PRELIMINARY ASSESSMENT OF SHORELINE SEPTIC SYSTEM IMPACT ON LAKE LANIER WATER QUALITY

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Abstract. Lake Lanier is a reservoir situated in North Georgia and is the primary drinking water source for Gwinnett County, one of the largest counties in Metro Atlanta with a population of 0.9 million. Lake Lanier has a TMDL (Total maximum daily load) for chlorophyll-*a* that calls for a reduction in nitrogen (N) and phosphorus (P). The overall objective of this cooperative project with Georgia Tech University is to develop an estimate of the contribution of nutrients and bacteria from homes along the shoreline in Gwinnett County with onsite wastewater treatment systems (OWTS). The specific objective of this paper is to describe the approach taken in the UGA groundwater study and preliminary results from two home sites. We installed 25-26 groundwater monitoring wells at each site and plan to monitor 7 more home sites. Sixteen wells at Site 1 and eighteen wells at Site 2 have been installed in a dense grid close to and running parallel to the shoreline to try and intercept the OWTS plume. Other wells were installed in a transect perpendicular to the shoreline between the shoreline screen and the OWTS drainfield. There is also, at each site, a well installed directly in or as close as possible to the drainfield and a well outside the OWTS influence used as a control. These wells have been sampled monthly and analyzed for chloride (Cl), N, P, and *E. coli*. Only Cl results are presented since the results are preliminary. Shoreline well samples from Site 1 showed high concentrations of Cl up to 21 mg/L at Site 1 in January and 77 mg/L at Site 2 in February 2019 indicating that we were able to intercept the OWTS plume. A four-step modeling process using HYDRUS two-dimensional hillslope models is being used to extrapolate the data from home sites to the entire Gwinnet County shoreline. An uncalibrated model predicted Cl concentrations as high as 30 mg/L, which is in the range of the measured values.

INTRODUCTION

Lake Lanier is a 150-km^2 lake approximately 48 km northeast of Atlanta. Its shoreline stretches 1012 km at normal water levels and its watershed drainage area covers 2,693 km^2. The summer full pool elevation of the lake is 326.4 m above mean sea level.

The importance of Lake Lanier derives from the fact that it is the principal source of water for the cities of Atlanta, Buford, Cumming, and Gainesville and for Gwinnett County in general. Other uses of Lake Lanier are hydropower generation, fish and wildlife management, recreation and flood control. Generally, many communities living in counties located in the lake watershed are dependent on the resources provided by the lake.

Among the six designated uses of waterbodies listed by Georgia's *Rules and Regulations for Water Quality Control* (GA EPD 2013), "Recreation" and "Drinking water supply" apply for Lake Lanier. Site-specific criteria for Lake Lanier were developed by the Georgia Department of Environmental Protection. The TMDL calls for a reduction in nitrogen and phosphorus loads. Point sources at Lake Lanier include discharge from municipal, industrial and private facilities. A total of 33 point sources exist in the lake watershed, with nine of them directly discharging into the lake. Non-point sources at Lake Lanier are farms and livestock, urban development, OWTS, landfills and wildlife.

Onsite wastewater treatment systems consist of a septic tank and a drainfield. The septic tank receives the wastewater from a house, separates the liquid phase from the solid phase and initiates treatment. The partially treated effluent then exits the tank and enters a system of trenches surrounded by a substrate of gravel, other coarse-textured synthetic material, or a chamber. This section is called the drainfield where the effluent is released from the trenches into the soil and treated through adsorption processes and microbiological degradation.

Household wastewater contains high levels of N, P and coliforms: in raw wastewater, total N concentrations can vary from 20 mg/L to 85 mg/L (Henze and Comeau, 2008; Lowe et al., 2009; Sedlak,1991) while P concentrations may be as high as 10 mg/L (Lowe et al., 2009). If installed and loaded properly, OWTS can remove up to 50% of N in clay soils (Bradshaw et al. 2013) but normally, as Van Cuyk et al. (2001) stated, conventional OWTS are capable of removing N at a rate varying from 10 to 20%. Bradshaw et al. (2012) estimated a total N load from OWTS to groundwater comparable to intense agricultural losses. Chloride can be used as a conservative (does not transform) tracer for OWTS effluent and typical concentrations are in the range 20-50 mg/L for homes (McQuillan, 2005). Bradshaw et al. (2012) found that the mean Cl concentration in effluent was 42 mg/L. Total N concentrations are usually similar to Cl concentrations in OWTS effluent.

This study is being conducted in cooperation with the Georgia Tech University and is funded by the Gwinnett

County Water Resources (GWR) Department. The overall objectives of the UGA portion of the study are to determine to what extent OWTS are contributing to water quality impairment at Lake Lanier in terms of nutrients and pathogens. Georgia Tech is focusing on lake water quality in the coves along the Gwinnett County shoreline. The GWR objectives and lake work by Georgia Tech are described in separate papers in these proceedings. The specific objective of this paper is to describe the approach taken in the UGA groundwater study and present preliminary results from two home sites. We are using an adaptive management approach and will modify the procedure used at the first two sites, as necessary.

MATERIAL AND METHODS

The study will be carried out in two main parts: monitoring and modeling.

Groundwater monitoring

Site selection has been performed through a comprehensive use of satellite data, analyzed with QGIS and ArcMap software, together with results of surveys and OWTS installation documentation.

This project provides for the groundwater monitoring of nine home sites with OWTS adjacent to the lake. A control site with no OWTS will be included in the study as well.

The study area encompasses two coves situated in the lower part of the lake (mostly Gwinnett County but some homes are in Hall County). For selecting the sites, three main attributes were considered: age of the OWTS, distance to the lake and household water usage. Age was obtained either from OWTS documentation (downloaded from the Gwinnett County website or provided by Hall County in hard copies) or from house-to-house survey results. Distance information was obtained in QGIS with the measuring tool, using the houses shown in the aerial image and the 327-m contour line (full pool lake level) as references. Monthly water usage data for the year 2017 was provided by the Gwinnett County Water Resources Department.

The monitoring wells consist of two sections: a casing and a 1.5-m long screen. Each well was inserted in a hole dug with either a hand auger or with a mechanical digger (Little Beaver Earth Drills and Augers). Sand was applied at the bottom of the well and around the screen while the rest of the well was surrounded by a layer of bentonite mixed with sand. Two transects of wells parallel to the shoreline were placed at each site. The first transect was approximately 1.5 m from the shoreline and designed to intersect the OWTS plume. In this transect, wells were installed in pairs, where each pair had a shallow and a deep well so that we could continue sampling as lake levels fluctuated.

The shallow well was installed 1.5 m below the water table and the deep well was installed 3 m below the water table at Site 1 when the lake level was at 327 m. Shallow and deep wells were positioned 0.6 m apart in each pair. The second transect consisted of just two or three wells approximately 6 m far from the shoreline and it is designed to estimate the hydraulic gradient in the shoreline area. Shoreline wells were installed at Site 2 so that they would have approximately the same water levels when the lake was at 327 m.

A YSI multi-parameter sonde was used to sample the shoreline wells immediately after installation. Using Cl and specific conductivity, the shoreline wells with the highest concentrations were identified and presumed to indicate the location of the OWTS plume. An upslope well transect perpendicular to the shoreline was then installed in an attempt to track the plume. Additionally, a well was placed in the drainfield area and another well was installed in the front of the house (the side away from the lake) as a control well, outside of the OWTS influence.

We installed 25 wells at Site 1 and 26 wells at Site 2. At Site 1 (Figure 1), wells 1 to 16 (8 pairs) are approximately 1.5 m from the shoreline, wells 17 to 19 are approximately 6 m from the shoreline, wells 20 to 23 constitute the upslope transect, well 24 is the control well and well 25 is the well in the drainfield. At Site 2 (Figure 2), wells 1 to 18 (9 pairs) are approximately 1.5 m from the shoreline, wells 19 and 20 are approximately 6 m from the shoreline, wells 21 to 24 constitute the upslope transect (well 22 is also the one that best represents conditions in the drainfield), well 25 is the control and well 26 was installed to verify the results of a Electrical Resistivity Tomography (ERT) test at the site.

Shoreline wells were installed in July 2018 at Site 1 and in October 2018 at Site 2. Upslope wells were installed in August 2018 at Site 1 and in October 2018 at Site 2.

Sampling procedures for wells were as follows. The day before samplin, each well was purged three times in order to remove stagnant water and ensure the collection of a groundwater sample representative of aquifer conditions. Monitoring wells were sampled monthly, filtered and analyzed for Cl using ion chromatography in the GWR lab.

A YSI multiparameter sonde was also used in the field for the measurement of temperature, specific conductivity, pH and dissolved oxygen at each well. At each purging and sampling event the water table level was measured for the estimation of the hydraulic gradient and of the approximate volume of water contained in each well.

Well samples have been taken monthly starting in August 2018 at Site 1 and October 2018 at Site 2. Sampling in December was skipped due to a late November sampling. Upslope wells at both Site 1 and Site 2 did not have enough water to analyze in certain months.

Figure 1. Site 1 showing the shoreline wells, W1-W16. OWTS septic tank and drainfield are upslope from well W23 (Bing Maps).

Figure 2. Site 2 showing the shoreline wells, W1-W18. OWTS septic tank and drainfield are near well W24 (Bing Maps).

Groundwater modeling

The software we are using for the modeling component is HYDRUS 2D/3D Version 2 (Šimůnek et al., 2018). The code develops a finite element numerical solution to the transport equations for saturated/unsaturated water flow and solute transport. We are using a four-step process to extrapolate the monitoring data from home sites to the entire Gwinnett County shoreline (Table 1).

Table 1. Four-step modeling approach.

Step	Process
Calibrate HYDRUS site-specific models	Calibrate HYDRUS 2D models using data from three home sites selected to represent variability in homes along Gwinnett shoreline.
Develop HYDRUS box model	Develop a HYDRUS 2D box model that has the essential features of the site specific models, but simpler geometry. Determine what factors are most sensitive such as slope, distance, number and location of septic system, type of system, number of people in the home, soils, and vegetation cover.
Run HYDRUS box model scenarios and develop statistical model	Determine type and number of HYDRUS model scenarios that are needed to represent all of the homes that are present in the Gwinnett shoreline including factors that are not covered in nine monitored homes. Run scenarios and use results to develop a simple statistical model to predict the average annual loads.
Use statistical model to estimate shoreline loads	Use the statistical model to calculate the average annual load for each home along the Gwinnett shoreline based on site characteristics (slope, distance, water use, system size, age, water use, etc).

RESULTS AND DISCUSSION

Groundwater monitoring results

Preliminary results of the well sample analyses showed localized high levels of Cl at both Site 1 and Site 2 (Figure 3 and Figure 4) and specific conductivity that suggested the shoreline wells intercepted the plume. Chloride concentrations were as high as 21 mg/L at Site 1 in January and 77 mg/L at Site 2 in February 2019.

Specific conductivity values were as high as 215.5 µS/m at Site 1 in August and 289.1 µS/m at Site 2 in October, 2018 (data not shown). At Site 1, the plume seemed to be near the center of the shoreline transect (shallow wells) or on the left and center of the transect (deep wells) when facing the home from the lake (Figure 3). At Site 2, both shallow and deep wells indicated that the plume was on the left side of the transect (Figure 4). Concentrations decreased slightly with time and this was probably due to increased rainfall starting in September of 2018 that diluted the Cl concentrations.

Groundwater modeling results

The two-dimensional HYDRUS hillslope model specific to Site 2 is shown in Figure 5. It contains three soil layers: a sandy loam A horizon, a clay B horizon, and a clay loam BC (saprolite) horizon. The left boundary is the top of the ridge and the right boundary is the lake. The OWTS drainfield is about 16.7 m downslope from left boundary. The soil surface is the top boundary and bedrock is the bottom boundary. The arrow points to an observation point near the lake where the shoreline well screens are located.

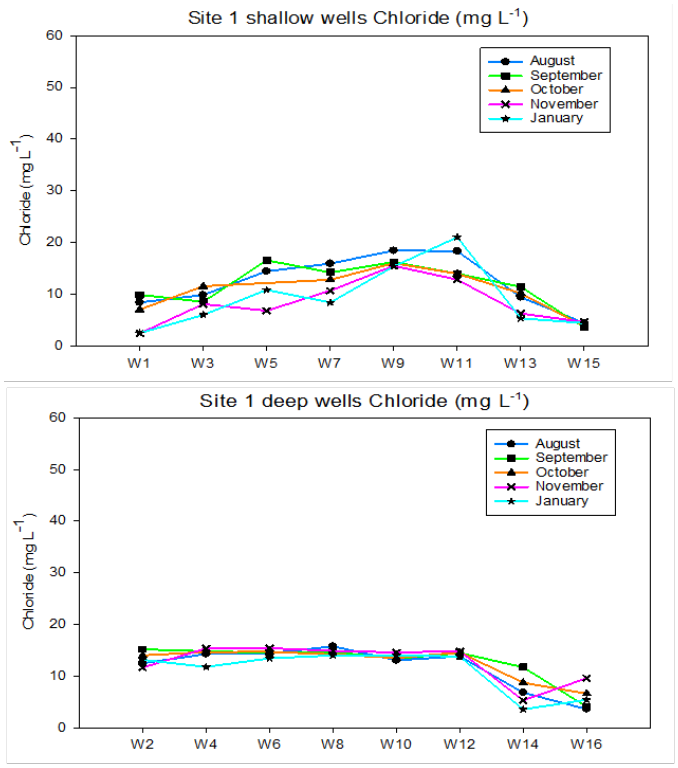

Figure 3. Concentrations of Cl (mg/L) in water sampled from the shoreline shallow and deep wells at Site 1.

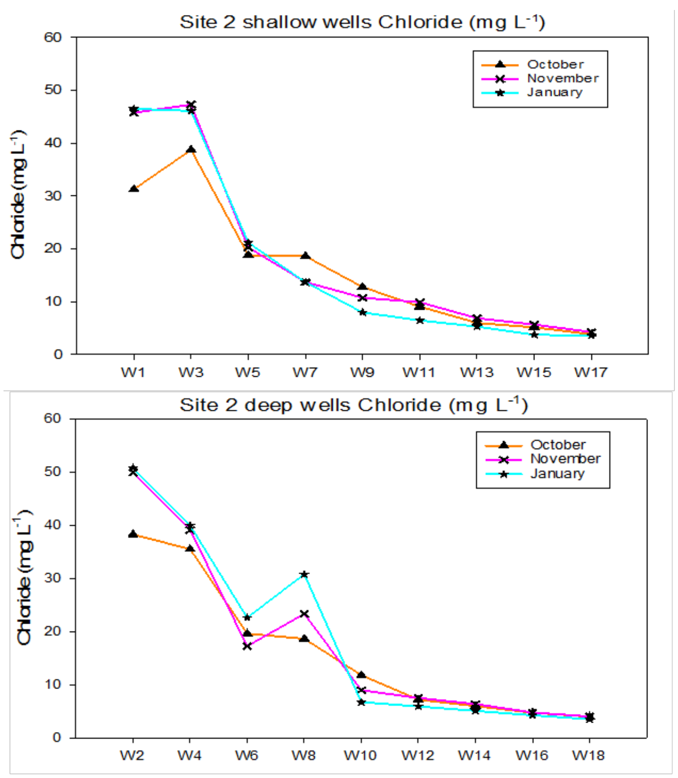

Figure 4. Concentrations of Cl (mg/L) in water sampled from the shoreline shallow and deep wells at Site 2

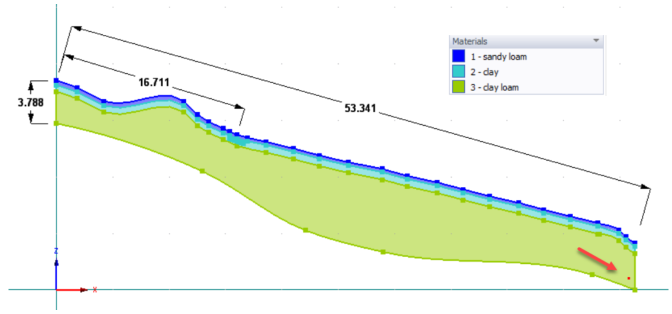

Figure 5. HYDRUS-2D hillslope model for Site 2. The red arrow points to an observation point.

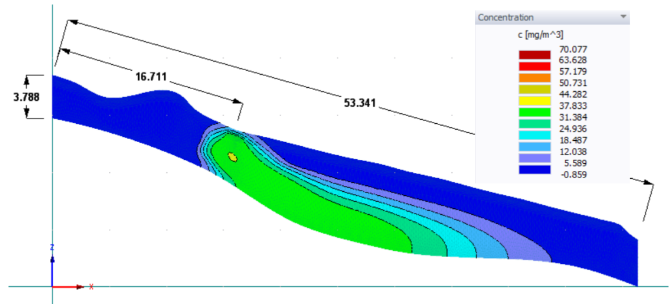

Figure 6. HYDRUS-2D hillslope model for Site 2 showing Cl concentrations after about 4 years (1460 days).

We used nine years of weather data (beginning of 2010 to end of 2018) from a weather station near Buford Dam to run the model. Lake levels at the right boundary were varied according to daily lake elevation data from the USGS. Average water use from Gwinnett County Water Department for the home at Site 2 in 2018 was used to load the drainfield which consisted of seven nodes situated in the second soil layer (Figure 5).

Simulated Cl concentrations after about four years (1460 days) are shown in Figure 6. We assumed Cl concentrations in the drainfield were 40 mg/L based on McQuillan (2005), Bradshaw et al. (2012), and total N concentrations measured in a well at Site 1 that was in the drainfield. The OWTS Cl plume moved down in the unsaturated zone just below the drainfield and then laterally in the saturated zone above the bedrock. After four years, the leading edge of the plume was about 10 m from the lake.

Simulated chloride concentrations after about 9 years (3280 days) are shown in Figure 7. The plume has reached the lake and concentrations are in the range of 25 to 30 mg/L.

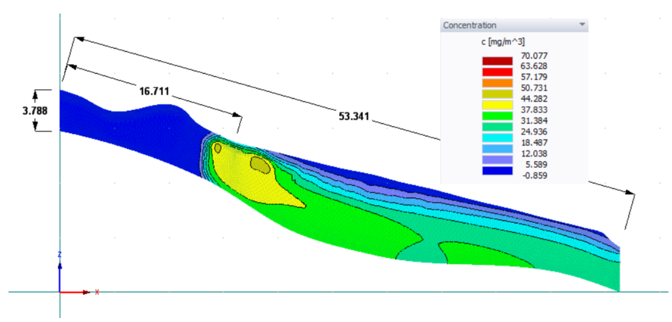

Figure 7. HYDRUS-2D hillslope model for Site 2 showing Cl concentrations after about 9 years (3280 days).

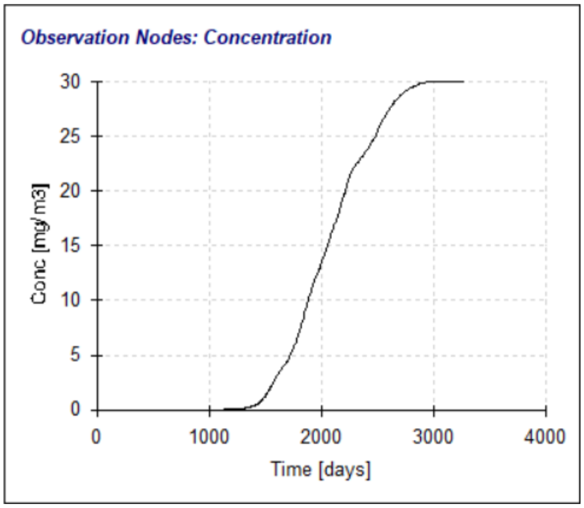

Figure 8. Concentrations of Cl (mg/L) at the observation point for the nine-year simulation of the site specific HYDRUS-2D hillslope model for Site 2.

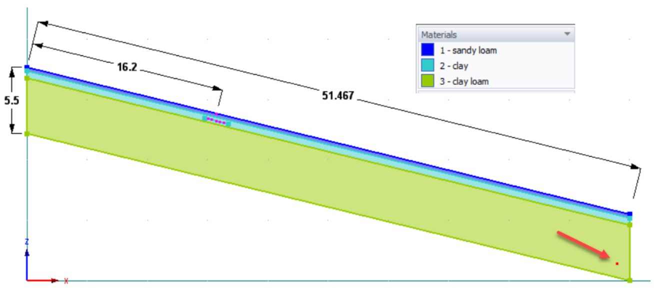

Figure 9. HYDRUS-2D box model for Site 2. The red arrow points to an observation point.

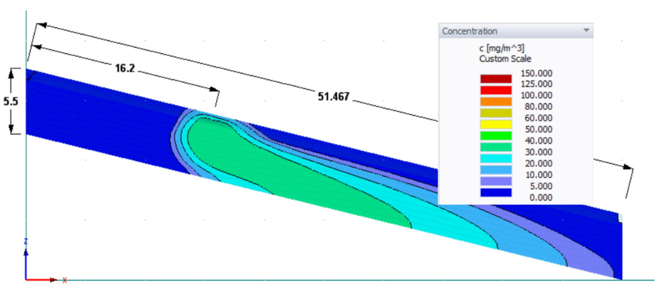

Figure 10. HYDRUS-2D box model for Site 2 showing Cl concentrations after about four years (1460 days).

Concentrations of Cl at the observation point near the lake are shown in Figure 8. The concentrations after 9 years are about 30 mg/L, which is comparable to the concentrations we observed in the plume in Figure 4.

The box model developed as part of Step 2 in the modeling approach (Table 1) for Site 2 is shown in Figure 9. The geometry was simplified to a parallelogram with vertical sides and a slope, slope length, and depth similar to the site-specific model in Figure 5. The same three soil layers were retained, and an observation point was inserted near the lake.

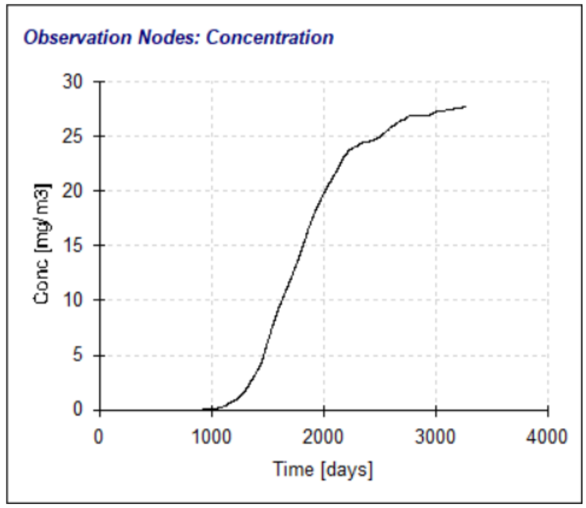

Figure 11. Concentrations of Cl (mg/L) at the observation point for the nine-year simulation of the HYDRUS-2D box model for Site 2.

The predicted Cl using the box model after about 4 years is shown in Figure 10. The pattern was similar to the site-specific model in Figure 6, although the maximum Cl concentrations were higher. Concentrations of Cl at the observation point near the lake using the box model are shown in Figure 11. The concentrations after 9 years were about 27 mg/L and the shape of the curve was similar to the results using the site-specific model (Figure 8).

The ability of the simplified box model to simulate the essential features of Cl movement was encouraging in that this is a model that has fewer nodes (curved boundaries such as those in Figure 5 require smaller finite elements) than the site specific model and runs faster (2.16 hours) than the site specific model (9.25 hours). Because of the simpler geometry it will be easier to vary the slope, slope length, and depth to represent the various types of home sites in Gwinnett County.

CONCLUSIONS

Using shoreline wells at the first two home sites in this study, we found that Cl concentrations were as high as 21 mg/L at Site 1 and 77 mg/L at Site 2. These preliminary monitoring results indicate that our approach can intercept the plume from the OWTS.

A-site specific two-dimensional HYDRUS hillslope model for Site 2 predicted long-term (after 9 years of simulated weather and lake level data from Lake Lanier) concentrations would reach about 30 mg/L. The site specific model seems to be capable of predicting the observed data and the simplified box model looks promising for testing the effects of site characteristic such as slope and distance to the lake.

Overall, our approach to the groundwater component of this study seems to be working adequately and we plan to use this approach for the other sites we will monitor and model.

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