

**Florida Department of Health
Onsite Nitrogen Reduction Strategies Study**

Contract CORCL

**TASK C.15
GCREC MOUND MONITORING
TRACER TEST NO. 1 MEMO**

June 2011

1.0 Background

Task C of the Florida Onsite Sewage Nitrogen Reduction Strategies Study includes monitoring at field sites in Florida to evaluate nitrogen reduction in soil and groundwater, to assess groundwater impacts from various onsite wastewater systems, and to provide data for parameter estimation, verification, and validation of models developed in Task D. The existing mound system at the Gulf Coast Research and Education Center (GCREC) is being monitored to serve as a bridge between the controlled GCREC pilot-scale testing conducted within the same type of soils and the uncontrolled monitoring at home sites in different soils throughout the state. The Task C objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the GCREC existing mound system site have been documented in previous reports.

2.0 Purpose

This memo documents the tracer test that was conducted at the GCREC mound in April, 2011. Tracer testing is a means for characterizing the subsurface by injecting a chemical compound into the subsurface. The test was conducted to assess expected travel times and uniformity of flow. It is an indirect method as aquifer properties are inferred from an observed behavior that is compared with a mathematical model. It follows that the test results are not unique, i.e. different aquifer descriptions can result in a given tracer test result. Of note, a tracer test is simply a method used to infer flow properties of the subsurface; hence, the only goal of a tracer test is to answer a question posed regarding flow and storage properties of a given medium.

3.0 Materials and Methods

3.1 Experimental Location and Design

The tracer test was conducted at the GCREC test facility located at the University of Florida Gulf Coast Research and Education Center (GCREC) in southeast Hillsborough County, Florida. The facility is situated on 475 acres of land that were donated by Hillsborough County govern-

ment. The test was conducted within the research site and in soils representative of the area where the existing nitrogen plume is located, but in an area that would not interfere with monitoring of the plume (Figure 1).

Prior to designing the test the direction of the groundwater flow was determined (220 degrees to true north). The groundwater elevations have been monitored over several months, and although the elevations fluctuate due to the season and due to precipitation events, little change in flow direction has been observed. Consequently, it was decided to deliver the tracer solution to an open-air trench that was positioned perpendicular to the groundwater flow (Figure 2). The trench was 5 feet long (perpendicular to flow) and 1 foot wide. Drive point piezometers were installed beneath the trench and in several rows down gradient of the trench at 1-foot, 2-feet, and 4-feet from the edge of the trench. Additional drive points were installed after the test had begun (Figure 2). The elevation of the trench bottom was estimated to be 6 inches or less above the groundwater, thus the delivered tracer solution was assumed to enter the saturated zone quickly (Figure 3).

Generally, the tracer is injected in as short a time as possible (a *spike* of tracer), but because groundwater velocity is typically low and tracer residence time relatively large, tracer injection may occur over the course of hours and still be considered spike injection. The tracer loading rate is typically 10% of the hydraulic conductivity (K_{sat}). K for the fine soil at the GCREC was assumed to be 1000 cm/day yielding a loading rate of 100 cm/day (~25 gallons/ft²/day). As the area of the trench was 5 square feet, a loading rate of 125 gallons/day was chosen. The tracer solution was made in a 250-gallon tank positioned adjacent to the trench (Figure 4). A peristaltic pump delivered the tracer solution to a PVC pipe (in which several holes were drilled) that was placed at the trench bottom (Figure 5). The solution was obtained from the middle of the 250-gallon tank.

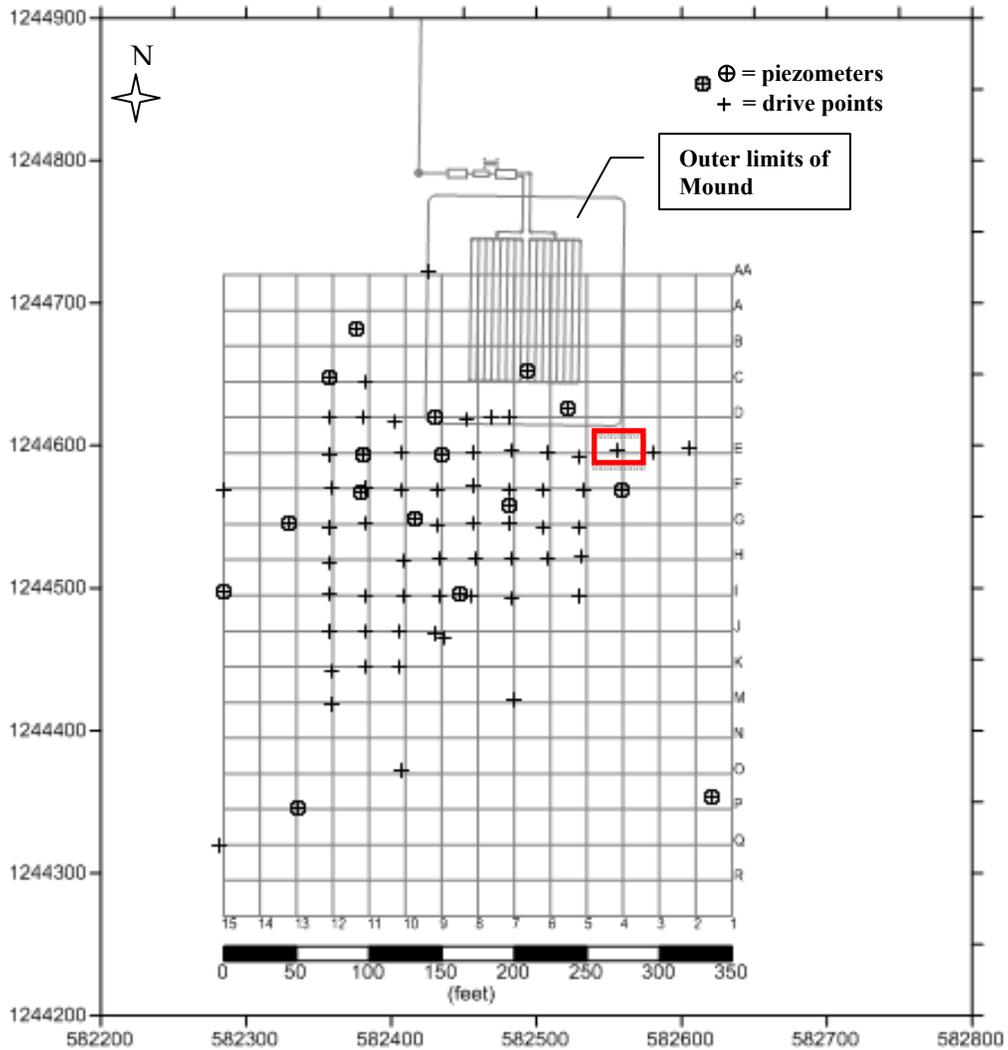


Figure 1
Schematic of GCREC Monitoring Network (UTM coordinates are used). The red box illustrates the location of the tracer test (Figure 2 illustrates a bigger picture of the same area)
 ⊕ denotes piezometers and + denotes drive points

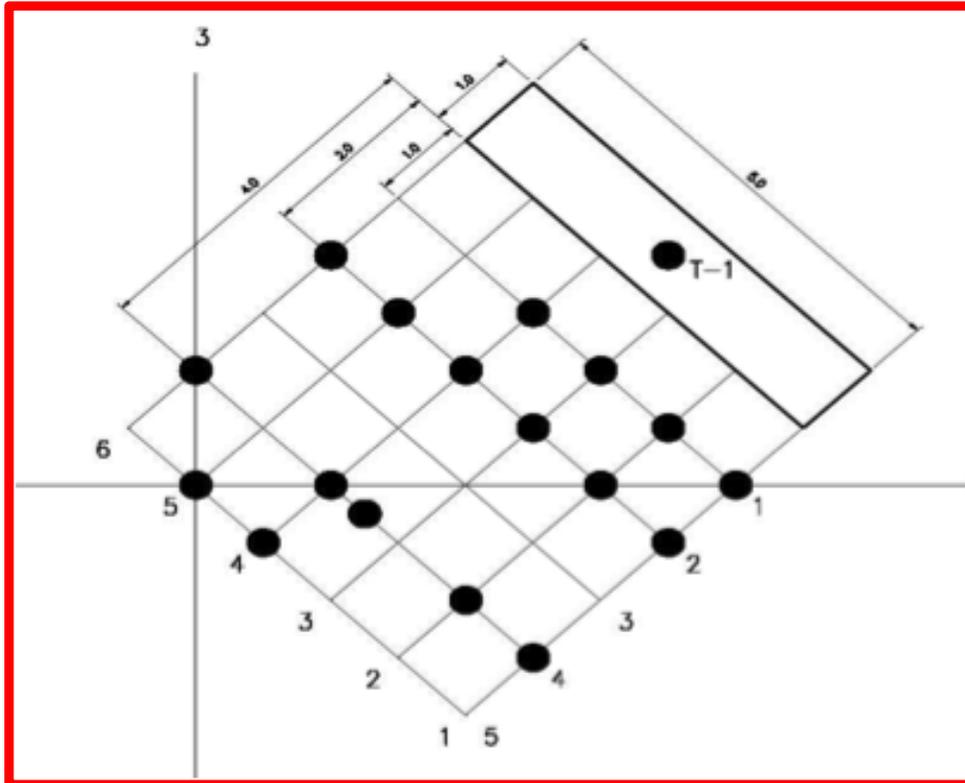


Figure 2

Enlarged schematic illustrating the area of the tracer test. The black dots depict the locations of the drive points.



Figure 3
The trench with drive point tubing.



Figure 4
The 250-gallon tank containing the tracer solution.



Figure 5
The PVC pipe delivering the tracer solution to the trench.

3.2 Tracer Solution and Standards

Tracers are usually chemical or radioactive compounds that flow in a fluid phase without altering the transport properties of the phase. Bromide (Br⁻) was chosen as the most appropriate tracer as it is conservative, and thus representative of the water movement through soil (although some diffusion from mobile to immobile water may occur). A target bromide concentration of 10,000 ppm was selected to ensure detection of the tracer in downgradient locations. To prevent density profiles the solution was mixed on site. A submersible pump to which a PVC stirring tree was attached was placed inside the 250-gallon tank to ensure that the solution was mixed during the experiment.

Seven bromide standards (ranging from 10 ppm to 10,000 ppm) were made prior to the start of the tracer test. The standards were used to make a calibration curve to which the probe could be calibrated. Two sets of bromide standards were made using two different methods (Stock 1 and Stock 2). The first method (Stock 1) used serial dilution as shown in Table 1, while the second method used standard dilution as shown in Table 2. After the standards were made, they were measured with a bromide ion selective electrode (ISE) connected to a pH/mV meter. The resulting readings (in mV) for the two sets of standards are shown in Table 3, and the calibration curves associated with the standards is illustrated in Figure 6.

Table 1. Stock 1 preparation method

CONCENTRATION	DILUTION	PREPARATION
10,000 ppm = A	1:1	14.8 g of KBr in 1,000 mL
5,000 ppm = B	1:2	500 mL of A plus 500 mL DI in 1000 mL flask
1,000 ppm = C	1:10	200 mL of B plus 800 mL DI in 1000 mL flask
500 ppm = D	1:20	500 mL of C plus 500 mL DI in 1000 mL flask
100 ppm = E	1:100	200 mL of D plus 800 mL DI in 1000 mL flask
50 ppm = F	1:200	500 mL of E plus 500 mL DI in 1000 mL flask
10 ppm	1:1000	200 mL of F plus 800 mL DI in 1000 mL flask

DI = deionized water

Dilution factor expressed as: volume of analyte:total volume

Table 2. Stock 2 preparation method

CONCENTRATION	DILUTION	PREPARATION
10,000 ppm = A	1:1	14.8 g of KBr in 1,000 mL
5,000 ppm	1:2	250 mL of A plus 250 mL DI in 500 mL flask
1,000 ppm	1:10	50 mL of A plus 450 mL DI in 500 mL flask
500 ppm	1:20	25 mL of A plus 475 mL DI in a 500 mL flask
100 ppm	1:100	5 mL of A plus 495 mL DI in 500 mL flask
50 ppm	1:200	2.5 mL of A plus 497.5 mL DI in 500 mL flask
10 ppm	1:1000	0.5 mL of A plus 499.5 mL DI 500 mL in flask

Table 3. The mV equivalent for each of the two methods for the seven standards.

Bromide Stock 1	Bromide Stock 2	Br Concentration
(mV)	(mV)	(ppm)
104.9	106	10
69.2	69.2	50
53.9	56.4	100
16.2	19.4	500
0.3	1.7	1000
-38.5	-37.8	5000
-54.5	-54.2	10000

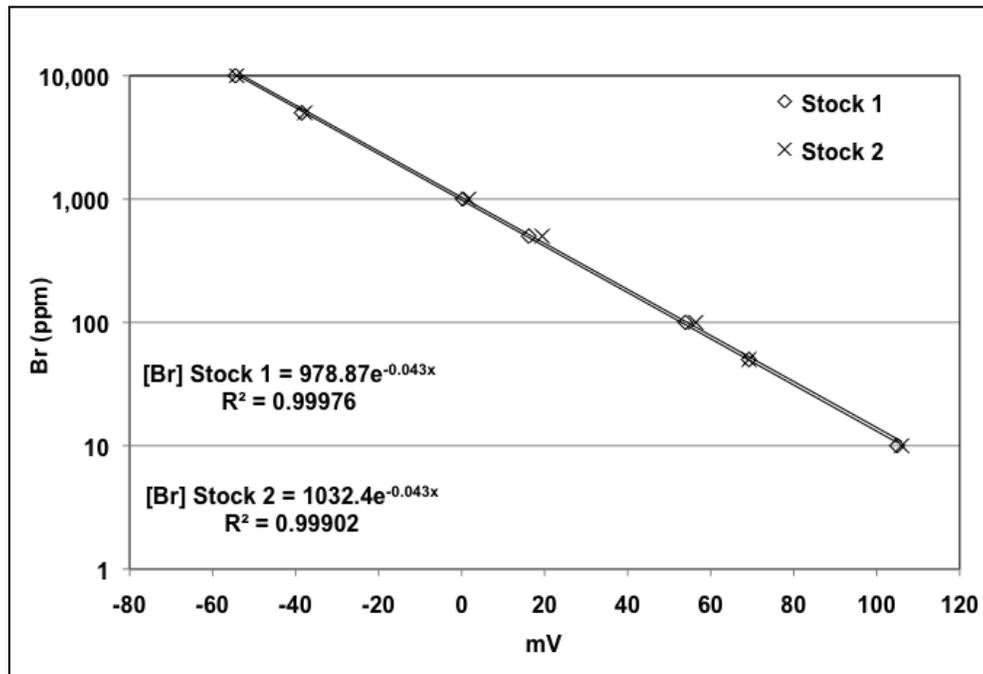


Figure 6
Bromide calibration curves for both Stock 1 and Stock 2.

3.3 Analysis

All analyses were conducted in the field. A peristaltic pump was used to collect the samples from each drive point. The well water was first purged until water quality indicators (turbidity) is stabilized. Groundwater was collected in a 100 ml beaker, a 10 ml sample was taken from the beaker using a pipette and placed in a 50 ml beaker, and 2 ml of 5M NaNO₃ ion strength adjustment solution (ISA) was added to each sample. A bromide ISE connected to a pH/mV meter or ion meter was used to measure the mV of the tracer solution. In addition, the concentration of the bromide solution in the 250-gallon tank was measured prior to and during the tracer test to ensure proper mixing of the solution.

4.0 Results

4.1 Bromide Breakthrough Curves

The tracer test was conducted at the GREC field site in April of 2011. Bromide solution was added to the trench for 27 hours at a loading rate of ~5.2 gallons/hour, after which clean water was added for 23 hours at the same loading rate. Samples were taken at the drive points starting with the closest one to the trench and continuing with those placed further away. One set of samples took on the average 30 minutes. Samples were collected 24/7 for five days, after which samples were taken less frequently. Breakthrough curves will be generated for all drive point locations as the data gets compiled. To date breakthrough curves have been generated for three locations at the 2-foot row of drive points (Figure 7). At these locations, the bromide tracer breakthrough started at approximately 24 hours after injection, and the peak occurred at approximately 40 hours after injection. Additional analysis of the data is necessary before any conclusions can be made.

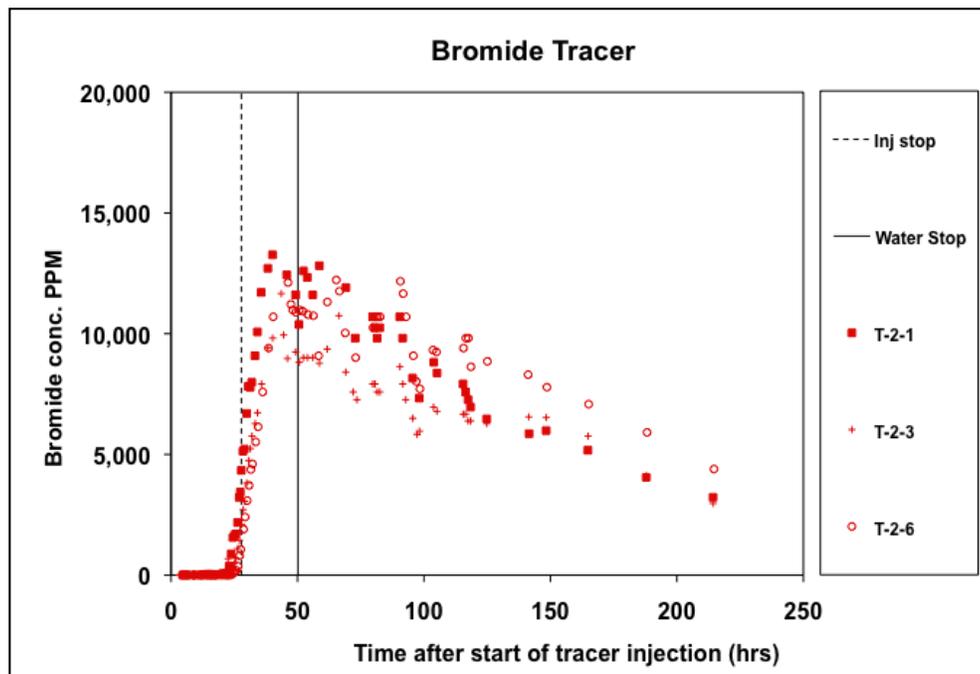


Figure 7
Breakthrough curve for three drive points at the 2-foot row

4.2 Groundwater Velocity Estimations

The linear velocity (v) of the groundwater can be estimated using Darcy's law as follows:

$$v = \frac{K * \text{gradient}}{n_e}$$

where K is the hydraulic conductivity, and n_e is the effective porosity. If one assumes that K for fine sand is approximately 33 ft/day and n_e for fine sand is 0.33, then the linear velocity would range from 0.66 to 0.94 ft/day. As both the hydraulic conductivity and the effective porosity are estimations, using the results from the breakthrough curves may provide better estimates of the average linear velocity using the follow two equations developed by Huang (1991):

$$U_{\max} = \frac{t_1 t_{\max}}{t_1 - t_{\max}} \ln \frac{C_1 \sqrt{t_1}}{C_{\max} \sqrt{t_{\max}}}$$

$$V = \sqrt{\frac{2U_{\max} - t_{\max}}{2U_{\max} - t_1}} \frac{x}{t_{\max}}$$

where C_{\max} is the max concentration and t_{\max} is the time associated with C_{\max} , C_1 is the concentration at time t_1 , x is the distance to the injection point, and V is the estimated average linear velocity. Additional analysis is necessary and will provide better estimations of the linear velocity, after which the hydraulic conductivity can be calculated using Darcy's Law. In addition, the CXTFIT Code for estimating transport parameters from field tracer experiments may be used for estimating transport parameters (Toride et al. 1995).

References

- Huang, H., 1991. On a One-Dimensional Tracer Model. *Ground Water* 29 (1):18-20.
- Toride, N., F.J. Leij, and M.T. Van Genuchten. 1995. *The CXTFIT code for estimating transport parameters from laboratory or field tracer experiments, Version 2.1*. Research Report No. 137. Prepared for US Salinity Laboratory, USDA, ARS, Riverside CA