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The City of Wichita Falls, Texas, made international news in 2014 when its water system became a water reuse pioneer. In response to a historic drought, the city simultaneously planned and implemented direct potable reuse (DPR) and indirect potable reuse (IPR) systems to see it through the drought and respond to future water shortages. Now, the city is a role model for water utilities around the world.

BY DANIEL K. NIX, MARK SOUTHARD, HAROLD BURRIS, HUNTER ADAMS, AND RUSSELL SCHREIBER

TRACKING WICHITA FALLS' PATH FROM DPR TO IPR

"Often when you think you're at the end of something, you're at the beginning of something else."

—Fred Rogers

Direct potable reuse (DPR), unlike the more common indirect potable reuse (IPR), lacks an environmental buffer, such as a reservoir, and sends highly treated wastewater effluent directly from a wastewater treatment facility to a drinking water treatment facility. Because of this unconventional route, the City of Wichita Falls, Texas, is one of only five cities in the United States and one city elsewhere in the world approved for DPR:

- Goreangab Water Reclamation Plant, Windhoek, Namibia—5.5 mgd (1969)
- Brownwood, Texas—approved but not constructed
- Cloudcroft, N.M.—approved but not constructed
- Colorado River Municipal Water District, Big Spring, Texas—approved for 2 mgd
- El Paso, Texas—approved and currently under construction
- Wichita Falls, Texas—approved for 10 mgd

About 15–20 public water systems operate IPR systems, but only the City of Wichita Falls has experience operating both. Driven to develop its DPR system in response to a catastrophic new drought of record in 2014 (the last one occurring in the 1950s), the city ensured its long-term water supply by simultaneously planning an IPR system to bolster long-term drought tolerance.

PHOTOGRAPH: CITY OF WICHITA FALLS

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The City of Wichita Falls' MF/RO plant was key to its DPR operation's success. After passing through primary and secondary treatment and clarifiers, the city's high-quality wastewater effluent passed through MF for protozoan removal and RO for nitrate-N and virus removal.

DRIVEN BY NECESSITY

The North Texas region regularly experiences cyclical periods of drought. Before 2008, Wichita Falls' water resources consisted of two surface water reservoirs: Lake Arrowhead and Lake Kickapoo. During the 1995–2000 drought, the city decided to press into service a brackish water reservoir, Lake Kemp, through the use of microfiltration (MF) and reverse osmosis (RO) membranes. That brought the number of available water reservoirs to three.

In 2011 and 2012, Wichita Falls had an abnormally high number of days of high temperatures and a significant reduction in rainfall. The region typically sees only 28 days of temperatures above 100°F. In 2011, Wichita Falls had 100 days over 100°F, earning it the Weather Channel's title of "#1 Worst Summer Anywhere in 2011." In 2012, 50 days reached above 100°F. Rainfall for the region is normally 29 inches annually. However, 2011 produced only 13.5 inches of precipitation; 2012, only 19.75 inches. Both of these conditions, combined with high winds, caused lake levels to decline from a combined 83% to 55% in 2011 and from 55% to 41% in 2012. Although the entire state of Texas had exceptional drought conditions in 2011, most of the state had recovered by 2014—except for the Wichita Falls region.

DETOUR TO DPR

Water supply projections made in early 2012, using 2011 weather data, indicated that Wichita Falls could be out of water by the summer of 2013, so the city approached the Texas Commission on Environmental Quality (TCEQ) about implementing a DPR project. Because TCEQ was more comfortable with the city pursuing an IPR project, it didn't approve the move to DPR, and IPR planning started in earnest. The projected completion time was five years (2017). As the city collected more data on weather patterns through 2012, it was projected that, although Wichita Falls had gained some ground, it would still be out of water by the summer of 2015. This was going to fall two years short of the IPR being online and producing drinking water. City officials approached the TCEQ again and made another case for an "emergency/temporary" DPR project.

A concept paper was put together outlining the city's analysis of its wastewater effluent, comparing it with US Environmental Protection Agency (USEPA) primary and secondary drinking water regulations. The paper detailed what drinking water treatment process would be used to remove contaminants in the wastewater effluent that didn't meet maximum contaminant levels (MCLs). Extensive records on the quality of the wastewater effluent demonstrated it was already meeting the primary drinking water regulations, with the exceptions of nitrate-N, trihalomethanes (THMs), and microbials. THM formation was reduced at the wastewater plant by adding liquid ammonium sulfate (LAS) at the chlorine contact basin to react with chlorine and produce chloramines, and nitrate-N and microbials were reduced/removed using the MF/RO system that had been built in 2008 to treat brackish water from Lake Kemp.

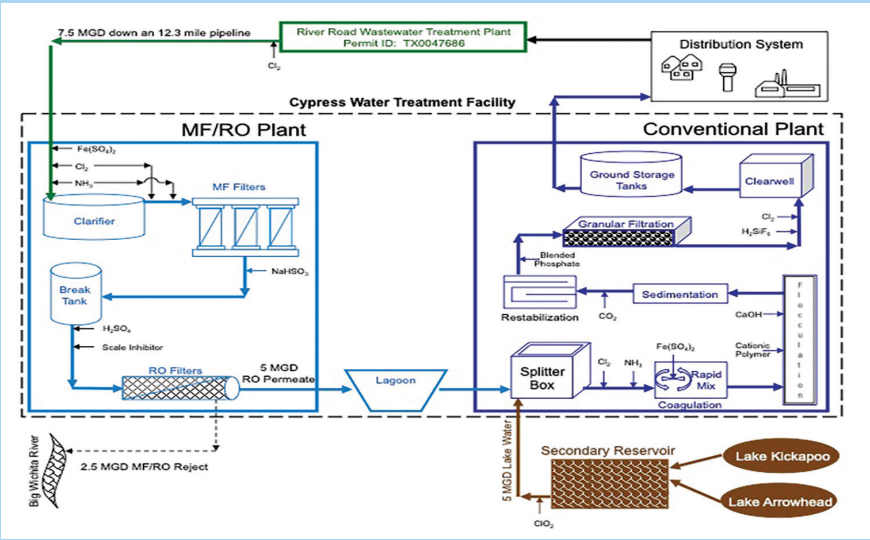
In January 2013, TCEQ allowed the city to begin work on an emergency DPR facility. Throughout 2013, the city's staff worked closely with TCEQ officials to develop the rules and regulations that would be used for the DPR operations, a monitoring plan, a set of alarms and shutdown triggers, and criteria to perform a full-scale verification of the complete DPR facility. Given that there were no existing standards or regulations for the city or TCEQ to use, this proved to be a critical 12 months of the project, as both parties had different interpretations and opinions. In the end, it was a valuable process. As a result, the city and TCEQ were better prepared for DPR operations. The emergency DPR facility was then operated from July 2014 to July 2015, when the drought was ended by a historic flood.

TREATMENT PROCESSES

A 45-day full-scale verification (FSV) test, the first of two, was conducted in the spring of 2014. The entire DPR plant was operated and produced water that was

Figure 1. Full-Scale Operation DPR Schematic

Full-scale operations, discharging DPR water to the citizens of Wichita Falls, began July 9, 2014.



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The city's water quality milestones were set and met, and its DPR facility operated from July 9, 2014, to July 21, 2015, with no failures or plant shutdowns.

discharged to the Big Wichita River. During this time, the Cypress Water Treatment Plant, where the MF/RO and conventional treatment facilities were located, had to be shut off from providing drinking water to the public during the FSV test. Therefore, all drinking water had to be supplied by the Jasper Water Treatment Plant on the opposite side of the city.

TCEQ required the DPR facility to be monitored at 42 locations during FSV-1 and 19 locations during FSV-2. After these two rounds of FSV testing, TCEQ was satisfied that the DPR treatment processes were going to perform in the planned manner and that regulated contaminants were reduced significantly below primary drinking water MCLs. The city was approved for full-scale operation (FSO) of the DPR facility and to distribute the water for public use. The city began discharging DPR water to the citizens of Wichita Falls on July 9, 2014 (Figure 1).

After primary treatment through primary clarifiers and aeration basins, and subsequent secondary treatment through secondary clarifiers, the high-quality wastewater effluent was dosed with LAS to react with the chlorine at the chlorine contact basin to produce a monochloramine residual. This effectively brought finished wastewater effluent total trihalomethane (TTHM) concentrations down from 106 to 7.3 µg/L. From the chlorine contact basin, 7.5 mgd of wastewater effluent was intercepted and pumped in an aboveground 32-inch high-density polyethylene (HDPE) pipeline 12.3 miles to the existing MF/RO plant at the Cypress Water Treatment Plant. This MF/RO plant was key to the operation's success, as it provided protozoan removal with MF and nitrate-N and virus removal with RO. After six months of operation, TCEQ also required the city to install an ultraviolet (UV) light system post-RO because it felt that if the DPR was needed longer than six months during the drought, it was more of a permanent facility. TCEQ also wanted the benefit of additional log removal for protozoan pathogens. The 7.5 mgd wastewater effluent yielded 5 mgd MF/RO permeate stored in a holding lagoon to better control its blending with raw water from the city's other two dwindling lake supplies at a 50% ratio. The blended water was then moved into a conventional treatment plant and treated again by conventional clarification, filtration, and disinfection. Once the water had gone through all of these processes, it was stored in a ground storage tank that provided a 24-hour detention time, which allowed time for the city to complete laboratory analyses to certify that the water was safe for consumption before it was discharged to the public.

The city's water and wastewater operators were asked to perform treatment functions that ran counter to their previous training, such as asking wastewater operators to leave in or add ammonia to the wastewater effluent to produce chloramines and then leave the disinfectant in the water before discharging it. Cross-training was heavily promoted to establish the new reality that the wastewater treatment and water purification divisions were now one unit and not operating separately. Water and wastewater operators were cross-trained and given plant tours of each other's facilities to better understand the process as a whole. During FSO, operational calls were initiated on odd hours by the water division and even hours by the wastewater division to check operation status and flows and to discuss potential alarms or shutdown triggers. This approach kept both sides in constant communication and achieved consistent plant operations.

DPR GOALS AND RESULTS

The DPR project's overarching goal was to supply 50% of the city's needed water resources while meeting the following metrics:

- Meet and exceed all national primary drinking water regulations.
- Meet and exceed all national secondary drinking water regulations.
- Achieve zero *Escherichia coli* (*E. coli*) detections post-MF/RO.
- Achieve log removal: 9 log for viruses, 6 log for *Giardia*, and 5.5 log for *Cryptosporidium*.

By reaching these milestones, the operators protected public health and extended the city's water supply. To demonstrate the milestones were met, 1.8 million discrete data points were collected on water quality during the 377 days of continuous FSO.

The city's water quality milestones were set and met, and its DPR facility operated from July 9, 2014, to July 21, 2015, with no failures or plant shutdowns. More than 2 billion gallons of wastewater effluent were reclaimed as drinking water in that 12-month period. No virus was ever detected in the water system, and *E. coli, Giardia,* and *Cryptosporidium* were never detected past the microfilters. Nitrate-N was reduced from an average 20 mg/L in the wastewater effluent to an average of 0.66 mg/L in the tap water. TTHMs averaged 14.2 µg/L at the distribution system point of entry, with a maximum of 16.7 µg/L.

The facility achieved 100 percent compliance with all primary and secondary drinking water regulations. It also achieved 100 percent compliance with microbial log removals established by TCEQ. Along with the Colorado River Municipal Water District's successful DPR project in Big Spring, the City of Wichita Falls had demonstrated that a larger DPR facility is a viable and reliable water source and that the public would accept DPR as a water supply, given early and intense public relations campaigns about the need and safety of the projects.

Most important, public health was protected. Years before the DPR facility, city staff had established a Water Quality Task Force as a collaborative, proactive partnership between the utility and public health sector. The task force was composed of staff from Water Purification, Wastewater Treatment, Public Works, and

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the Wichita Falls-Wichita County Public Health District. During FSO, the task force met monthly to review operational data and get updates from the health district's epidemiologist on any anomalies with health concerns. This ensured the water system stayed in communication with local health care professionals during the project.

TRANSITIONING TO IPR

Record rainfall in May 2015 returned the region's reservoirs to 100 percent within three weeks. The City of Wichita Falls elected to decommission the DPR facility in July 2015 to begin the transition to IPR. Work on the IPR system had never stopped and continued while the DPR facility was in operation.

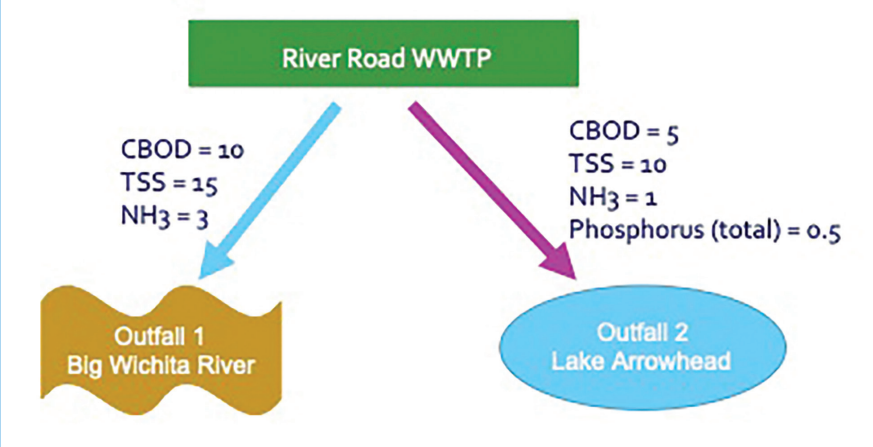
The DPR pipeline was purchased with plans to eventually repurpose it for the IPR system. In late 2015, the 12.3-mile DPR pipeline was disassembled and repositioned from Lake Arrowhead to the wastewater treatment plant for IPR operations. Then, 5.5 miles of additional ductile-iron pipe were added from the wastewater treatment plant to meet the repositioned pipeline. The outfall was run 3,000 feet into the lake, and construction was completed in July 2017.

Improvements and additions to the wastewater plant to meet the new stricter discharge permit limits were started in March 2016 and completed in December 2017. Baseline testing on Lake Arrowhead began in January 2017, and full-scale lab testing of the new wastewater effluent quality began in December 2017.

The new discharge permit limits required the city to further reduce carbonaceous biochemical oxygen demand (CBOD), total suspended solids (TSS), and ammonia-N, with the addition of a phosphorus limit in the effluent before it could be discharged into Lake Arrowhead (Figure 2). Lime was added in primary clarifiers for phosphorus removal and to boost alkalinity. Ferric chloride was also added for phosphorus removal in primary clarifiers and secondary clarifier influent. Other plant improvements included a disc filter for phosphorus polishing (and a protozoan barrier) as well as liquid oxygen to boost effluent dissolved oxygen levels when needed (Figure 3).

Figure 2. New Discharge Limits Compared With Original Discharge Point

Improvements and additions to the wastewater plant to meet the new stricter discharge permit limits were started in March 2016 and completed in December 2017.



The River Road Wastewater Treatment Plant was renamed the Wichita Falls Resource Recovery Facility to highlight the importance of its new permanent reuse work and the fact that the facility had also been reusing biosolids produced in digesters for decades. A new supervisory control and data acquisition (SCADA) system was installed, and the facility went paperless for routine daily data collection, using tablet computers for operators.

IPR OPERATION

Full-scale IPR operations began in January 2018, reclaiming about 8 mgd to the watershed and putting the water back into Lake Arrowhead. Previously, the water would have been discharged into the Big Wichita River, ending up in Lake Texoma, which supplies the Dallas/Fort Worth area. Now, through the IPR and amending adjudicated rights to encompass the additional water, the City of Wichita Falls can hold on to that resource to help improve the local water supply's reliability.

Although analytical testing of the wastewater effluent continued as it had in the DPR system, Lake Arrowhead monitoring was greatly increased. Three points on the lake are monitored monthly: the wastewater effluent outfall (O), upstream (U) of the outfall, and downstream (D) of the outfall near the intake. Profiling is conducted every foot of depth with a multiparameter sonde that provides temperature, pH, dissolved oxygen (DO), oxygen reduction potential, chlorophyll a, and phycocyanin pigments as well as samples for cyanobacteria and algae monitoring. Samples are also collected at every 3 feet of depth with a Van Dorn sampler, allowing lab technicians to monitor metals and nutrients like nitrogen species and phosphorus.

The four main tributaries are monitored monthly and after significant rain events to get an idea of how dairy farm and agricultural runoff affect water quality. This helps technicians determine if

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The City of Wichita Falls has been recognized with several reuse awards over the past five years, representing a tremendous amount of hard work and long days, nights, and weekends.

anomalies in water quality are due to the IPR outfall or to runoff. The wastewater effluent has shown a more consistent chemical profile than the tributaries. Altogether, this creates a more complete water quality picture and establishes a continuous historical baseline.

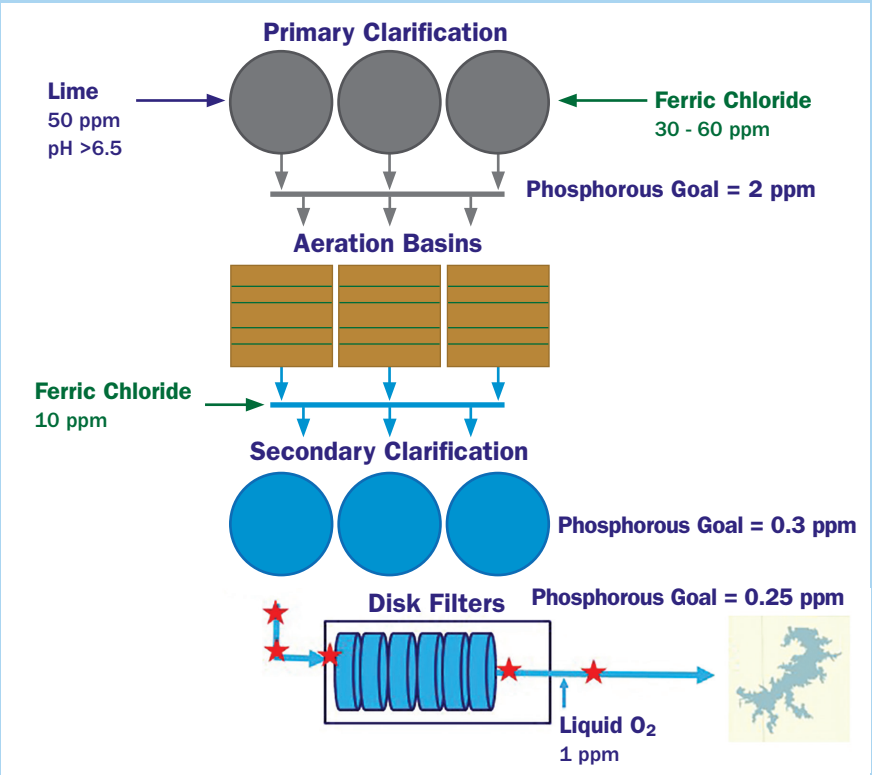
POTABLE REUSE STANDARDS DEVELOPMENT

Immediately following the success of the two operational DPR plants in Texas, the AWWA Standards Committee convened a panel of experts from across the nation to create the first-ever DPR standard, G485-18. The standard was released in 2018, and soon the same panel of experts began working on an IPR standard. The two standards are being combined into a single standard to help guide water providers, engineers, and regulatory agencies in potable reuse development throughout the United States.

In 2017, USEPA amended its 2012 Guidelines for Water Reuse (EPA/600/R-12/618) with a Potable Reuse Compendium (EPA/810/R-17/002), greatly enhancing the available information on potable reuse and signaling recognition of potable reuse as a growing concept that needed the agency's input. To help address future water resource challenges, the agency followed up that commitment with its most recent National Water Reuse Action Plan, which was published in February 2020 (see "USEPA Develops National Water Reuse Action Plan," *Opflow*, July 2020, https://doi.org/10.1002/opfl.1393).

Figure 3. Plant Improvements to Wichita Falls Resource Recovery Facility for IPR

Full-scale IPR operations began in January 2018, reclaiming about 8 mgd to the watershed and putting the water back into Lake Arrowhead.



The plan was deliberately set up as a national framework to protect the public health, be usable yet flexible, and provide sustainable solutions. Only 6.6% of national municipal wastewater is being reused, leaving a massive amount of water that can be reclaimed. Ultimately, this plan targets a largely untapped resource that can enhance US water resilience, security, and sustainability.

NEXT STEPS

So what's next for Wichita Falls? City staff recognized early the gaps that exist in standards, regulations, training, and other elements that relate to potable water reuse. Therefore, city staff are working closely with AWWA's Texas Section to develop a self-paced correspondence course track in advanced treatment and plan to develop a reuse certification (along with Water Environment Association of Texas and WateReuse Texas) that will complement state-issued water/wastewater operator licenses. For more information, visit the section's website (www.tawwa.org) and click on the Advanced Treatment Courses under the Training & Events tab. Also, city staff have contributed to the USEPA's 2017 Potable Reuse Compendium; the AWWA G485 DPR standard, which describes the critical requirements for the effective operation and management of a DPR system; and many Water Research Foundation projects.

The City of Wichita Falls has been recognized with several reuse awards over the past five years, representing a tremendous amount of hard work and long days, nights, and weekends. But the hundreds of men and women who have been involved in this process realize the importance of the work that has been done and that they are lucky to have been able to serve the public in this capacity. Some water professionals say they didn't choose water, water chose them. But for the city's DPR and IPR veterans, it's definitely now true to say that water reuse chose them.

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