

Sediment Phosphorus Comparisons Between White Lake and Lake Waccamaw

Diane Lauritsen, LIMNOSCIENCES

John Holz and Tadd Barrow, HAB Aquatic Sciences

Shannon Brattebo, Tetra Tech

William James, Univ. of Wisconsin-Stout

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Two Bay Lake Systems:

White Lake

1,067 acres, no surface inlet, clear water
Lake water pH historically <5, now above 6
Lake comprises 70% of bay, wetlands on W side

4.8 miles of lakeshore, commercial and residential development, no protected land

Sewer in all areas; \$5 M in loans for rehabilitation projects

No stormwater ordinances

Primary production mostly in benthic zone: filamentous algae, low-growing SAV

Lake Waccamaw

9,067 acres, Big Creek inlet, blackwater
Lake water pH neutral
Lake comprises 90% of bay, wetlands on N side

14.2 miles of lakeshore, residential development, state park-owned lands

Sewer in most areas, 1 trailer park on septic

Stormwater ordinances, \$4.5 M in grants for stormwater projects

Primary production mostly in benthic zone: emergent and submerged vegetation, filamentous algae

Sediments Important in Shallow Lakes

Lower water volume : sediment surface area

Serve as phosphorus storehouse

Frequent sediment resuspension

***Mean depths: White Lake 1.9 m,
Lake Waccamaw 2.3 m***



White Lake Sediment Sampling Feb. 11, 2019

3 Sites Sampled

All three in the mucky sediments described
as “pulpy peat” in Frey 1949

This sediment type comprises half of the
lake bottom



Lake Waccamaw Sediment Sampling Feb. 12, 2019

4 Sites Sampled

Three in the mucky sediments described as
“pulpy peat” in Frey (1949)

This sediment type comprises a third of the
lake bottom

Two of the three sites were in the *Hydrilla*
treatment zone in the NW region of the lake

One sandy sediment site near the mouth of
Big Creek

P-Fractionation of Sectioned Cores and Anoxic Incubation of Intact Cores

One sediment core sectioned into 2 cm segments up to 10 cm, and 5 cm segments thereafter

Samples placed on ice and express-shipped to IEH Analytical Labs in Seattle

P fractions determined from successive extractions with NH_4Cl , Bicarbonate/Dithionate, NaOH , and HCl (after Rydin and Welch 1998)

Total Aluminum, Total Iron, Total Calcium and % Solids also measured

One intact sediment core was collected from each muck site and sealed in its coring tube after the overlying water was carefully removed

Cores placed on ice and express-shipped to UW-Stout

14-day incubations under anoxic conditions, measuring Soluble Reactive Phosphorus release

Higher P at Waccamaw, Total Al Values Similar

Table 1. *Means for Total Phosphorus (TP), Total Aluminum (Al), Total Iron (Fe), and Total Calcium (Ca)* in sediment core samples from Lake Waccamaw and White Lake, NC. The means include all depth increments for each core sample. All data reported as milligrams per kilogram dry weight of sediment.

| Sample ID | Mean TP (mg /kg DW) | Mean Al (mg/kg DW) | Mean Fe (mg/kg DW) | Mean Ca (mg/kg DW) |
|------------------|----------------------------|---------------------------|---------------------------|---------------------------|
| Waccamaw1-M | 935.4 | 10599 | 10564 | 4266 |
| Waccamaw2-M | 901.6 | 13334 | 10993 | 3666 |
| Waccamaw3-M | 937.4 | 14014 | 11559 | 3866 |
| Waccamaw4-S | 32.4 | 172 | 301 | 1395 |
| | | | | |
| WhiteLake1-M | 601.6 | 13973 | 6004 | 1300 |
| WhiteLake2-M | 421.0 | 10425 | 4150 | 1371 |
| WhiteLake3-M | 843.7 | 14494 | 6443 | 1262 |

Al-Bound Phosphorus Dominant in Muck Sediments of Both Lakes

Table 2. *Means for Sediment Phosphorus Pools (as a % of Total Extractible P) in muck sediments (all depth increments, 3 cores/lake).*

| | <i>% Loosely-Bound P</i> | <i>% Fe-Bound P</i> | <i>% Al-Bound P</i> | <i>% Biogenic P</i> | <i>% Ca-Bound P</i> | <i>% Organic P</i> |
|-------|--------------------------|---------------------|---------------------|---------------------|---------------------|--------------------|
| Wacc | <1 | 14.2 | 56.1 | 17.1 | 3.8 | 26.0 |
| White | <1 | 22.2 | 45.4 | 26.1 | 1.6 | 31.0 |

Total P

Sandy site at Lake Waccamaw had much less P

Muck sediments at Waccamaw had higher P than White Lake sediments

Trend of decreasing P with sediment depth

One outlier at White Lake—high Fe-Bound P

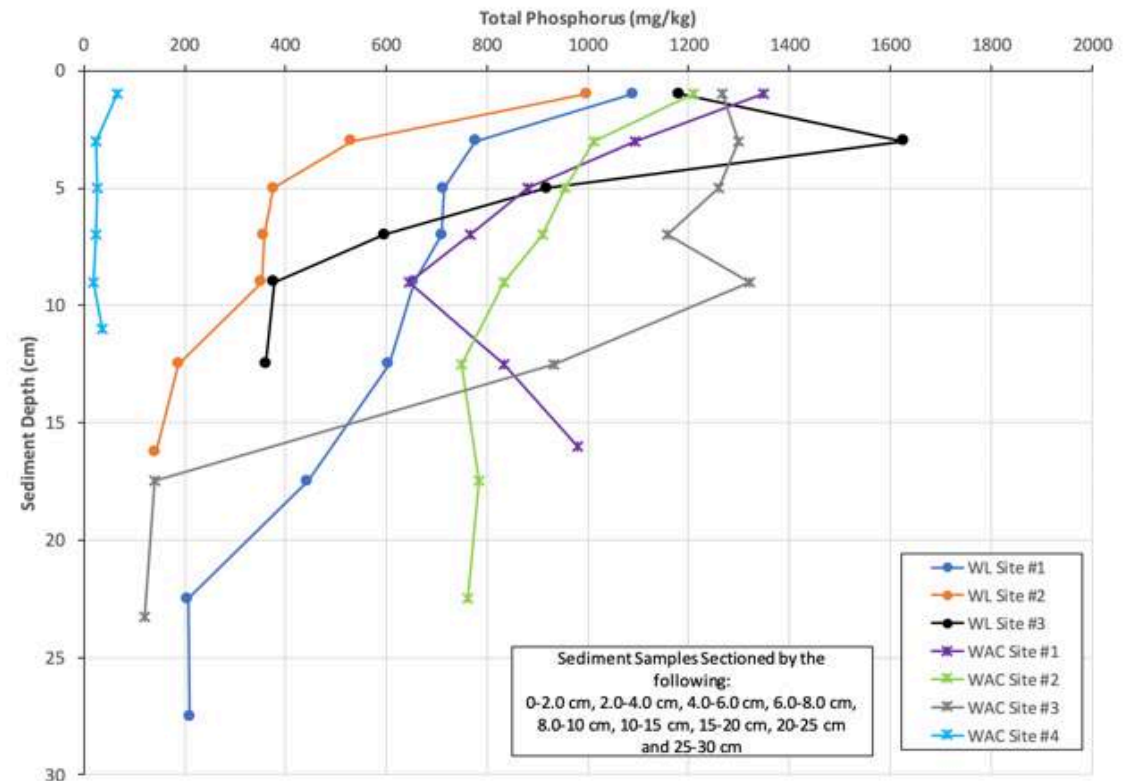


Figure 1. *Total extractible P* (mg/kg DW) from Lake Waccamaw (sites 1-3 muck, #4 sand) and White Lake (sites 1-3 muck) sediment cores.

Al-Bound P

Very little Al-P at Waccamaw sand site

Tight range of values in 0-2 cm depth increment for both lakes

Greater decline with depth in White Lake sediments

Highest value at Waccamaw in 8-10 cm depth increment

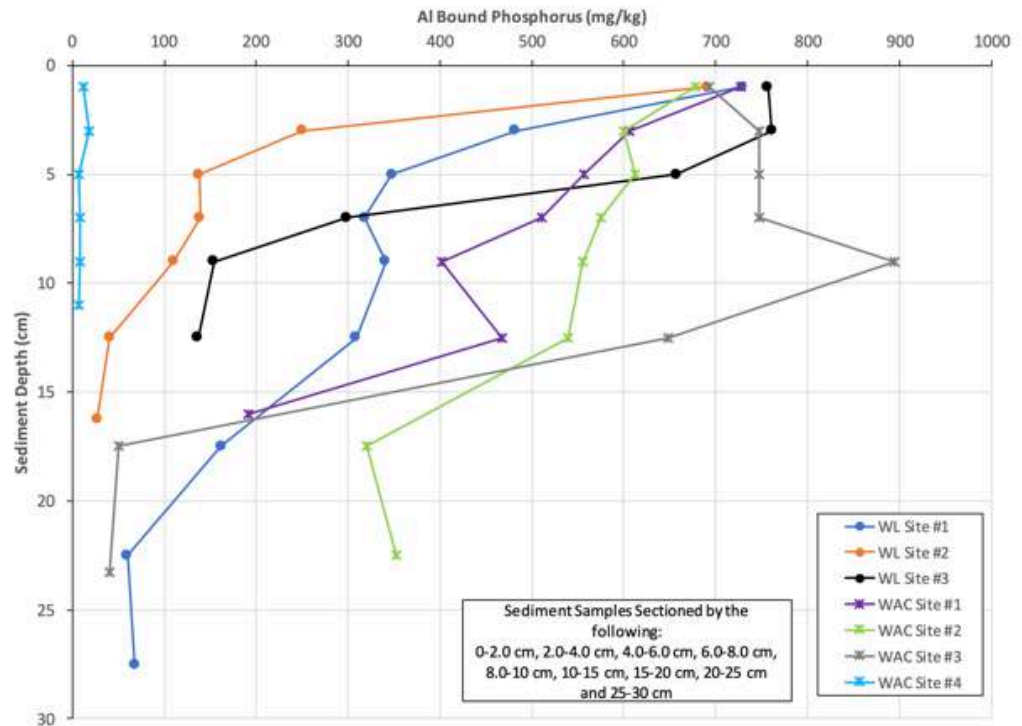


Figure 2. *Al-Bound P* (mg/kg DW) for and White Lake (sites 1-3 muck) sediment core samples from Lake Waccamaw (sites 1-3 muck, #4 sand)

Mobile P (Fe-P)

Very little Fe-P at Waccamaw sandy site

Similar values between lakes

Little decline in Fe-P with sediment depth; two Waccamaw cores had highest values in deeper sediment increments

White Lake outlier—very different value of Fe-P in one depth increment

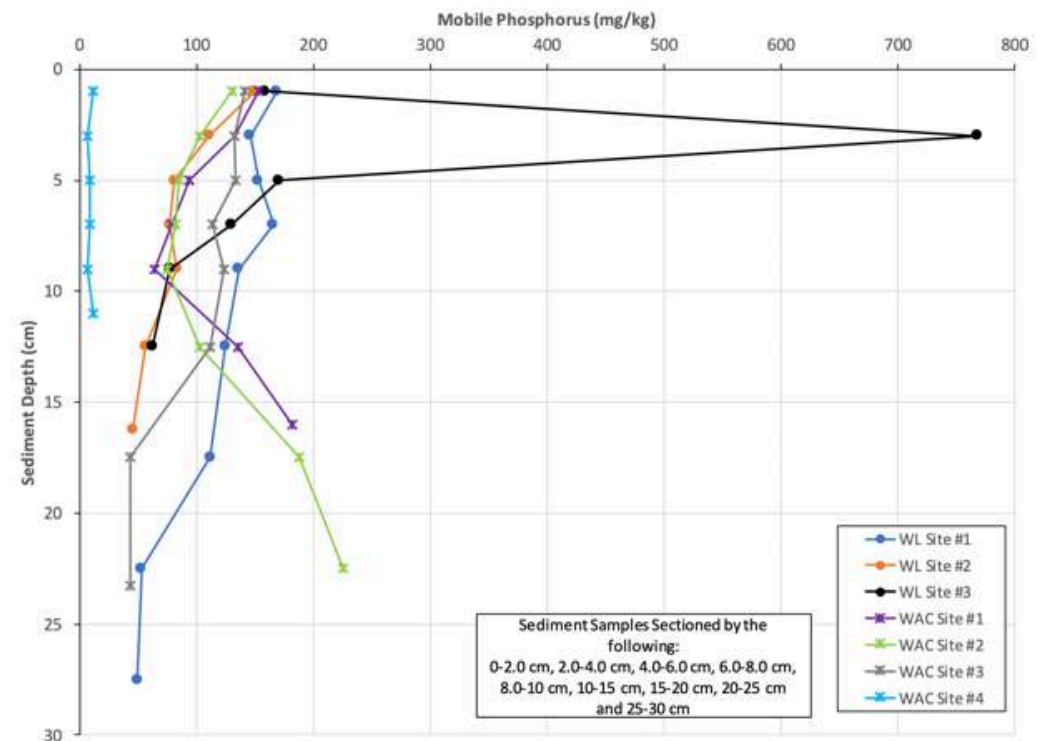


Figure 3. *Mobile P* (mg/kg DW) for and White Lake (sites 1-3 muck) sediment core samples from Lake Waccamaw (sites 1-3 muck, #4 sand)

Why No Significant P Release Under Anoxia?

The naturally-occurring and abundant metal Aluminum in the sediments of both lakes is available to adsorb soluble reactive (dissolved) Phosphorus that can be released during hypoxia/anoxia

Wetland soils have natural capacity to retain P--high Al and Fe

(Richardson, 1985. Mechanisms controlling phosphorus retention capacity in wetlands. Science 228: 1424-1427)

Phosphorus inactivation of sediments with a binding agent (alum, Phoslock) is typically done when Mobile P (Fe-P) is the dominant form of sediment P and anoxic conditions are extended (lake stratification)

Processes That Regulate P Cycling in Lakes

Dissolved oxygen concentration—anoxic conditions at Waccamaw after 2012 SAV die-off significant enough to affect benthic invertebrates

Temperature—seasonal variability, climate change

Microbial activity = Biogeochemistry--dependent on pH, temp, DO

 *pH*—changed at White Lake

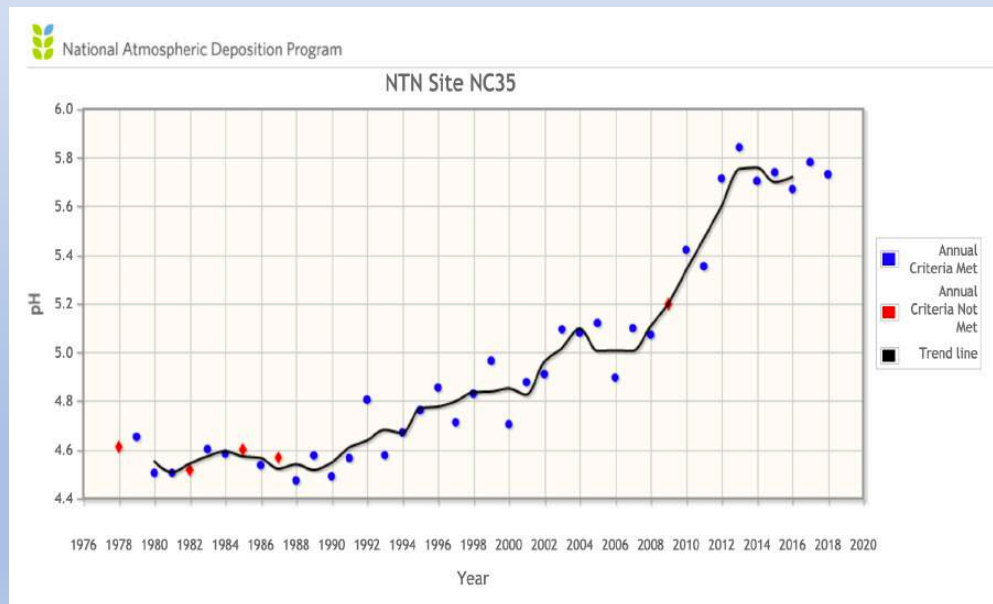
White Lake Was an Acid Rain Lake

Rainfall pH Has Increased From 4.5 to 5.8

STATE ENVIRONMENTAL POLICY INNOVATIONS: NORTH CAROLINA'S CLEAN SMOKESTACKS ACT

BY
RICHARD N. L. ANDREWS*

An important and longstanding limitation of the federal Clean Air Act was its failure to assure cleanup of the hundreds of old coal-fired electric power plants that were built prior to the 1970s, most of which were "grandfathered" and thus continued to operate. In 2002, North Carolina enacted an unusually innovative state-level solution to this problem: a permanent, year-round cap on overall NO_x and SO_2 emissions from each of its two major utilities, stringent enough to require cleanup or retirement of all forty-five of their coal-fired units. Using the leverage of this law, North Carolina also brought legal actions against its principal upwind source (TVA) and the EPA, leading to a similar cleanup commitment by TVA and a federal judicial decision to assure protection of downwind states under EPA's Clean Air Interstate Rule.



Biogeochemical Changes with Changing pH

Bioavailability of P—Sorption with Aluminum

P and Al in Sediments, in groundwater, in surface water runoff

Low Alkalinity of lake water

2018 Low-Dose Alum Treatment to mitigate persistent cyanobacterial bloom—pH levels had shot up rapidly in early May

pH range in White Lake for 2019: 6.2-6.9

Management Focus for White Lake

Relative Importance of Phosphorus Sources:

Sediments + Biogenic > Atmospheric + Groundwater + Runoff + Birds

Internal > External

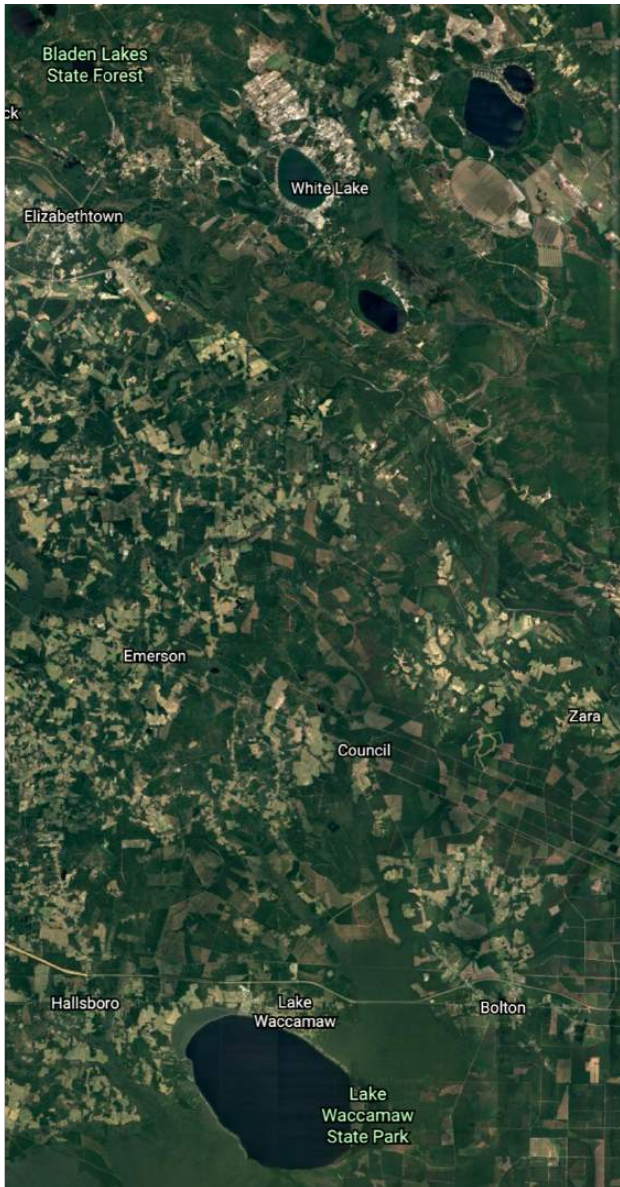
Sediment resuspension provides a significant P source—moderate boating activity to reduce its impact

Aesthetics vs. Lake Health—

Change the narrative (Bad Algae vs. Algae Bad)

Manage elevated water column P if it occurs (trigger point 0.04 mg/L ?)

Mean water column P in 2019 was 0.018 mg/L



Thank You:

Town of White Lake for providing funding for
White Lake sediment sampling

Lake Waccamaw State Park for providing a boat
and staff for sediment sampling at Lake
Waccamaw

Contact: ddlauritsen@gmail.com

www.whitelakewatch.com