Lake City Treatment Wetland: Water Quality Performance and Operation

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In much of central and north-central Florida, the landscape is dominated by permeable sands and discontinuous clay layers that overlay the limestone/dolomite Floridan aquifer. The karst hydrogeology of the region makes it home to a large number of artesian springs where water from the aquifer discharges at the land surface, creating clear streams that support unique wildlife and plant species and that are highly prized for the recreational opportunities they provide to the public.

Activities that occur on the land surface, such as fertilizer application and the land disposal of treated municipal and industrial wastewaters via spray irrigation and rapid infiltration, have been shown to contribute nitrogen loads to the groundwater (Elder et al., 1985; Katz and Griffin, 2007) and can result in undesirable changes to the spring's ecosystems (Florida Springs Task Force, 2000). Withdrawals of groundwater for water supply purposes and long-term rainfall deficits may further exacerbate the condition by reducing flows.

The concept of using groundwater recharge wetlands has been gaining acceptance as a cost-effective tool to remove excess nitrogen and other water quality constituents and to direct polished reclaimed water back into the aquifer.

Figure 1. Lake City Wetland Layout *(source: Google Earth Imagery)*

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The Ichetucknee Springshed Water Quality Improvement Project (ISWQIP) is a first-of-its-kind conversion of an existing wastewater spray irrigation site to a groundwater recharge wetland. Treated effluent from the City St. Margaret's water reclamation facility (WRF) meets current effluent quality limitations; however, the WRF was identified as a potential source of nutrient loading to the Santa Fe River. The ISWQIP was implemented under the Santa Fe River Basin Management Action Plan (BMAP) to reduce regional total nitrogen (TN) loads and provide beneficial recharge to the Upper Floridan aquifer and the Ichetucknee Springs system.

Specific project objectives included:

- Converting the City of Lake City's wastewater effluent disposal system into constructed treatment wetlands, reducing the system's TN loading to the Ichetucknee Springshed by up to an estimated 84 percent and nitrate load by more than 89 percent.
- Improving water quality by reducing overall TN loading to the Ichetucknee River by up to an estimated 20 percent.
- Providing over 1 mil gal (MG) of beneficial recharge to the Upper Floridan aquifer each day.

This project was constructed in the city in 2015-2016. The wetland began operations in late 2016 and early 2017, with normal operations beginning in 2017. As part of the operation of this system, water quality samples have been collected at 12 locations monthly and used in conjunction with detailed water-level data to develop water and nutrient balances. These data are being used to develop an improved understanding of the water quality performance and treatment dynamics of this system.

Water quality sampling between February

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2017 and January 2018 has shown decreases in TN from an average of 12.2 mg/L in the inflow to less than 2.3 mg/L at the most hydrologically downstream stations, which is an 81 percent reduction. Furthermore, nitrate concentrations during this period have been reduced from an average of 1.8 mg/L to 0.02 mg/L at the most hydrologically downstream stations, a 99 percent reduction.

This article summarizes the design, operation, and performance of the project during the first full year of operation, with recommendations for future similar projects.

The Complexities of Florida Water

Florida water resources are characterized by complex relationships between surface water and groundwater. These relationships are particularly important with regard to ensuring renewable water supplies for future use. Of particular importance is the net impact that water users cause through their withdrawals, consumptive use, and recharge. One technique to increase the available water supply is by recharging high-quality water that is not consumed as part of its use.

Enhancing recharge has been a major goal of Florida's water management districts, but the geology underlying the state is far from homogeneous and is instead defined by areas of confinement, with low recharge potential or areas lacking confinement with high recharge potential.

In areas with low recharge potential, fewer options exist to replenish the aquifer and much of the nonconsumed water runs off to tide. In areas with suitable geology, however, "leftover" water can be recharged to the aquifer and can be available for other purposes.

Wastewater treatment plants represent one source of centralized and "leftover" water that can be recharged to the aquifer. This recharge has historically occurred through rapid infiltration basins (RIBs) or slow-rate land application (sprayfields); however, these historic recharge methods, although often effective, do not necessarily represent the optimum method of accomplishing the two-part goal of maximizing recharge and improving water quality.

Over the past 15 years treatment wetlands have been adapted to provide exceptional levels of water quality treatment, while recharging the aquifer in areas with suitable geology. This process improves on the water quality performance of both RIBs and sprayfields and also provides higher recharge capacity than typically occurs on sprayfields.

With design beginning in 2014 and construction beginning in 2015, the city committed to improving water quality and recharge by partnering with the Florida Department of Environmental Protection (FDEP), the Suwannee River Water Management District (SRWMD), and Columbia County to convert a portion of the city's sprayfields into a groundwater recharge wetland. This project took the largest of the sprayfields (~180 acres) and converted it into approximately 120 acres of wetlands. This project is now having direct positive impacts on the Ichetucknee Springshed and Floridan aquifer by reducing nitrogen loading to groundwater, while increasing recharge.

During the first full year of operation, the city sampled water quality in the treatment wetland to facilitate management decision making and to document performance; sampling began in February 2017 and is continuing. The results of this sampling and the annual performance from February 2017 through January 2018 are discussed, with additional detail about the design and operational challenges.

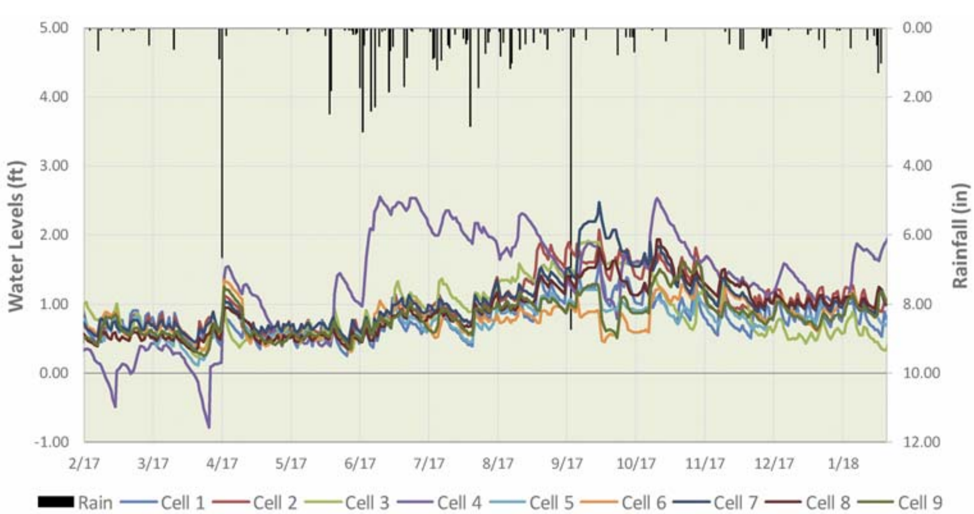

Figure 2. Water Levels and Rainfall

Design

The city sprayfield was initially put into use in the 1980s to dispose of treated wastewater effluent through spray irrigation on pastures; over time, this system was converted from pasture to planted pine. With increasing awareness of nutrient loading to groundwater and a desire to increase spring flows, Florida began providing funds to create projects to further the goals of springs restoration. The city project was selected for evaluation based on a conceptual groundwater recharge wetland design that had been proposed by Wetland Solutions in 2006. This concept recommended full conversion of all of the sprayfields to infiltrating wetlands to provide additional water quality treatment. With the ISWQIP, the decision was made to convert just the largest of the sprayfields to an infiltrating wetland.

Based on site topography that included almost 30 ft of elevation difference, the site was divided into nine separate cells to balance cut and fill (Figure 1). The cells were configured to allow for three inlet structures to provide all inflows to the wetland, with one at the north end and two at the southwestern end. Based on site geotechnical work, two primary recharge areas were identified. These two recharge areas were placed in different cells (Cell 3 and 4) based on elevation differences. At the site, topography was generally high near the northern and southern ends, with lower areas in the center and at an existing lake on the central eastern portion of the property where one of the two recharge features is located. The nine cells were designed to take advantage of topography to allow for cell-to-cell flow by gravity, with no pumping beyond the inflow. Because the site is designed to dispose of all water onsite, no surface discharge (with the exception of an emergency overflow) was part of the design.

All cell-to-cell structures are sharp-crested weirs between 2 and 5 ft in length, with one or two outlet structures per cell (except the terminal cell, Cell 4). These structures are used to maintain desired water levels and can be raised to capture more water during significant rainfall periods or lowered to reduce water levels for maintenance. Because Cell 4 is the terminal cell with no surface outflow, levels are dictated by the combination of inflows, rainfall, evapotranspiration (ET), and infiltration.

Wetland Hydrology

Hydrologic conditions during the study period were far from normal. Total rainfall for the site was 70.6 in. (February 2017-January 2018) and included two single-day rainfall events with totals of 6.7 and 8.8 in. The second of these occurred during Hurricane Irma, which passed over the site in September 2017. To further challenge operations, June 2017 saw nearly 17 in. of rainfall at the site, significantly raising wetland water levels. During 2017, the estimated direct rainfall contribution to the wetland was about 270 MG.

Wastewater flows are directed to the city's lined reservoir from the wastewater treatment facility before being delivered to the wetlands or sprayfields through an outlet pump station. Flows to the wetland were made 169 days during the year and delivered about 365 MG of effluent. The hydroperiod (portion of time the cells held standing water) was 365 days, or 100 percent for most of the cells with short dry-outs (two to 14 days) in Cells 1, 3, 4, and 5. Water levels varied for the individual cells, but generally increased during the wet summer before recovering in the fall to the design water depth (~1 ft). Water levels were initially maintained at about 0.5 ft to encourage plant growth and spreading after the initial planting; this level was then raised as rainfall increased in May and June. The time series of water levels and rainfall is shown in Figure 2.

Water Quality Performance

During the first year of operation, the wetland was sampled monthly beginning in February 2017 and continuing through January 2018. Samples were collected at each of the structures between cells and also within the most-downstream cell (Cell 4). The inflow was also sampled when flows were being delivered to the wetland. When inflows were not occurring during wetland sampling events (June and December), water quality data from the city's WRF effluent sampling were used to indicate water quality for that monthly period. Sampled parameters included temperature, dissolved oxygen, specific conductance, pH, total Kjeldahl nitrogen (TKN), ammonium (NH_4), nitrate-nitrite (NO_x), total phosphorus (TP), and orthophosphorus. The TKN, NH_4, and NO_x data were then used to calculate TN and organic nitrogen.

During the sampled period, major changes occurred in the inflow water quality. Upsets upstream in the wastewater treatment plant initially caused high concentrations of nitrogen and phosphorus to enter the reservoir, and then the wetland. Inflow concentrations of TN during the sampling varied between 6.2 and 22.0 mg/L, and for TP varied between 0.7 and 4.2 mg/L. The time series of TN and nitrogen species inflow concentrations are shown in Figure 3 and TP and orthophosphorus are shown in Figure 4. Inflow concentrations largely returned to more typical values beginning around July 2017.

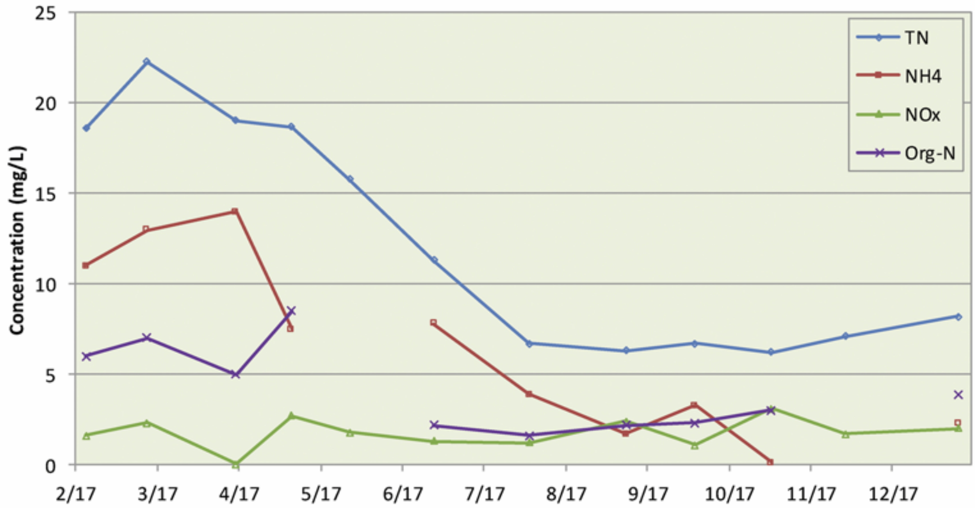

Figure 3. Nitrogen Inflow Concentrations

Water quality generally improves at downstream structures as water moves through the wetland cells receiving treatment. For the purposes of estimating outflow concentrations (given no outflow structure), water quality samples at each of the structures entering Cell 4 (Cell 3, Cell 6, and Cell 9), and internal Cell 4 samples were averaged to provide an "outflow" quality estimate. The reason for this averaging is that samples collected in Cell 4 are collected in the large open-water area and have been impacted by wind during some sampling events.

The TN outflow concentrations ranged from 0.92 to 4.3 mg/L during the year, with higher concentrations occurring during periods with higher inflow concentrations. The TP outflow concentrations varied between 0.12 and 1.53 mg/L during the year. Removal rates for TN ranged from 78 to 86 percent during the year, with relatively little variation. Removal rates for TP varied from 37 to 94 percent during the year, with the highest removal rates during summer. Inflow and outflow concentrations for TN and TP are shown in Figure 5.

The total mass of nitrogen removed in the wetland was estimated by using monthly inflow concentrations and flows to calculate the total mass of nitrogen entering the system. The outflow concentrations were estimated by using estimated infiltration rates by cell to calculate the mass of nitrogen infiltrated in each cell. Rainfall was incorporated with an assumed TN concentration of 0.88 mg/L based on data from the National Atmospheric Deposition Program (NADP, 2018). Estimated TN loading from the combination of effluent and rainfall during the study period was approximately 41,600 lbs of nitrogen, with removal in the wetland of 30,600 lbs during the 12-month period.

Lessons Learned

This project, like most, was not immune from challenges. These included construction-related and weather-related challenges, and the operational learning curve associated with a new system. Each of these challenges was overcome and the system has functioned as intended, although more oversight was required than was initially intended during the first year.

Challenges associated with construction included the timing of construction and the associated wetland planting. The nine cells were not completed at the same time, and to avoid the growth of undesirable vegetation, wetland planting followed the completion and initial filling of each wetland cell. The earliest cells completed were finished in early August, with planting commencing approximately one week later, but the specifications required all planting to cease after September 1 to provide time for plant establishment before the onset of cold weather.

Because of the cell completion schedule, the necessity of the site for disposal, and a short-staffed planting crew, the decision was made to continue planting until late November before being stopped due to freeze concerns. This late planting, combined with documented plant shortages and wildlife herbivory, led to open-water areas that, when exposed to sunlight and warmer temperatures, allowed extensive colonization by algae. This algae in turn fueled a large midge emergence that led to complaints from neighbors. As emergent plant coverage expanded in early 2017, and populations of natural predators caught up, the midge problem was naturally resolved.

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The second problem the project encountered was above-normal precipitation during the summer that contributed to both increased levels and increased wastewater flows from infiltration and inflow in the sewer system. This additional water, in association with infiltration occurring to varying degrees across the site, led to operational challenges to balance storage at the site. During this period, cells were operated progressively deeper to gain storage.

As rainfall decreased in the fall, storage was recovered with careful operation of the wetland and sprayfields. These conditions were particularly challenging given the necessity of the site for disposal and because of deviations from the original concept of recharge occurring primarily in Cells 3 and 4. Based on infiltration estimates, approximately half of the infiltration occurs outside of these "recharge" cells.

Other project challenges were overcome by consistent communication, and when necessary, operational modifications. Planting issues were largely resolved through maintaining shallow levels to encourage plant expansion in the spring, combined with localized supplemental planting. Precipitation was managed by adjusting water levels and communicating about the operations to set weirs and inflows to accommodate the rainfall and inflows. Furthermore, the data collected as part of the first year of operations for water levels and water quality provide insight about the system performance that can be used to better manage the system in future years under variable conditions. Finally, this groundwater recharge wetland can be used to guide design and operation of similar future systems, while also providing improved understanding of expected water quality improvement.

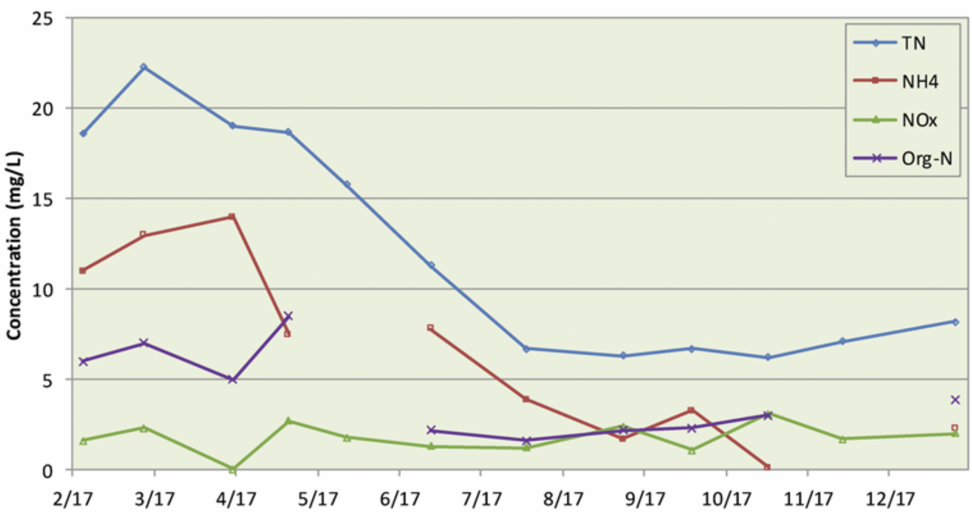

Figure 4. Phosphorus Inflow Concentrations

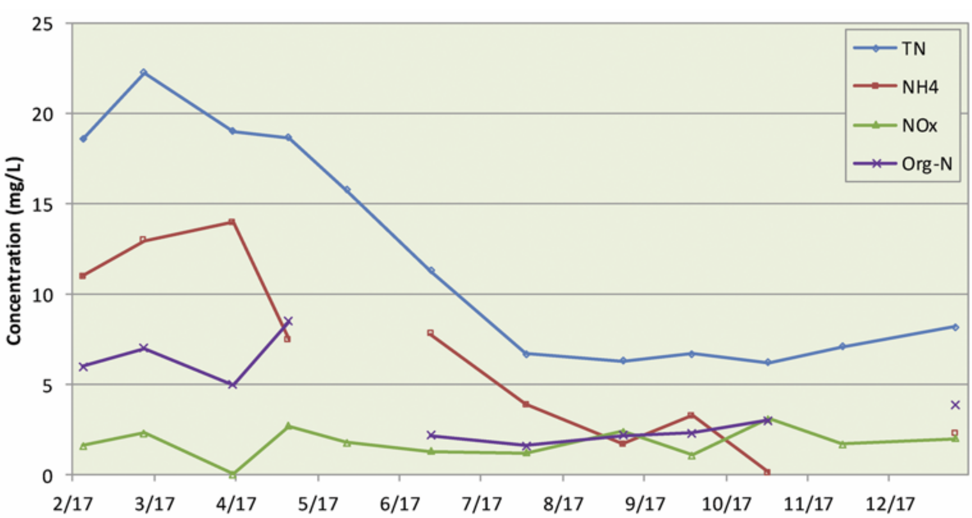

Figure 5. Nitrogen and Phosphorus Inflow and Outflow Concentrations

Conclusions

The city's recharge wetland is the first of its kind—a full-scale conversion of a spray irrigation site to groundwater recharge wetlands. This project provides substantial additional nutrient removal within the Ichetucknee Springshed. During the first full year of operation, the system removed an estimated 30,600 lbs of nitrogen from the 365 MG of effluent and 270 MG of rainfall that were treated in the wetland. This treatment occurred despite operational challenges, including new wetland vegetation planting and establishment, above-average rainfall, and the operational learning curve. This technology offers an excellent method to improve treatment, while maintaining or shrinking the existing system footprint and without major operational requirements.

Acknowledgments

This project relied on a large number of partners, including FDEP, SRWMD, City of Lake City, and Columbia County. The project design and construction oversight was completed through the collaboration of AMEC Foster Wheeler and WSI, with construction completed by Barco-Duval. This project and the water quality monitoring could not have been completed without the continued cooperation of the City of Lake City. Special thanks go to Hugh "Sonny" Van-Skyhawk, Cody Pridgeon, Bill Fish, David Durrance, and all the other team members who have been involved in this project.

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