16-inch diameter pipelines, to serve future reclaimed water customers in the southeast part of the LBWD service area. Identified potential users include three commercial laundries and several landscape irrigation sites, including grounds at a high school. A 2002 market survey indicated that the potential customer demand served by Phase 2 facilities is about 960 ac-ft/yr. Future customers include California State University, Long Beach (an existing customer) and other sites for irrigation uses, two large power generation plants, and commercial laundries. A large planned residential development area, encompassing about 238 acres within the City of Long Beach, has recently been identified for inclusion in this phase. Planned for completion by 2015, this project would use approximately 450 ac-ft/yr of reclaimed water for irrigation.

Phase 3—The facilities planned for Phase 3 include improvements to the reclaimed water system, including rehabilitation (redesign and expansion) of the THUMS pumping plant, which would result in a significant increase of about 1,600 ac-ft/yr to the available supply to THUMS and other new customers along the pipeline route. This is in addition to THUMS' current reclaimed water demand of 1,100 ac-ft/yr.

Phase 3 also is planned to include conversion of an existing 3.3 million-gallon potable water storage tank to reclaimed water storage. Together with this tank conversion, LBWD plans to construct a booster pump station to pressurize supply to the western portion of the reclaimed water system.

Phase 4—Phase 4 is intended to bring reclaimed water into the western part of the City via construction of 95,000 feet of 12- and 20-inch diameter pipe. It is estimated that Phase 4 facilities can supply an additional 4,400 ac-ft/yr of reclaimed water. Potential customers include two large power generation plants, two deep-well injection operations, an oil refinery, various municipal and private irrigation users, car washes, and laundry facilities.

Alamitos Barrier Recycled Water Project

A series of coastal injection wells have been installed to prevent seawater intrusion into drinking water aquifers in the region. Traditionally, potable water purchased from MWD has been used for this purpose. In order to lessen the demand on this resource, the Leo J. Vander Lans Water Treatment Facility (WTF) was constructed by the Water Replenishment District of Southern California (WRD) to inject both reclaimed water (up to 50%) and potable water into aquifers susceptible to intrusion. Injection of reclaimed water began in October 2006.

Tertiary treated effluent from the LBWRP is pumped to the adjacent WTF where it receives additional treatment via microfiltration, reverse osmosis, and ultraviolet (UV) radiation prior to injection. LBWD operates and maintains the WTF under a contract with WRD. The Los Angeles County Department of Public Works operates and maintains the barrier, including the transmission pipeline and the injection, extraction, and monitoring wells. There are 43 injection wells and four extraction wells located seaward of the injection wells. About 3 mgd of reclaimed water currently are injected. There is a potential to inject as much as 9 mgd in the future.

MF UNITS AT LEO J. VANDER LANS WTF

Public Outreach

LBWD initiated a Water Ambassador Program in 1998 to expand the Department's public education programs, community involvement, and outreach. The program is administered by volunteers who donate their time to educate the public and others about water conservation and use of reclaimed water.

Water Ambassadors visit local schools and other venues and plan activities and events for children that are both fun and educational. Community outreach is an important component of the program. The Water Ambassadors attend city-wide events (e.g., Earth Day at the Aquarium of the Pacific, CPR Sunday through the Red Cross, Water Awareness Month activities, and monthly band concerts) to pass out information about potable and reclaimed water, water conservation, rebates, and available programs.

Problems Encountered

While there have not been any major problems associated with the reclaimed water program, there have been a few minor problems, some of which have resulted in delays in implementing the reuse program. Some of these are as follows:

- Occasional pressure fluctuations in the system due to demand changes of large customers adversely affected pressure in the distribution system, resulting in some main breaks. Pressure regulators were installed in the affected areas to remedy this situation.
- Delays in various approval processes by grant agencies have caused some delays in execution of the project. Some implementation schedules have had to be revised to account for these unforeseen delays.
- Proposition 50 grant funding requires that users execute agreements with LBWD to guarantee use of reclaimed water once available. Execution of some agreements was not feasible within the grant schedule, and construction on specific pipe segments was cut back to accommodate the grant schedule.

Project Funding

The U.S. Bureau of Reclamation (USBR) has approved 25% matching grants for projects in Phases 1 through 4 of the reclaimed water program (up to a total capital expenditure of $35.2 million). In addition, Phase 1 projects received a 25% matching grant from the State Water Resources Control Board (up to a capital expenditure of $13.4 million under Proposition 13). LBWD currently is processing grant funding for the future projects in Phases 2 through 4 under Proposition 50.

Under a 1996 agreement between LBWD and MWD, LBWD will receive a rebate of $154 per acre-foot of recycled water used. This agreement is under MWD's Local Projects Program and has a cap of 2,750 ac-ft/yr. Projects in Phases 1 and 2 will be eligible for this rebate.

Seawater Desalination

In an effort to improve water reliability, LBWD has been aggressively pursing water conservation programs and a seawater desalination research program. The desalination program is a 10 year, $20 million effort that addresses intake and pretreatment issues, desalting membrane energy, operations, water quality issues, and post-treatment issues. LBWD will not pursue seawater desalination unless its research efforts determine that this can be accomplished cost-effectively and with minimal environmental impact.

The first phase of studies at Long Beach began with a small-scale 9,000 gallon/day (gpd) pilot plant, which was started in 2001. A 300,000 gpd prototype facility, initiated through a partnership with the Los Angeles Department of Water and Power, and the USBR, was subsequently constructed and became operational in 2006, and testing has been initiated to test LBWD's patented two-stage nanofiltration (NF) process against the more well-established reverse osmosis (RO) process for desalinating seawater. The research will include testing new concepts for disinfection and microbial fouling control of the membranes utilizing UV and chlorine dioxide. The research will conclude by 2010 and planning efforts are underway for a 10-mgd full-scale facility, which is projected to make up about 10% of LBWD's water portfolio.

The primary research at the prototype facility is centered on further development of the Long Beach two-stage NF method, known as the "Long Beach Method." Due to lower membrane operating pressures required for NF as compared to RO, studies have indicated that the Long Beach Method requires less energy than traditional desalination (up to 20%).

Seawater Intake and Discharge—LBWD and USBR are undertaking design and construction of an Under Ocean Floor Seawater Intake and Discharge Demonstration System to demonstrate the efficacy of an environmentally responsible intake and discharge system. Traditionally, seawater is withdrawn in open ocean intakes using mesh screens to prevent fish and other marine life from being sucked into the intake line. Use of these open ocean intakes often has adverse impacts on the environment, particularly when fish and other marine life become entrained or impinged on the screens. While the intake screens prevent debris and most aquatic life from entering, suspended solids and other constituents still have to be removed, and pretreatment is needed to prevent fouling of membranes.

With the proposed Under Ocean Floor Seawater Intake and Discharge Demonstration system, the environmental impacts typically associated with open ocean intakes are minimized by drawing seawater through beach sand into pipes embedded in the ocean floor. The concept would also be applied to the discharge of the brine concentrate stream in order to minimize the environmental impacts of a brine plume.

The Under Ocean Floor Seawater Intake system will provide a natural, biological filtration process that reduces organic and suspended solids loading on the desalination plant, thus reducing the need for pretreatment and associated costs. The advantages of this intake system over open ocean intakes with desalination pretreatment processes include the following:

- The flow rate and operation of the under ocean floor intake system is unaffected by wave action and tidal forces;
- It is virtually maintenance free, eliminating operation and maintenance costs; and
- It serves the dual role of both an intake and pretreatment component in an environmentally sensitive manner.

For further information, contact: K. Eric Long, Director of Water Resources, Long Beach Water Department, 1800 E. Wardlaw Avenue, Long Beach, CA 90806

SANTA ROSA SUBREGIONAL RECYCLED WATER PROGRAM

Background

THE CITY OF SANTA ROSA is located in Sonoma County, California, about 55 miles north of San Francisco, and has a population in excess of 150,000. In addition to being in one of the state's premier wine grape growing regions, there is a considerable amount of agricultural crop irrigation, although the area is becoming increasingly urbanized. From a water resources management perspective, increasing urbanization results in additional water supply and wastewater disposal needs, and water reuse is proving to be a critical component in helping to satisfy those needs.

The Santa Rosa Subregional Water Reuse System (Subregional System) was formed in 1975 and provides treatment and disposal and reuse services for the Cities of Santa Rosa, Cotati, Rohnert Park, and Sebastopol and the South Park County Sanitation District (collectively known as the Subregional Partners). The City of Santa Rosa Utilities Department manages the Subregional System and operates the Laguna Wastewater Treatment Plant (LWTP), which is part of the Subregional System providing treatment of wastewater from more than 225,000 residents and 6,500 businesses. In addition to operating the LWTP, the utilities department oversees industrial pretreatment systems and distribution of the reclaimed water.

Subregional System

Since its opening in 1968, the LWTP has increased its production of reclaimed water from 2 mgd to an average of 22 mgd in 2006. During the summer, the average daily flow to the plant is about 17 mgd but can exceed 60 mgd during the winter. More than 500 miles of pipes convey wastewater to the LWTP, where it is treated to tertiary standards specified in the California Department of Health Services Water Recycling Criteria for high level nonpotable uses. Treatment processes include grit removal in aerated grit removal chambers, primary sedimentation, activated sludge secondary treatment (includes alum addition prior to clarification), filtration with deep-bed monomedia (anthracite) filters, and UV disinfection with medium-pressure, high-intensity lamps.

Average values for selected parameters in the product water are as follows:

- pH: 7.5
- Turbidity: 0.7 NTU
- Total coliforms: $<$2/100 mL
- Total suspended solids: 1.1 mg/L
- Total dissolved solids: 442 mg/L
- Biochemical oxygen demand: 2.5 mg/L
- Nitrate nitrogen: 11–13 mg/L
- Phosphorus: 2.2 mg/L
- Sodium adsorption ratio: 2.8 mg/L

Reclaimed water produced at the plant is used for multiple purposes, including agricultural irrigation (5,800 acres of vineyards, silage, pastures, and produce farms), and urban irrigation (650 acres of parks, golf courses, and school grounds). Approximately 2.8 billion gallons of reclaimed water was used for agricultural and urban irrigation in 2006. Most irrigation occurs during the summer months when rainfall is low and irrigation needs are high. A series of storage ponds, with a total capacity of 1.8 billion gallons, store water produced in winter months when irrigation needs are minimal. Reclaimed water also is used in two small created wetlands in the Santa Rosa Plain and for recharge of the Geysers steam field for electricity generation.

FOOD CROPS IRRIGATED WITH RECLAIMED WATER

Treated effluent that cannot be reused or stored in ponds is discharged to the Russian River via the Laguna de Santa Rosa. The discharge of effluent from the LWTP to the Russian River or its tributaries is prohibited during the period of May 15 through September 30 of each year. During the period of October 1 through May 14 (discharge season), discharges of treated wastewater cannot exceed 5% of the flow of the Russian River. About 1.8 billion gallons of effluent was discharged to the river in 2006 during the discharge season, which was less than 20% of the total recycled water produced.

The Oakmont Treatment Plant is a satellite facility that has an average flow of 0.5 mgd; it operates during summer months to provide reclaimed water to the Oakmont Golf Course. The Oakmont Treatment Plant is owned and operated by the City of Santa Rosa but is not part of the Subregional System.

Geysers Recharge Project

In 1985, a violent storm forced the Subregional System to make releases of treated wastewater in excess of what was allowed in its discharge permit to relieve pressure on the storage ponds; this led to Santa Rosa's search for a viable weather-independent solution to the area's wastewater disposal problems. That solution was the $200 million Geysers Recharge Project, which consists of a 41-mile pipeline, four pump stations, and a terminal tank that sits high in the mountains just above natural geothermal steam fields that energy companies have harnessed to create electricity. The innovative project went online in December 2003 and pumps an average of 11 mgd of reclaimed water from the LWTP to the Geysers steam fields, where it generates enough electricity for more than 85,000 households. In 2006, 4.1 billion gallons was reused for energy production.

Future Program Description

As a result of population growth and increasingly stringent regulatory requirements applicable to wastewater discharged into the Russian River, the City of Santa Rosa adopted the Incremental Recycled Water Program (IRWP) Master Plan in 2004 to expand the current Subregional System. The IRWP Master Plan includes five components that will work in tandem to meet resource demands and be responsive to regulatory changes: Geysers expansion; agricultural irrigation; urban reuse; water conservation; and discharge compliance. All five components are currently in various stages of studies, planning, and design. Additional storage is fundamental to the program's success; thus, surface storage options for additional capacity of around 1.2 billion gallons also are being studied and developed in areas where urban and agriculture reuse expansion is planned to occur. Brief descriptions of the five IRWP components are provided below.

Geysers Expansion—This component will increase the amount of reclaimed water supplied to the Geysers steam field by up to 400 million gallons per year by utilizing additional capacity built into the Geysers Recharge Project pipeline. The additional system capacity was designed to allow for "off peak" pumping during times when electrical demand and power costs were low and to provide flexibility in the event deliveries to the Geysers were disrupted.

GEYSERS GEOTHERMAL POWER PLANT

Agricultural Irrigation—The goal of this component is to expand agricultural irrigation with reclaimed water by at least one billion gallons per year over the next two decades to lands that currently are being irrigated with water from other sources or are not being irrigated at all. This component was developed in coordination with local agricultural groups interested in using reclaimed water for crop irrigation and may include providing potable water offsets. The Sonoma County Water Agency also is studying additional agricultural reuse options that could use the Subregional

RECLAIMED WATER STORAGE AT GALLO VINEYARD

System's reclaimed water. The Geysers Recharge Project includes pipeline turnouts that would allow for future diversions of water for agriculture reuse.

Urban Reuse—This component examines options for increasing the annual amount of water used for urban reuse by 500 million gallons or more over the next couple of decades. New residential and business developments in southeast and southwest Santa Rosa and northern Rohnert Park will be considered for dual piping systems. Existing public and commercial landscapes and new residential and business developments in specific areas of the City are being considered for reclaimed water irrigation. Studies for the urban reuse component also include consideration of using reclaimed water for commercial or industrial purposes.

Water Conservation—Future conservation programs for the Subregional Partners are being considered as a way to further reduce indoor water usage and, hence, wastewater flows into the LWTP. It is anticipated that as much as 300 million gallons per year of water can be conserved through implementation of additional conservation programs. Because earlier conservation measures, such as the toilet rebate programs, have been so successful, additional water savings are likely to cost more on an incremental basis.

Discharge Compliance—Currently, discharge of treated wastewater into the Laguna de Santa Rosa during winter when supply exceeds storage capacity and irrigation reuse opportunities are minimal does not meet technical regulations during certain weather and streamflow conditions. Compliance may not be possible unless the discharge is relocated to the Russian River. Therefore, the discharge compliance component addresses the volume, timing, and location of wastewater discharge, either directly or indirectly into the Russian River and/or its tributaries. This program component includes additional treatment options such as expansion of the commercial/industrial pretreatment program.

Environmental and Growth Concerns

For many years there has been a certain amount of outcry from communities located downriver from where Santa Rosa's discharge meets the Russian River. Plans to relocate the wastewater discharge from the Laguna de Santa Rosa to the Russian River are being closely scrutinized by several community and environmental groups. Their concerns are focused on the ability to maintain the quality of their drinking water—which comes from the river—and the possible impacts of discharge on aquatic life and the river ecosystem. Concerns also have been expressed that relocation of the wastewater discharge directly to the Russian River will result in allowance of increased wastewater flows and ultimately result in unfettered growth in the region.

Public Outreach

Though still early in the process, there has been little public resistance to the use of reclaimed water for agricultural or urban reuse. Outreach to date has been focused on those most likely to be directly impacted by new facility locations and/or construction activities. Future outreach efforts will be directed primarily at new reclaimed water users/customers and will emphasize the environmental benefits of limiting the amount of water needed to be discharged into local waterways and using reclaimed water to offset potable water supplies. These messages, along with water quality and safety information, will be featured in brochures, utility inserts, e-mail broadcasts, and project websites, each aimed at specific audience segments.

Program Costs

The annual operations and maintenance budget for the Subregional System is currently about $24 million. Of that, 33% is expended on treatment, 20% on water reuse and disposal, and 6% on the Geysers recharge project. The remainder is spent on administration, biosolids reuse and disposal, industrial waste, and mechanical and laboratory services. Estimated costs for the IRWP components being pursued are: $100–120 million for expanded urban reuse; $50–400 million for increased storage capacity, $5–10 million to increase the flow to the Geysers recharge project; $10–100 million to expand agricultural reuse; $5 million for an expanded water conservation program; and $30–120 million for discharge compliance.

The residents of Santa Rosa already pay among the highest water and wastewater rates in northern California. The estimated costs of the IRWP components and associated projects will be difficult for ratepayers to afford. It is anticipated that some costs will be recouped by higher sewer hookup fees on new construction and cost participation by partners who may want a share of wastewater for agricultural and urban reuse or energy production. However, not all costs can be covered through these sources, and the ratepayers would still be required to pay a significant portion of the long term costs.

For further information, contact: Daniel Carlson, Deputy Director, Subregional Operations, City of Santa Rosa, 69 Stony Circle, Santa Rosa, CA 94501

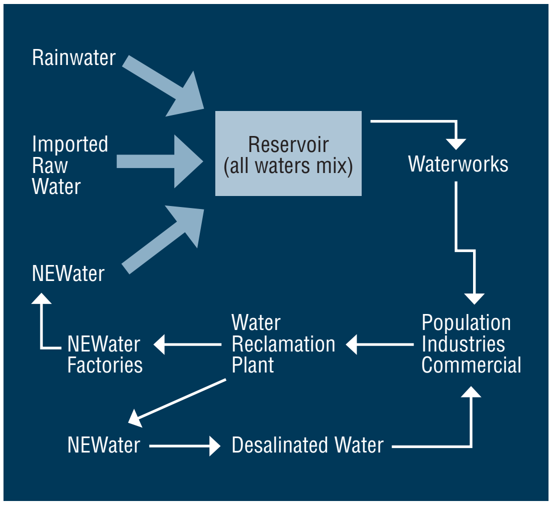
SINGAPORE NEWATER PROJECT

Background

THE REPUBLIC OF SINGAPORE has a population of about 4.2 million people. Although rainfall averages 98 inches per year, Singapore has limited natural water resources due to its small size of approximately 270 square miles. Singapore obtains approximately 50% of its water supply from Malaysia under two bilateral agreements which are due to expire in 2011 and 2061.

To have a diversified, robust, and sustainable water supply, Singapore initiated the Four National Taps strategy in the late 1990s which identified four sources of water supply:

- Local catchment water;
- Imported water from Johor, Malaysia;
- Reclaimed water; and
- Desalinated water.



SCHEMATIC OF THE FOUR NATIONAL TAPS

One of the National Taps, reclaimed water (called NEWater), is the product of a comprehensive and extensive study (NEWater Study) that was started in 1998. The primary objective of the study was to construct and operate a demonstration scale advanced dual membrane water treatment plant to determine the reliability of membrane technology to purify secondary treated wastewater effluent to a quality that consistently surpasses World Health Organization (WHO) drinking water guidelines and U.S. Environmental Protection Agency (USEPA) drinking water standards. By achieving that high quality, NEWater could then be supplied to industries, commercial buildings for nonpotable use, and for planned indirect potable reuse (IPR) via discharge to raw water supply reservoirs.

While nonpotable reuse has been an important component of Singapore's water resources since the early 1970s when tertiary treated wastewater began to be used for industrial applications, the NEWater Study included evaluation of the use of higher quality water for nonpotable applications such as process water at wafer fabrication plants and air conditioning cooling water in commercial buildings.

NEWater has been supplied to the wafer fabrication plants since early 2003; it is the first use of reclaimed water for this purpose in the world. Supplying the water to the wafer fabrication plants helps to demonstrate the consistent and reliable high quality of NEWater as the plant operators require a water quality that is more stringent than that for drinking. Because of the purity of the NEWater, the fabrication plant operators have reported 20-30% savings in their process water operating costs.

NEWater Study

The NEWater Study included the following three major areas of investigation:

- Operation of an AWT demonstration plant using microfiltration (MF), reverse osmosis (RO), and ultraviolet (UV) radiation to test the ability of the treatment train to reliably and consistently produce high quality water;
- A Sampling and Monitoring Program (SAMP) that included comprehensive physical, chemical, and microbiological sampling and analysis of water samples;
- A Health Effects Testing Program (HETP) to complement the SAMP to determine the safety of NEWater. The HETP involved the toxicological assessment of NEWater against Public Utilities Board (PUB) source water from Bedok Reservoir.

A 2.6 mgd NEWater demonstration plant was built at the Bedok Water Reclamation Plant (WRP) and placed into operation in 2000. The Bedok WRP receives more than

95% of its wastewater from domestic sources. Feed water to the demonstration plant was activated sludge secondary effluent with the following quality: 10 mg/L BOD_5, 15 mg/L TSS, < 5 mg/L ammonia-nitrogen, 400 to 1,600 mg/L TDS, and 12 mg/L TOC. AWT processes included microscreening (0.3 mm screens), MF (0.2 μm nominal pore size), RO with thin-film aromatic polyamide composite membranes configured for 80-85% recovery in a three-stage array, and UV with broad-spectrum medium pressure UV lamps delivering a minimum design total calculated UV dosage of 60 mJ/cm^2. Chlorine was added before and after MF to control membrane biofouling. One of the objectives of the treatment plant design was to incorporate MF, RO, and UV into the treatment train as multiple barriers for the removal of microbial pathogens and chemical contaminants.

Sampling and Monitoring Program

An extensive water quality monitoring program carried was out at the demonstration facility for a period of two years and is still on-going. The SAMP included systematic measurement of a suite of physical, microbial, and chemical parameters across the process train to evaluate the suitability of using NEWater as a raw water source for potable use. The USEPA National Primary and Secondary Drinking Water Standards and WHO Drinking Water Quality Guidelines were used as the benchmarks for NEWater quality. Routine testing also was performed for many unregulated constituents, such as N-nitrosodimethylamine and 1,4-dioxane. More than 50,000 individual physical, microbiological, and chemical water quality analytical results have been determined from multiple monitoring locations across the treatment train. In total, about 287 constituents and parameters currently are monitored, including the USEPA's Priority List of Contaminants.

The overall quality of NEWater consistently met the drinking water quality standards/guidelines of the USEPA and WHO. The sampling and analyses of the product water for microbial agents during the NEWater Study indicated that all microbial contaminants of concern were removed or destroyed during treatment. Disinfection byproducts, polycyclic aromatic hydrocarbons, pesticides/herbicides, natural and synthetic human hormones, and other organic pollutants were at or below the technical detection limits or determined to be present at concentrations that do not pose any known health risk. The majority of the measured parameters had values which were lower than PUB potable water.

Health Effects Studies

A two-year Health Effects Testing Program (HETP) was initiated in 2000 to evaluate the potential health impact of unidentified and unregulated chemical contaminants in the NEWater. The study involved a comparative toxicological assessment of NEWater with an existing raw water supply from Bedok Reservoir using both rodents (B6C3F1 mice) and fish (medaka). The mouse study was a two-year *in vivo* study, and the fish study was a two-generation study. The findings of the HETP indicated that NEWater did not have short-term or long-term carcinogenic effects on either the mice or fish and did not have any estrogenic (reproductive or developmental) effects on the fish.

Expert Panel

An Expert Panel consisting of both local and international experts in engineering, biomedical science, chemistry and water technology was formed in 1999 to provide independent advice to PUB and Ministry of the Environment (ENV) on the NEWater Study. The panel was tasked with providing review and advice on the planning and implementation of the study, reviewing and evaluating the study's findings, and making recommendations on the suitability of NEWater as a source of raw water for potable use.

The panel concluded that NEWater would be a safe supplement to the existing water supply for the following reasons:

- NEWater consistently met the USEPA drinking water standards and WHO drinking water guidelines;
- Health effects studies did not indicate that consumption of the water would result in any short or long-term adverse health effects;
- Trace minerals necessary for health and taste removed in the reverse osmosis process will be added to the water via blending with reservoir water; and
- Storage provides additional safety beyond the advanced technologies used to produce safe high quality NEWater.

The panel emphasized that implementation of planned IPR should include a vigilant and continuous monitoring program. Since commissioning of the NEWater factories, Singapore has instituted an External Audit Panel and an Internal Audit Panel. The panels meet several times a year to audit the NEWater plants' operation, maintenance, and water quality.

NEWater Factories

The NEWater factories at the Bedok and Kranji Water Reclamation Plants, which include the same treatment processes as evaluated during the demonstration plant study, were commissioned at the end of 2002 and went into service in February 2003. The Bedok and Kranji Water Factories have current capacities of 11 mgd and 15 mgd, respectively. Both plants are undergoing further expansion to meet growing demands for NEWater, especially by the industries.

SELETAR NEWATER FACTORY

A third NEWater factory at the Seletar Water Reclamation Plant was commissioned in 2004. The current capacity of this facility is 6.3 mgd. The fourth plant, Ulu Pandan Water Factory, has been built with a capacity of 39 mgd and is scheduled to go into operation in 2007.

The NEWater Factories all produce high quality product water (e.g., turbidity $<$0.5 NTU, TDS $<$50 mg/L, and TOC $<$0.5 mg/L) that meets all drinking water limits included in the USEPA drinking water standards and WHO guidelines. Constituents monitored include many organic compounds, pesticides, herbicides, endocrine disrupting compounds, pharmaceuticals, and unregulated compounds of concern. None of these constituents have been found in the treated water at health-significant levels.

A small portion (2.4 mgd) of NEWater was used for planned IPR in 2003 via discharge to raw water reservoirs, which accounted for less than 1% of the total water supply. This will increase by 1.2 mgd each year; currently, 6 mgd is used for planned IPR. The blended water is subsequently treated in a conventional water treatment plant using coagulation, flocculation, sand filters, ozonation, and disinfection prior to distribution as potable water.

Most of the reclaimed water from all three plants, about 22 mgd, is supplied to industries for nonpotable reuse. The goal is to increase reclaimed water use to 66 mgd for nonpotable applications and 12 mgd for potable reuse by 2011.

Visitor Centre

A NEWater Visitor Centre was built as the focal point of the PUB public education program to build public awareness and acceptance of advanced wastewater treatment technologies that treat reclaimed water to drinking water standards. The 24,000 square-foot Visitor Centre, the most sophisticated of its kind in the world, opened in 2003 and is incorporated within the Bedok NEWater production plant.

The center is fully integrated with the Bedok Water Factory and includes an elevated walkway through the process area and a multimedia interactive exhibition/education area. It includes multimedia displays, videos, interactive computer programs, and guided tours to educate the public, particularly school children, about the importance of water to the community. A small portion of the water produced for potable reuse is bottled and given to visitors and others in Singapore to demonstrate the water's high quality. More

NEWATER VISITOR CENTRE

than 450,000 people have visited the center since its opening, an average of more than 2,200 per week.

Costs and Funding

The capital costs for all of the NEWater factories built to date were $2.2 million per mgd capacity. Annual operation and maintenance (O&M) costs for the three water factories currently in operation are about $985 per million gallons produced. The PUB charges industries and others $2.84/1,000 gallons for NEWater on a full cost recovery approach. This includes the capital cost, production cost, and transmission and distribution cost.

For further information, contact: Harry Seah, Director, Technical Office, Public Utilities Board, 40 Scotts Road, #15-01 Environment Building, Singapore 228231

SCOTTSDALE, ARIZONA

Background

THE CITY OF SCOTTSDALE is a desert community in the Phoenix area that lacks natural surface water sources and has relied heavily on groundwater supplies, resulting in lowered groundwater levels in the area. In 1980, statewide legislation (the Groundwater Management Act) was enacted to address this issue. The act established active management areas, within which groundwater safe yields cannot be exceeded; that is, groundwater users must achieve a balance between groundwater recharge and withdrawals.

Scottsdale had a population of approximately 183,000 in 1996, at which time the annual water use was about 23 billion gallons per day (bgd). The 2006 population of greater than 225,000 is expected to increase to about 285,000 by the year 2012 with an estimated water requirement of 43 bgd. Recognizing the need to address future water needs, the city began implementing an Integrated Water Resources Management Plan in 1992. It was estimated that reclaimed water would eventually provide 18% of the City's water resources. A multi-phased plan was developed that ultimately led to development of a water treatment and water reclamation facility (named the Water Campus).

Water Campus

Prior to building the Water Campus, Scottsdale sent its wastewater to a regional facility, the Phoenix Multi-Cities 91st Avenue Wastewater Treatment Plant (WWTP), for treatment and disposal. While Scottsdale owns 13.1 mgd of capacity at that facility, its wastewater flows exceeded that amount by the mid-1990s, and the City rented available capacity to meet is needs. An economic analysis comparing continued treatment at the 91st Avenue WWTP versus construction of a Scottsdale water reclamation facility indicated significant cost and long-term sustainability advantages of reclaiming and reusing wastewater within the City, thus leading to construction of the Scottsdale Water Campus.

The Water Campus, operated by a staff of 28 full-time employees, is a state-of-the-art water treatment and wastewater reclamation facility encompassing 141 acres. It is the cornerstone of the City's integrated program to meet Scottsdale's water needs and comply with Arizona's Groundwater Management Act, which requires either natural or artificial recharge to at least equal groundwater withdrawals.

The main components of the Water Campus include: a 54-mgd surface water treatment plant; a 20-mgd water reclamation plant to provide tertiary treated reclaimed water for landscape irrigation; a 14-mgd advanced water treatment plant for indirect potable reuse via groundwater recharge; 55 injection wells; and a state-certified water quality laboratory that performs the full range of microbiological and chemical analyses.

AERIAL VIEW OF WATER CAMPUS

The first two phases of the project—including a 12-mgd tertiary treatment facility (the Water Reclamation Plant) and a 12-mgd advanced water treatment (AWT) plant—went into operation in 1998. The ultimate design capacity will be 24 mgd based on flow projections through the year 2020.

Design of Phase III of the Water Campus was initiated in 2003, and construction will be completed in 2007. Upgrades and expansion of the tertiary facility include the following: capacity increase from 12 mgd to 20 mgd; conversion of deep-bed monomedia anthracite filters to disk filters; and upgrading of several treatment processes (e.g., reconfiguration of aeration equipment, addition of an acetic acid feed system to supplement BOD in the aeration system, and installation of a "swing zone" after the anoxic zone to provide the potential for additional detention time in the anoxic zone).

Phase III upgrades to the AWT plant include addition of a third lime silo and an enhanced lime feed system, replacement of the two decarbonation towers with new towers, and additional flexibility in the reverse osmosis (RO) chemical feed system. In addition, testing indicated that the RO flux rate could be increased by approximately 10% to 12.2 gallons/foot/day. This increased the theoretical RO feed capacity to 16 mgd and the product water capacity to about 14 mgd.

Water Reclamation Plant

The Water Reclamation Plant includes the following treatment processes:

- Preliminary screening with mechanically cleaned bar screens;
- Primary clarification;
- Secondary biological treatment including complete-mix aeration basins with nitrification/denitrification;
- Secondary clarification;
- Tertiary treatment with disk filters; and
- Disinfection with chlorine gas.

Effluent from the tertiary treatment plant is of a higher quality than that required in the Arizona Department of Environmental Quality water reuse standards for open access irrigation. Tertiary effluent enters a distribution system delivering water to 23.5 golf courses and nearby recreational areas and medians in north Scottsdale to meet their irrigation demands. Approximately 10.2 mgd of reclaimed water is used for irrigation during the dry months of the year. When the irrigation demand is reduced, the effluent is diverted to the advanced water treatment plant for further treatment prior to groundwater recharge.

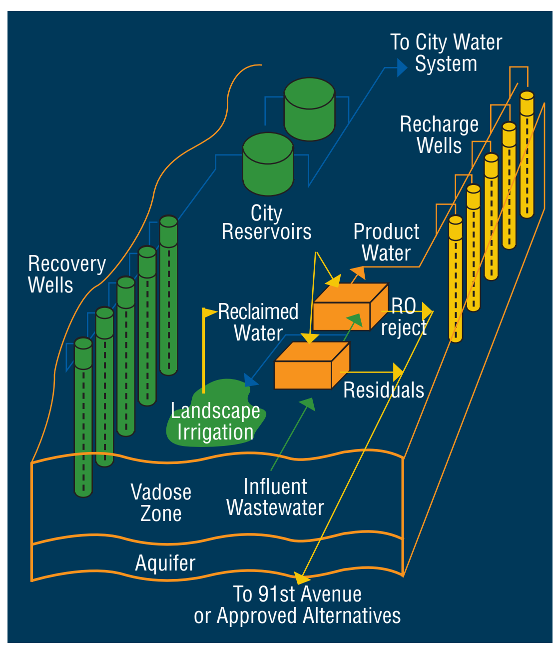
Advanced Water Treatment Plant—The AWT Plant treats tertiary effluent from the Water Reclamation Plant after storage in an equalization basin to allow the AWT facilities to operate at a constant flow for indirect potable reuse treatment via microfiltration (MF) and RO prior to vadose zone well injection. MF backwash water is returned to the tertiary treatment plant, and RO reject water and other residual streams are sent to the 91st Avenue WWTP for further treatment.

The AWT Plant currently has a feed capacity of 16 mgd. More than 4,000 acre-feet (1.3 billion gallons) of reclaimed water were recharged in 2006 to augment the potable water supply. Very little reclaimed water—about 1.7 mgd on average—is recharged in the summer months when most of the tertiary treated water is used for golf course irrigation, while the AWT facility operates near capacity (almost 14 mgd) during the winter months.

The use of reclaimed water from the Water Campus requires several permits. A Wastewater Reuse Permit and an Aquifer Protection Permit are required by the Arizona Department of Environmental Quality, while the Arizona Department of Water Resources requires an Underground Storage Facility Permit. In addition, an Air Quality Emissions Permit and Operating Permit are administered by Maricopa County. All aquifers in Arizona currently are classified for drinking water protected use, and the state has adopted National Primary Drinking Water Maximum Contaminant Levels (MCLs) as aquifer water quality standards.

The Advanced Water Treatment Plant's basic treatment processes are as follows:

- 400-μm strainers;
- Ammonia addition to eliminate free chlorine;
- Microfiltration units;
- Antiscalant;
- pH adjustment using H_2SO_4 ;



OVERVIEW OF WATER CAMPUS

- 20-μm cartridge filters;
- Thin film composite polyamide RO elements in a three-stage configuration @ 24:10:5 with a recovery rate of 85%;
- Degasifier towers for reduction of CO_2;
- Lime feed for RO permeate stabilization; and
- Vadose zone injection wells.

Reclaimed Water Quality

Although the reclaimed water used for irrigation readily meets all regulatory limits, the total dissolved solids (TDS) concentration in the water is about 1,100 mg/L and represents a major concern to irrigation customers. Scottsdale is addressing this issue and reviewing alternatives, including RO treatment, to reduce the TDS—particularly the sodium level—to provide higher quality water for golf course irrigation.

The product water from the AWT facility meets all drinking water standards. In recent years, however, unregulated contaminants such as N-nitrosodimethylamine (NDMA) have become a concern. While NDMA is present in low levels in the product water, it was not detected in water from monitoring wells until 2003—four years after injection began. NDMA concentrations in water extracted from monitoring wells range from below detectable levels to approximately 30 nanograms/L. As a result, Scottsdale is considering incorporating an advanced oxidation process using H_2O_2/UV into the next expansion of the AWT facility. The concentration of other constituents varies depending on the blend of AWT product water and Colorado River water from the Central Arizona Project (CAP) canal at the point of injection. For example, the TOC in the blended water varies from 0.2 mg/L to about 2.9 mg/L, clearly indicating the influence of CAP water, which has a considerably higher level of TOC than the AWT product water.

Vadose Zone Injection

The vadose zone extends from the ground surface to the water surface at the top of the underground aquifer; thus, in this case, the injection wells are sometimes called "dry wells." The injected water quality is further improved by soil aquifer treatment as it percolates through several hundred feet of soil after injection and commingles with local groundwater. The commingled water is extracted by potable water supply wells at locations downgradient from the injection wells.

Both reclaimed water from the AWT plant and CAP water that receives MF treatment are used for vadose zone injection. CAP water is used for recharge primarily during the summer months when irrigation demand is high to fully utilize existing production capacity, while reclaimed water is used for recharge primarily during the winter months when irrigation demand is low. To achieve a TDS goal of 450 mg/L prior to recharge, some reclaimed water receives RO treatment year round to blend with CAP water, which has a TDS of about 700 mg/L. The TDS of RO-treated reclaimed water is 25 mg/L.

There are 55 injection wells at the Water Campus; 27 standard wells and 28 emergency wells. There are seven monitoring wells downgradient of the injection wells. The standard wells are individually monitored and controlled and discharge into the vadose zone directly at about 180 feet below the ground surface. The groundwater table is approximately 600 feet below the ground surface. Emergency wells are designed to recharge tertiary effluent that is diverted from the AWT plant to prevent hydraulic overloading during the wet season. They are monitored and controlled collectively and discharge into a ¾-inch gravel pack roughly 20 feet below the ground surface. The gravel pack extends to a depth of about 180 feet below the ground surface in a 4-inch bore.

Although the standard vadose zone wells were designed to recharge up to 480 gpm per well, for a total recharge capacity of 18.7 mgd, they currently recharge an average about 400 to 450 gpm per well. The emergency wells each recharge an average of about 200 to 250 gpm.

Costs

The initial construction costs for the first two phases of the tertiary and AWT facilities totaled $75 million. Phase III construction costs to convert the deep-bed filters to disc filters and to expand capacity of the Water Reclamation Plant were approximately $3.2 million and $20 million, respectively. The cost to produce potable quality water has been estimated to be less than $1.30/1,000 gallons.

For further information, contact: David M. Mansfield, General Manager, Scottsdale Water Resources Department, 9388 East San Salvador Drive, Scottsdale, AZ 85258

WateReuse Association
1199 North Fairfax Street, Suite 410
Alexandria, VA 22314
(703) 548-0880
Fax: (703) 548-5085
Information@WateReuse.org
www.WateReuse.org