KANAPAHA HYBRID STORMWATER/RECLAIMED WATER RECHARGE WETLAND

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Introduction

Since 2008, Gainesville Regional Utilities (GRU) has been pioneering the use of infiltrating or recharge wetlands as an environmentally-sound technology for polishing reclaimed water and recharging the surficial and Floridan aquifers. Demonstration-scale projects at the Kanapaha Water Reclamation Facility (KWRF) and Kanapaha Middle School (KMS) have proven that infiltration rates up to several inches per day are sustainable and that nitrogen removal is better than what can be achieved with conventional land application methods such as spray irrigation and rapid infiltration basins. The key to maximizing the nutrient removal effectiveness is to maintain anaerobic subsurface conditions through consistent hydraulic loading. The wetland vegetation provides the carbon source and attachment sites for denitrifying microbes.

Much of GRU's service area is characterized by sandy, rapidly-draining soils, and dry retention is the favored method for residential and commercial stormwater management. These stormwater basins sit idle between runoff events and are not utilized to their full potential. The absence of biological treatment processes in dry retention basins limits their effectiveness for water quality improvement. The realization that infiltrated stormwater may still transport nutrient loads to sensitive receiving waters, such as springs, has led several municipalities to require design enhancements for new dry retention basins that increase pollutant removal efficiency. In neighborhoods and along rights-of-way near existing or planned reclaimed water distribution mains, dry retention systems can be designed or retro-fitted as infiltrating wetlands to serve multiple purposes: providing the necessary stormwater management function during rainfall events; recharging the aquifer with highly polished reclaimed water between rainfall events; replacing grass cover with aesthetically pleasing wetland vegetation; and maximizing ecological function and wildlife value.

In cooperation with the Alachua County School Board and the St. John's River Water Management District (SJRWMD), GRU has retrofitted an existing dry retention basin into the first combined stormwater/reclaimed water infiltrating wetland system. Full-scale infiltration tests were conducted to evaluate the sustainable infiltration rate, and drawdown modeling showed that the design storm requirements could still be met with the basin receiving a continuous supply of reclaimed water. The SJRWMD issued a permit authorizing the modification of the retention stormwater system to a stormwater/reclaimed water hybrid pond. The conversion from a dry, grassed basin to a functional wetland ecosystem was completed in August 2016. Operational hydrologic and water quality data collection began in July and September 2016, respectively.

The technical and regulatory feasibility of converting dry retention basins to infiltrating wetlands has been demonstrated and this strategy offers utilities the opportunity to maximize the use of existing or planned water resource infrastructure.

Project Background

Beginning in 2007, GRU began evaluating the feasibility of using infiltrating groundwater recharge wetlands as an alternative to traditional reclaimed water management methods. GRU's objective was to diversify their reuse system in a cost-effective manner that was protective of the region's karst geology and sensitive springs ecosystems. A series of demonstration projects were implemented, starting with the rehabilitation of an aesthetic water feature at KMS in 2008. Existing constructed water features were reconfigured to facilitate side-by-side comparisons of water quality improvements and infiltration capacities between shallow marshes and deeper, open water systems. Though the hydraulic loading rates between the wetland and pond flow were not the same, the study results confirmed GRU's expectation that wetlands constructed over permeable soils could recharge water at sustainable rates and that wetlands provided greater nitrogen reductions in the surface water and in the groundwater than open water ponds (WSI 2010). Inflow total nitrogen (TN) and nitrate+nitrite-nitrogen (NOX) in the reclaimed water averaged 4.9 mg/L and 4.2 mg/L, respectively over the two-year study. Wetland surface water concentrations were reduced to 2.2 mg/L for TN and 1.3 mg/L for NOX. Upgradient groundwater TN and NOX averaged 2.2 mg/L and 1.3 mg/L, respectively. Downgradient groundwater concentrations were 0.93 mg/L for TN and 0.65 mg/L for NOX. The average infiltration rate was estimated to be 5.0 inches per day (in/d).

In parallel with the study at KMS, GRU constructed three approximately 1-acre recharge wetland cells at the KWRF. Phase 1 of the KWRF study compared parallel operation of two wetland cells with operation of a third cell as an unvegetated rapid infiltration basin (RIB). The results of this study phase were similar to those from the KMS site: wetland water quality was better in both the surface water and underlying groundwater than in or under the RIB; and wetland recharge rates were high enough to make the concept a cost-effective reclaimed water management alternative (WSI 2012). In the second phase of the KWRF study, the RIB was planted with wetland vegetation and was operated with continuous inundation, rather than alternating loading and resting cycles. The Phase 2 results showed that the converted cell performed better with respect to water quality improvement as a wetland than it did as a RIB. Infiltration rates declined after planting, but remained high enough to maintain concept feasibility (WSI 2013). The three wetland cells operated at average infiltration rates ranging between 0.7 in/d (Cell 1) and 3.2 in/d (Cell 3). Nitrogen in the applied reclaimed water averaged 3.3 mg/L for TN and 2.8 mg/L for NOX. Average surface water concentrations in the wetland cells were <2 mg/L for TN and <1 mg/L for NOX. Shallow groundwater NOX concentrations were <0.1 mg/L.

Conceptualization of the Hybrid Wetland Project

With the consistent successes GRU documented using infiltrating wetlands for beneficial reuse and aquifer recharge, the utility began looking for additional sites to implement the technology. One early candidate site was the school's stormwater dry retention area (DRA) that sits immediately adjacent to the KMS study wetlands. During two years of field work, the project team never observed an accumulation of stormwater in the basin, leading to the presumption that infiltration rates were potentially higher than measured in the study wetlands and that the basin may have excess capacity. The concept of converting the DRA to an infiltrating wetland that would be sustained with reclaimed water and would provide better treatment for stormwater runoff was hatched. However, there were two key questions that required answers: first, was it feasible from a regulatory standpoint to comingle stormwater and reclaimed water in the DRA; and second, did the existing DRA have additional capacity?

Discussions with the SJRWMD and Florida Department of Environmental Protection (FDEP) ensued, and the permitting approach was established. Because the reclaimed water meets Public Access Reuse (PAR) standards prior to being sent into the reclaimed water distribution system, and is metered at the KWRF, the FDEP does not require separate monitoring for new "water features" that do not discharge to surface waters. The SJRWMD required demonstration through field evaluation and modeling that the DRA could receive reclaimed water while storing the design storm runoff volume without offsite discharge, and that the system would recover the storm volume within 72 hours.

Full-scale Infiltration Tests

In preparation for evaluating infiltration rates in the DRA, GRU tapped a nearby reclaimed water distribution main and constructed a 4-inch diameter PVC supply line to the basin. The first full-scale infiltration test was conducted between June and September 2011. After the initial filling, reclaimed water was added when the basin water depth dropped to 6 inches and inflows were terminated when the depth reached 12 inches. Water level data were logged at 15-minute intervals for the duration of the test. Figure 1 shows reclaimed water levels in the DRA during the initial infiltration test. Infiltration rates were estimated based on the slope of the declining water level curve between pumping events and corrected for rainfall. Nighttime data were used to account for evaporation. Infiltration rates were found to average about 19 in/d but declined over time and averaged about 12 in/d by the end of the testing period (Figure 2). At the conclusion of the testing phase, the water level was increased to about 2 feet and held for 5 days. Inflows were then turned off and the recovery time to infiltrate the entire volume was measured at approximately 36 hours.

Field infiltration rates, along with other engineering data collected during the original basin design effort, were used to model the long-term performance of the DRA once converted to a continuously-loaded hybrid wetland system. PONDS v3.3 was used to evaluate stage increases and recovery for a variety of storm events. The modeling demonstrated that the basin could be reconfigured to receive a continuous supply of reclaimed water and maintain a water depth of 1 foot, while still providing sufficient storage volume for the design storm event and meeting SJRWMD recovery criteria.

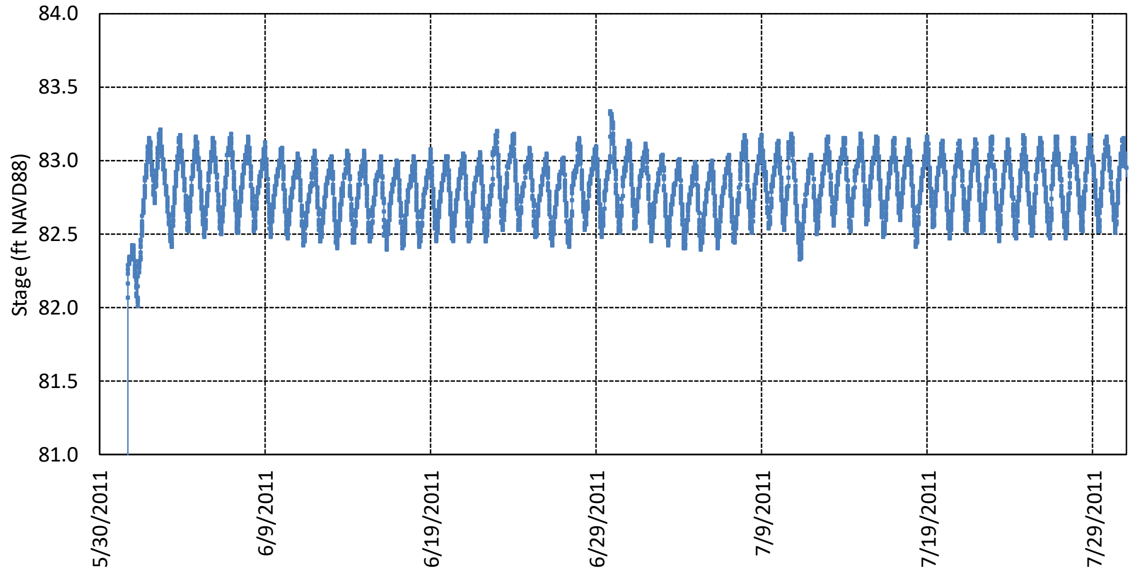

Figure 1. Representative Kanapaha Middle School Hybrid Wetland Water Levels during Initial Infiltration Test
The basin bottom is at elevation 82.0. Valve set points were approximately 82.4 (ON) and 83.1 (OFF).

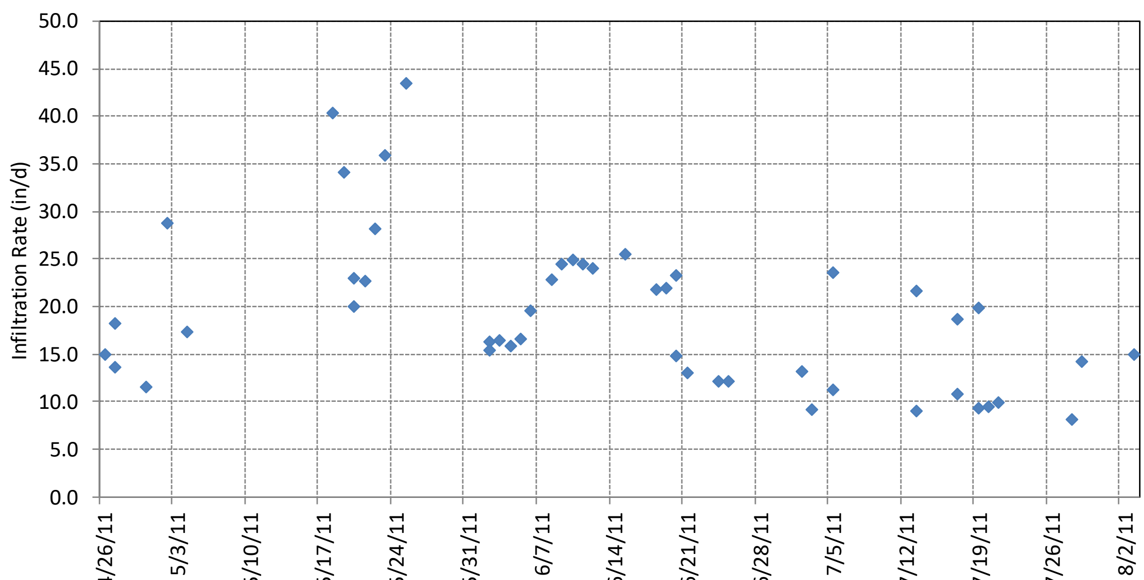

Figure 2. Kanapaha Middle School Hybrid Wetland Initial Infiltration Test Results

Infiltration rates were evaluated a second time in mid-2015 and the results were confirmatory of those measured in 2011. Rates at the start of the test in May 2015 exceeded 24 in/d, but declined to about 14 in/d by the end of July 2015. Figure 3 shows the basin during one of the extended full-scale infiltration tests.

Figure 3. Kanapaha Middle School Hybrid Wetland During Infiltration Test

<u>Construction and Startup</u>

As the basin was already constructed and GRU had an existing reclaimed water distribution main within 1,000 feet of the site, the conversion from DRA to wetland required minimal additional construction. The reclaimed water main and inflow controls were installed in 2011 to facilitate the initial infiltration tests. The control system consists of an electrically-actuated valve, flow meter, ultrasonic level indicator, and a panel that houses level and flow display units, data logger, and programable logic controller. The system can be remotely operated through GRU's supervisory control and data acquisition (SCADA) software by operators at the KWRF. Other constructed features include an energy-dissipating splash pad where reclaimed water enters the basin. Three monitor wells were installed by hand-auger and outfitted with pressure transducers to record surface and shallow, subsurface water levels. These data were used during the initial infiltration test in 2011, but the instruments have been repurposed as they provided redundant data with the ultrasonic instrument. A short deck was constructed to provide access to one of the monitoring wells and to provide structural support for the ultrasonic water level sensor that controls the inlet valve.

In preparation for planting, the grass bottom of the basin was mowed and disked. After inundating the basin for several weeks, 7,400 wetland plants were installed in August 2016 following the vegetation plan shown in Table 1. Plants were installed 3-feet on-center throughout the marsh zone. Littoral species were installed 3-feet on-center around the perimeter of the site, at the normal high water line. Transitional grasses were installed 5-feet on-center just above the normal high water line.

Table 1. Kanapaha Hybrid Wetland Planting Plan

Zone	Botanical Name	Common Name	Quantity
Marsh Zone	*Pontederia cordata*	Pickerelweed	2,375
	Sagittaria lancifolia	Lanceleaf arrowhead	2,035
	Eleocharis cellulosa	Spikerush	1,700
	Schoenoplectus validus	Softstem bulrush	680
Littoral Zone	*Canna flaccida*	Yellow canna	165
	Iris virginica	Blue flag	165
	Crinum americanum	Swamp lily	80
Transitional Zone	*Muhlenbergia capillaris*	Muhly grass	100
	Spartina bakeri	Sand cordgrass	100
Total			7,400

Immediately following planting, the control system was configured so that water depths ranged between about 3 and 6 inches. The control valve opened at the low set point (3 inches) to allow reclaimed water to be applied, and closed at the high set point (6 inches). As the plant community matured, the set points were raised to gradually increase the depth of water in the system. After acclimation of the plants, the low and high set points were programmed to approximately 10 and 12 inches, maintaining continuous inundation and creating a cycle of loading events.

Early Performance Summary

Flow and level data collection began at the end of July 2016 with hydration of the basin to facilitate wetland plant installation in mid-August. As noted above, water levels were gradually raised in response to plant growth and expansion. By November 2016, the system began a relatively stable operational cycle with water depths fluctuating between about 10 and 12 inches (Figure 4). However, there were several interruptions between November 2016 and February 2017 when the system was off for periods ranging from 2 days to 2 weeks. During this period, the average daily input, excluding "off" days, was 648,000 gallons. There were no interruptions during January 2017, and average daily inputs increased to 845,000 gallons.

Analysis of the ultrasonic level data during January 2017 indicated that when the control valve closed at the upper set point, it only took 2 hours for levels to decline 2 inches and trigger the valve to open again. Refilling 2 inches of water across the 1-acre site typically required 10 to 12 hours of pumping at a rate of approximately 650 gallons per minute (GPM).

SCADA flow data showed that the system received about 80.6 million gallons of reclaimed water between July 27, 2016, and March 24, 2017, and that the inflow valve was open approximately 45% of the time. Over the basin surface area, reclaimed water additions totaled 2,970 inches, compared with 21 inches of direct rainfall during the same period. Estimated infiltration rates are consistent with those from the pre-conversion tests in 2011 and 2015, and vary between about 12 and 24 in/d.

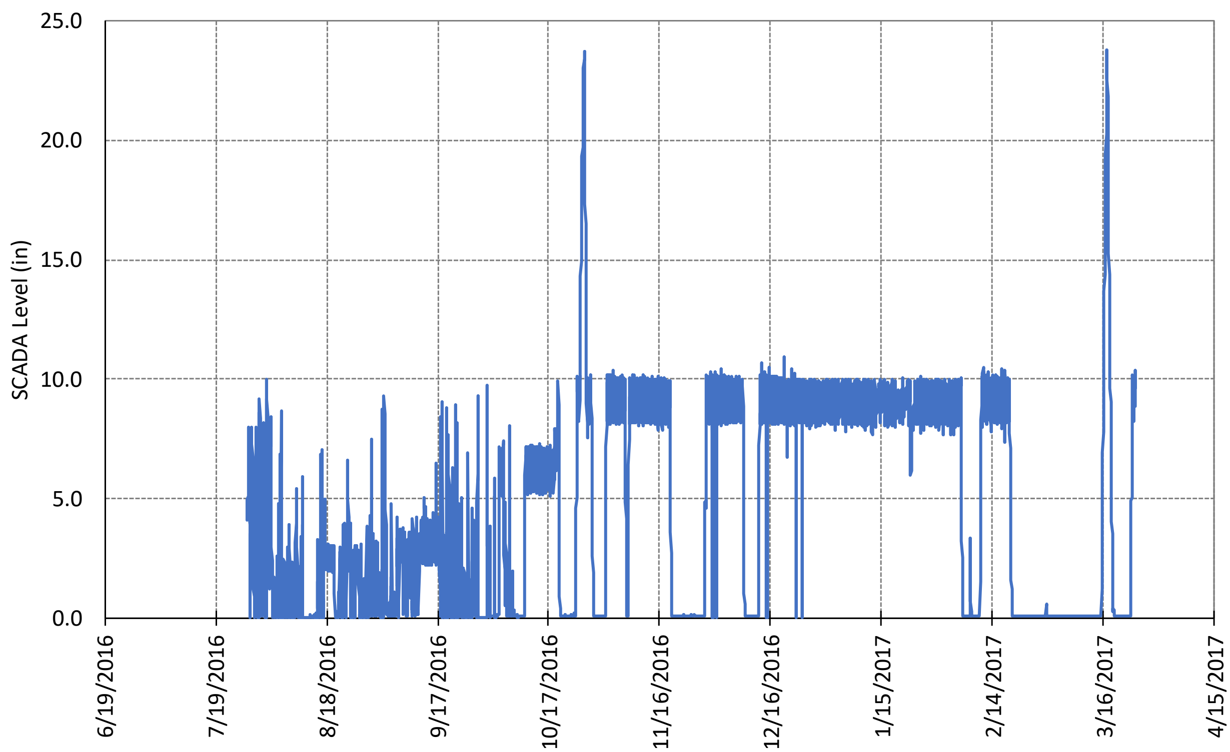

Figure 4. Kanapaha Middle School Hybrid Wetland Operational Water Levels
Reported SCADA levels are approximately 2 inches lower than corresponding wetland water depths.

GRU staff collected monthly water quality samples from two surface water stations and from a horizontal monitor well that collects water from a depth of approximately 3 feet below the wetland bottom (Figure 5). Water quality sampling was initiated in September 2016. Samples were analyzed for the following field and laboratory parameters:

- Temperature,
- pH,

- Specific conductance,
- Dissolved oxygen (DO),
- Total kjeldahl nitrogen (TKN),
- Ammonia nitrogen (NH3),
- Nitrate+nitrite nitrogen,
- Total nitrogen, and
- Chloride.

Table 2 summarizes field parameter data for sampling conducted between September 2016 and January 2017. Water temperature did not vary much between the surface water and groundwater samples. Groundwater pH was slightly lower than surface water pH. Specific conductance was consistent between the surface water and groundwater, indicating that the applied reclaimed water was being measured in the horizontal well. DO was typically much greater in the surface water than in the groundwater and was associated with the presence of filamentous algae over much of the wetland bottom. Algal dominance will decrease as the emergent plant cover expands and surface water DO will decline in response.

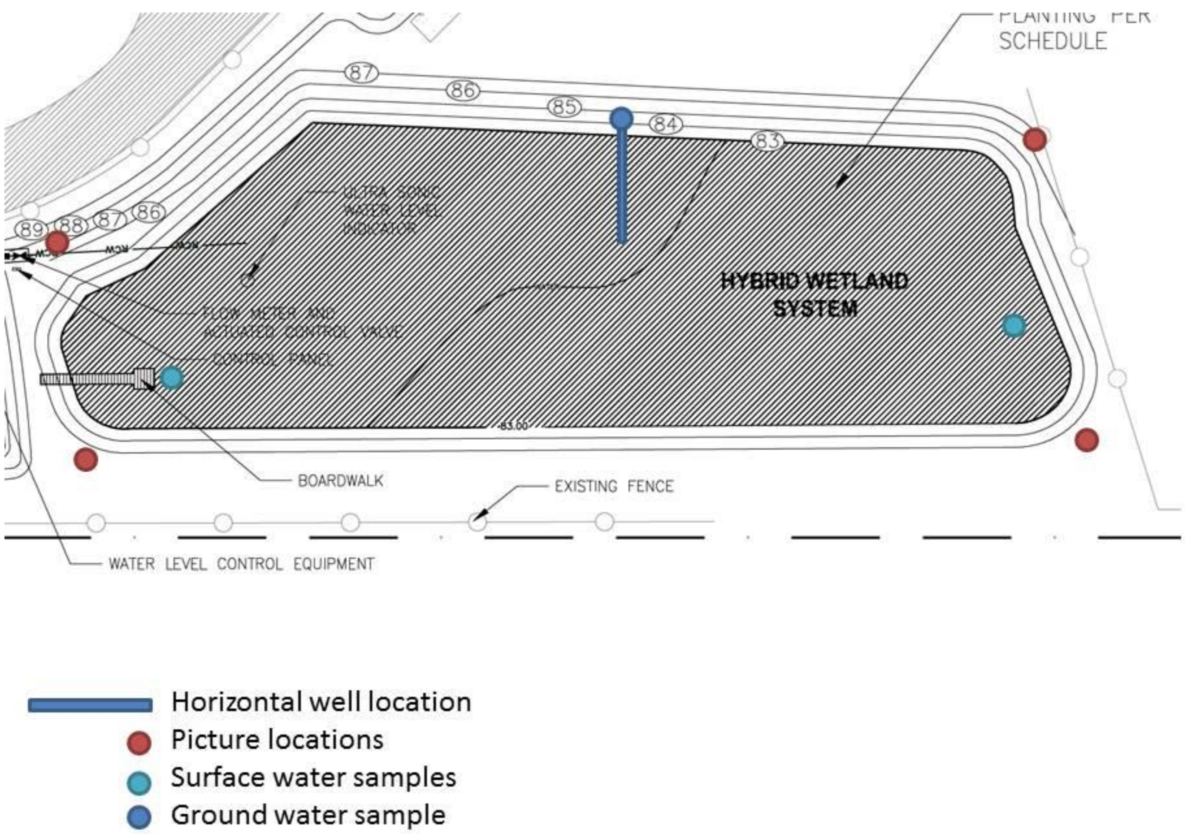

Figure 5. Kanapaha Middle School Hybrid Wetland Monitoring Stations

Table 2. Kanapaha Middle School Hybrid Wetland Field Parameter Data

Parameter	**Date**	**Station**		
		SW1	**SW2**	**GW**
DO (mg/L)	10/17/16	11.5	16.1	1.96
	11/14/16	16.6	17.3	4.28
	12/13/16	7.55	5.21	8.06
	01/13/17	10.4	18.0	5.55
pH (s.u.)	09/16/16	9.00	7.90	6.66
	11/14/16	7.42	8.58	7.05
	12/13/16	7.55	7.54	7.50
	01/13/17	7.04	8.14	6.99
	02/10/17	8.52	8.75	6.97
Specific Conductance (µmhos/cm)	10/17/16	640	590	660
	11/14/16	660	640	620
	12/13/16	660	640	680
	01/13/17	600	600	600
	02/10/17	580	640	660
Temperature (°C)	10/17/16	28.2	28.7	29.3
	11/14/16	23.9	22.6	21.8
	12/13/16	21.5	20.4	22.7
	01/13/17	22.5	24.2	21.5

Figure 6 summarizes analytical parameter data for sampling conducted between September 2016 and February 2017. As a combined effect of low vegetation density and limited carbon availability, Fall and Winter temperatures, elevated DO from a robust algal community, and rapid infiltration rate, nitrogen removal performance has been less dramatic than measured at earlier GRU demonstration projects. The data indicate that some of the applied NH3 was nitrified to NOX in the highly-oxygenated surface water column. NH3 declined from about 0.8 mg/L in the reclaimed water to 0.2 mg/L in the shallow groundwater. Nitrification of NH3 would increase the NOX load to the wetland beyond what was applied with the reclaimed water. NOX removal was therefore minimal with a reduction from 4.4 mg/L in the reclaimed water to 4.2 mg/L in the shallow groundwater. Despite a hydraulic loading rate that is several times greater than the maximum reported in earlier GRU studies, it is expected that reductions in NOX concentrations will improve as the plant community matures, building up dissolved organic carbon through seasonal plant decomposition cycles.

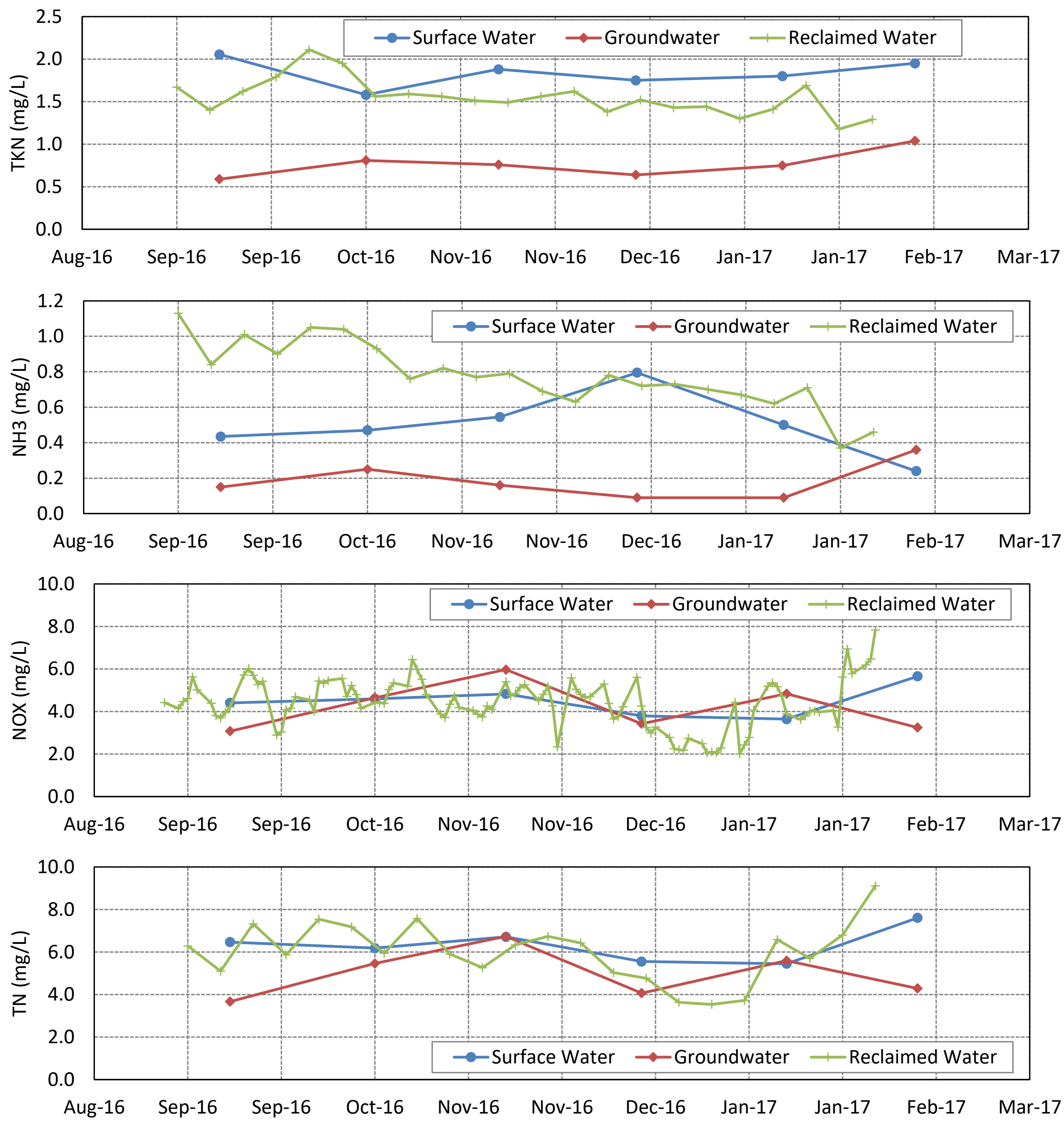

Figure 6. Kanapaha Middle School Hybrid Wetland Analytical Parameter Data

Project Benefits

The conversion of an existing DRA to a hybrid wetland system provides multiple benefits. Most significantly, the space meets the site's original purpose for stormwater management, but now serves a dual function as a reliable reclaimed water recharge facility. This gives GRU additional reuse options, particularly during wet weather periods when the reclaimed water demand from other users is minimized. The establishment and maintenance of a sustainable biological treatment system further polishes the applied reclaimed water and provides treatment mechanisms for stormwater runoff that were not previously available. As noted above, it is expected that the water quality benefits will increase as the system matures.

Prior to project implementation, the basin consisted of a mowed, dry bottom with a bahiagrass (*Paspalum notatum*) monoculture. The basin now supports a variety of flowering emergent wetland species that have increased habitat diversity and improved the site's aesthetic appeal (Figure 7).

Figure 7. Kanapaha Middle School Hybrid Wetland Plant Community

To maximize system benefits, GRU has recently worked with the middle school science teachers to develop a variety of lesson plans that use the KMS wetlands as an outdoor laboratory. Lessons cover topics such as aquatic microbiology, water chemistry, wetland plant identification and biomass measurement, soil permeability, soil classification, and particle filtration.

Based on the cumulative successes of the demonstration recharge wetland projects, GRU continues to explore opportunities to expand the use of these systems into existing neighborhoods and to partner with developers to incorporate them into new residential and commercial development sites.

References

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