THE ROLE OF AQUIFER STORAGE RECOVERY IN OPTIMIZING A PUBLIC ACCESS REUSE SYSTEM IN ST. PETERSBURG, FLORIDA

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Abstract

The City of St. Petersburg has successfully operated a public access reuse system since 1976. Over the past 28 years, the reuse system has grown to serve over 10,300 total customers in 2002, including more than 9,500 residential customers. Potable water use in the City has declined from approximately 41 million gallons per day (mgd) in the mid-1980s to less than 32 mgd in 2002. Of the approximately 40 mgd annual average of reclaimed water produced at the City’s four Water Reclamation Facilities (WRFs), typically 50 percent of the water is reused for urban land irrigation and other beneficial water resource alternatives. The City treats the water to secondary treatment standards. This treatment is followed by filtration and disinfection to provide a safe product for City customers. Nutrient removal is not part of the treatment process, because this costly added treatment would offer no environmental benefit. In fact, nutrient removal would actually devalue the reclaimed water by decreasing its “fertigation” potential. “Fertigation” refers to the beneficial fertilizing effects of slightly elevated nutrient levels in reclaimed water used for lawn and landscape irrigation.

Considerable variation exists, however, in seasonal demand for reclaimed water. During the rainy season (mid-June through mid-September), an average of 25 to 30 mgd is “wasted” because of lower demand for irrigation water. Conversely, during the drier spring months (March through May), extended periods occur when insufficient reclaimed water is available to meet existing customer demands. Other property owners are anxious to connect to the reuse system, but additional connections are on hold because of the lack of sufficient reclaimed water supply during these dry weather periods.

The City has used deep injection wells to discharged excess wet weather reclaimed water flows into a saline aquifer underlying its service area for more than 20 years. Operation of the deep well injection system has dramatically improved the conditions of the surface waters surrounding the City, such as Tampa Bay. The deep injection wells utilized by the City have resulted in considerable localized freshening into a previously saline permeable interval overlying the injection zone. Solute transport modeling strongly suggests that this zone was not previously suitable for storage of excess reclaimed water, with less than 5 percent recovery likely. As a result of the freshening, however, this zone appears to offer the City a viable storage interval to implement Aquifer Storage Recovery (ASR), a technology becoming increasingly popular for seasonal storage of large volumes of excess reclaimed water. The City recently installed its initial ASR well, and operational testing will begin in mid-2004.

This paper discusses the changes that have been observed in the reclaimed water recharged in the long-term operation of the deep injection wells, and presents the results of initial ASR cycle testing activities. A plan is presented that demonstrates how the City can expand its reclaimed water use to 75 percent or more (an additional 10 mgd) through an integrated water resources management strategy that includes ASR and other potential supplemental supplies. This could result in an additional 10 mgd or more of reclaimed water use in the City’s service area, which should further reduce potable water use in the City while decrease the City’s reliance on its deep injection well system over the next 10 to 20 years.
**Introduction**

Proper management of the limited available water resources is of utmost importance to the City of St. Petersburg, Florida (City). Since no potable water supplies are available in southern Pinellas County, the City must import its water from adjacent counties. Therefore, water conservation is a top priority to the City. Potable water use in the City has declined from approximately 41 million gallons per day (mgd) in the mid-1980s to less than 32 mgd in 2002. This is due in part to conservation, but also directly attributed to the City’s reclaimed water reuse system. Figure 1 shows the potable water use and reclaimed water use in the City of St. Petersburg since 1951.

The City is a recognized leader in water reclamation. The importance of the role of reclaimed water in total resource management has been clearly understood by the City for nearly three decades. The City has successfully operated a public access reuse system since 1976. Over the past 28 years, the reuse system has grown to serve 10,300 total customers, including more than 9,500 residential customers. More than 7,300 acres are successfully irrigated year round. Over this period, no negative public health and safety effects have been known or suspected to be linked to the City’s urban reclaimed water system. The City takes great pride in the safe operation and maintenance of its reuse system, and understands that thousands of customers count on this system each day to provide a safe, reliable water supply for irrigation and other non-potable uses. As further efforts continue to identify and implement additional reuse applications, the ratio of reclaimed water use to potable water use will continue to increase. The City has pursued additional reuse customers, but is effectively built-out because of seasonal storage constraints and until additional dry season reuse supply sources can be developed.

![Figure 1 – City of St. Petersburg Potable Water and Reclaimed Water Use](image)
The City currently has 10 operational deep injection wells among its four Water Reclamation Facilities (WRFs). These wells provide an environmentally safe method of managing wet weather effluent flows. The injection wells, which range from 20 to 30 inches in diameter, discharge into a fractured dolomite zone between approximately 600 and 1,000 feet below land surface (bls). This zone has native groundwater with Total Dissolved Solids (TDS) concentrations of approximately 35,000 milligrams per liter (mg/L), which is similar to the salinity of seawater. Permitted flows of between 9 and 24 mgd of excess reclaimed water are discharged to each of the injection wells during wet weather periods.

Without the deep injection wells, the City would be forced to discharge excess reclaimed water produced during the rainy season into surrounding surface water bodies, such as Tampa Bay. Tampa Bay and adjacent estuaries have shown significant water quality-related improvement since the City eliminated its surface water discharges in the 1970s and 1980s. Even if advanced wastewater treatment was implemented at the City’s treatment facilities, renewed surface water discharge would significantly increase the nutrient loading to these estuaries. These added nutrients would present a considerable setback to the water quality improvements observed in Tampa Bay and other local estuaries over the past two decades. Other utilities in the Tampa Bay area have implemented advanced wastewater treatment and continue to discharge to surface waters. In fact, the City of St. Petersburg is the only utility on the shores of Tampa Bay that has completely eliminated surface water discharges.

The City treats its wastewater to secondary treatment standards through the activated sludge process. This treatment is followed by sand or dual-media filtration and high level disinfection to provide a safe product for reuse customers. The City requires that the reclaimed water contain a chlorine residual of 4 mg/L or greater before the reclaimed water enters the reuse system. Nutrient removal is not part of the treatment process, because this costly additional treatment would offer no environmental benefit. In fact, nutrient removal would actually devalue the reclaimed water by decreasing its “fertigation” potential. “Fertigation” refers to the beneficial fertilizing effects of slightly elevated nutrient levels in reclaimed water used for lawn and landscape irrigation. Aboveground storage is used to offset diurnal and hourly fluctuations in reclaimed water supply and demand. If excess water is available, or if the reclaimed water does not meet the City’s stringent water quality standards, it is discharged to the deep injection wells. Only a very small percentage of the discharge to injection wells results from poor water quality.

Even without nutrient removal, the City’s reclaimed water is performs in an excellent manner and reliably meets or exceeds most primary and secondary drinking water standards (DWSs). Parameters that occasionally exceed the primary maximum contaminant level (MCL) include nitrite, nitrate, and sodium, whereas aluminum, chloride, color, iron, odor, and TDS are the only secondary DWSs exceeded in the reclaimed water. The secondary DWSs are considered aesthetic in nature and are not typically major concerns at the levels at which they are found in the City’s reclaimed water. The City attempts to maintain chloride levels below 350 mg/L, although chloride concentrations of up to 600 mg/L are sent to the reuse system. Nitrite concentrations averaged between 0.2 and 0.7 mg/L in 2002, and were typically well below the MCL of 1 mg/L. Nitrate ranged from 0.5 to 0.7 mg/L in 2002, well below the MCL of 10 mg/L. Most of the nitrogen in the reclaimed water is in the form of ammonia, with a typical concentration range of 10 to 15 mg/L. Total phosphorus in the reclaimed water typically ranges from 1 to 3 mg/L. The elevated phosphorus and nitrogen concentrations in the reclaimed water are beneficial to users of the reclaimed water system, decreasing the amount of fertilizer that reclaimed water customers need to apply themselves. Elevated nitrogen levels are common in groundwater monitoring wells in areas where individuals self-apply fertilizer, but wells monitoring reuse application sites do not typically

1 CH2M HILL, March 2004.
indicate the presence of elevated nitrogen levels in groundwater because the low-level consistent nutrient loading is taken up primarily by turf grass.

**St. Petersburg’s Supplies and Demands**

Figure 2 shows the amount of water reused by the City annually compared to the amount of excess water discharged annually to the injection wells. Of the approximately 40 mgd annual average of reclaimed water produced at the City’s four WRFs, typically 50 percent of the water is reused for urban land irrigation and other beneficial water resource alternatives. Considerable reuse opportunities remain in the City’s service area, but during dry periods essentially all of the reclaimed water is used, and considerably more would be used if a supplemental supply was available. Figure 3 shows the seasonal nature of irrigation demands, although the monthly average over this 11-year period includes wetter years and drought periods. During extended dry periods low pressure is common on the reuse system, due to insufficient supplies, for several months before the summer rains arrive to reduce irrigation demands.

**Figure 2** – City of St. Petersburg Annual Average Daily Flow (1992 through 2002)

**Figure 3** – City of St. Petersburg 1992 – 2002 Monthly Average Daily Flow
Seasonal Storage Opportunities

Seasonal storage of reclaimed water is required if the City is to expand its reuse program to additional users. The City’s service area is densely populated and urbanized, making seasonal storage in aboveground reservoirs less practical than it might be for other communities. Underlying St. Petersburg is brackish groundwater at relatively shallow depths, which allows consideration of seasonal storage in the subsurface. Generally speaking, Florida’s reuse rules (Chapter 62-610, Florida Administrative Code [FAC]²) allow storage of reclaimed water in aquifers containing greater than 1,000 mg/L TDS if the applicant can demonstrate that primary and secondary DWSs are met in the reclaimed water. In aquifers containing greater than 3,000 mg/L TDS, the permittee must only meet primary DWSs. In aquifers containing greater than 10,000 mg/L TDS, only secondary treatment is needed and DWSs need not be met. Other additional requirements must be met if the storage zone contains less than 1,000 mg/L TDS, such as limits on total organic carbon and total organic halogens, rendering these aquifers impractical for reclaimed water storage without considerable additional treatment.

Aquifers overlying the deep injection wells at the City’s WRFs have freshened considerably since injection began. For example, the first permeable unit overlying the City’s Southwest WRF injection zone has freshened from a native TDS concentration of approximately 30,000 mg/L to approximately 5,000 mg/L as a result of the arrival of a mixture of reclaimed water and native groundwater. Solute transport modeling was used to evaluate the potential use of this zone for seasonal storage via Aquifer Storage Recovery (ASR) wells³. The modeling suggested that the freshening in this zone would make recoverability of the reclaimed water much more practical, with initial recovery estimated to be 35 percent in the affected zones (compared to less than 3 percent in the native saltwater aquifer). Based in part on the results of this modeling, the City constructed a test ASR well into this zone, which is used extensively in southwest Florida for storing potable water at inland locations. Permitting was also much less complicated in this zone as native water quality (30,000 mg/L) governed the water quality requirements rather than the fresher water quality currently present. Therefore, the City did not have to commit to meeting DWSs. Compliance with DWSs must be demonstrated within the lowermost permeable unit containing less than 10,000 mg/L, and the City has constructed a monitoring well to make this demonstration.

At the City’s Albert Whitted WRF, the degree of freshening in this same zone has been even more dramatic. The arrival of reclaimed water injected from below has caused this zone to freshen from a pre-injection water quality of approximately 35,000 mg/L TDS to 1,000 mg/L TDS (400 mg/L chloride concentration) in 2002.

Based on the degree of freshening that has occurred at this site, the City constructed a test non-potable supply well into this zone to evaluate the potential to use this zone as a supplemental dry season water supply. This concept, known as REclaimed Water Aquifer Recovery on Demand (REWARD), is similar to the ASR concept, with the deep injection wells providing aquifer recharge and the shallower well serving as a recovery well. The well was constructed to the same stringent standards as ASR wells in anticipation of the possibility that the well might be converted to an ASR well in the future to enhance its performance.

Figure 4 shows a cross-section of the City’s ASR well, REWARD well, and one of its deep injection wells. Native and current water quality in each zone are also shown on the figure.

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² FDEP, August 1999.
³ CH2M HILL, June 1998.
Figure 4 – St. Petersburg Well Cross-Sections and Generalized Water Quality
Initial Testing Results

**REWARD Well**
The REWARD well has undergone 2 years of testing and began its third year of testing in June 2004. The REWARD well was constructed in 2001 and first tested in May/June 2002 with a 14-day recovery test. A total of 15.7 million gallons (MG) of groundwater was recovered from the well at an average rate of 772 gpm (1.11 mgd). Chloride concentration in the REWARD well increased from 1,200 mg/L to 2,400 mg/L during the test. Water was returned to the influent flow to the Albert Whitted WRF to allow blending with the other plant flow, thereby avoiding elevated chloride concentration in the reclaimed water leaving the facility. In July 2003, the test was repeated and a total of 24.7 MG was recovered from the well at an average rate of 780 gpm. Chloride concentration was measured daily from the well, and samples were analyzed for a more detailed set of analyses (chloride, conductivity, TDS, sulfate, TSS, fecal and total coliform, iron, ammonia, nitrate, nitrite, pH, sulfate, and temperature) at the early, middle, and late stages of the test. During the second test, chloride concentration increased from approximately 2,000 mg/L to 4,280 mg/L. This level was still well below the native water quality in this zone (approximately 19,000 mg/L chloride concentration), suggesting that this zone still contained approximately 80 percent reclaimed water at the end of the test that has migrated up from the injection zone underlying this well. The operators at the WRF developed an operating protocol during the second test that allowed effective use of this higher chloride water without violating the City’s self-imposed reuse standard of 600 mg/L chloride concentration. Figure 5 provides TDS concentrations recovered from the REWARD well during the first two annual recovery events.

![Figure 5 – St. Petersburg REWARD Well Recovery Chloride Data](image)

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CH2M HILL, October 2003.
Total and fecal coliform were absent in the three samples collected from this well during the second test. This was not surprising, since the majority of the water arriving in this zone has undergone high level disinfection, and microorganisms introduced into the groundwater are believed to die off fairly rapidly. Extensive microbiological sampling has been conducted in the monitoring wells at this facility and no pathogens or viruses have been detected in previous sampling events. Ammonia concentration decreased from 13.7 mg/L to 10.5 mg/L during the test, suggesting more native water was recovered at the end of the test. Nitrate and nitrite were below their method detection limits (MDLs), which is also consistent with monitoring data from this zone over the past 15 years. While no phosphorus data were collected during the second test, data collected from the monitoring well completed into this zone approximately 150 feet away suggest that the phosphorus concentration is less than 0.5 mg/L, well below the average phosphorus loading of 2 to 3 mg/L, suggesting that phosphorus attenuation occurs during storage at this site.

Although the chloride concentrations are well above the desired concentration in the reclaimed water, the City has been able to utilize this well as a peaking supplemental water supply. Following the second recovery test, the City modified its injection operations at the site to determine whether additional freshening would be observed in the REWARD zone by utilizing injection well IW-2 at the site rather than injection well IW-1. Results from the third test should be available in July 2004 to determine whether this mode of operation will improve the quality of water recovered from the REWARD well. If preferential operation of the injection wells at this facility demonstrates that better recovery water quality can be manipulated, the future operation of this well will likely be used to provide an additional 1 mgd for approximately 30 days during peak demand periods (typically May each year). Otherwise, this well may be converted to an ASR well to expedite freshening of this zone by direct injection, rather than from below. The data suggest that this well will function well as an ASR well, if such a conversion is deemed appropriate in the future as the best use of the well. The City is currently constructing permanent piping from the REWARD well to the WRF filtration system to bypass full treatment in the future.

**ASR Pilot Well**

The initial ASR well at the Southwest WRF was constructed in 2001, with the wellhead and ancillary equipment completed in 2003. A monitoring well (B-10) was completed under the same drilling contract. Only one additional monitoring well was needed because of the extensive monitoring well array already in place at the Southwest WRF. Three storage zone monitoring wells are located at various distances from the ASR well, and four monitoring wells have been completed into permeable intervals overlying the ASR well. Most of these monitoring wells have water level and water quality data available from 1979 through the present, providing an excellent record of background conditions at the site.

In September 2003, the City conducted an Aquifer Performance Test (APT) on the completed ASR well. The test duration was approximately 50 hours at an average recovery rate of 940 gpm. The specific capacity of the well during the testing was 11 gpm/foot of drawdown. Groundwater samples were analyzed for TDS, chloride, sulfate, pH, temperature, specific conductivity, nitrite, nitrate, Total Kjeldahl Nitrogen (TKN), and ammonia concentrations. Water quality generally deteriorated during the test, with TDS concentration increasing from 4,180 mg/L at the start of the test to 5,700 mg/L near the end of the test. Chloride concentration increased from 1,860 to 2,720 mg/L over this same period. This zone has been freshened considerably as a result of injection activities underlying the ASR storage zone, as evidenced by the freshening that has occurred as well as by the nitrogen concentrations in this interval. Ammonia and TKN ranged from 7.2 to 7.9 mg/L during the APT, which was approximately 50 to 70 percent of the average concentration in the reclaimed water. Nitrate and nitrite were detected at

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5 CH2M HILL, December 2003.
less than 0.05 and 0.02 mg/L, respectively, which suggested that the occasional MCL exceedances for these parameters in the reclaimed water were not of concern once the water was introduced into the groundwater system. This was not surprising, because the City’s injection system monitoring data has supported the absence of nitrite and nitrate in the groundwater for years, even with some monitoring intervals containing 90 percent or more of reclaimed water. No significant water quality changes were observed in the monitoring wells during the APT.

Through May 2004, the City had not conducted any cycle testing in this well. The City has maintained that it has been ready to begin cycle testing on several occasions, only to be delayed by regulatory agency requests for more information. The final remaining issue at this time is an operating protocol revision to be in place at the WRF. This protocol is being prepared by City staff and will be submitted in June 2004. It is anticipated that cycle testing will begin shortly thereafter.

**Future Alternative Water Supply Strategies**

The City currently has an estimated 20 mgd of excess reclaimed water available for reuse. To move toward full beneficial reuse of this resource, the City must:

- Increase wet weather storage, and
- Develop additional dry weather non-potable supplies

The City is pilot testing these two concepts with construction and testing of the initial ASR and REWARD wells. Since only approximately 20 mgd is used on an annual basis when system demands reach approximately 40 mgd during the dry season, it is reasonable to assume a maximum day demand of two times of the average day demands. Therefore, to achieve 80 percent reuse (32 mgd), an estimated 64 mgd of dry season supply would be needed to operate a reliable reuse system. Since only 40 mgd of reclaimed water is expected to be available, the remaining 24 mgd would need to come from ASR or alternative non-potable water supplies. At an estimated capacity of 1.1 mgd per ASR or REWARD well, approximately 22 wells would be needed to achieve 80 percent reuse.

To minimize hydraulic restrictions, the supplemental dry season supplies should be dispersed among the four WRFs to the extent possible. Ideally, a few storage wells would be placed at various locations where bulk users such as golf courses would recover directly from these wells. However, this would require storage of the water in shallower permeable zones and the City would be required to meet all DWSs at the ASR wells prior to recharge. It becomes more problematic to meet DWSs at the far ends of a reuse system such as the City’s, and additional treatment (such as UV disinfection) would likely be required as a minimum to meet recharge water standards. The benefit of developing the ASR wells at the WRF sites is that the deeper zones that have been freshened by deep injection well operations can be utilized to improve recovery efficiencies without being subject to DWSs prior to recharge. At this time, it is prudent to first consider storage options onsite before considering offsite options.

Figure 6 is a conceptual 22-well layout among the City’s four WRFs. If initial results from the ASR cycle testing at the Southwest WRF are promising, additional ASR wells would be warranted in a phased build-out approach. This may include two to three additional ASR wells at the Southwest WRF and possibly one test ASR well at the Northwest WRF and another at the Northeast WRF. The future success of the REWARD well at the Albert Whitted WRF will dictate the number of REWARD wells and ASR wells warranted at this location.
Figure 6 – Conceptual ASR and REWARD Build-out for the City of St. Petersburg
Other non-potable water supplies could be utilized to decrease the total number of wells required, or to increase reliability while the ASR wells are in their early phases of development. For example, Lake Maggiore is a freshwater lake in the southeastern portion of the City’s service area that may be able to provide a short-term peaking water supply during the dry season. Raw water could be discharged into the sanitary sewer system and treated at the WRFs to increase dry weather flows.

Another opportunity may be to utilize slightly brackish groundwater in the area. In the early 1900s, the City used shallow wells in the vicinity of Mirror Lake as a public water supply. The City was forced to abandon these wells in the 1920s because of saltwater intrusion. While the wells were not reliable potable water sources, sufficient shallow groundwater resources may be available for use as short-term supplemental reuse supplies. The safe yield of shallow groundwater resources is unknown at this time, and one or more test wells will be needed to better assess this potential supply. Similar to surface water supplies, this groundwater could be pumped into the sanitary sewer system for treatment. Alternatively, it might be possible to use this groundwater for direct augmentation into the reuse system with minimal or no treatment if groundwater quality was adequate for direct non-potable reuse.

Golf courses and other major users could also be asked to develop shallow groundwater pumping systems in areas that support this short-term pumpage to help offset peak demand periods by going offline until sufficient flow is again available in the reuse system. If the shallow groundwater was too brackish to be used alone, larger users could potentially blend onsite groundwater with reclaimed water delivered to their sites to help offset peak demands.

Finally, a few limited opportunities exist for minor amounts of aboveground storage. For example, a small freshwater pond at the Northwest WRF could potentially hold an estimated 10 MG of reclaimed water. This water could be used sparingly to mitigate peak week demands, and then replenished during periods when excess reclaimed water was available. In essence, this open reservoir storage would serve in much the same capacity as aboveground storage tanks. The City is currently investigating options to increase aboveground storage. City staff believes that additional aboveground storage would increase system reliability. The above ground storage is used to meet diurnal and peak day demands, whereas the ASR wells and REWARD wells would help meet seasonal storage (90 to 120-day) demands.

Summary and Conclusions

The City of St. Petersburg, Florida, has long been a leader in urban reuse. The City’s system is essentially built-out at this time, until the development of seasonal storage or supplemental supplies can be accomplished. Although 40 mgd of reclaimed water is typically available and fully used during the dry season, the system demands decline dramatically during wet weather periods when most of the non-potable demands for this resource are absent. This results in an annual average use of about 20 mgd or only 50 percent of the available supply.

The City is exploring two methods of increasing its dry season supplies to allow future expansion of its reuse system. An ASR well and a REWARD well have been constructed at the City’s Southwest WRF and Albert Whitted WRF, respectively, to evaluate water quality and well performance. Once these programs are deemed successful, the City will be in a better position to expand its reclaimed water reuse program while still maintaining the high degree of reliability expected by its customers. A conceptual 22-well build-out is presented that could potentially increase the City’s reuse from 50 percent to an estimated 80 percent of available supplies. Other reclaimed water management strategies are also presented to further expand the reuse system or increase its reliability during extreme dry weather conditions.
References Cited


