Evaluation of Nitrogen Reduction from Onsite Wastewater Treatment Systems as Provided by Soils and Shallow Groundwater

by

Maria B Tucholke

Kathryn S Lowe, Damann Anderson, Josefin Edeback

NEHA 2011 AEC – OWS Summit

June 18th, 2011

Project Background

- The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Project was initiated in 2009
- The project aims to further develop more "passive" & cost-effective nitrogen reduction strategies for OSTDS
- Directed by FDOH
- Collaborative effort between:
  - Hazen and Sawyer, P.C.
    - Damann Anderson, Josefin Edeback
  - Colorado School of Mines
    - Dr. Siegrist, Dr. McCray, Dr. Geza, Kathryn Lowe, Maria Tucholke
  - Applied Environmental Technology
    - Dr. Smith
  - Otis Environmental Consultants, LLC
    - Dr. Otis

FOSNRS Study Objectives

- Task A:
  - Nitrogen treatment and removal options for Florida
- Task B:
  - Performance verification of nitrogen removal in full scale systems
- Task C:
  - Evaluation of N reduction in Florida soil and groundwater
- Task D:
  - Decision support tools for OSTDS planning & mgmt; N-removal goals for Florida

HAZEN AND SAWYER
Environmental Engineers & Scientists

Task C – Goal and Objectives

The overall goal of Task C is to critically characterize nitrogen reduction in Florida soils and groundwater

- Objectives:
  - determine the cumulative mass loading of N to the soil and groundwater
  - identify how currently designed and implemented OSTDS perform
  - understand treatment processes involved
  - obtain/refine parameter for model inputs

HAZEN AND SAWYER
Environmental Engineers & Scientists

Task C - Approach

- Characterization of nitrogen from onsite wastewater treatment systems in sandy soils
- Delineation of a nitrogen plume in shallow groundwater at existing mound
- Conduct tracer tests to obtain relevant site information for future modeling (Task D)
- Evaluation of nitrogen transformations
- Mini-mounds & Home-sites
  - Controlled fieldwork

HAZEN AND SAWYER
Environmental Engineers & Scientists

Presentation Overview

- 1. Field site
  - Description of GCREC
- 2. Installation of monitoring points
  - Drive-points and piezometers
- 3. Monitoring groundwater elevations
  - Determine direction, gradient & velocity
- 4. Water quality analysis
  - Field & analytical parameters
  - Nitrogen plume delineation
- 5. Tracer test
- 6. Next step

HAZEN AND SAWYER
Environmental Engineers & Scientists

1. Field Site

Source: http://gcrec.ifas.ufl.edu/

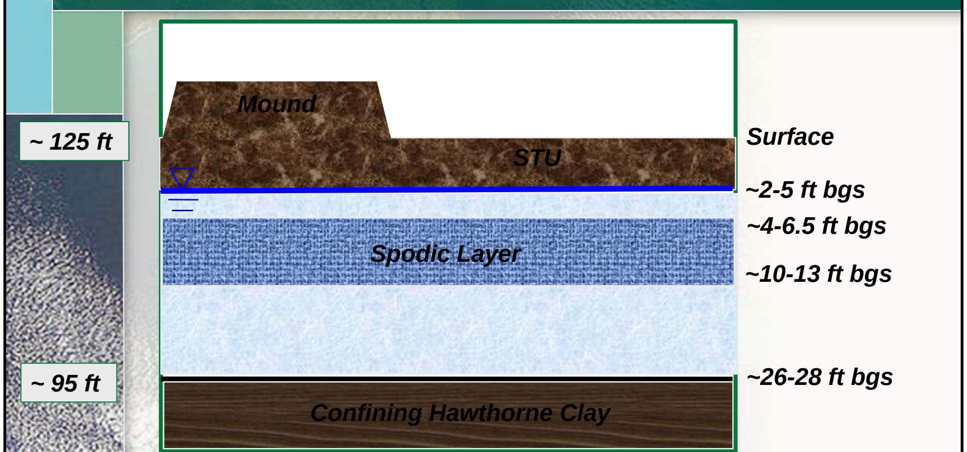
- The GCREC mound is located at the University of Florida Gulf Coast Research and Education Center (GCREC) in SE Hillsborough County, Florida
- GCREC conducts agricultural research & trials for vegetables, fruit and ornamental plants
- 16 laboratories housed onsite (1 water quality lab), offices and housing

1. Field Site

- Wastewater from the GCREC research offices and onsite dormitories flow to an existing OSTDS
- The OSTDS consists of a pressure dosed mound system designed for 2,850 gallons/day
- Two septic tanks (2,500 and 1,250 gallons) provide primary treatment followed by a dosing tank (3,000 gallons)
- The mound soil treatment unit has 4,351 ft^2 of infiltrative area (design hydraulic loading rate of 0.65 gpd/ft^2)

1. Field Site

1. Field Site



Conceptual picture of subsurface at the field site
All elevations are in feet above sea level

2. Installation of Monitoring Points

6620 Geoprobe

Diedrich 120

HAZEN AND SAWYER
Environmental Engineers & Scientists

2. Installation of Monitoring Points

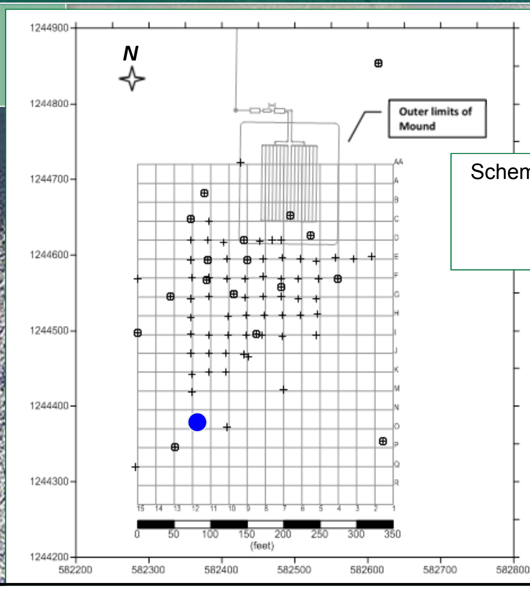
121 Drive Points were installed
(Stainless steel, with mesh screen, umbrella and tubing to the surface)

4 DP above spodic layer
54 DP within the spodic layer
63 DP below spodic layer

26 Piezometer were installed
(¾-in., 1¼-in., or 2-in. diameter PVC with 1-ft, 4-ft, 5-ft, or 10-ft long screens and risers extending to the ground surface)

HAZEN AND SAWYER
Environmental Engineers & Scientists

2. Installation of Monitoring Points



Schematic of GCREC Monitoring Network
(UTM coordinates are used)
⊕ denotes piezometers
+ denotes drive points

HAZEN AND SAWYER
Environmental Engineers & Scientists

3. Groundwater Monitoring

Groundwater elevation measurements

↓

Generate contour map

↓

Determine the direction of flow

↓

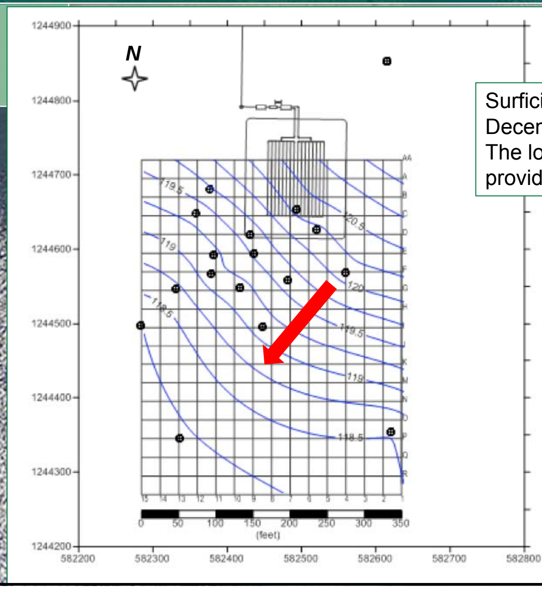
Calculate gradient

↓

Estimate linear velocity

HAZEN AND SAWYER
Environmental Engineers & Scientists

3. Groundwater Monitoring



Surficial Groundwater Contours
December 9, 2011
The locations of the piezometers are provided for reference

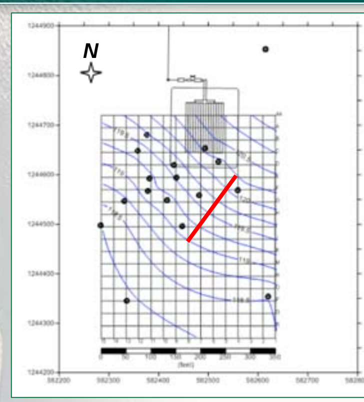
Direction of flow:
~ 220 degrees

HAZEN AND SAWYER
Environmental Engineers & Scientists

3. Groundwater Monitoring

Gradient Determination
(Dec 9, 2010)

Red line = 160 ft
Elevation drop = 1.25 ft
Gradient = 0.0078



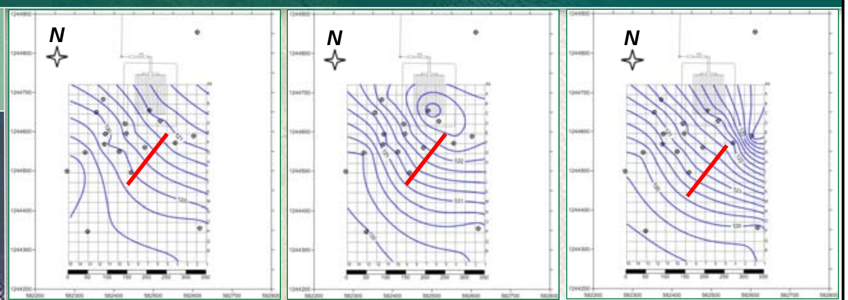
Estimate Linear Velocity (v)

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

K = hydraulic conductivity ➔ K for fine sand ~ 33 ft/day
n_e = effective porosity ➔ n_e for fine sand ~ 0.33
Linear Velocity = 33*0.0078/0.33 = 0.78 ft/day

HAZEN AND SAWYER
Environmental Engineers & Scientists

3. Groundwater Monitoring



Feb 21	Apr 1	Apr 6
Gradient ~ 0.0066	Gradient ~ 0.0094	Gradient ~ 0.0094
Velocity ~ 0.66 ft/day	Velocity ~ 0.94 ft/day	Velocity ~ 0.94 ft/day

Actual hydraulic conductivity may range from 0.05 to 50 ft/day yielding a range in linear velocity of 0.001-1.5 ft/day

HAZEN AND SAWYER
Environmental Engineers & Scientists

3. Groundwater Monitoring - Summary

- 26 piezometers
- Frequent monitoring during the year show:
  - No variation in groundwater flow direction
  - Depth to groundwater varies with the season and with rain events, but there is:
    - Little change in gradient
    - Little change in velocity
- Linear velocity is estimated to be 0.001-1.5 ft/day depending on the actual hydraulic conductivity at site
  - Estimate was used when designing the tracer test

HAZEN AND SAWYER
Environmental Engineers & Scientists

4. Water Quality Analysis

Completed Sampling Events:
December 2010
March 2011

HAZEN AND SAWYER
Environmental Engineers & Scientists

19

4. Water Quality Analysis

Field Parameters

Field Parameters	Range	K2R
Temperature (°C)	20.7-27.5	21.8-22.7
pH	4.2-5.7	4.5-5.0
DO (mg/L)	0.4-3.2	0.5-1.4
Specific conductance (µS)	16[illegible]-8[illegible]	282-342

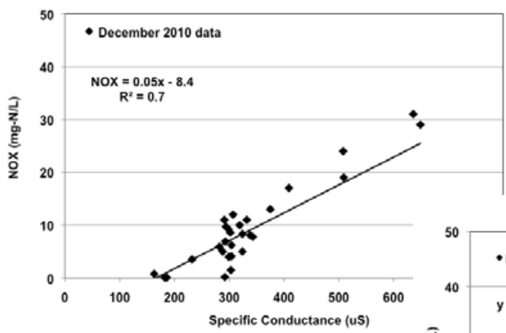
Analytical Parameters:

- total alkalinity (as $CaCO_3$), < 10 mg/L
- total Kjeldahl nitrogen (TKN-N), < 4 mg/L
- ammonia nitrogen (NH_3-N), < 3 mg/L
- nitrate/nitrite nitrogen (NOX-N)
- TOC & DOC

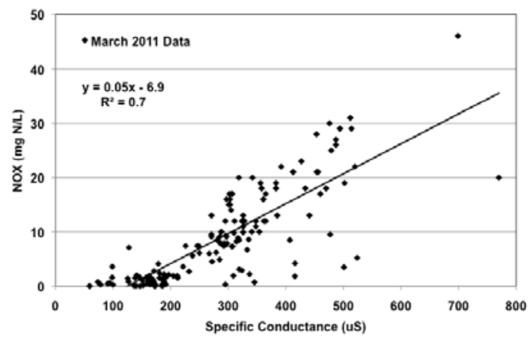
HAZEN AND SAWYER
Environmental Engineers & Scientists

20

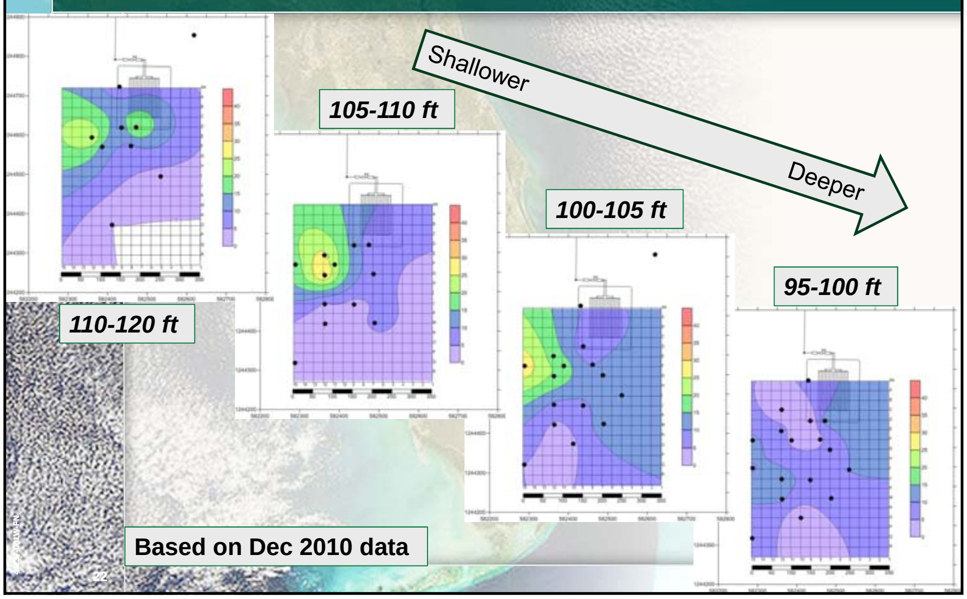
4. Water Quality Analysis



Correlations can be used to estimate design parameters

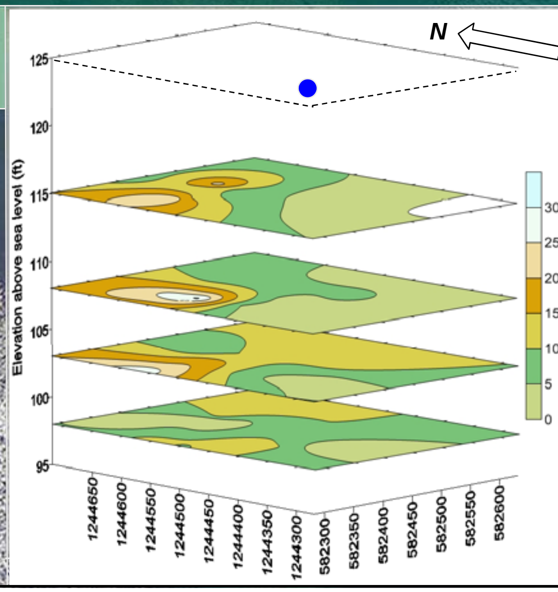


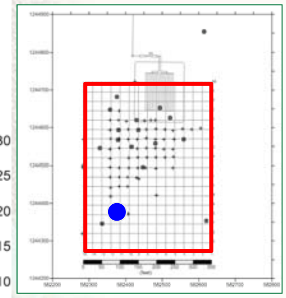
4. Water Quality Analysis – NOX Plume



Based on Dec 2010 data

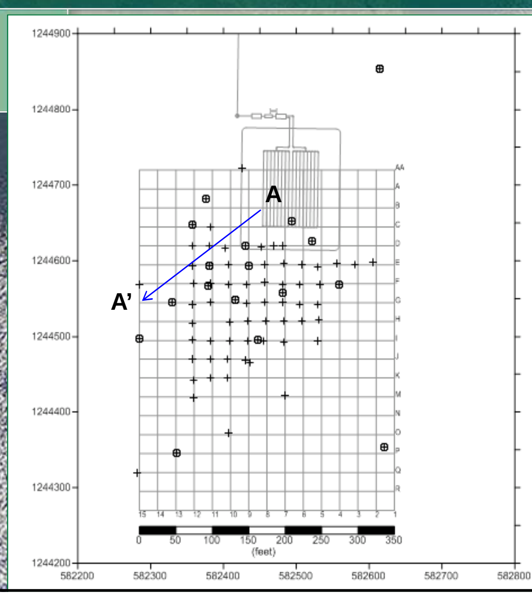
4. Water Quality Analysis – NOX Plume





HAZEN AND SAWYER
Environmental Engineers & Scientists

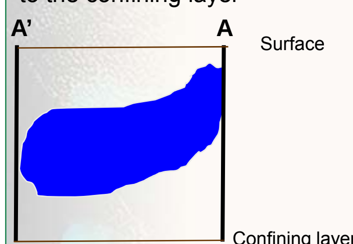
4. Water Quality Analysis – NOX Plume



Highest concentrations of NOX (>10 mg-N/L):

- shallower depths close to mound
- deeper depths further away

Concentrations decrease close to the confining layer



Conceptual picture

HAZEN AND SAWYER
Environmental Engineers & Scientists

4. Water Quality Analysis – Summary

- Field parameters (temp, pH, DO & SC) vary little
- TKN and NH_3-N are consistently low (<4 mg/L)
- Alkalinity is typically low (<10 mg/L)
- Correlation between NOX and Specific Conductance (R^2=0.7)
- Nitrogen plume appears to be confined within 300 feet of mound in a SW direction
  - little vertical gradient keeps the plume relatively depth confined
  - Highest concentrations of NOX are present at 100-110 ft (below spodic layer)

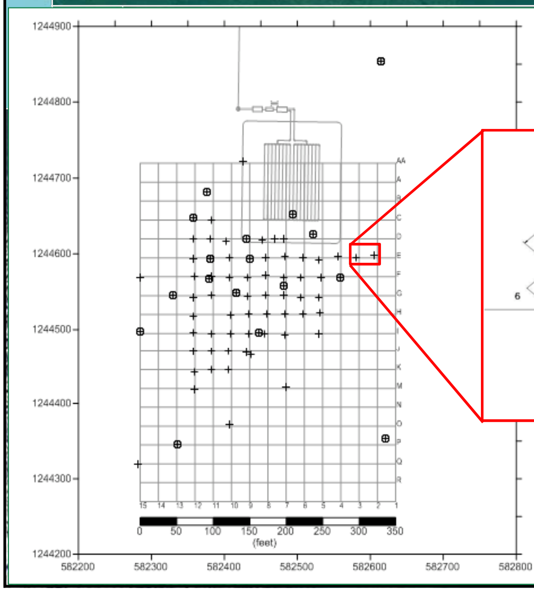
HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test

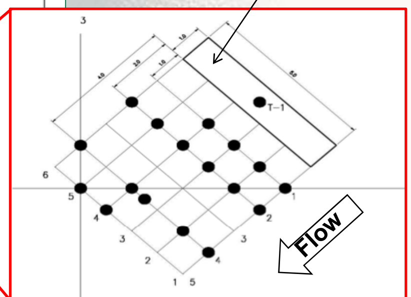
- Characterize aquifer properties
  - Velocity
- Conservative tracer
  - 10,000 ppm Potassium Bromide (KBr)
- Conduct in area that is representative of area of interest without having any negative impacts
- Determine tracer loading rate:
  - Common rate is ~10% of K_{sat}
  - K_{sat} ~ 1000 cm/day ➔ tracer loading ~100 cm/day
  - 100 cm/day = 25 gal/ft^2/day
- Ambient tracer test
  - Dosing an open trench over a period of 27 hours

HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test



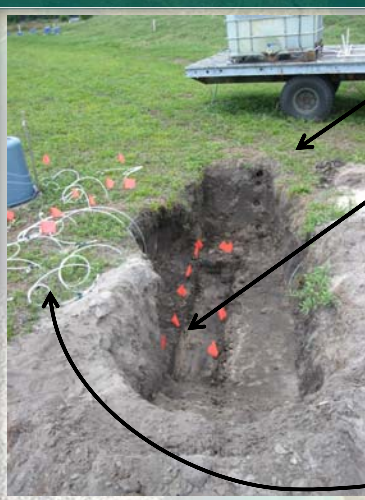
Trench is 5 ft long by 1 ft wide, and perpendicular to direction of flow



Several drive points were installed for monitoring

HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test



Surface: elevation – 126.42 ft

Trench: elevation - 123.77 ft

Installed drive points:
- 10 initial drive points
- 1 x 6” under trench
- 6 x 2’ down gradient
- 3 x 4’ down gradient

HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test – Bromide Solution

250 gallon tank with bromide solution

Submersible pump with stirring tree

Continuous dosing rate - 125 gal/day using a peristaltic pump
Followed by continuous flushing with clean water at the same rate

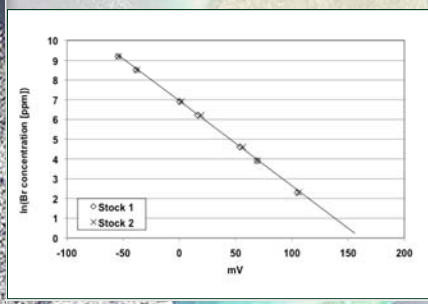
HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test – Dosing Setup

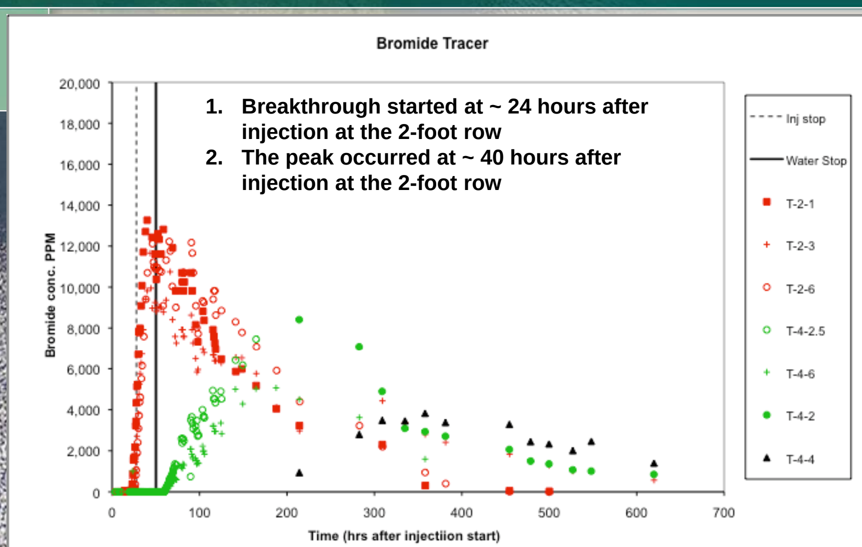
HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test - Measurements

- Samples were collected at all DPs using a peristaltic pump
- Measurements were taken using a bromide meter measuring concentrations in mV
- Concentrations were determined from calibration curves



5. Tracer Test – Breakthrough Curves



5. Tracer Test – Velocity Calculations

The linear velocities were calculated from the breakthrough curves at the 2-foot row using the follow equations developed by Huang (1991):

[illegible]

[illegible]

Early estimates suggest linear velocities from of 0.4-1.2 ft/day

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

Hydraulic conductivity can be calculated using Darcy's Law

Huang, H., 1991. On a One-Dimensional Tracer Model. Ground Water 29 (1):18-20.

HAZEN AND SAWYER
Environmental Engineers & Scientists

5. Tracer Test - Summary

- Total tracer volume ~ 140 gallons
  - Concentration ~ 10,000 ppm
  - Total mass ~ 5.3 kg
- Breakthrough started at ~ 24 hours after injection at the 2-foot row
- The peak occurred at ~ 40 hours after injection
- Average linear velocity is estimated to be 0.4-1.2 ft/day
- Hydraulic conductivity can be estimated
- Additional analysis of the tracer test data will provide further insight into the aquifer properties at the site

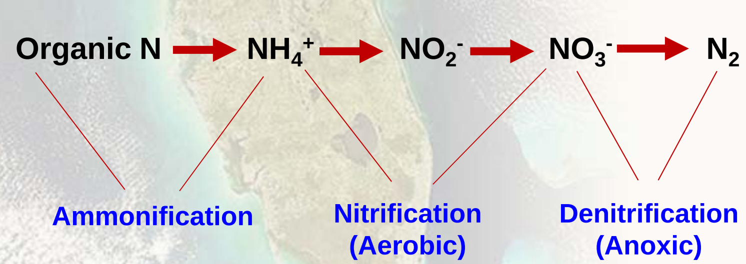
HAZEN AND SAWYER
Environmental Engineers & Scientists

6. Next step – Additional Field Work

- Additional field monitoring
  - Home-sites (4):
    - Evaluate nitrogen reduction in different soil conditions throughout Florida
    - Seasonal variability
  - Controlled field testing at GCREC
    - 4 mini-mounds 20 ft x 2 ft
    - STE & nitrified effluent
    - Groundwater monitoring
- More efficient instrumentation and monitoring
- Results will provide data for parameter estimations, and validations of models developed in Task D

6. Next Step – N transformations

- Gain a better understanding of nitrogen transformations in the groundwater by collecting appropriate data, i.e.:
  - accurately quantify the transformations
  - refine model parameter inputs

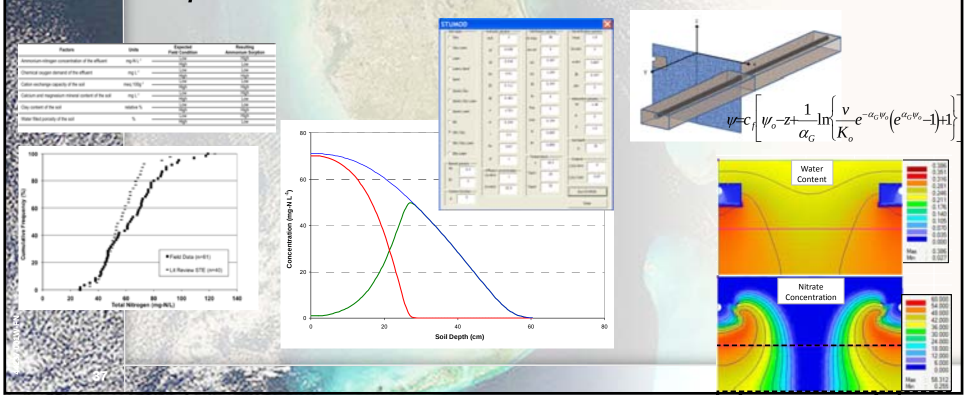


6. Next step – Task D

- Simple tools vs. complex models

increasing complexity

Tables & Graphs	*Spreadsheet Tools*	*Numerical Models*



6. Next step – Task D

- Model Development
  - Adapt existing soil model (STUMOD) for Florida specific conditions
    - Simple to use model can be calibrated to site specific data
    - Based on Darcy's Law and a simplification of the advection dispersion equation
    - Incorporates nitrification and denitrification based on estimates of the water filled porosity
  - Incorporate the effects of evapotransporation and high groundwater tables

Summary

- A monitoring framework has been established at GCREC for the existing mound
- The existing nitrogen plume has been identified
- Direction of groundwater flow has been determined
- Tracer test will provide relevant aquifer properties
- The information gained at the GCREC will be confirmed with additional field work at home sites and more controlled mini-mound work

- Our approach will provide Florida specific information on nitrogen transformations in the soil and groundwater from onsite wastewater treatment systems

HAZEN AND SAWYER
Environmental Engineers & Scientists