field report

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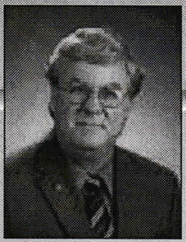

Markus

The Groundwater Replenishment System

The Groundwater Replenishment (GWR) System, operated by the Orange County Water District (OCWD), is the world's largest water purification and reuse project of its kind. The new system increases Orange County's water independence by providing a locally controlled, drought-proof supply of safe, high-quality water. At full capacity, the GWR System generates enough pure water to meet the needs of 500,000 people. GWR System–purified water exceeds all state and federal drinking water standards and has water quality similar to distilled water. The GWR System takes highly treated wastewater that would have gone to the ocean and recycles it to produce 265,000 m^3/d of purified water.

OCWD was formed in 1933 as a California Special District to manage the groundwater basin that underlies north and central Orange County. The groundwater basin supplies more than half of the water needs for 2.3 million residents in the service area. The Orange County Sanitation District (OCSD) is a partner in this project and is a wastewater collection and treatment agency serving 2.5 million residents and businesses.

GWR SYSTEM BENEFITS

The GWR:

- helps maintain and improve the reliability of Southern California's water supply;
- helps protect against future droughts;
- produces high-quality water to replenish the groundwater basin;
- helps protect the environment by reusing a precious resource;
- uses approximately one-half the amount of energy that is required to transport water from Northern California to Southern California—saving enough energy to power 21,000 homes each year;
- eliminates the need to build another ocean outfall;
- provides "water diversity" in an arid region, similar to the concept of "financial diversity."

THE GWR SYSTEM IS MADE UP OF VARIOUS COMPONENTS

The upgraded Water Factory. The GWR System replaced Water Factory 21 (WF-21), a wastewater reclamation plant that provided water for a seawater intrusion barrier. The plant reclaimed approximately 19,000 m^3/d of clarified secondary wastewater effluent using lime clarification pretreatment, reverse osmosis (RO), and recently, ultraviolet (UV) treatment. The GWR System replaced WF-21 by using more advanced treatment processes, expanding the existing seawater intrusion barrier, and using the remaining water produced for recharge into the groundwater basin.

The Advanced Water Purification Facility. The heart of the GWR System is the Advanced Water Treatment Facility (AWPF). The major AWPF processes include microfiltration (MF), RO, and advanced oxidation processes (AOP), which consist of UV light and hydrogen peroxide.

Following filter screening, OCSD clarified secondary effluent, normally disposed of in the ocean, receives MF membrane treatment. MF is a low-pressure membrane process that removes suspended matter from water. MF is specifically used to separate suspended and colloidal solids including bacteria and protozoa from the OCSD secondary effluent. Sodium hypochlorite is added to the MF feedwater to minimize MF membrane fouling. MF filtrate is fed to RO, and MF reject streams are returned to OCSD's Plant Number 1 for treatment. MF has demonstrated exceptional effectiveness as a pretreatment for RO. On the basis of a design recovery of approximately 90%, 86 mgd of filtrate is produced by MF. Excess filtrate is used to supplement tertiary nonpotable reuse.

MF filtrate is sent to the RO treatment process. The feed water passes through polypropylene wound cartridge filters prior to RO treatment. The RO process rejects most dissolved contaminants and minerals and reduces dissolved organics, pesticides, total dissolved solids, pharmaceuticals, silica, and viruses from MF filtrate. Generally, constituents with a molecular weight above 100 are removed by RO. Sulfuric acid is added to the RO feedwater for pH reduction and carbonate scaling control. A threshold inhibitor or antiscalant is also added to minimize membrane fouling. The RO permeate is directed to UV treatment. The RO concentrate or brine is then discharged into the ocean via the OCSD ocean outfall. Based on a design recovery of approximately 85%, the production rate of RO is 265,000 m^3/d. The plant may be upsized in the future to produce 490,000 m^3/d.

Following RO treatment, the permeate undergoes UV treatment. UV treatment involves the use of UV light to penetrate cell walls of microorganisms, preventing replication and inducing cell death. UV provides additional bacterial and viral inactivation and, combined with RO treatment, increases removal efficiency. With the addition of hydrogen peroxide, UV and the hydroxyl radicals oxidize organic compounds for ultimate removal from water. UV and peroxide treatment is used for *N*-nitrosodimethylamine (NDMA) and other low-molecular-weight organic removal. UV product water undergoes additional chemical treatment prior to groundwater injection and recharge. The product water is so low in mineral content that it has a corrosive nature. If not mitigated with the addition of lime, the concrete transmission pipe would corrode in the presence of the unstabilized water.

GRANTS REDUCE TOTAL PROJECT COST

The GWR System total capital cost was $480,900,000. Approximately $90 million in federal and state grants were used to reduce the capital costs. After the grants were factored in OCSD and OCWD split the remaining cost. The annual operating cost is approximately $30 million. Almost $4 million of this annual cost is being subsidized by the Local Resources Program from Metropolitan Water District of Southern California. With grants and subsidies factored in, the cost to recharge or inject GWR System water is approximately $520 per acre foot.

PROJECT REQUIRED TO MEET SPECIFIC QUALITY TESTS.

During the start-up phase of the AWPF, monitoring water quality was an important component of the permit issued by the (California) Regional Water Quality Control Board in conjunction with the California Department of Public Health. During the acceptance testing of the AWPF, specific water quality tests were required. Specific criteria were monitored directly using online instrumentation or indirectly by taking water quality grab samples.

Water quality is available for the MF feed, the RO permeate and the finished product water after lime addition. The AWPF water quality was acceptable and the purification processes worked as designed.

The primary measure of the plant's performance is based on water quality parameters that include total organic carbon (TOC), total nitrogen, total dissolved solids, and NDMA. Many of the water quality requirements are beyond those for primary and secondary drinking water standards. Table 1 shows the RO and AOP processes are functioning properly especially with regard to TOC (< 0.5 mg/L) and NDMA (< 10 ppt). On the basis of this information, the plant construction was accepted.

SUMMARY OF OPERATIONAL EXPERIENCES

Since the first water was injected into the Talbert Barrier from the GWR System on Jan. 10, 2008, and the first water was sent to the Kraemer/Miller Basin on Jan. 17, 2008, OCWD has been working to optimize the AWPF. Currently, plant production is limited by the flow available from OCSD because of diurnal flow fluctuations. The new Steve Anderson Lift Station scheduled for completion in April 2009 will allow the operation of the plant at a continuous production rate of approximately 265,000 m^3/d. Currently, plant production has been limited to approximately 75,000 m^3/d from 2 a.m. until 9 a.m. and 208,000 m^3/d from 9 a.m. to 2 a.m. OCWD has embarked on a number of efforts to increase production out of the plant.

- Conducting a microfiltration pilot study on the trickling filter effluent in an effort to resolve concerns a GWR System Independent Advisory Panel had about operating the AWPF with an 80/20 blend of activated sludge and trickling filter effluent. Incorporating trickling filter effluent resulted in approximately 19,000 m^3 more water available during the day.
- Improvements were made to the lime-dosing system at the end of the treatment process. Initially, a concern was raised that constituents in the lime were contributing to accelerated fouling of the injection wells.
- Optimization of the MF recovery by limiting the number of MF cells available during the nighttime low-flow period. The cells are designed to operate across a range of flow rates based on plant demand. However, when a large number of cells are run at lower flow rates, the recovery is reduced. Decreasing the number of available cells increases the flow rate per cell, which also increases the process recovery. A higher process recovery allows for greater production. This can increase overall production by 5–10%.
- Optimizing plant process control strategies to allow taking the maximum flow from OCSD throughout the diurnal flow swings involved complex programming to prevent the plant from inadvertently shutting down.

VISIONARY PARTNERSHIP RESULTS IN THE ADVANCEMENT OF WATER REUSE

More than a decade in development, the elected leaders of OCWD and OCSD were visionary in their pursuit of the GWR System and their understanding of water reuse and its potential as a new water resource. The partnership between the two agencies is groundbreaking and has already significantly assisted in the advancement of water reuse throughout the world.

The GWR System is approaching completion of one year of successful operations. Although there have been minor challenges along the way, water quality has consistently been excellent, meeting and exceeding all regulatory requirements. The next few months of operation will be dedicated to increasing production from the plant by treating more OCSD secondary effluent made available by the construction of the Steve Anderson Lift Station.

—Michael R. Markus is the general manager of the Orange County Water District. He has more than 27 years of experience in the industry with expertise in construction management, planning, and water resource management. He can be contacted at mmarkus@ocwd.com.

TABLE 1 Water quality results

Constituent	Microfiltration Feed—*mg/L*			Reverse Osmosis Product—*mg/L*			Finished Product Water—*mg/L*		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Total suspended solids	2.3	5.8	22.0						
Total dissolved solids	834	925	974	4.0	16.6	25.5	14.0	33.5	52.0
Total organic carbon	2.7	14.0	15.2	0.005	0.179	0.480	0.060	0.198	0.360
Turbidity—*ntu*	1.6	2.6	6.7						
pH	7.6	7.8	8.0	5.9	6.7	7.5	6.9	8.2	9.3
Total alkalinity	298	312	335	14.0	16.5	21.4	25.4	31.4	37.0
Total hardness	262	293	313	< 0.10	< 0.10	< 0.10	16.0	21.6	27.2
Total nitrogen—*as N*	20.9	29.8	33.0				0.90	1.7	2.5
Ammonia—*as N*	19.6	27.6	30.8	1.0	1.4	1.8	1.0	1.4	1.8
NDMA—*ug/L*	19.6	27.6	30.8	11	11	11	0.20	1.6	14.0
1,4-Dioxane—*ug/L*	< 0.10	1.8	3.3				< 0.10	< 0.10	< 0.10