



# Atmospheric Influences on a Shallow Seepage Lake in North Carolina: A Management Conundrum



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# White Lake

**An Elliptical “Carolina Bay”**

**Surface Area = 432 ha**

**Mean Depth 1.9 m, Max. 2.9 m**

**No Defined Inlet**

**>90% of Source Water From Rainfall  
on Lake Surface**

**Shallow Aquifer Groundwater Source  
 (“springs”)**

**= Seepage Lake, Clear Water**



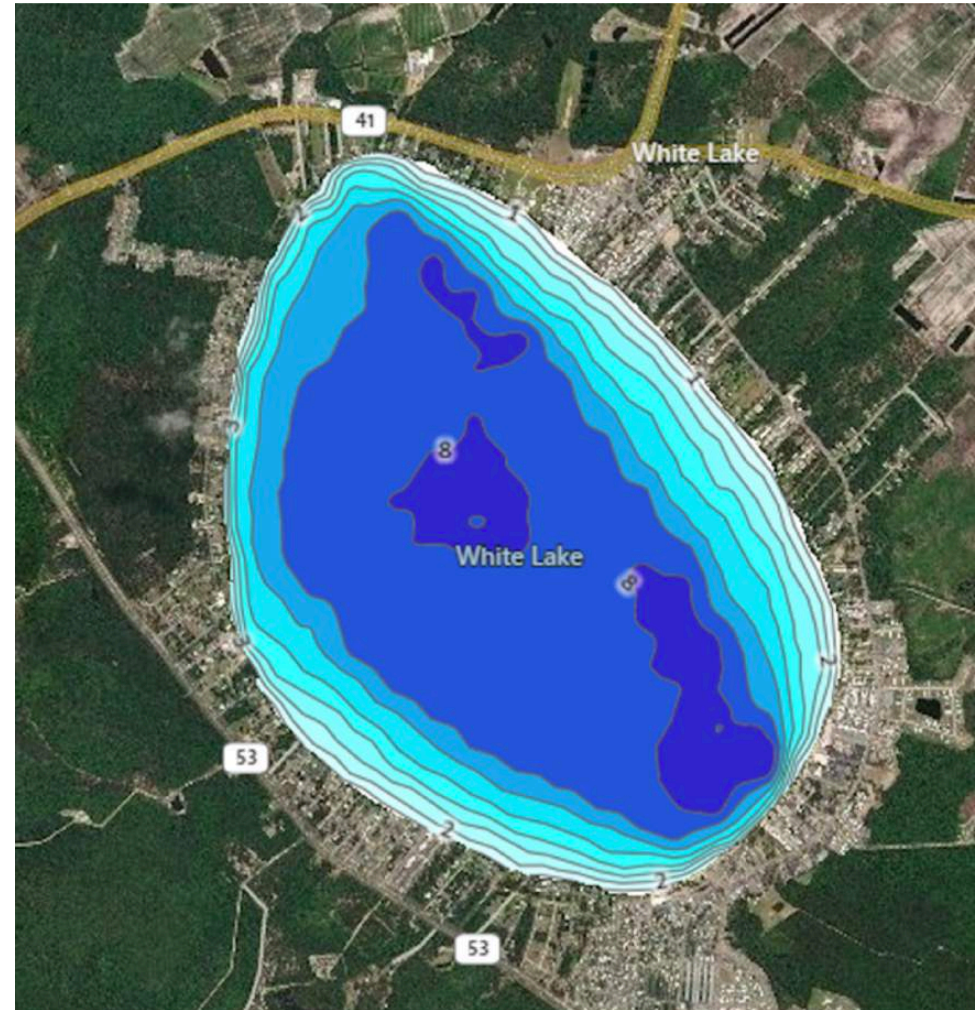
Digital Compilation of 1949 Aerial Photos, Provided by NC Mountains to Sea Trail

# Sediments Important in Shallow Lakes

**Water Volume/  
Sediment Surface Area  
is Relatively Low**

**Same Reasoning  
Applies for  
Potential Importance of  
Atmospheric Deposition in a  
Shallow Lake:**

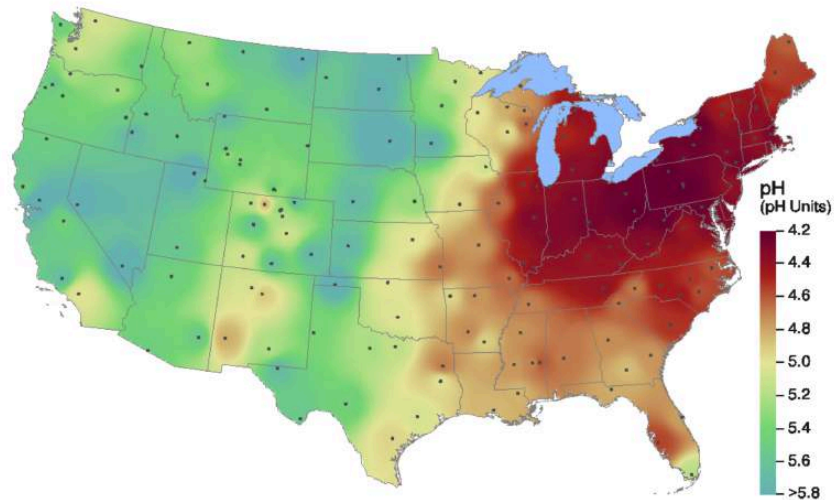
**Low Water Volume/  
Lake Surface Area**



Bathymetric Map Provided by NCSU Aquatic Weed Program

# Atmospheric Change: Less Acidic Rainfall

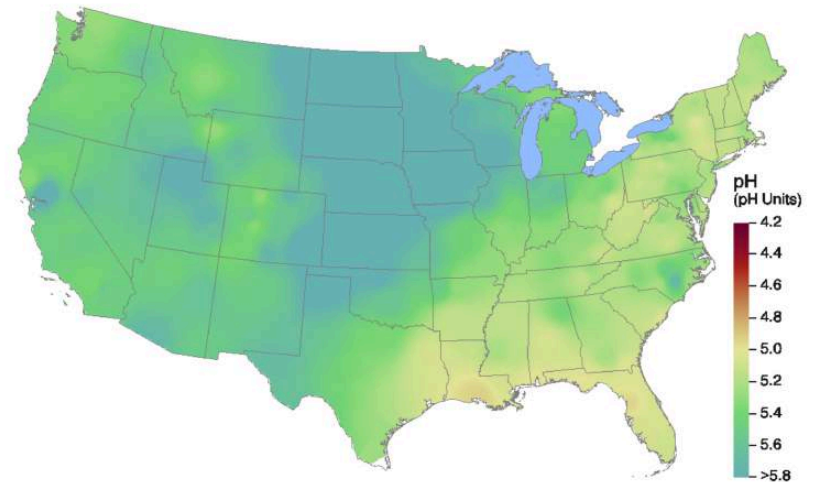
pH, 1989



Source: NADP

USEPA/CAMD 01/25/18  
<https://www.epa.gov/castnet>

pH, 2016-2018



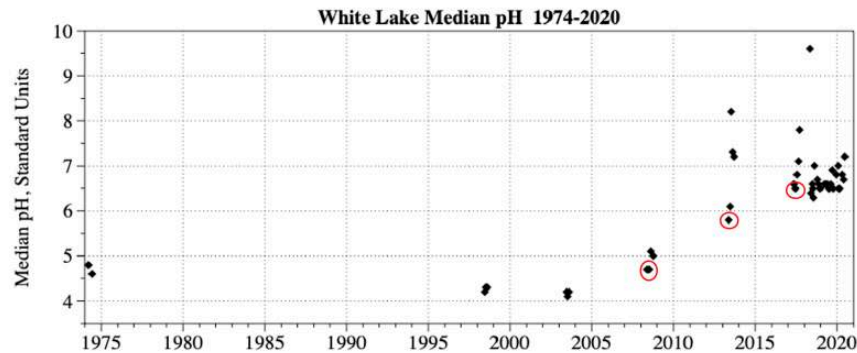
Source: NADP

USEPA/CAMD 10/18/19  
<https://www.epa.gov/castnet>

Data from National Atmospheric Deposition Program, US EPA Clean Air Status and Trends Network (CASTNET)

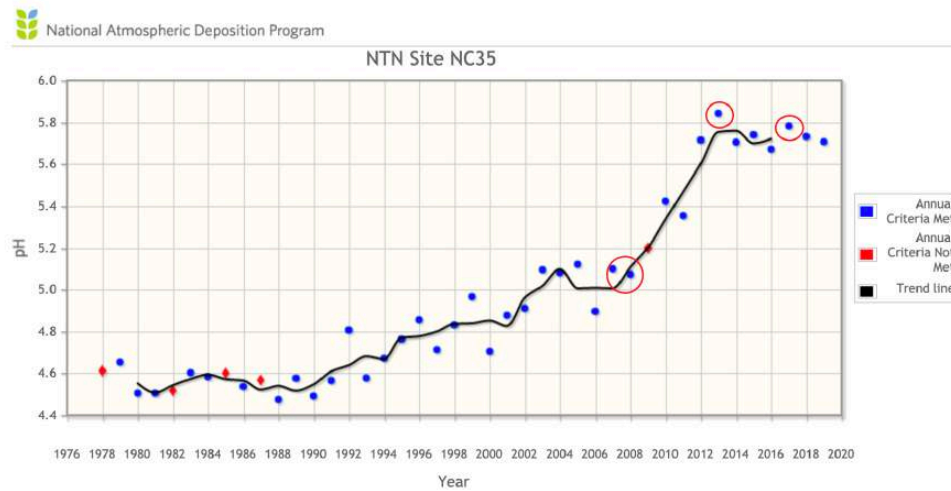


# Rainfall Primary Source Water: pH Change

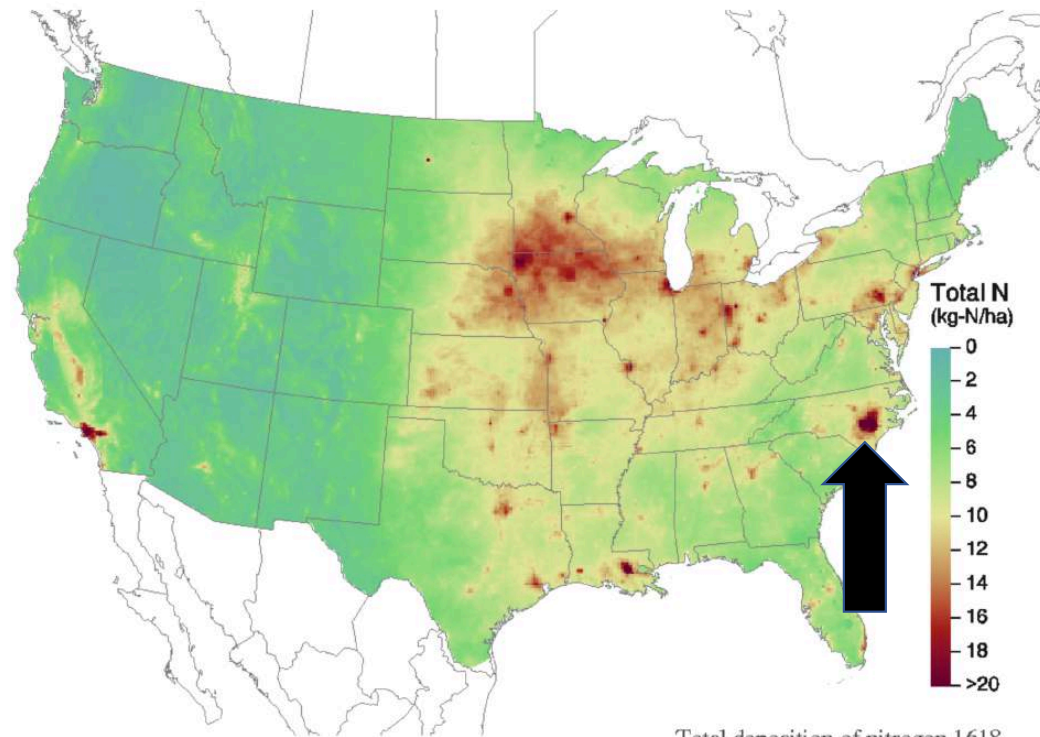


**Lake Water Very Low Alkalinity**

**Increase in Lake pH Over Same Period That Rainfall pH Was Increasing At Nearby NADP Station**



# Atmospheric Change: A Nitrogen Hot Spot in North Carolina



Reduction in  $\text{NO}_x$  (acid)  
5x Increase in  $\text{NH}_3$  (base)

Dry Deposition High

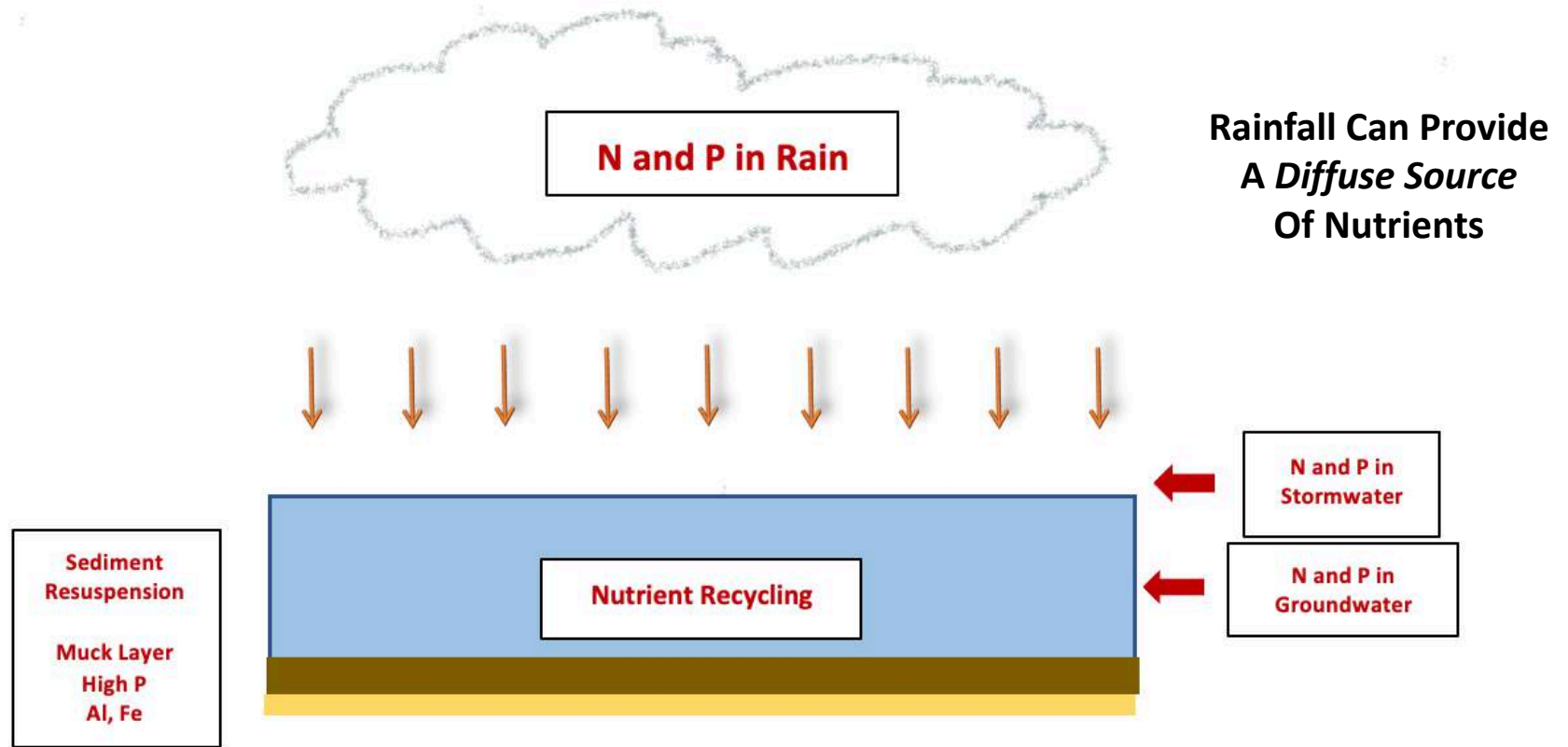
TN Deposition = Wet + Dry  
in kg-N/ha/year  
(2018 Data)

Source: CASTNET/CMAQ/NADP

Total deposition of nitrogen 1618  
USEPA 10/21/19

Data from National Atmospheric Deposition Program, US EPA Clean Air Status and Trends Network (CASTNET)

## Assessing the Relative Importance of Nutrient Sources to White Lake



# White Lake Monitoring and Rainfall Sampling

White Lake Nutrients and Rainfall Nutrients February-April 2020

	TP (mg/L)	TN (mg/L)	NH4-NH3 (mg/L)	NO3-NO2 (mg/L)	TON (mg/L)	Chl <i>a</i> (ug/L)
<b>Feb 12</b>						
<b>Lake Mean</b>	0.024	0.671	0.044	0.013	0.615	8.1
<b>Mar 6</b>						
<b>Lake Mean</b>	0.021	0.474	0.050	0.013	0.411	4.56
<b>Apr 24</b>						
<b>Lake Mean</b>	0.021	0.553	0.033	0.012	0.516	5.0
<b>Feb-Apr</b>						
<b>Rainfall Mean</b>	<b>0.012</b>	<b>0.331</b>	<b>0.124</b>	<b>0.061</b>	<b>0.127</b>	

***Nannochloris***  
***Dominant in Feb***  
***(Large Surface Area:***  
***Volume Ratio,***  
***Rapid Nutrient Uptake)***

***High Ammonium***  
***in Rain***  
***(Preferred N Source***  
***For Algae)***

**Lake TN/TP**  
**(mass) = 30**

**Rainfall TN/TP**  
**(mass) = 27**





**A Comparison of White Lake Water Quality Data for July, From 2003-2020**

	<u>2003</u>	<u>2013</u>	<u>2017</u>	<u>2018</u>	<u>2019</u>	<u>2020</u>
<b>T (C)</b>	29.1	28.6	30.4	29.2	29.0	31.0
<b>Secchi Depth (m)</b>	2.9	1.25	1.5	1.75	1.5	1.0
<b>Turbidity (NTU)</b>	1.7	4.3	3.0	1.9	1.9	2.6
<b>Chl <i>a</i> (µg/L)</b>	4	27.7	9.6	6	8.5	9.7
<b>pH Range (su)</b>	4.1	8.0-8.3	6.6-6.8	6.5-6.9	6.5-6.6	6.9-7.0
<b>Total N (mg/L)</b>	0.11	0.41	0.61	0.70	0.616	0.641
<b>Total P (mg/L)</b>	0.02	0.02	0.02	0.02	0.018	0.024

## **Overview of White Lake Changes**

**High Chlorophyll In July 2013 After Big Rains: "Tipping Point" For Lake Clarity**

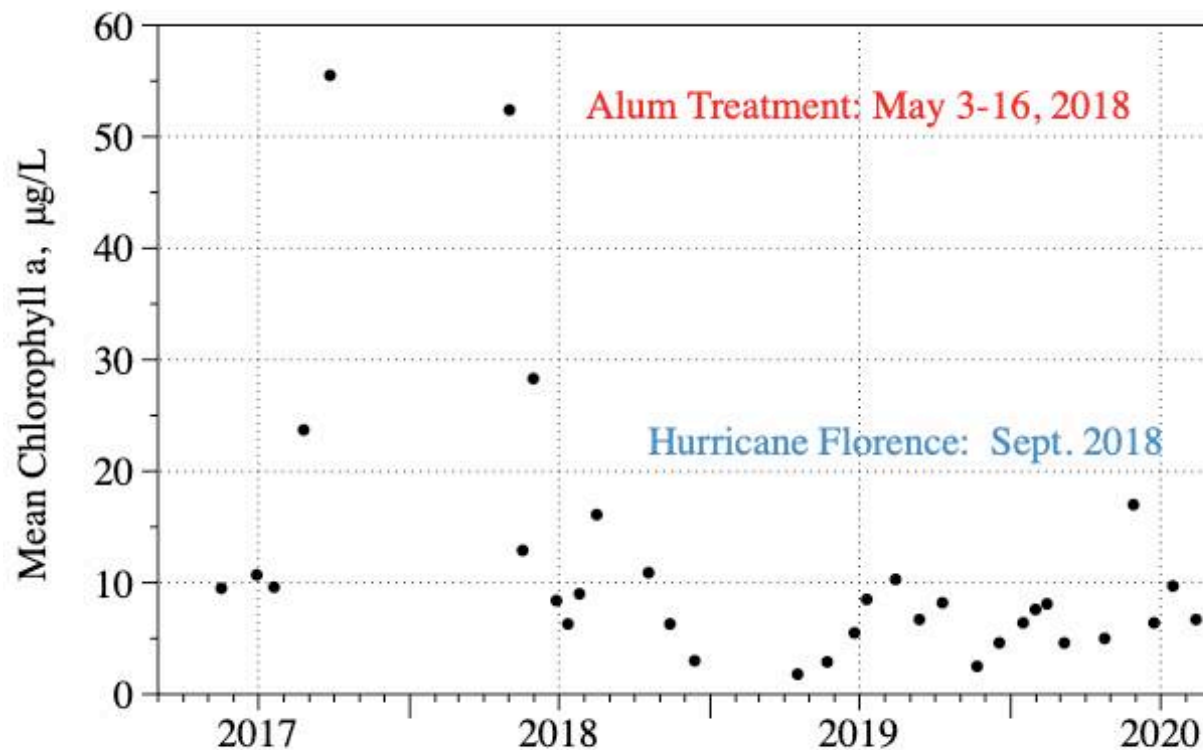
**Substantial Increase in TN Over Time**

**Historical TN/TP Ratio (mass) = 12 (1974-2008)**

2003-2017 Data From NC DEQ; 2018-2020 Data From LIMNOSCIENCES



## White Lake Chlorophyll a Concentrations 2017-2020



*Filamentous Cyanobacterial  
Bloom September 2017,  
Persisted Over Winter*

*In May 2018,  
pH Spiked to > 9  
Fish Kill*

*Low-Dose Alum Treatment  
Removed  
Filamentous Cyanobacteria,  
pH Dropped to 6+*

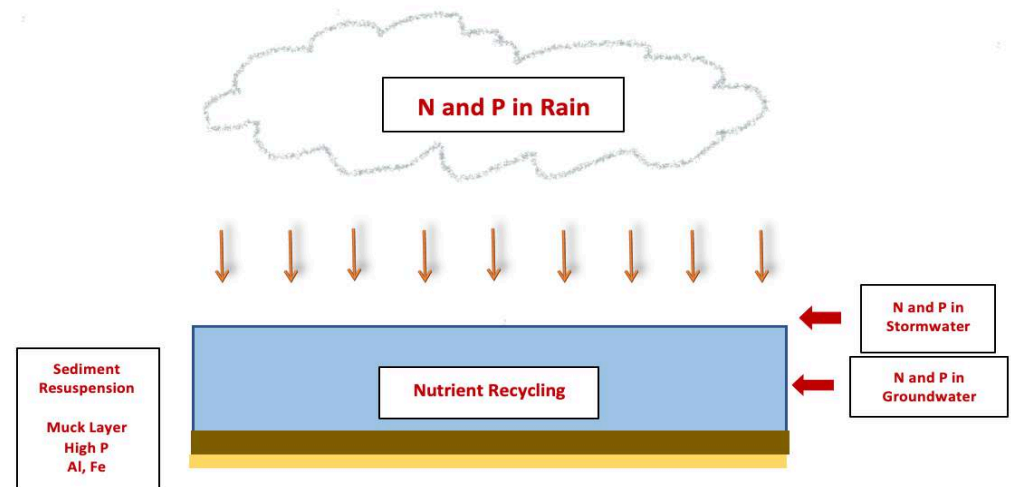
*Since Treatment:  
Picoplankton (Synechococcus)  
Chrysophytes (Dinobryon)  
Desmids  
Other Unicellular Greens  
pH Stable (6.5-7)*

## Rainfall Can Provide A Diffuse Source Of Readily Available N and P To White Lake

Picoplankton and Nannoplankton  
"First Responders" To Big Rains

Phytoplankton Community Becoming  
More Diverse, Desmids Continue to  
Dominate in Summer

Aluminum in Sediments, in Stormwater, in  
Groundwater—Moderating Influence on  
Productivity?



Check Out the Clean Air Status and Trends Network  
[www.epa.gov/castnet](http://www.epa.gov/castnet) Data for Your Area

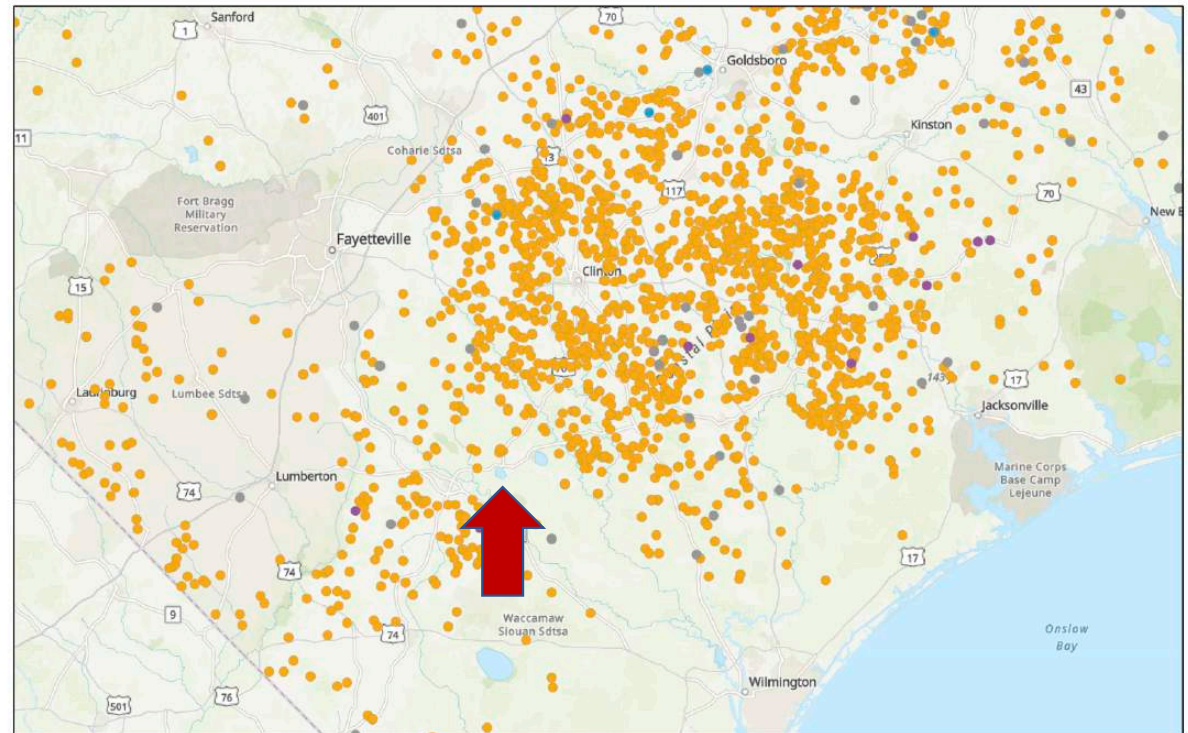
# Management Conundrum #1

**Is Atmospheric Deposition Of  
Nutrients Controllable?**

**Modeling By NCSU Researchers  
Indicates Substantial Ag  
Influence On Atmospheric  
Deposition of N**

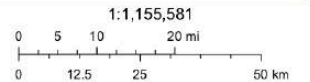
**“Sensitive” Topic for  
Stakeholders**

Animal Feed Operations Permits 2020--NC DWR



8/18/2020

Data from NC Division of Water Resources Web Site



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NOAA, NCEAS

# Management Conundrum # 2

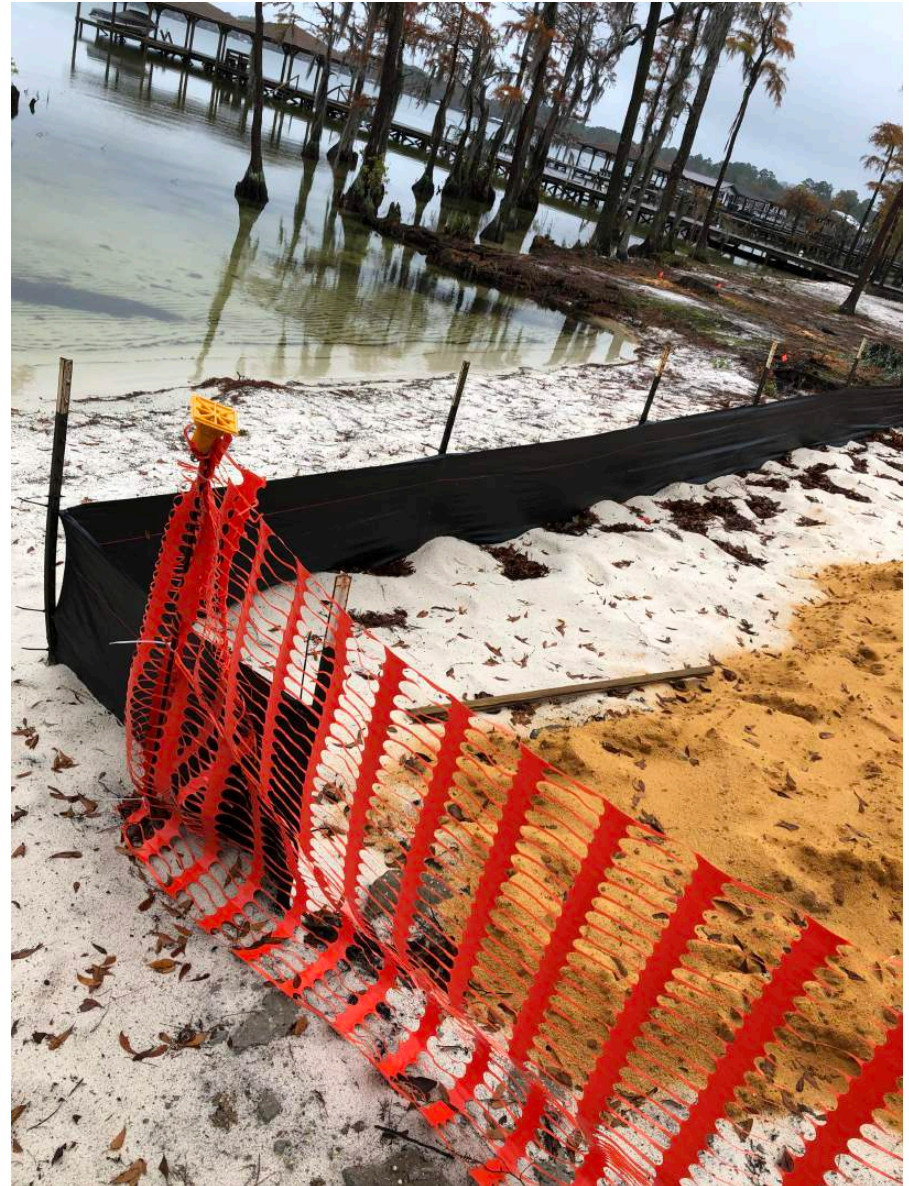
**Large Rainfall Events Becoming More  
Common Due to Climate Change**

**Presently NO Stormwater  
Management, Except to Direct it to  
the Lake**

**45% of Lakeshore Has Seawalls**

***Desire For a Crystal-Clear Lake,  
24/7/365***

**A New Church for White Lake, 20' Setback From Lake**





*Thanks to Dr. Linda Ehrlich, Ed Wilkerson with NC State Parks, the Town of White Lake for supporting monitoring and special studies, and the EPA's CASTNET Monitoring Program*





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***White Lake Watch Web Site: [www.whitelakewatch.com](http://www.whitelakewatch.com)***