

Aquifer Storage and Recovery: Exploring a Real Solution for Reclaimed Water Supply Needs

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Polk County Utilities (PCU) operates the Northwest Regional Wastewater Treatment Facility (Facility), which serves wastewater and reclaimed water customers in its northwest region utility service area. During wet weather periods, PCU has to manage the excess reclaimed water resulting from limited public-access reclaimed water demands as its primary effluent disposal option. Wasting water, even reclaimed water, is not a viable option for public utilities with water use permits, and it becomes a challenge with the continuous water and alternative water supply and demand variations, married with a diminishing water supply. Consequently, PCU decided to explore an innovative approach for managing its reclaimed water supply needs using aquifer storage and recovery (ASR).

Large storage reservoirs and tankage provide finite wet weather storage and can be costly to build and maintain. There is, however, a viable alternative in ASR. After experiencing a significant lull as a result of the lowering of allowable concentrations of the release of arsenic from 50 µg/L to 10 µg/L, ASR is rebounding as a result of revised implementation of existing regulations, allowing by permit specific exceedances that are determined locally. However, institutional controls may then become a significant component in the operation of an ASR system.

Actively ahead of the curve, PCU is electing to construct an exploratory ASR well to

store reclaimed water in a deep, brackish storage zone. There are many unique features of this well:

- ◆ Deepest ASR well known to exist in the world (2,944 ft)
- ◆ First ASR well in Florida utilizing the Lower Floridan Aquifer (LFA)
- ◆ First ASR well, with potable or reclaimed water, in Polk County

The depth of freshwater that exists in Polk County required the well to be completed to this great depth to store the highly treated reclaimed water. This article presents the comprehensive issues encountered during the drilling and cycle testing program and presents some of the design features unique to this ASR system, including the ability to recover the stored water to four different points in the wastewater treatment process, depending on the quality of the recovered water and control of Stage 2 disinfection byproducts (DBPs) and dissolved oxygen concentrations in the source water to the ASR well. Applying these principles can allow for a flexible storage and supply system for reclaimed water, which meets the utility's customer needs in a timely manner.

Background

The Facility is a 3-mil-gal-per-day (mgd), three-month rolling average flow (3MRAF) ox-

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idation-ditch-type domestic wastewater treatment facility. The plant's permitted capacity is currently limited to 1.515 mgd 3MRAF based on the reuse system's effluent disposal capacity. Working with the Florida Department of Environmental Protection (FDEP), PCU anticipates increasing the current limit of 1.515 mgd to at least 2.515 mgd, with the addition of the ASR well to manage wet weather flows. The facility was designed, and is operating, utilizing public-access reuse as its primary effluent disposal option. Polk County currently provides reclaimed water for nonpotable use (primarily restricted-access spray irrigation and public-access golf course irrigation) and is planning to expand its existing reuse system to provide reclaimed water to an increasing number of customers.

Polk County entered into a cooperative funding agreement with Southwest Florida
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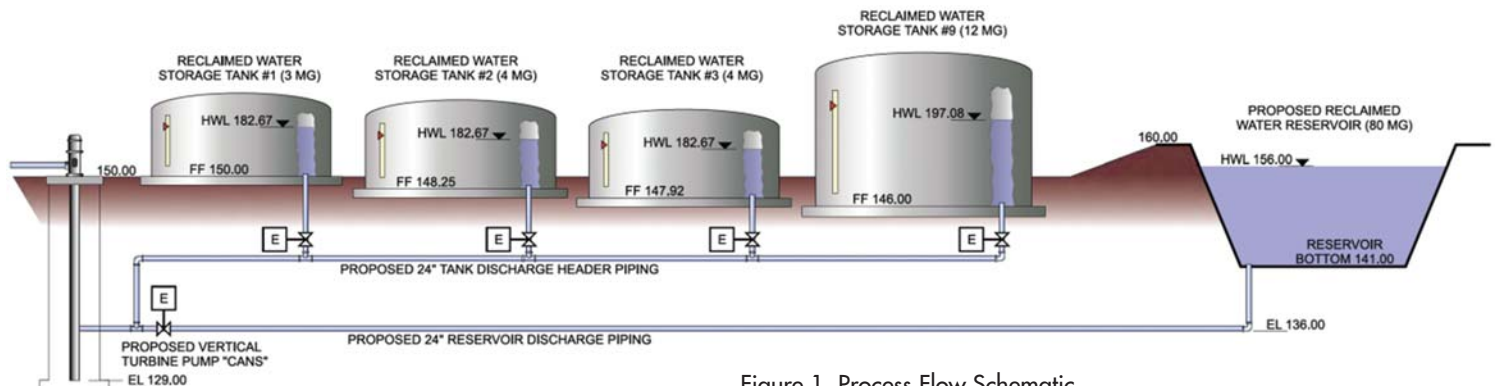


Figure 1. Process Flow Schematic

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Water Management District (SWFWMD) in 2009 for an 80-mil-gal (MG) reclaimed water earthen storage reservoir (storage pond) to supplement its reclaimed water system during the dry season. The County already had 23 MG in aboveground reservoirs (storage tanks) at the Facility. Figure 1 presents the original concept for the 80-MG storage pond. The County purchased a 50-acre parcel located adjacent to the south property line of the Facility to house the 80-MG reservoir in 2010. At the same time, a neighboring utility was in a law-

suit with an engineering firm for an above-ground reservoir with an earthen berm breach. Coincidentally, the design of Polk County's reservoir required a 35(+)-ft embankment to accommodate the 80-MG storage, which caused the County concern, considering the current lawsuit; consequently, it began to consider other options, and its cooperative funding agreement was still for an 80-MG reservoir. Figure 2 presents the conceptual plan view of the 80-MG reservoir on the 50-acre parcel.

In order to avoid risky construction of a large earthen reservoir, the County contem-

plated an ASR well, but there were many challenges ahead, with the first considerations being feasibility and cost. The County contracted with Reiss Engineering and ASRus to complete a desktop evaluation to determine if an ASR well was a feasible alternative at this site for extended wet weather periods when reuse demand is low. The study also compared the costs of the ASR system to the proposed earthen storage reservoir, which at the time was cofunded by SWFWMD. An ASR well was not part of the cofunding agreement with SWFWMD.

The feasibility evaluation served several purposes for these two options, including determining technical feasibility, cost-effectiveness, and presenting the ASR as a viable alternative to an earthen reservoir for storage. It was necessary to determine if the local geologic and hydrogeologic conditions would provide cost-effective storage of surplus reuse water and subsequent recovery of reuse water during high demand periods. The evaluation identified that, for permitting through the FDEP underground injection control (UIC), the targeted water quality in the receiving zone of the ASR well would be greater than 3,000 mg/L total dissolved solids (TDS), with the possibility of a preferred storage zone being greater than 10,000 mg/L, because then the reclaimed water would not need to be treated to drinking water standards (DWS). One of PCU's major advantages was that there were no other competing groundwater users in the LFA within 1 mi of the plant site.

A conceptual-level cost comparison determined that the ASR system would be about \$1 million less expensive than an earthen reservoir. The primary reason for the cost difference was the need for treatment of water stored in an open reservoir for algae and suspended solids removal prior to discharge into the reclaimed water system. Other major considerations were that the reservoir has a finite storage volume and more operational and maintenance requirements than the ASR system. Table 1 outlines several considerations for comparison between an earthen reservoir and an ASR well.

Phasing, Funding, and Schedule

In 2012, SWFWMD approved the change to the project plan from the 80-MG groundwater storage and recovery (GSR) to a 1 mgd ASR project. The SWFWMD agreement was fully executed in May 2013. During this time, the scope definition was being shaped, together with SWFWMD. As a result of the inherent risk of drilling a reclaimed water ASR well in an area



Figure 2. Reclaimed Water System Modification - Site Layout and Proposed Reservoir

Table 1. Considerations: Reservoir versus Aquifer Storage Recovery

Reservoir	Aquifer Storage Recovery
Requires prescreening	Unknown water quality until pilot hole drilled
Requires flushing	Requires flushing
Finite storage volume (80 MG)	Nearly unlimited storage volume (>1 bil gal [BG])
Control/treat biological growth	Arsenic release potential
35(+)-ft high embankment	Lower Floridan Aquifer about 3,000 ft below land surface (bls)
Slight wastewater treatment plant process modifications	Achieve drinking water standards if aquifer water quality less than 10,000 mg/L TDS and greater than 3,000 mg/L TDS (See Note 1)
Potential costs to retreat water	Chloramination potential to meet DBPs
Significant use of land	Nominal use of land
\$6.3 million conceptual cost	\$5.3 million conceptual cost
FDEP minor modification	FDEP minor modification
Immediate FDEP operation permit	Multiyear cycle testing prior to FDEP operation permit
FDEP domestic wastewater permit	FDEP underground injection control (UIC) exploratory/construction and FDEP domestic wastewater permits
Higher operation and maintenance (O&M) requirements	Minor operation and maintenance (O&M) requirements
Rapid filling and withdrawal	Recharge/recovery rates limited from 1 to 2 mgd

Note 1. The goal was to find TDS exceeding 3,000 mg/L and, if possible, a zone containing 10,000 mg/L TDS groundwater.

and in a storage zone that has no history of previous installation, SWFWMD and Polk County agreed to install the system in two phases: the injection well pilot hole (ASR-1) as Phase I; and completion of the ASR well, the two monitoring wells, the cycle testing facilities, and surface facilities improvements as Phase II.

The cooperative funding agreement was written to enforce phasing of the contract, and it provided measured successful milestones needing to occur prior to continuing with the second phase of the contract. Another consideration was timing and a mechanism to reach the next wet season, in order to maintain the schedule commitments with SWFWMD and avoid missing one or two wet weather cycles. Subsequently, PCU decided to divide the project in three parts, as follows:

- **Drilling (Design-Bid-Build)** - Includes the drilling of three wells: one injection well (ASR-1) with a total depth of 2,944 ft below land surface (bls) and two monitoring wells; the shallow monitor well (SMW-1) is 1,130 ft bls; and the storage zone monitor well (SZMW-1) is 2,100 ft bls. Figures 3 and 4 depict the record drawing of the ASR and storage zone wells and the location of the wells on the Facility site, respectively.
- **Cycle Testing Facilities (Design-Build)** - Connects the new ASR well to the existing covered-ground storage reservoirs (23 MG) at the Facility for the cycle testing process of injecting and recovering reclaimed water. This phase also includes connection of the ASR and monitoring wells to the supervisory control and data acquisition (SCADA) system of the plant.
- **Surface Facilities (Design-Bid-Build)** - To complete the ASR system, the existing high-service pump station for the reclaimed water distribution system will be replaced, which includes additional pipe connections between the 2-MG GSRs, a new mechanical building, and SCADA connection with the cycle testing component for the final operation of the Facility.

The drilling of the ASR well began in November 2012 and was completed in May 2014, including the two monitoring wells. The well was drilled with much anticipation, but with only minor complications, including considerable dredging during drilling of the well and an inconclusive water quality test.

In May 2014, PCU initiated construction of the second part, the ASR cycle testing facilities, which required a design and contracting strategy to meet an aggressive schedule resulting from the imminent wet weather season. The cycle testing facilities provided for water

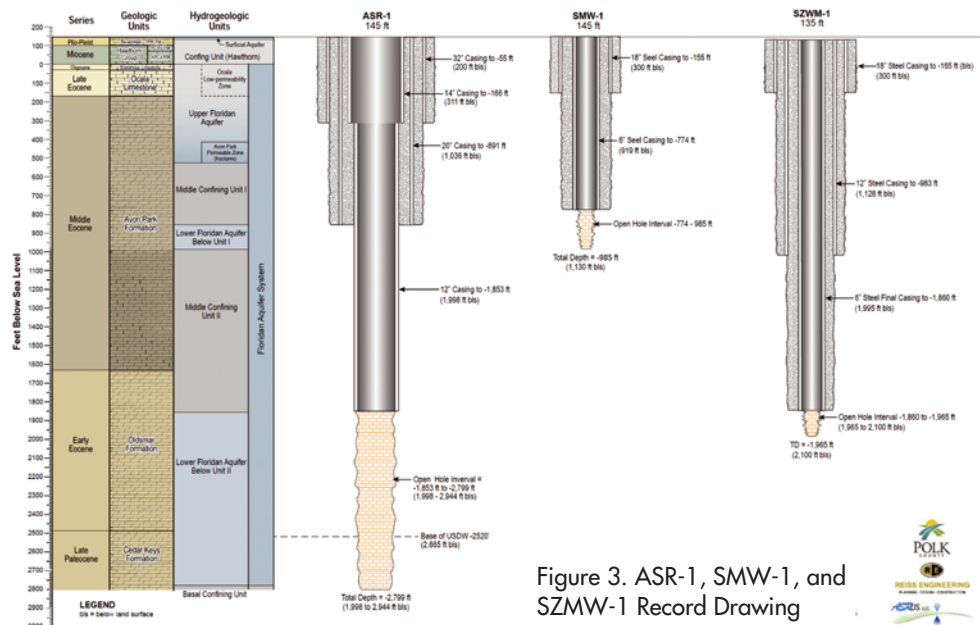


Figure 3. ASR-1, SMW-1, and SZMW-1 Record Drawing



Figure 4. Overall Site Plan

from the chlorine contact effluent chamber wet well to be transferred to the ASR well for recharge via the 23-MG GSRs, and recover water from the ASR well through a vertical turbine well pump to the chlorine contact effluent chamber or the plant's reject tank. The first flush from the recovered water is sent directly to the reject tanks to confirm that it meets DWS; then, it is diverted to the chlorine contact chamber and the water is blended with reclaimed water generated from the treatment plant. The first round of cycle testing was successfully completed by PCU, and it began the second round of cycle testing in August 2015.

Currently, the surface facilities are under construction and they will improve the performance of the reclaimed water system and allow additional treatment of the reclaimed water from the ASR, if required to meet public-access reuse standards. Included in this part of the project is a new reclaimed water high-service pump station (HSPS) and piping to transfer recovered water to the chlorine contact influent chamber and to the head of the filters, if needed for added chlorine contact time or filtration to reduce total suspended solids. This is the last component of the ASR system for

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final operation. Construction of the HSPS is anticipated to be completed by July 2016.

The overlapping in dates reflects the best effort to keep timeline commitments with SWFWMD, while working out the sequence, logistics, and scope details of PCU's first ASR system. This is the primary reason for the three distinct phases for the project.

Building the Aquifer Storage and Recovery Well

Very little was known of the geology and well production of the LFA in northwest Polk County. The initial step toward completing the reclaimed water ASR well was to install a pilot well in order to determine geologic conditions and the optimum casing setting depth, and most importantly, understand the existing water quality in the LFA. As with all reclaimed water ASR wells, there is the challenge of finding the perfect balance of water quality that does not require excessive treatment prior to storing the reclaimed water and that will not require extensive treatment after recovery and distribution to reclaimed water customers. The goal was to find TDS exceeding 3,000 mg/L and, if possible, a zone containing 10,000 mg/L TDS groundwater with sufficient permeability to store 1 to 2 mgd of reclaimed water. Initial water quality tests suggested a water quality from 2,500 mg/L to 3,300 mg/L TDS at 1,500 ft to 2,300 ft bls, respectively. However, this included a large inflow of freshwater from the Upper Floridan Aquifer (UFA), which artificially "freshened" the water and was later cut off with the installation of the final casing in the ASR well. At this stage, therefore, the inferred water quality was greater than 3,000 mg/L TDS. A significant volume of water, which had cascaded to the lower depths, was calculated to determine approximate TDS concentrations at the receiving elevations. Fortunately, SWFWMD (providing the 50 percent funding source) and FDEP (permitting agency) agreed with the methodology and allowed the continuation of the project to the next phase, which is completion of the ASR well and drilling and installation of the shallow and storage zone monitoring wells. The preliminary testing, after completing the drilling and wellheads, indicated that an injection rate of 1.5 mgd was feasible, although PCU currently only has an estimated 0.5 mgd available for recharge.

Almost immediately following startup of the cycle testing activities, scaling (chemical precipitation) occurred in the ASR well, which reduced the flow rate to between 200 and 300 gal per minute (gpm). Polk County initially attempted to rehabilitate the ASR well using carbon dioxide (CO₂) injection to restore previous recharge capacity in the well. This ended up being relatively high-cost and high-maintenance, and PCU elected to acidize the well. A unique approach to acidizing the well using 500 gal of 32 percent hydrochloric acid (HCL), which was diluted to 8 percent HCL before emplacement, resulted in increasing the flow to

the well to over 1 mgd, while wellhead pressure was reduced from approximately 55 pounds per sq in. (psi) at approximately 200 gpm to 0 psi at 1 mgd. The increase in specific injectivity to the well was an order of magnitude, from approximately 2 gpm/ft to over 20 gpm/ft, with no noticeable reduction in specific capacity during the final two months of recharge activities. The cost to acidize the well was approximately \$10,000, which was considered an excellent investment in the ASR well.

Meeting Drinking Water Standards

The preliminary results from the effluent characterization indicated that the total trihalomethanes (TTHMs) and haloacetic acids (HAA5) were not currently meeting the primary DWS of 80 µg/L and 60 µg/L, respectively, which would be required prior to going into the ASR well if the background ASR storage zone TDS was determined to be less than 10,000 mg/L. After extensive technical and regulatory review, PCU decided to utilize ammonia as the disinfectant by modifying the free chlorine disinfection system to a combination of free chlorine followed by chloramination to reduce the TTHM and HAA5 concentrations. This treatment modification was implemented for less than \$50,000 without significant instrumentation and control modifications. The FDEP regulates primary DWS on a single-sample exceedance basis; therefore, it was paramount that these standards are reliably met in the reclaimed water prior to initiating the cycle testing activities.

The Facility operations staff was successful in switching from free chlorine to chloramine disinfection in a relatively short period of time, and the result of this process change has been positive; fewer chemicals are used at the site, with approximately one-half of the amount of chlorine previously utilized. There is also expected to be less water rejected at the site due to low chlorine residual, as the chloramine disinfection process, once in place, appears to offer a more stable residual than the previous free chlorine disinfection.

Summary

While the ASR system is under a fairly stringent cycle testing program, PCU will attempt to continue cycle testing, recharging during wet weather periods and recovering during drier periods, to get the most beneficial use from the ASR well. Once sufficient data have been collected during the cycle testing, a Class V operation permit will be requested from FDEP. The goal is to have the ASR system fully permitted by 2017. ◊