Influence of Groundwater Flows and Nutrient Inputs on White Lake Water Quality

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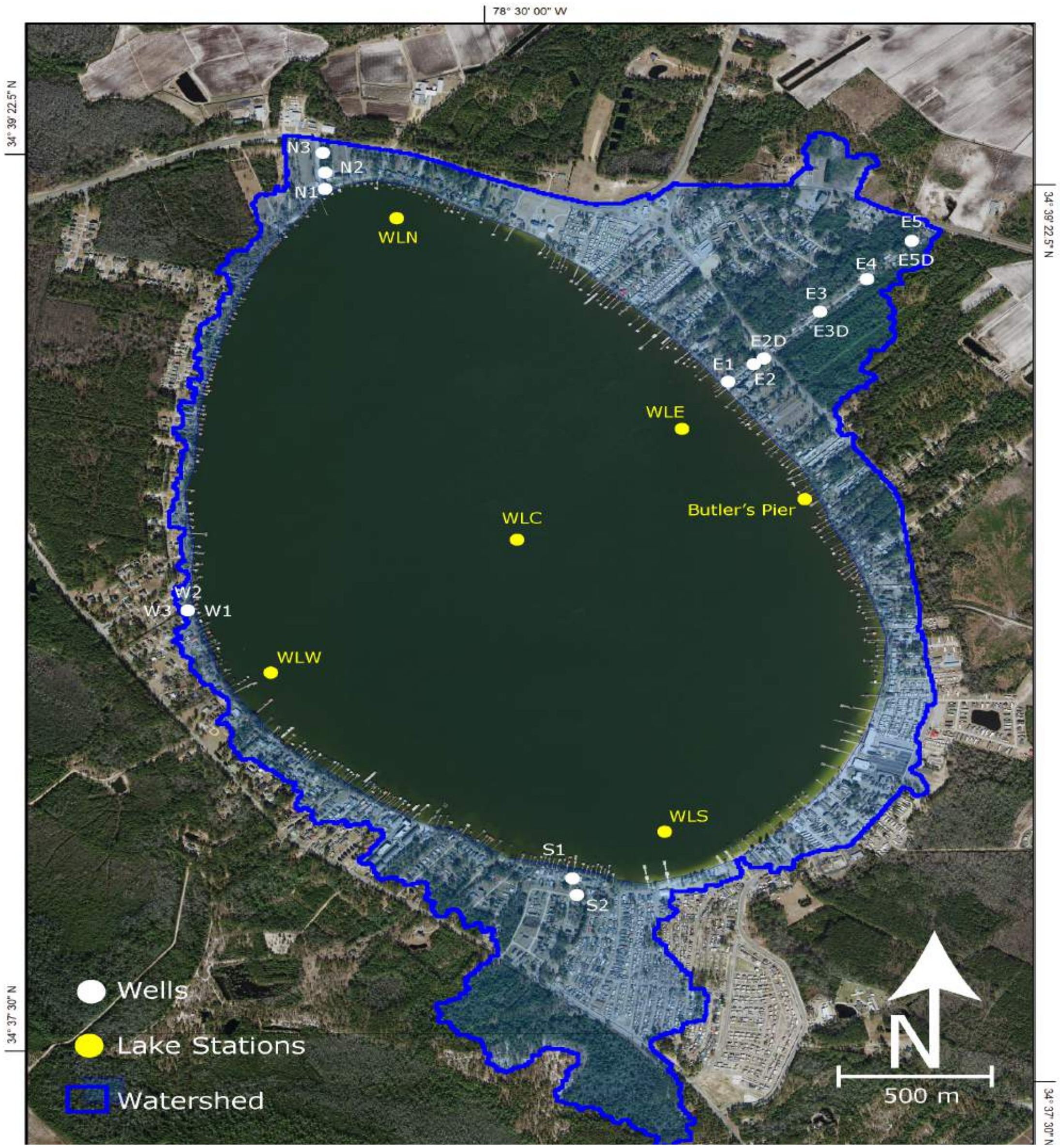


Study Plan

Sampling Locations

5 Lake sites – sampled 8 times

5 GW transects – sampled 6 times

Water Quality in Lake & GW

pH & dissolved oxygen

nutrients

fecal coliform bacteria

Hydrologic Modeling

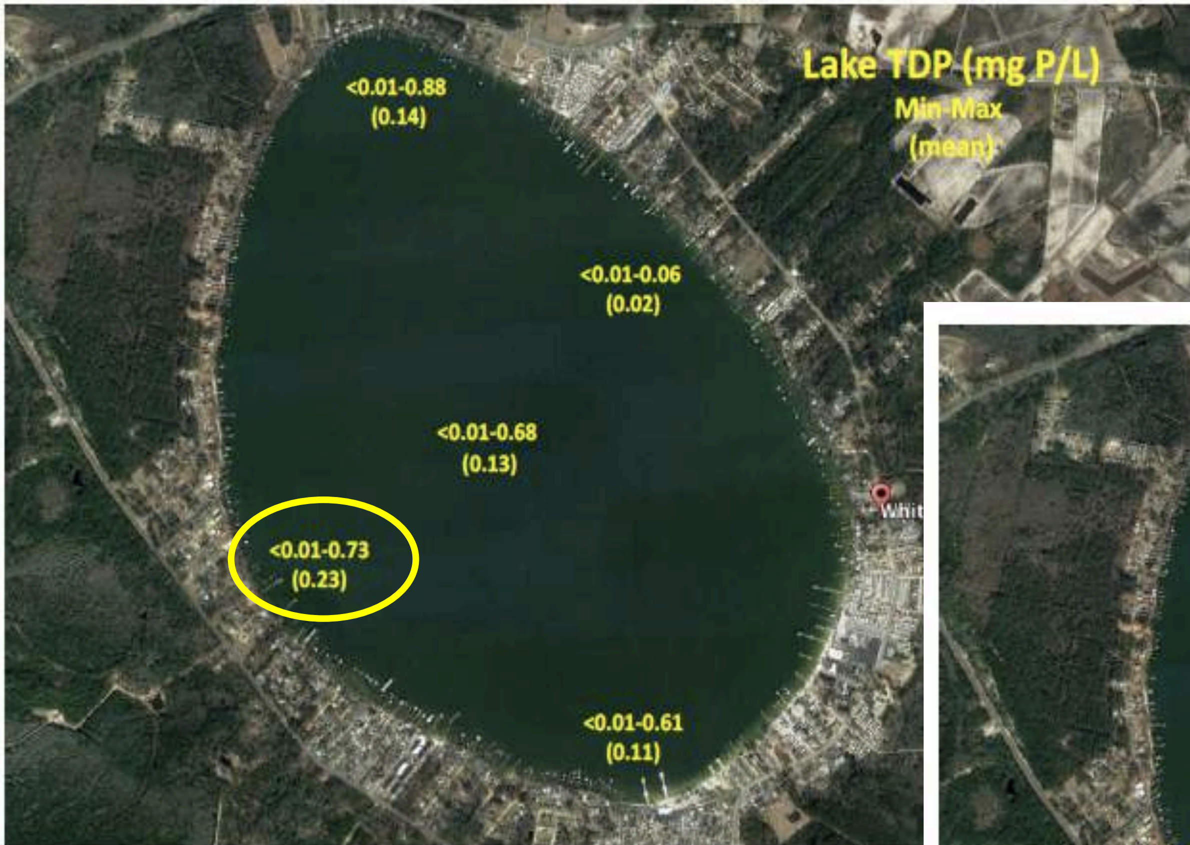
depth to water

water source identification

GW flowpaths

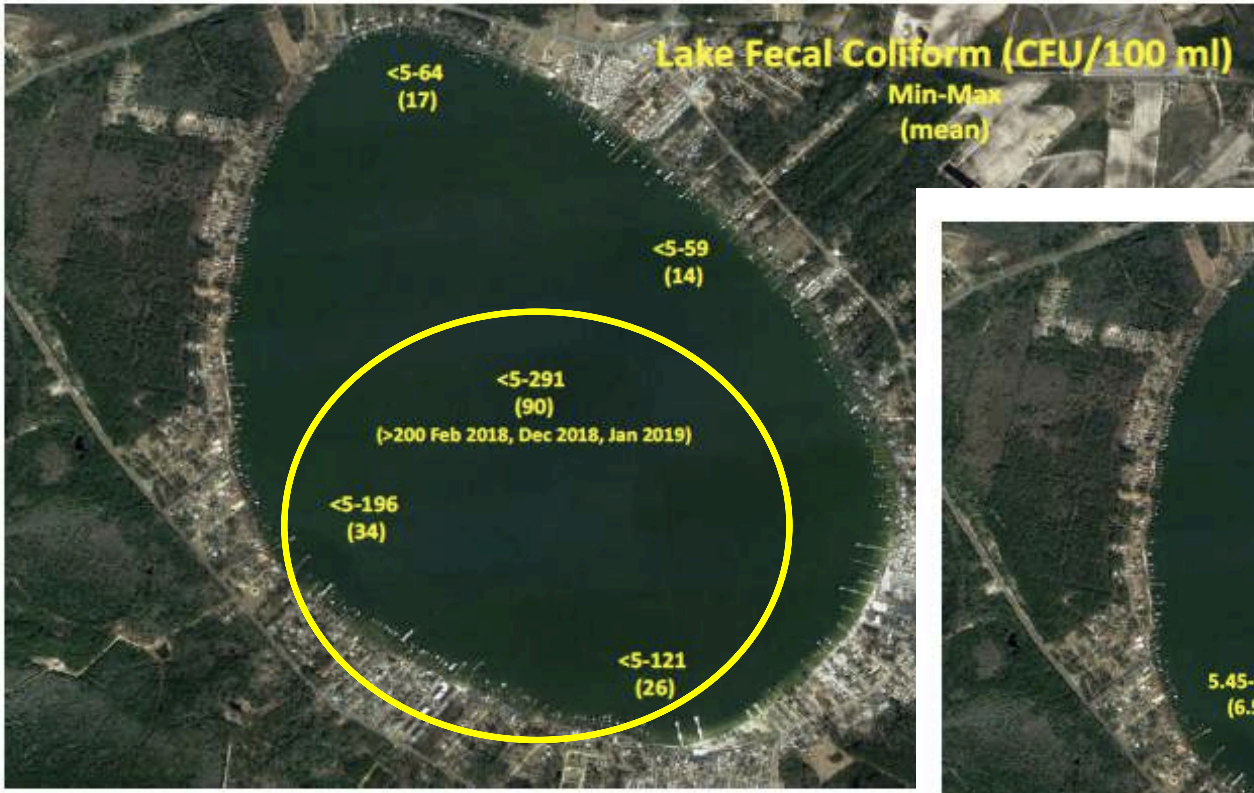
Groundwater and Lake Water Quality Results

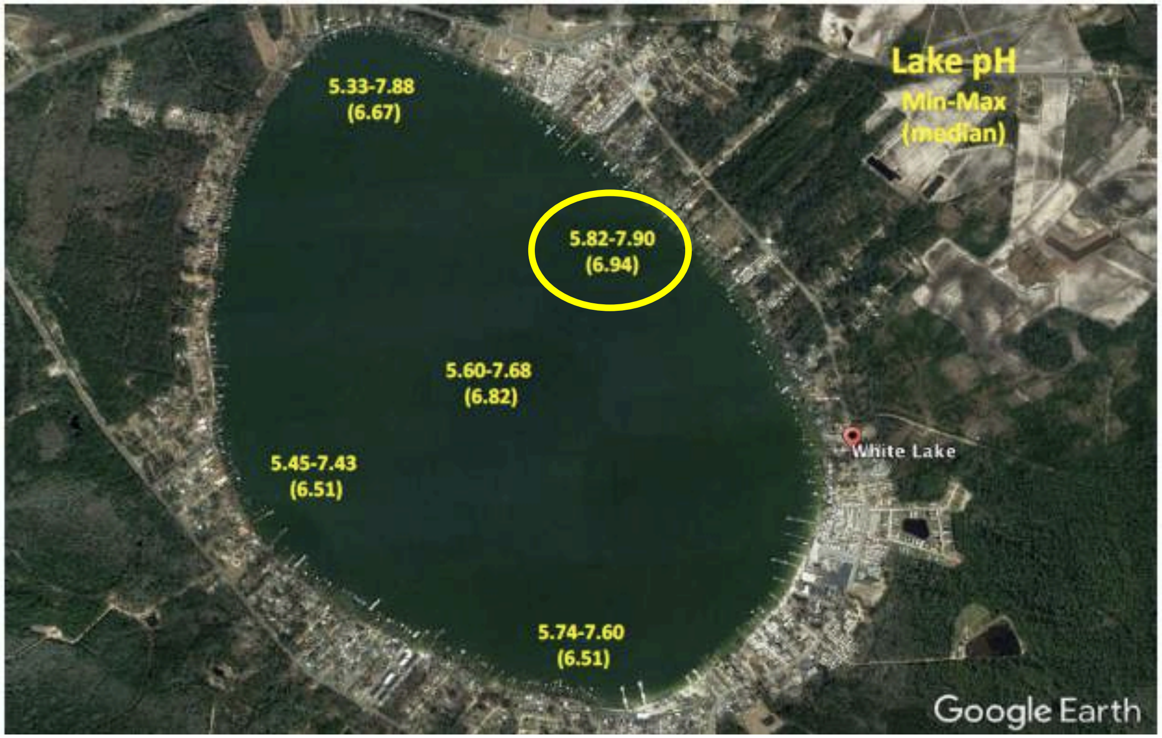
Lake WQ Spatial Results
Nutrients



Lake WQ Spatial Results

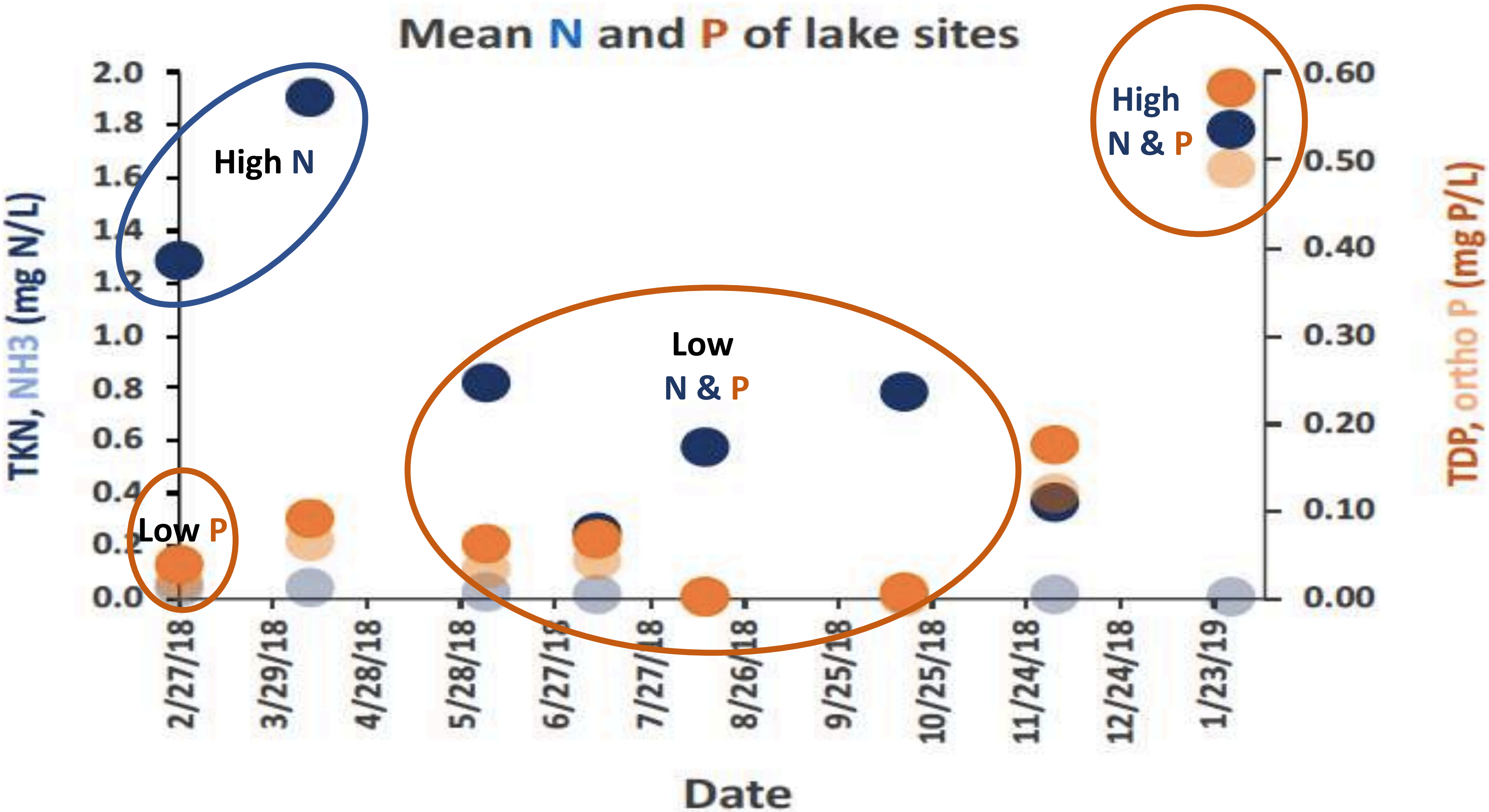
Fecal Coliform Bacteria & pH



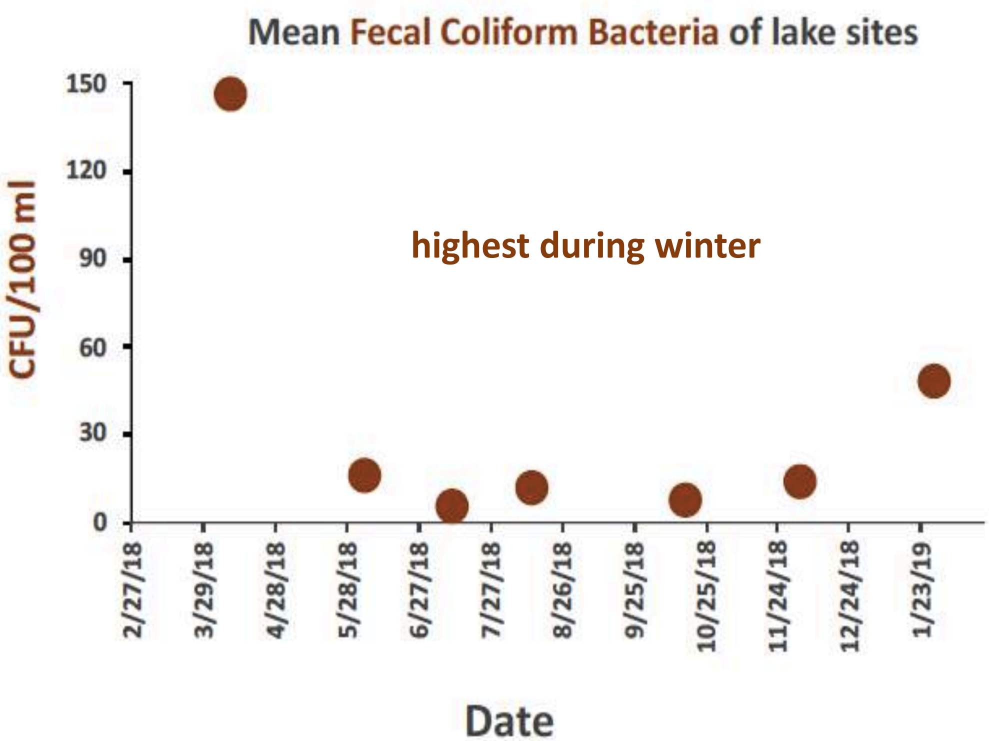


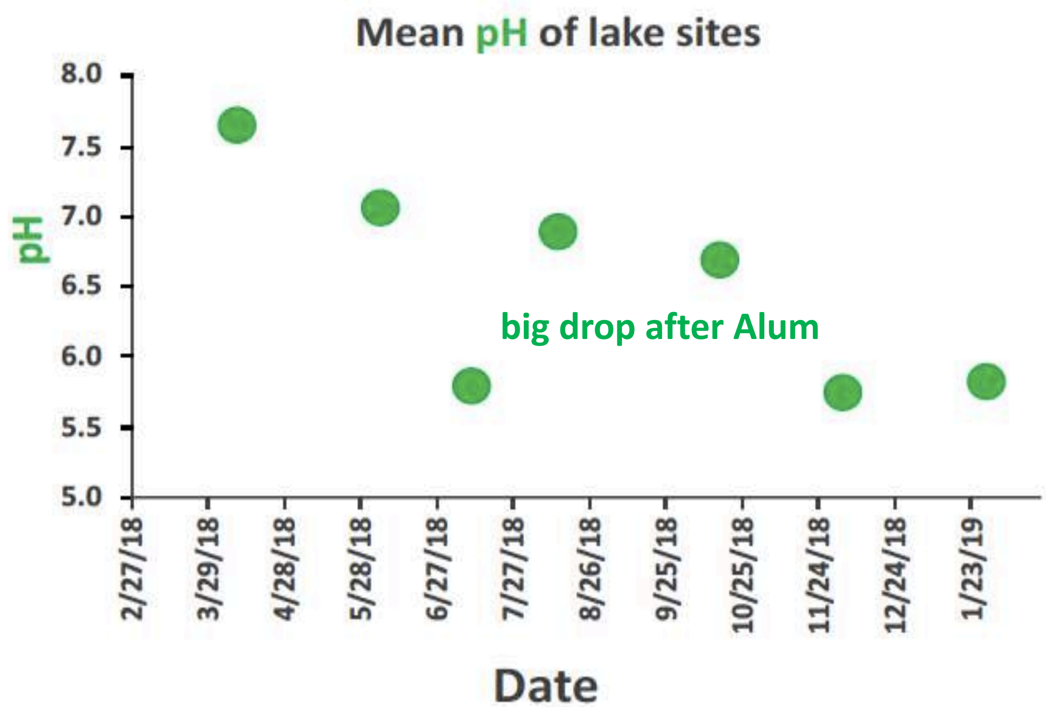
Lake WQ Temporal Results

Nutrients



Lake WQ Temporal Results
fecal coliform bacteria & pH





Quick Summary of Lake WQ Results

Spatial Variability

nutrients = highest in South & West

fecal coliform bacteria = highest in center and South & West

pH = very similar across lake (maybe higher East)

Temporal Variability

nutrients = highest during winter

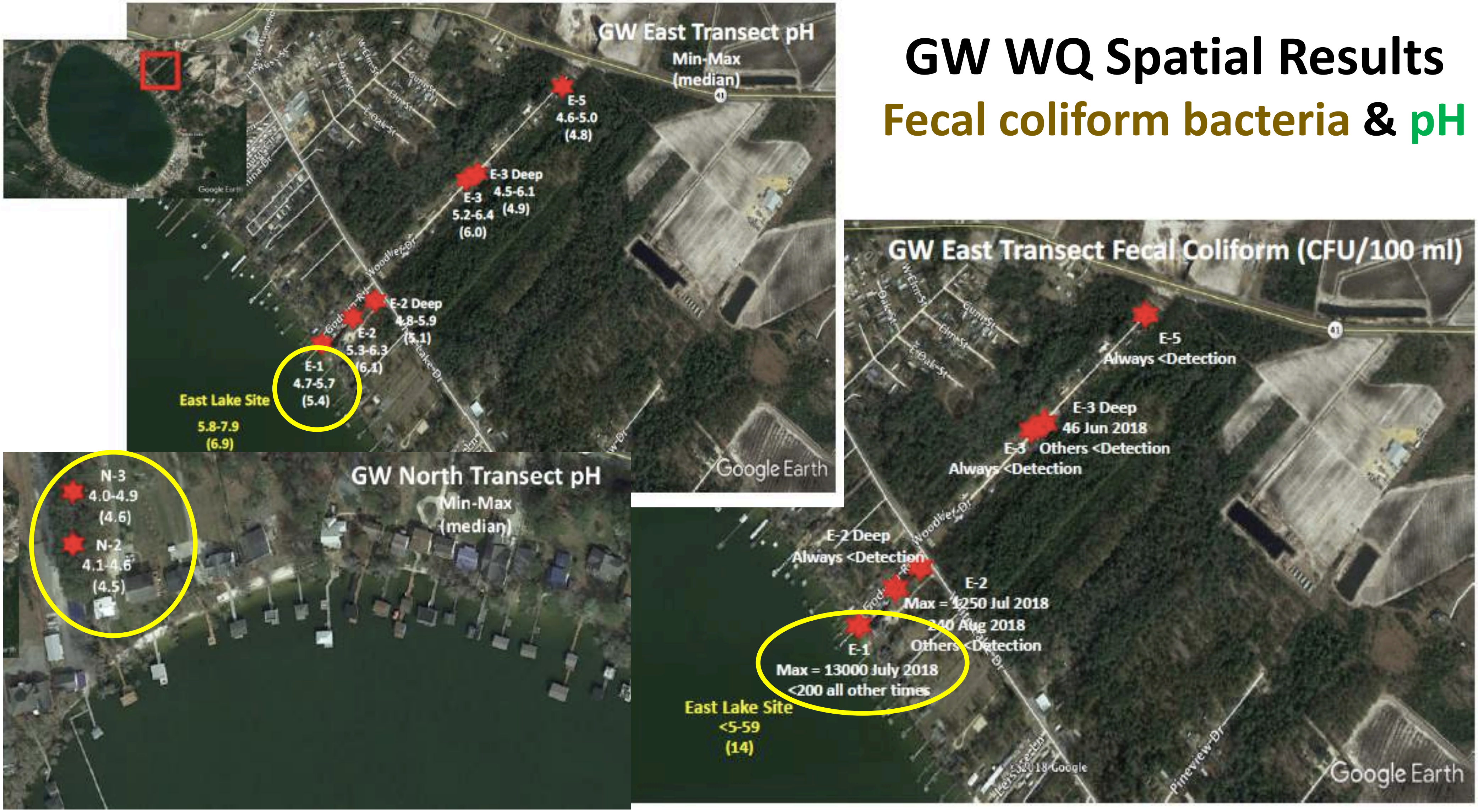
fecal coliform bacteria = highest during winter months

pH = dropped dramatically after Alum treatment

GW WQ Spatial Results
Nutrients

GW WQ Spatial Results

Fecal coliform bacteria & pH



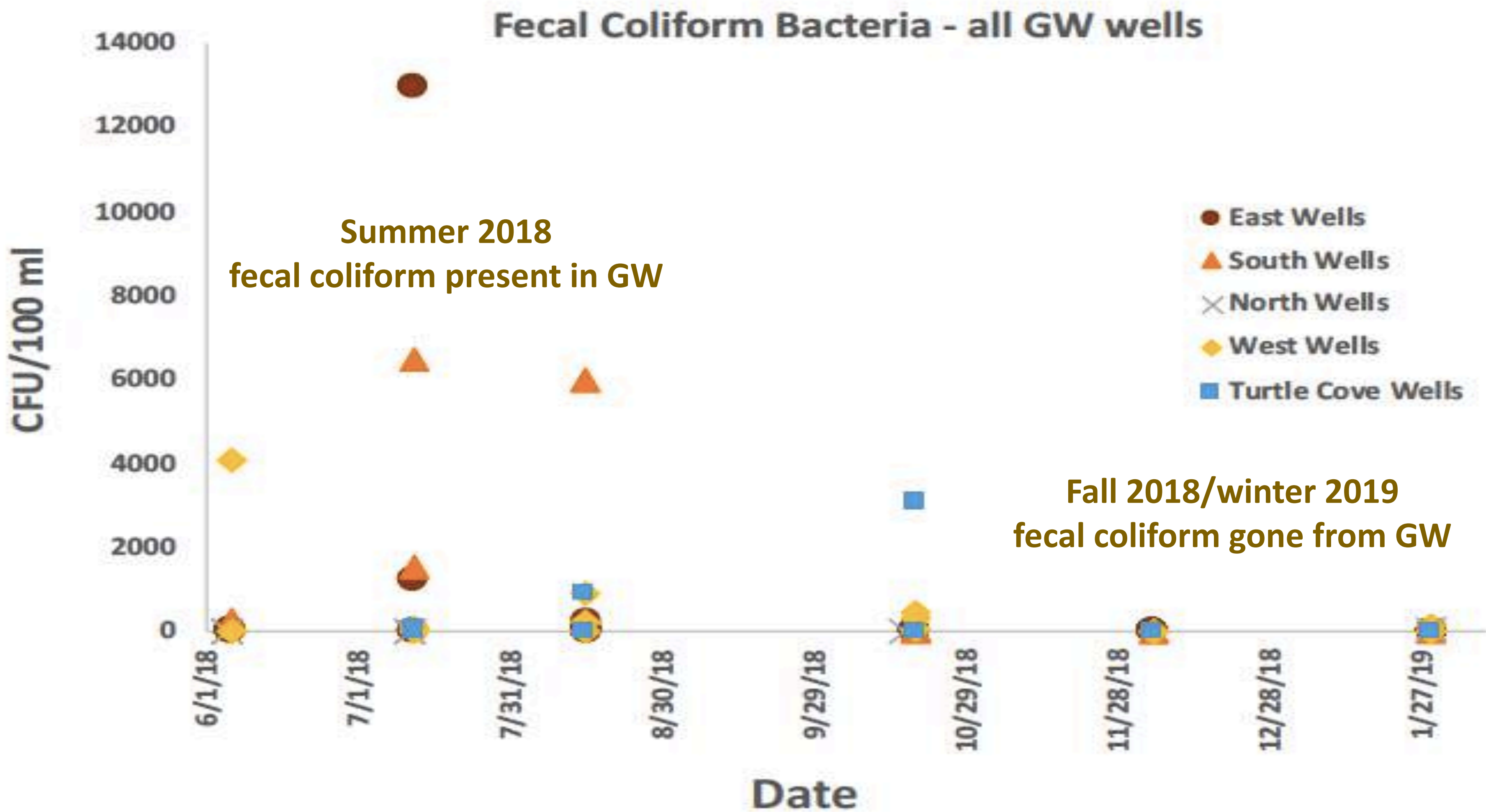
GW WQ Spatial Results
Nutrients

GW WQ Spatial Results

Fecal coliform bacteria & pH

GW WQ Temporal Results

fecal coliform bacteria



Quick Summary of GW WQ Results

Spatial Variability

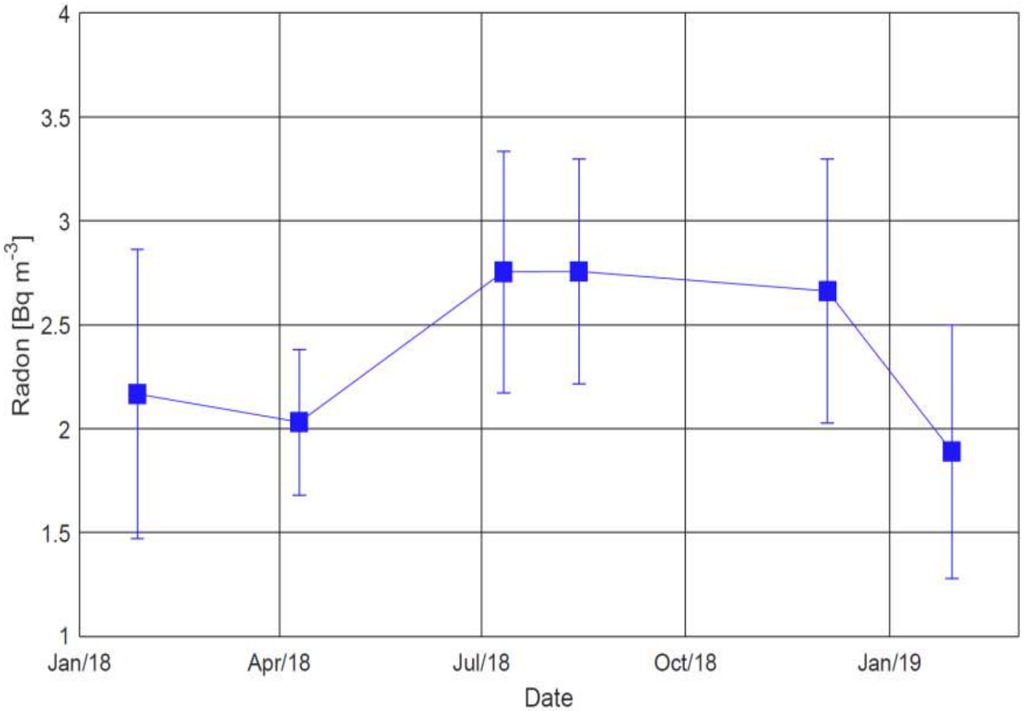
nutrients = highest East and South wells nearest lake
fecal coliform bacteria = highest East and South wells nearest lake
pH = lowest North and East transect away from lake

Temporal Variability

nutrients = highest summer/fall but persist in winter
fecal coliform bacteria = highest during summer, gone after fall
pH = no obvious temporal patterns

Hydrologic Modeling Results

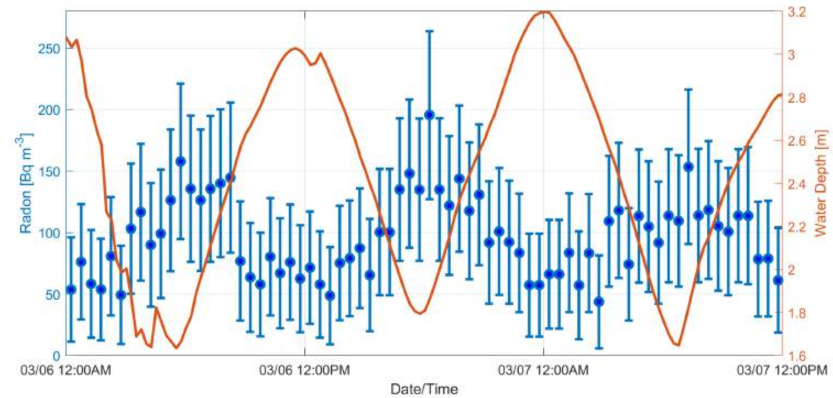
How much groundwater is lake receiving?



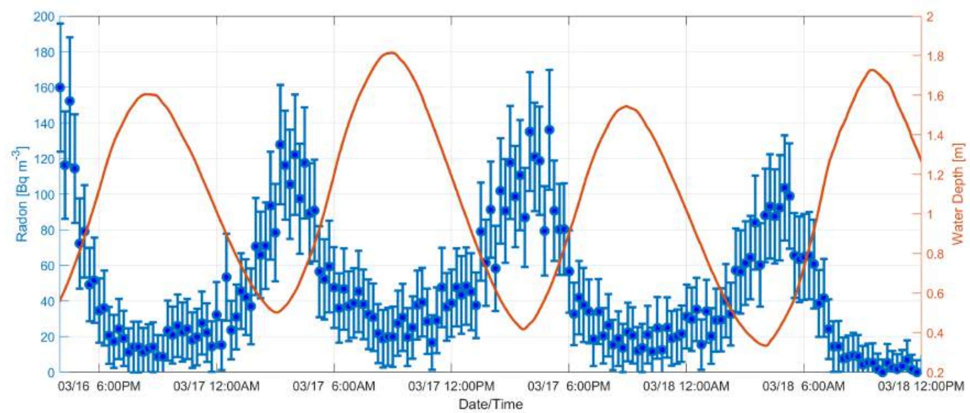
$42 - 1714\ m^3/d$

(0.16 to 6.4% of the volume of White Lake)

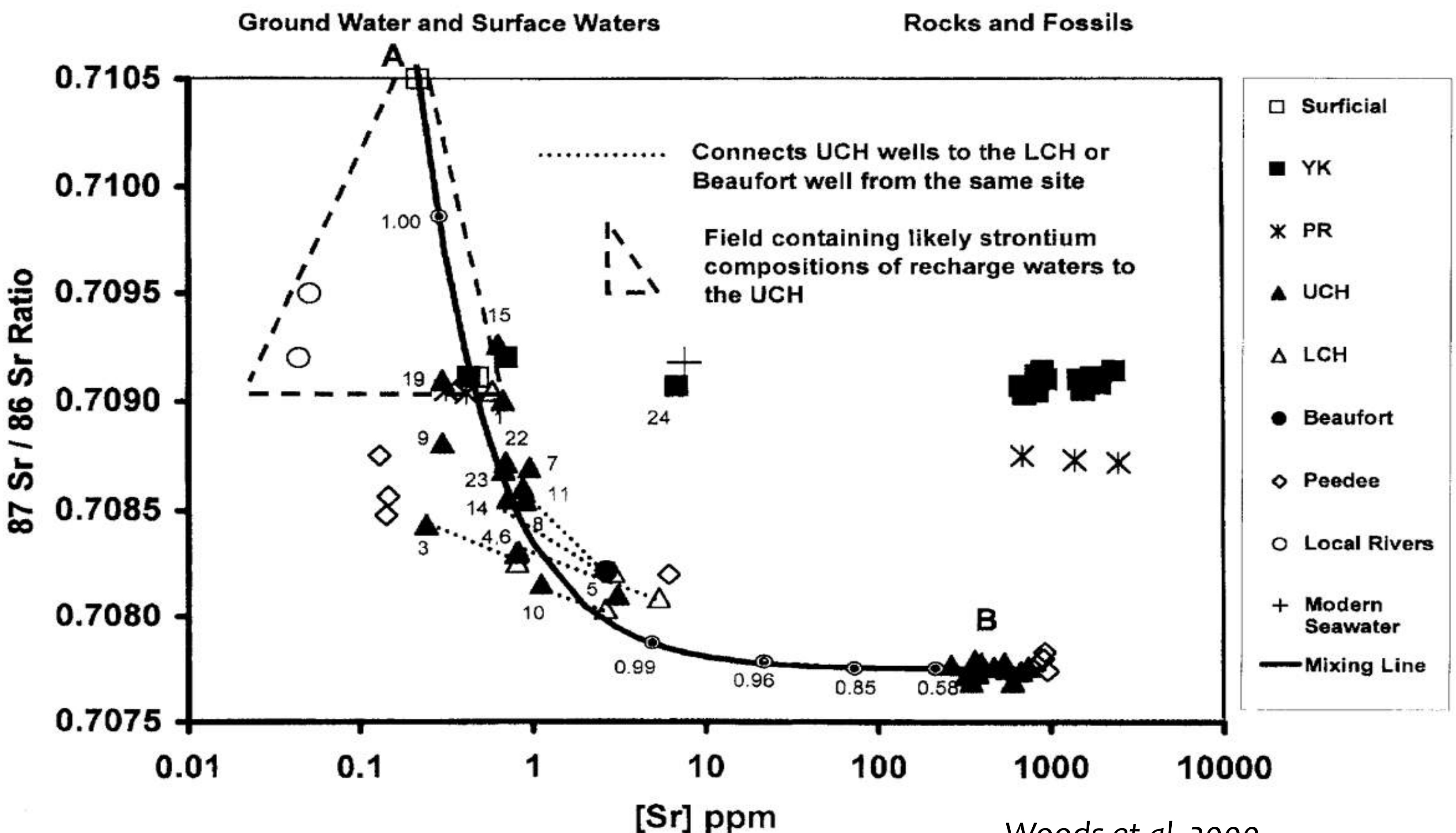
Bald Head Creek, BHI



Hewletts Creek, Wilmington

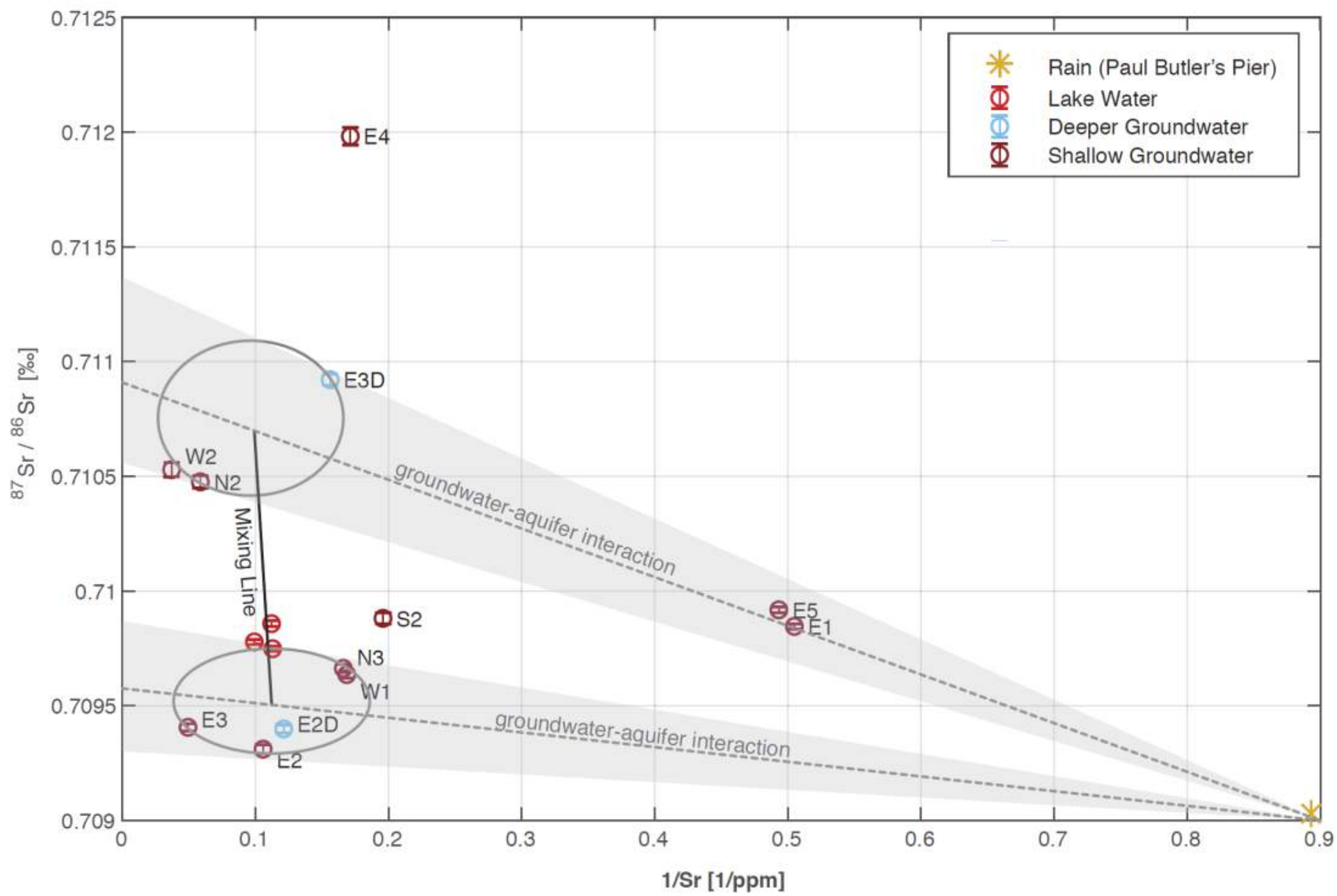


Water Source ($^{87}Sr/^{86}Sr$)

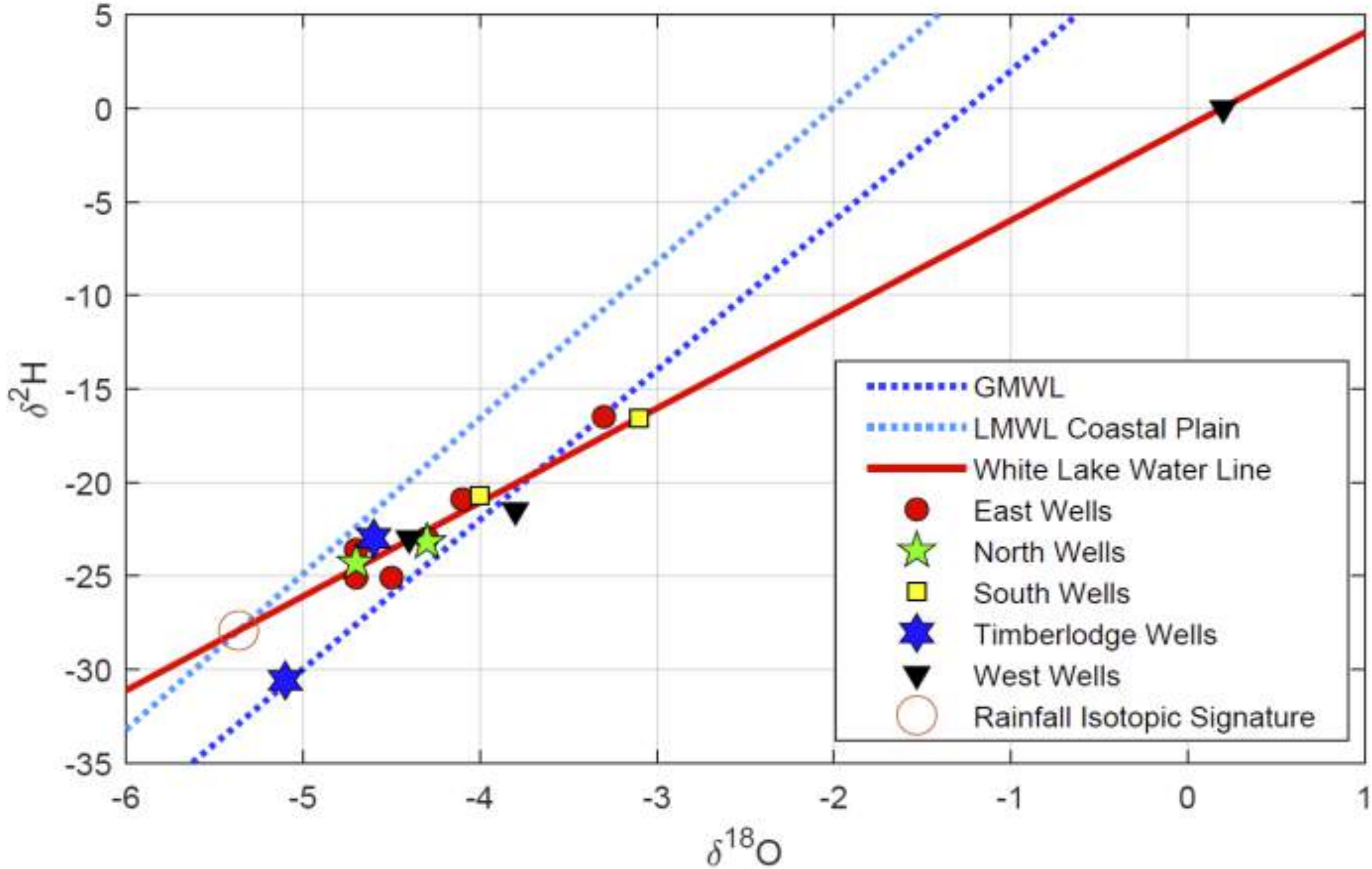


Woods et al. 2000

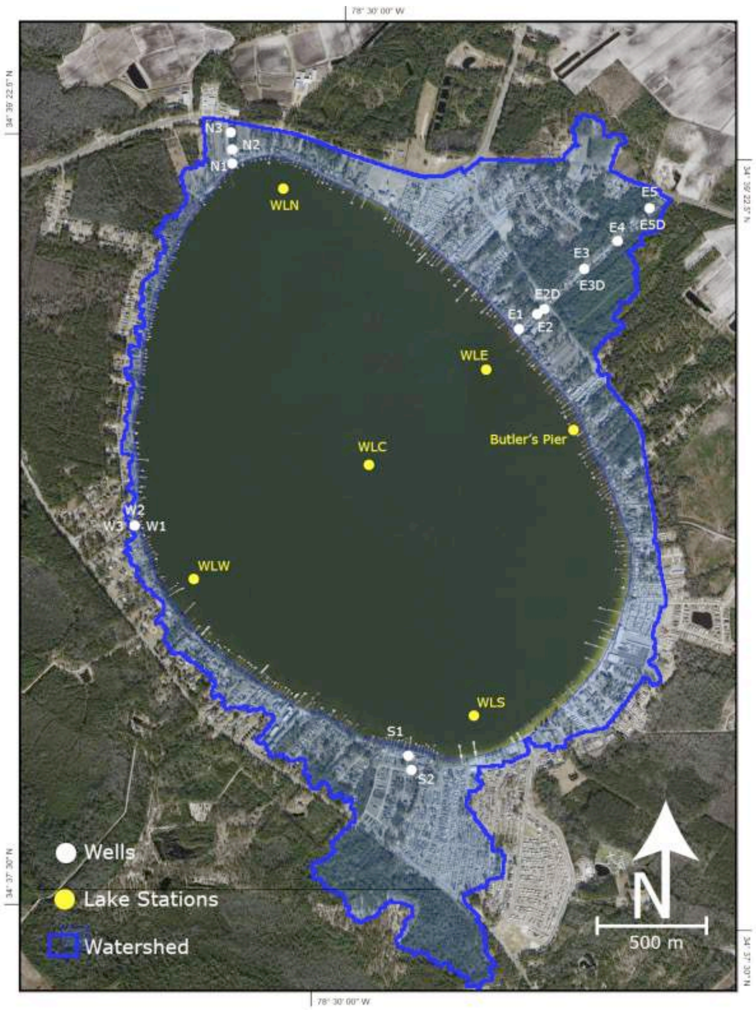
Water Source ($^{87}Sr/^{86}Sr$)

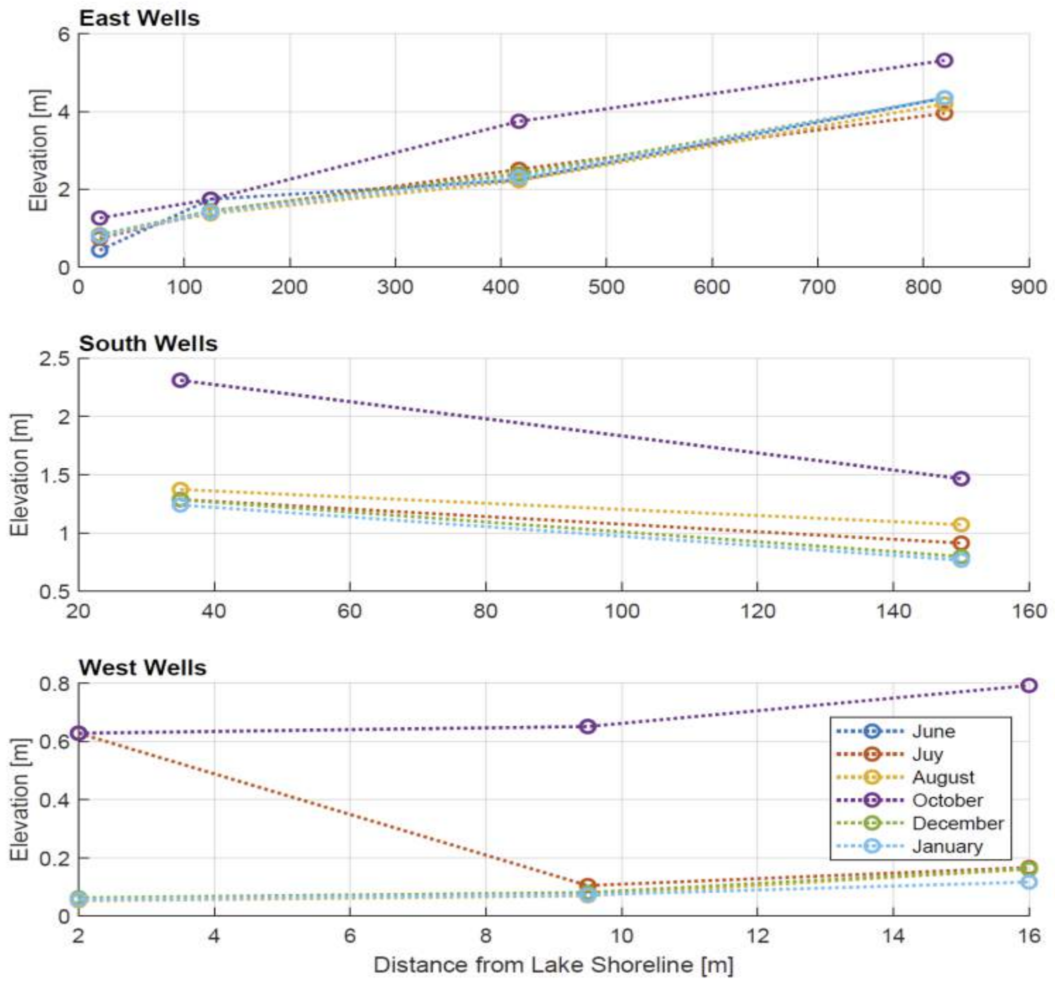


Water Source (δ^{18}O and δ^{2}H)

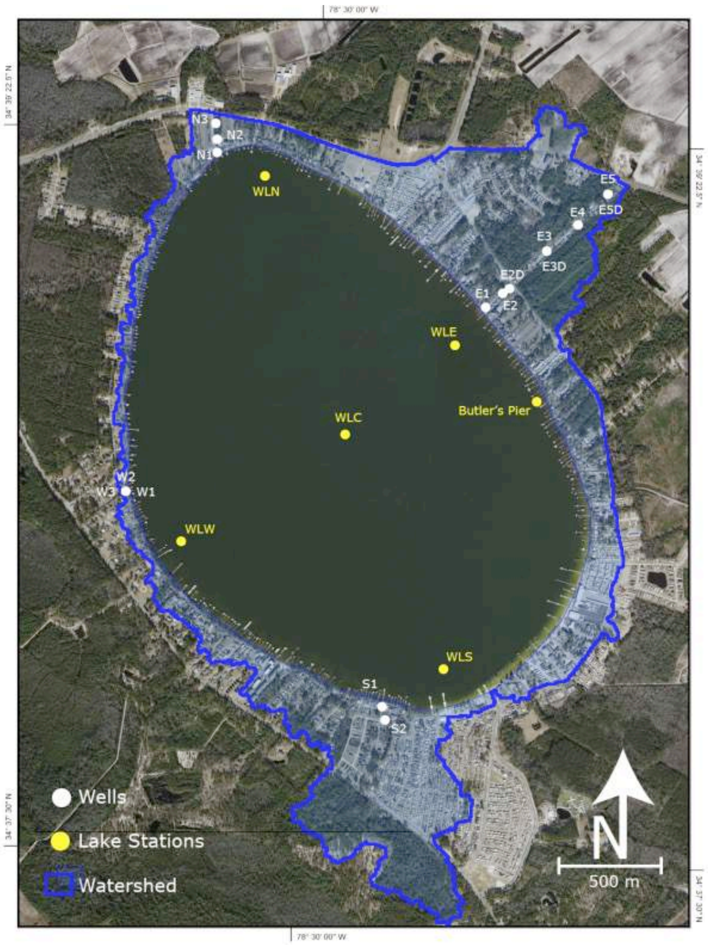


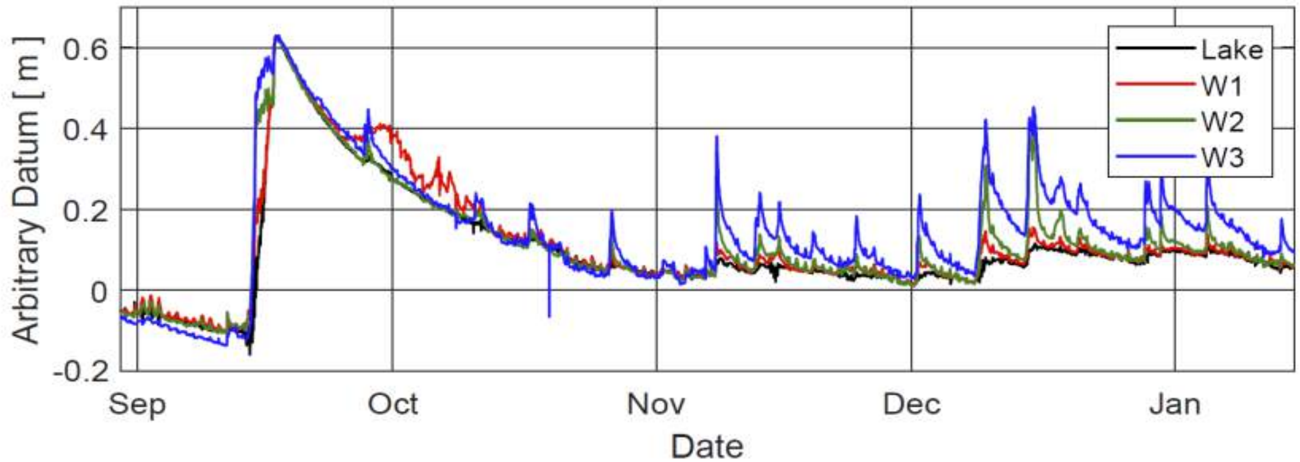
Groundwater Level Profiles

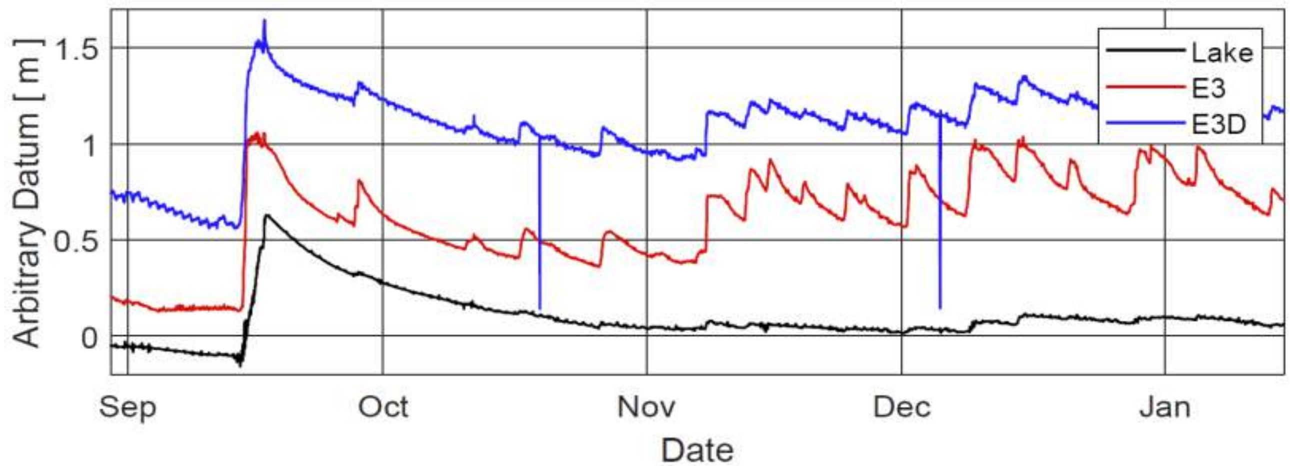




Groundwater Level Through Time

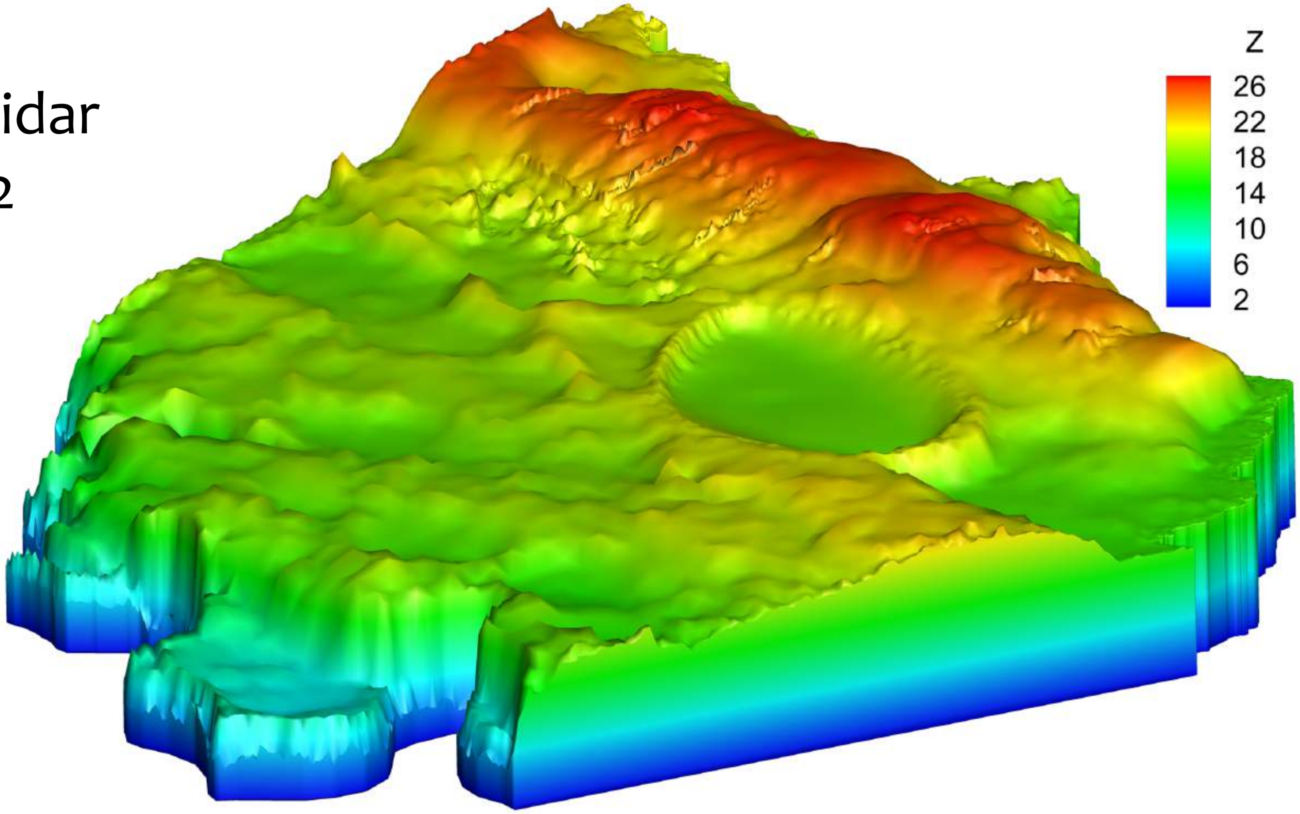






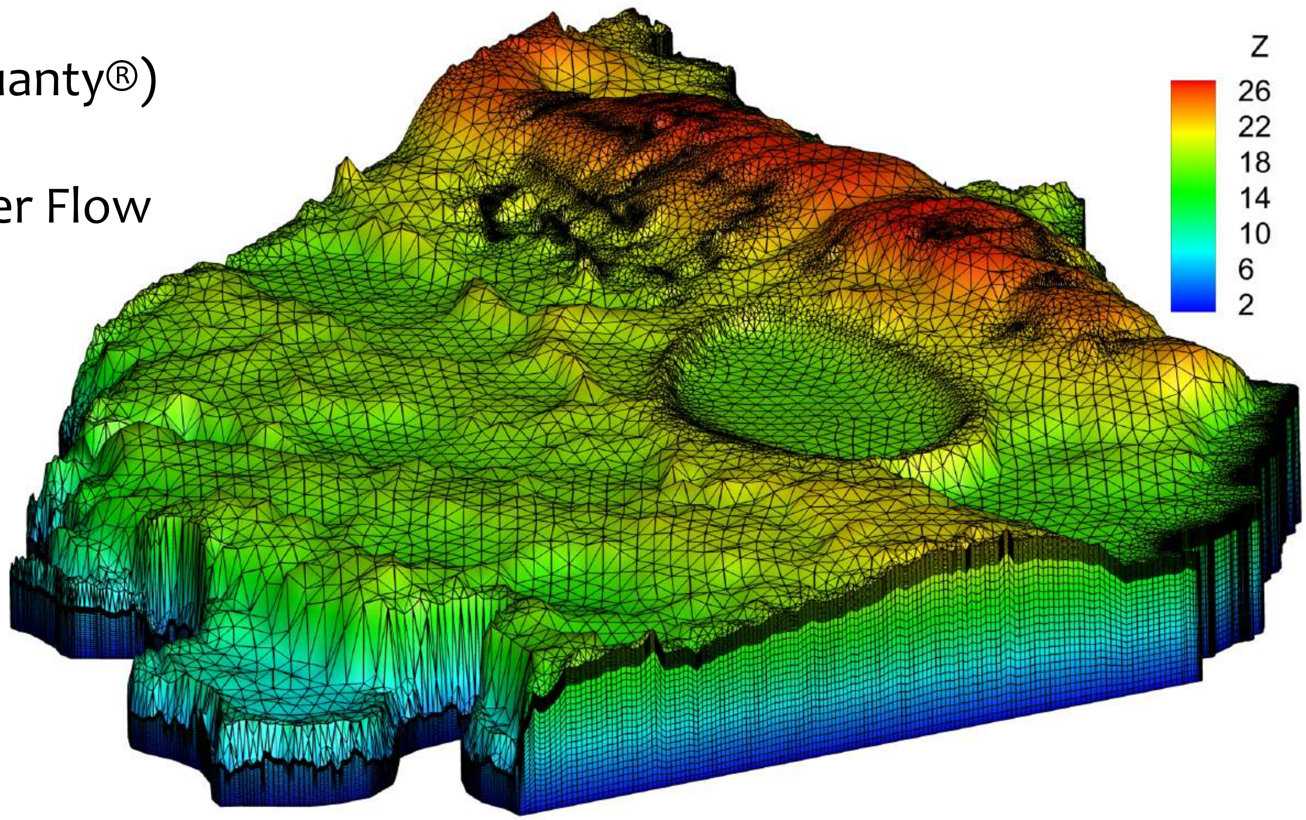
3D Topographic Model

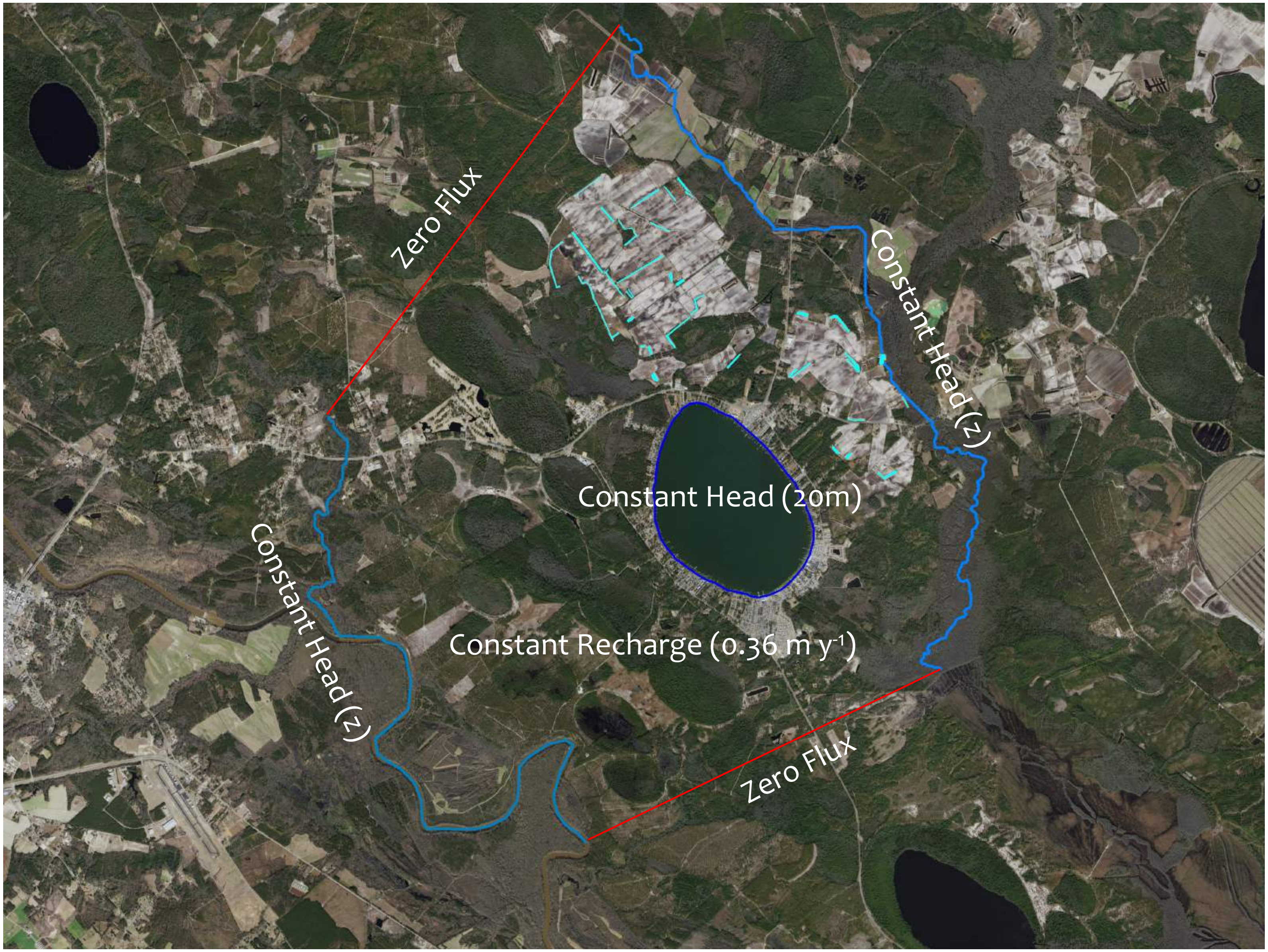
Topo from 2013 NC Lidar
Bathy from Frey 1942



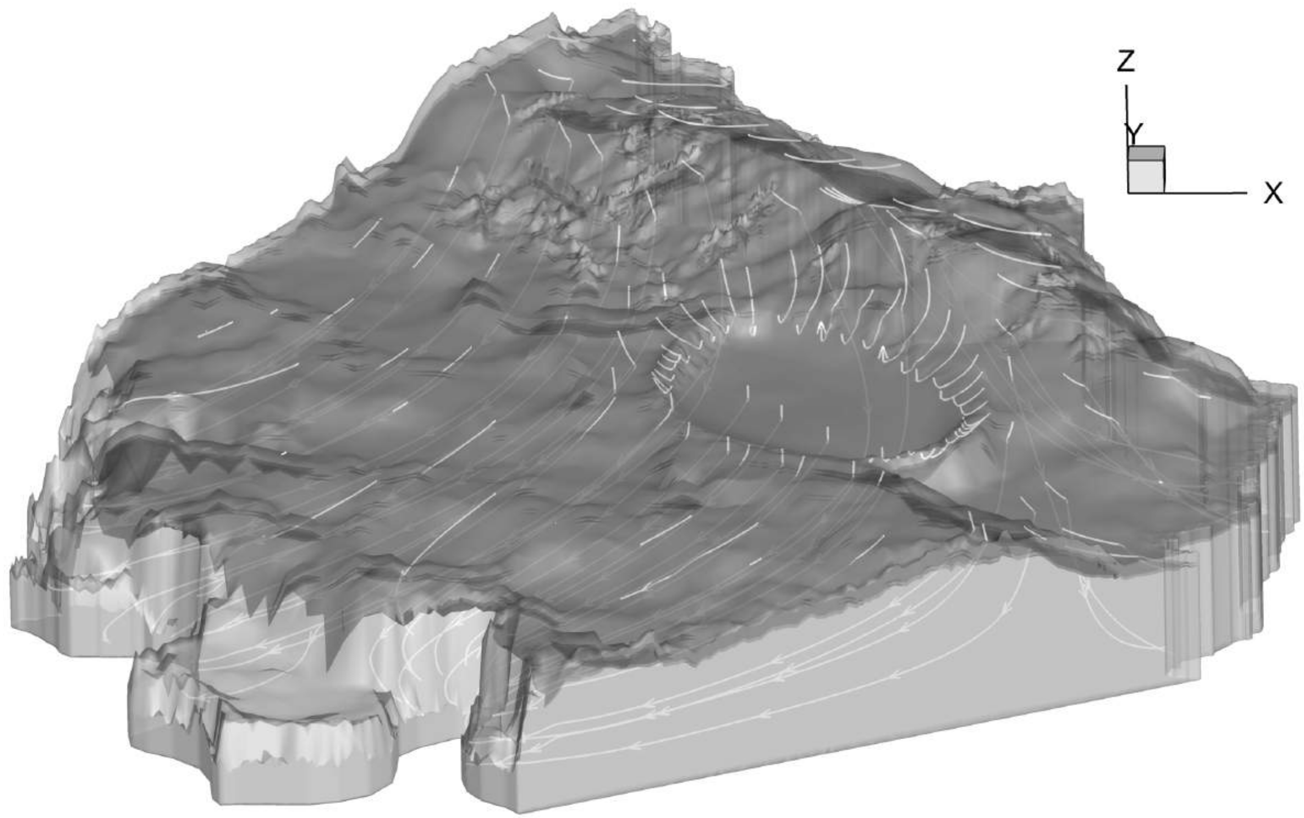
3D Mesh for Groundwater Model

- HydroGeoSphere (Aquanty®)
- 1.5 M elements
- Saturated Groundwater Flow
- Steady-State

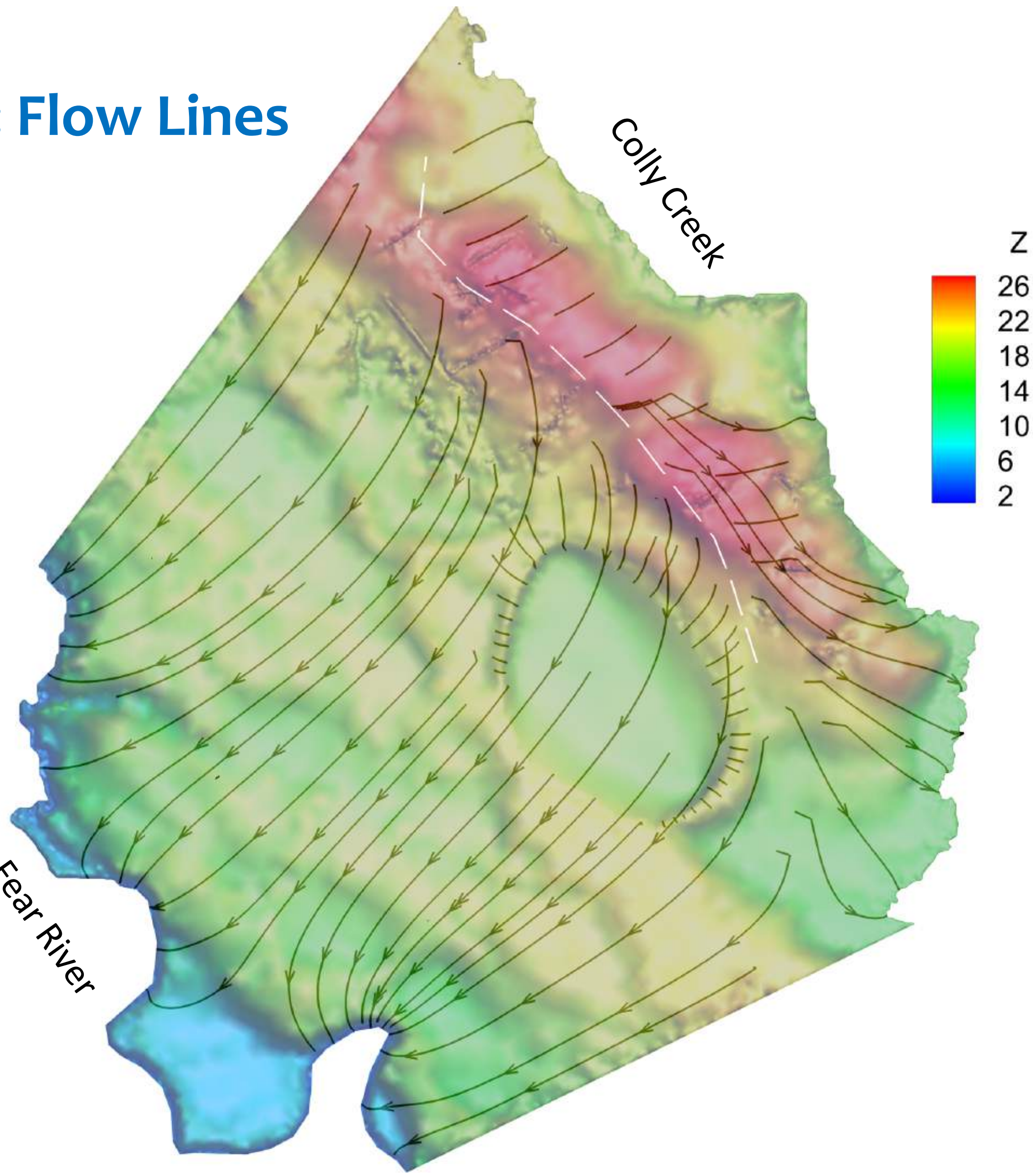


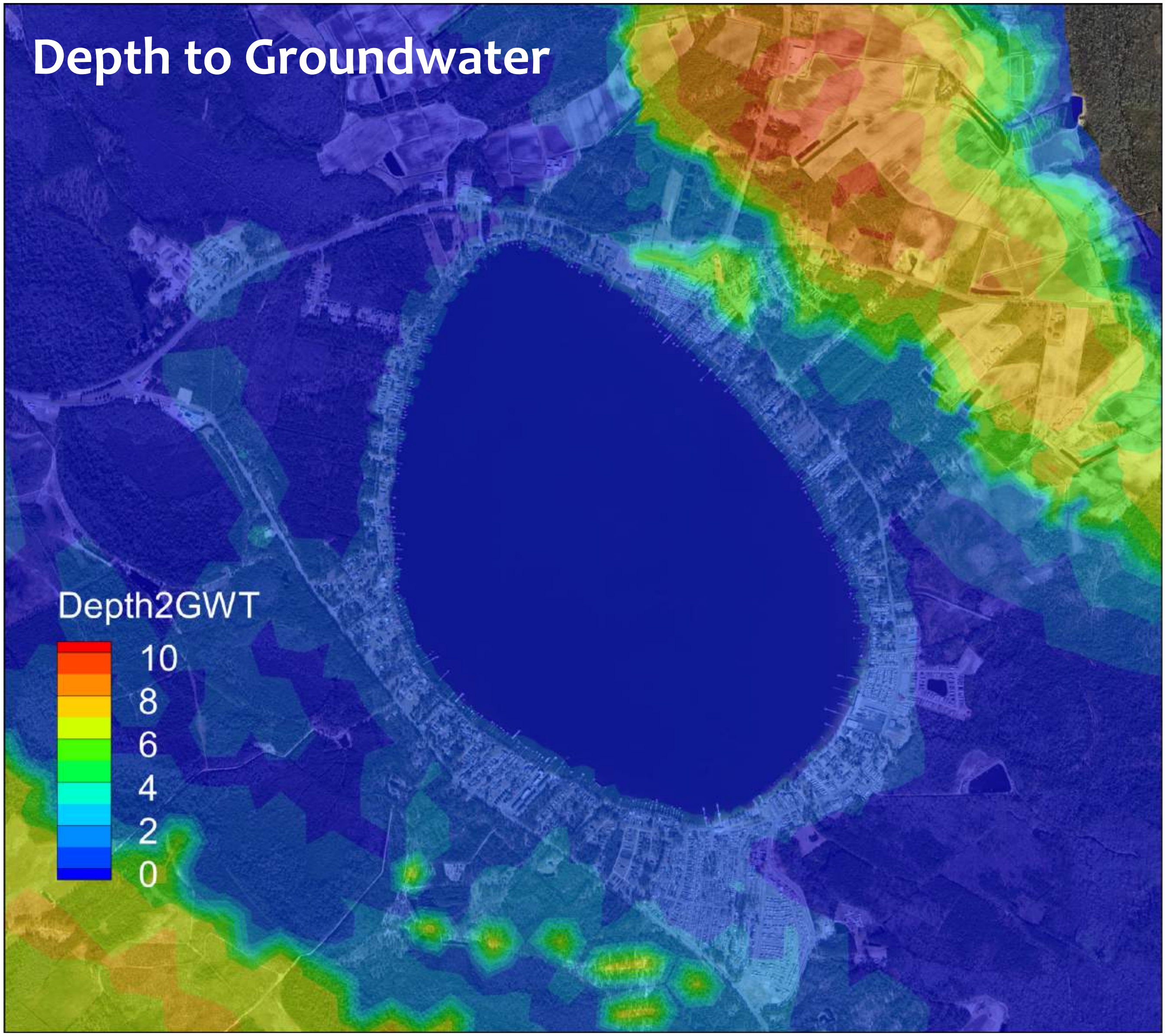

Zero Flux
Constant Head (z)
Constant Head (20m)
Constant Head (z)
Constant Recharge (0.36 m y-1)
Zero Flux

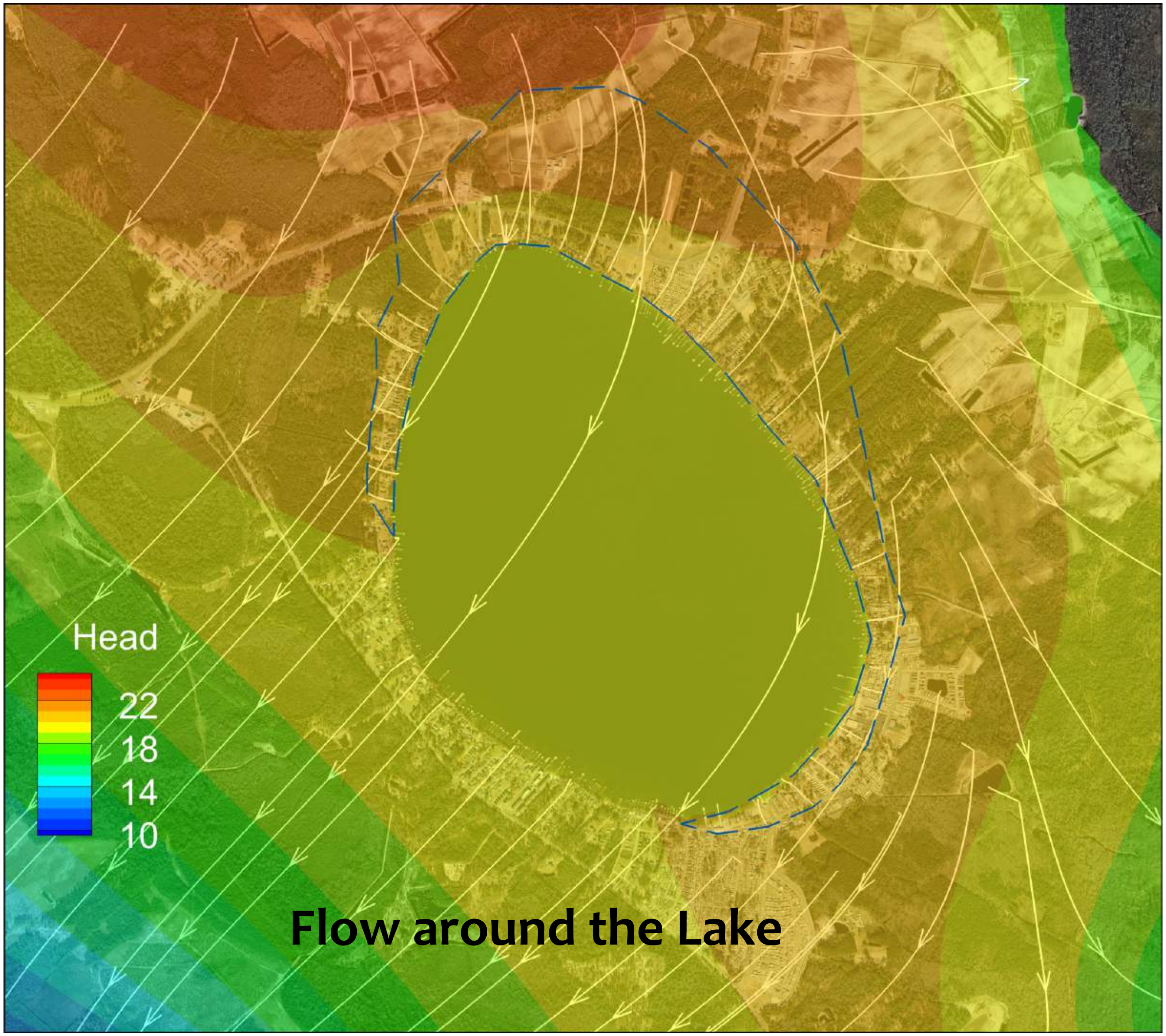
RESULTS: Effect of "Hardpan"



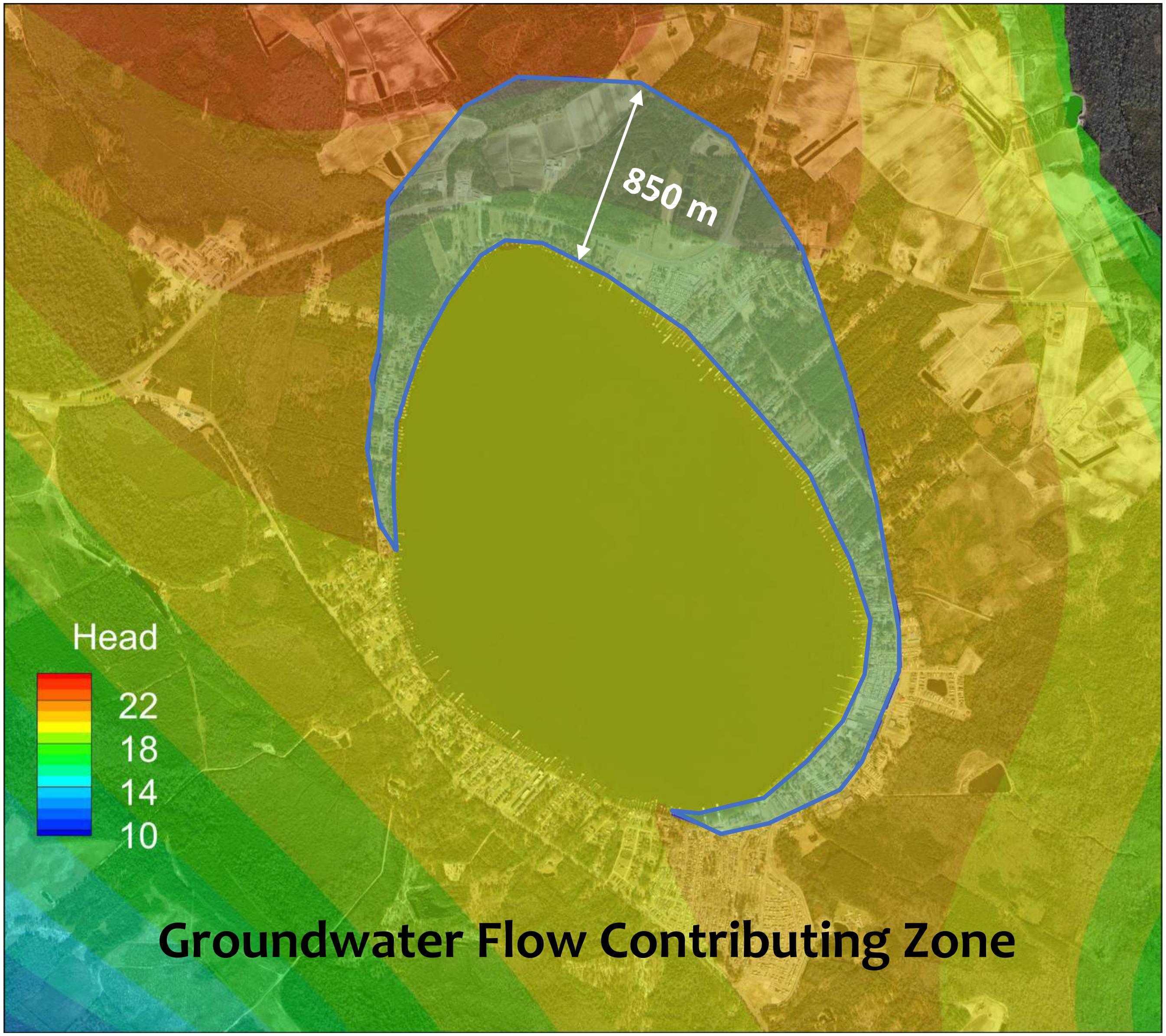
RESULTS: Flow Lines

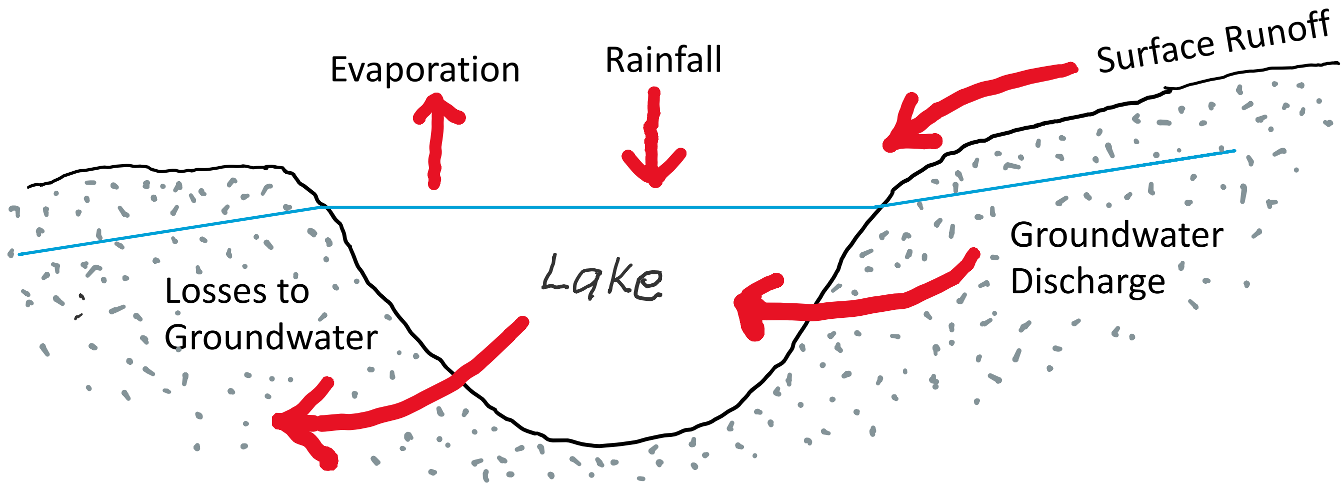



Depth to Groundwater
Depth2GWT
10
8
6
4
2
0



Flow around the Lake


850 m
Head
22
18
14
10
Groundwater Flow Contributing Zone



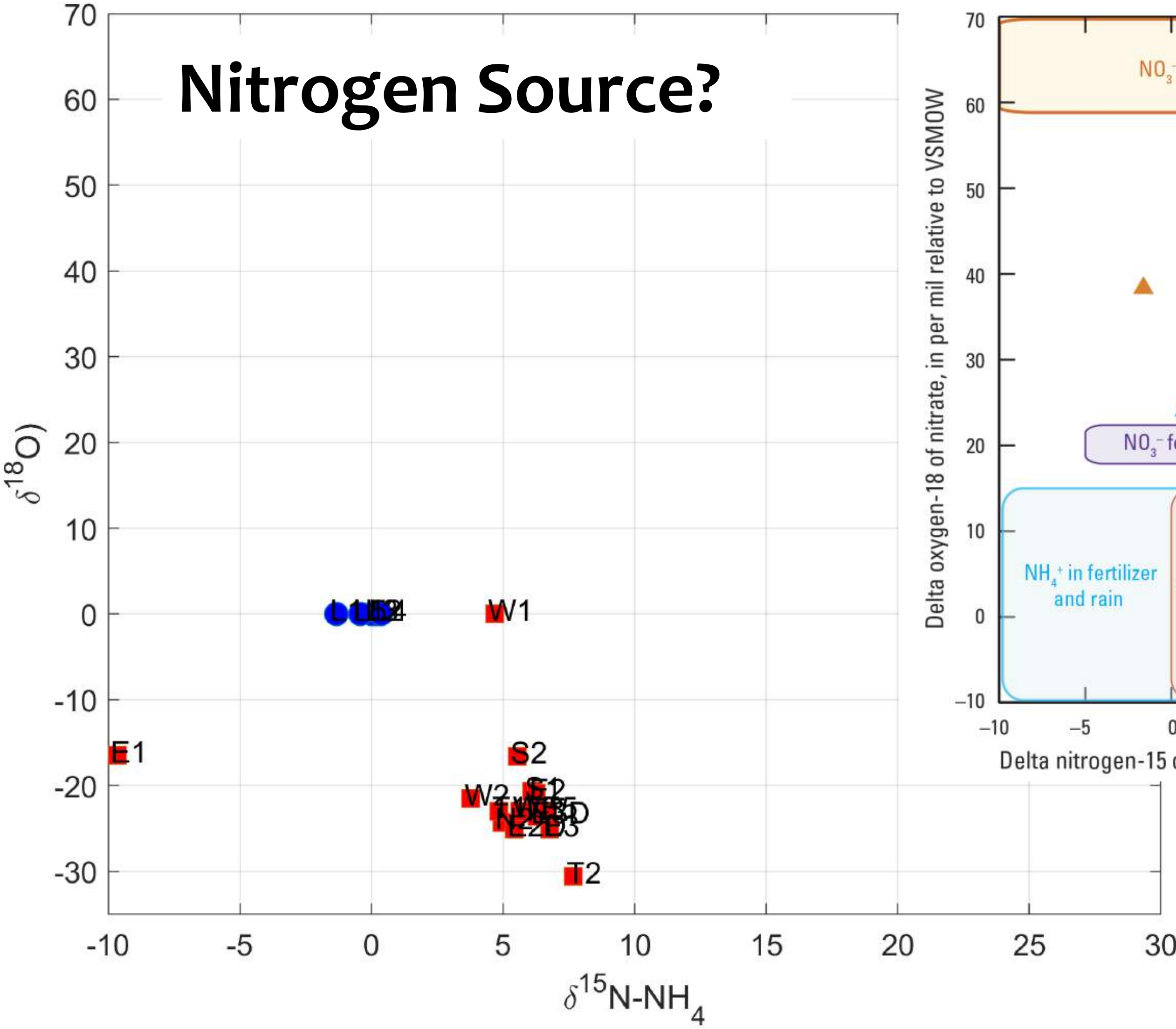
	Magnitude [m³/d] (per lake area)
Sources	
Rainfall	13,574 (3.10 mm)
Groundwater Discharge	42-1,714 (0.01-0.39 mm)
Surface Runoff	6,709 (0.68 mm)
Sinks	
Evaporation (NC average)*	12,068 (2.8 mm)
Evaporation (estimate)	9,660-11,332 (2.2-2.6 mm)
Losses to Groundwater	8,590 (2 mm)

*Kohler et al. 1959 in Abtew and Melesse 2013

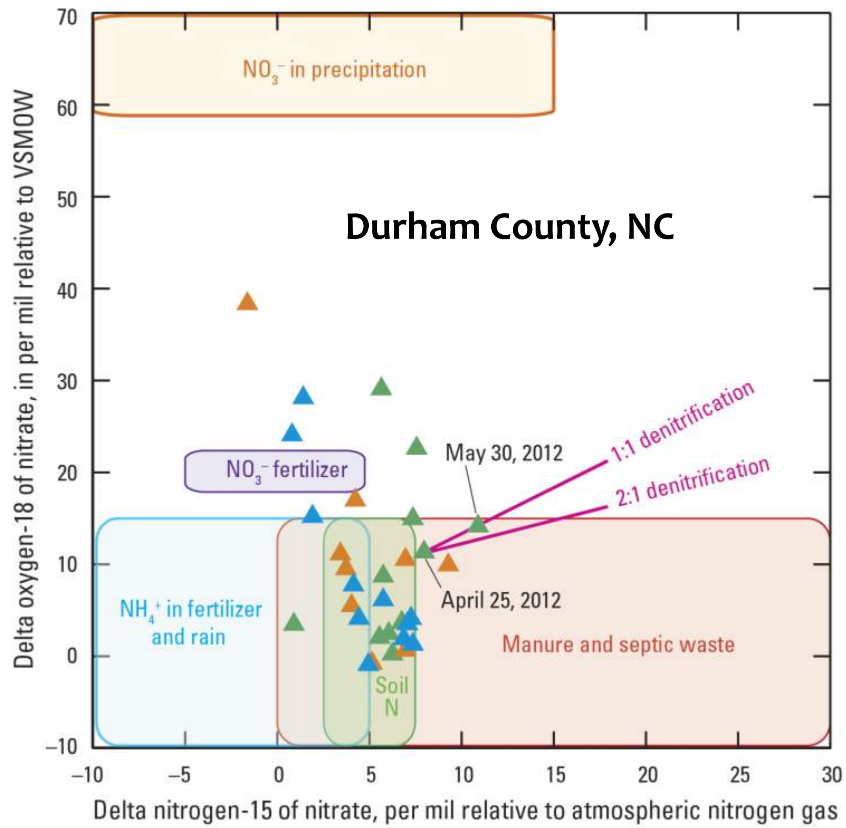
<u>0.89</u> and <u>0.14</u> g/m^3 of N and P

Greenfield Lake, Wilmington
0.73 and 0.09 g/m^3

Nitrogen Source?



Durham County, NC



Summary Findings

1. Rainfall >> GW for lake water supply
2. GW flows in NE quadrant & out SW quadrant (most of the time)
3. No evidence for recent spring inputs from deep confined aquifers
4. GW hotspots of nutrients/fecal coliform bacteria East and South
5. Lake fecal coliform bacteria highest during winter (opposite from GW)
6. GW flow small, but important long-term source of nutrients
7. Clean GW in NE quadrant flowing into lake pH 4-5
8. Alum treatment completely changed lake algae – now oligotrophic

Unknowns and Needed Research

1. How widespread are main and individual sewer line leaks?

2. What is volume of nutrient inputs delivered via stormwater runoff?

3. Do blueberry farms influence GW nutrients and water budget during spring fertilization period?

4. How much N and P are locked up in sediments and live & dead algae?

Management Recommendations

1. Comprehensive wastewater system testing – #1 priority NE, #2 priority SW
2. Develop stormwater runoff plan including drainage ditches and lawn pipes
3. Educate folks about fertilization practices
4. Reduce bulkheads in favor of vegetated buffers around lake periphery
5. Keep open Turtle Cove weir to reduce residence time of pollutants
6. Seek funding for future Alum treatments


Thanks - it's been a pleasure getting to know
y'all!