North Lake Ecological Report

A Biological, Chemical, and Morphometric Lake Study
Conducted by

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Presented to
The North Lake Association
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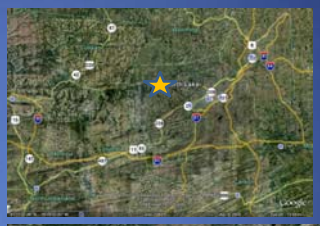
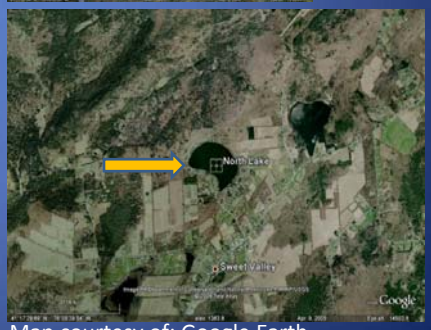
Project Objectives

- Obtain limnological data from North Lake (chemistry, morphology, biology, etc.)
- Use the data to comparatively analyze environmental conditions prior to a remediation program in 2004 with present conditions
- Analyze the effectiveness of the CLEAN-FLO aeration system
- Use these data to make initial recommendations

Geographic Setting/Geology

- Located in western Luzerne Co. ; Sweet Valley, PA
- Lake was formed by an ice gouge from the Illinoian and Wisconsin Ice sheets during the Pleistocene Epoch
- Lake age ~12,000 years





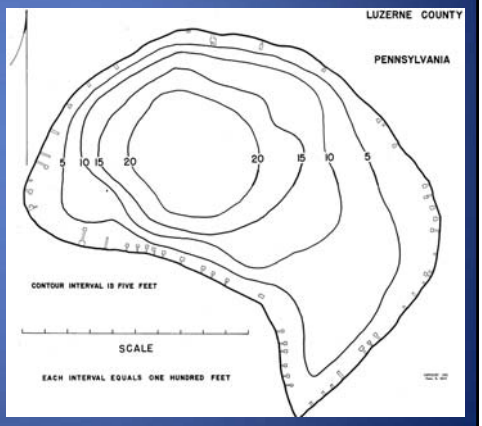
Map courtesy of: Google Earth

Lake Morphometry

Morphometric Parameters

Surface Area	38.9 acres
Watershed Area	137 acres
Catchment Area	175.9 acres
Volume	1.253 x 10^8 gallons
Max Length	1,853 Feet
Max Breadth	1,474 feet
Max Width	907 Feet
Max Depth	22.1 Feet
Mean Depth	10.1 Feet

Bathymetry of North Lake



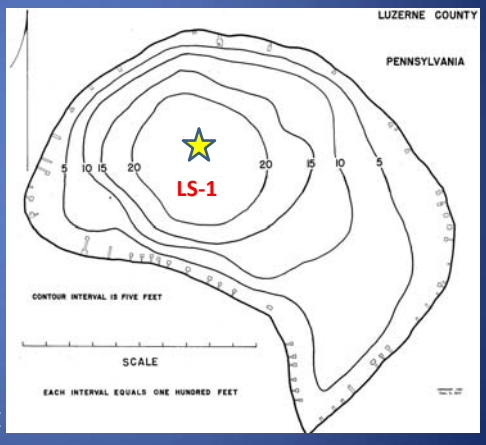
Reif, 1961

Prior Studies, History, and Background Information

- 1963: lake was "crystal clear;" ~90% of residency was seasonal; Indoor plumbing "unheard of"; 55 gallon drums sometimes received sewage wastewater.
- Mid 1970's lake began to show noticeable changes; large increase in seasonal residency
- 1978: Dr. C Houseknecht Wilkes College quotes "septic sewage main threat to lake"
- Rapid decline in aquatic life; large blooms of cyanobacteria (blue-green algae) start to appear
- North Lake proposed a sewage wastewater system but was turned down by the surrounding community
- 2001-2004: Association hired EcoScientific Solutions to manage lake; began $CuSO_4$ treatments/ CLEAN-FLO aeration system introduced and installed on lake bed.
- September 2008: Wilkes University Limnology Class Study

Limnological Data

- Temperature
- Dissolved Oxygen
- pH
- Turbidity
- Light Transmissivity
- Phosphorus & Nitrogen
- Biology
- Loss on Ignition
- Theoretical Flush rate
- Bottom Sediment Core Sampling
- All measurements taken at Lake Station 1 (LS-1)



Temperature

- Affects chemical, biological, and physical processes
- Increase in temperature decreases the dissolved oxygen
- Usually climate controlled, but humans can alter temperature such as the case at North Lake
- Spring and fall--uniform temperature profile throughout lake
- Area lakes usually stratify into 3 layers during summer/early fall--Epilimnion, Thermocline, and Hypolimnion

Lake Stratification

- Epilimnion: warmest water and highest D.O. levels
- Thermocline: middle layer of water where a rapid decline in temp and D.O. is observed
- Hypolimnion: coldest layer and lowest, if any, D.O. levels

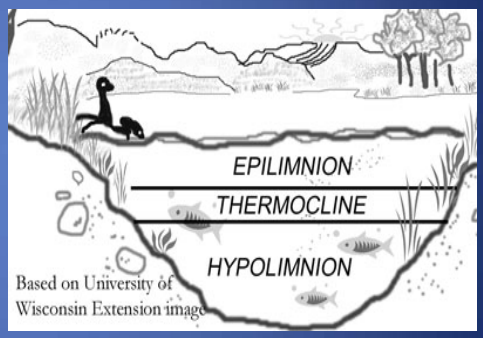
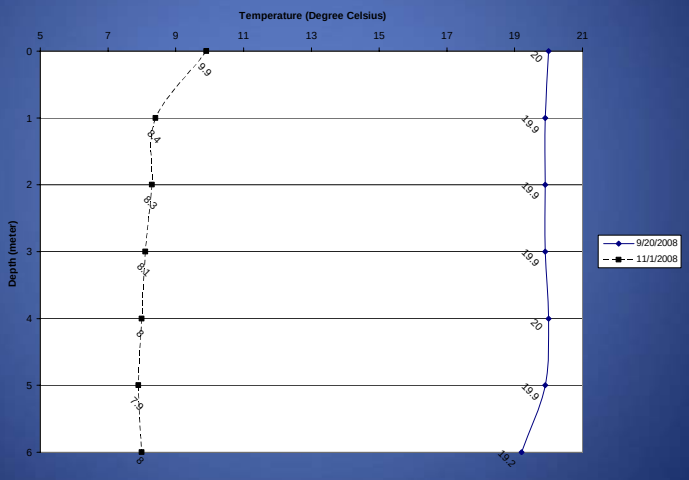


Image courtesy of: University of Wisconsin

Lake Stratification (cont)

- In 1978 study, North Lake stratified
- Since introduction of diffusers, it has de-stratified
- This was expected and was a major objective of the system
- Temperature profiles are now consistent from top to bottom

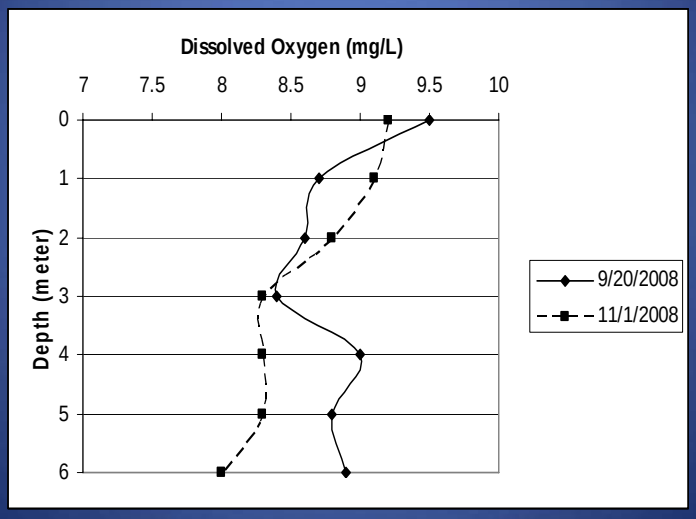
Temperature Profile



Dissolved Oxygen

- Temperature dependant (warmer water holds less D.O.)
- Photosynthesis and diffusion provide O_2 naturally
- Decomposition of organic matter, respiratory processes, and oxidation of inorganic wastes deplete it
- Important indicator of the "health" of lake
- Most organisms require minimum of 4 mg/L of D.O.
- North Lake is very well mixed and D.O levels remained high as expected
- However, some depths greater than 6m showed little, if any D.O. near bottom (anoxic conditions); CLEAN-FLO system was supposed to add oxygen to all depths and rid bottom of reduced gases

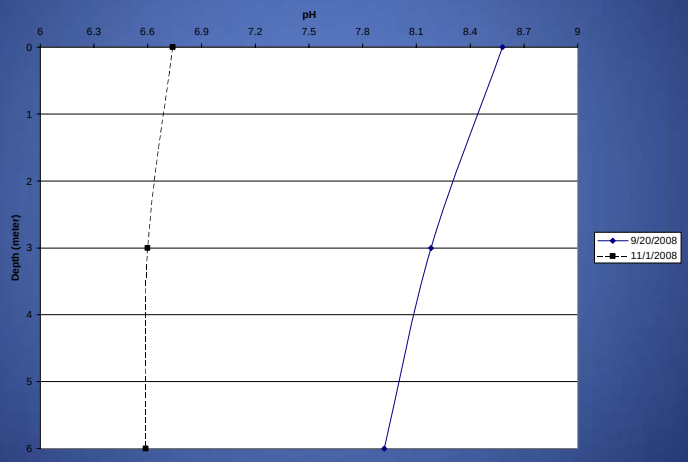
Dissolved Oxygen (cont)



pH

- Logarithmic scale of 0-14
- 7 is neutral (water)
- Major factor to chemical and biological processes
- North lake's pH was 6.74-8.58; Average to slightly above average
- Above average results due to more sunshine aiding photosynthesis, hence, lake was taking in more CO_2

pH Profile



Turbidity and Secchi Disc

Turbidity Meter

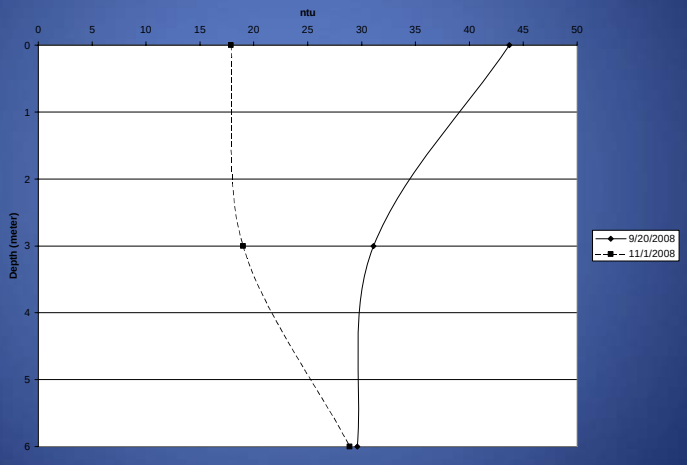
- Provides measure of water clarity and particulate matter (PM)
- PM includes algae, sand, silt, mud and plant matter
- Average lake value 5 ntu
- North Lake measured extremely high values between 18 and 44 ntu's
- High values were caused by the excessive amount of algae

Secchi Disc

- Easiest for common lake user to understand
- 20cm black and white circular disk
- Lowered through water column until no longer visible and depth recorded

Secchi Disc

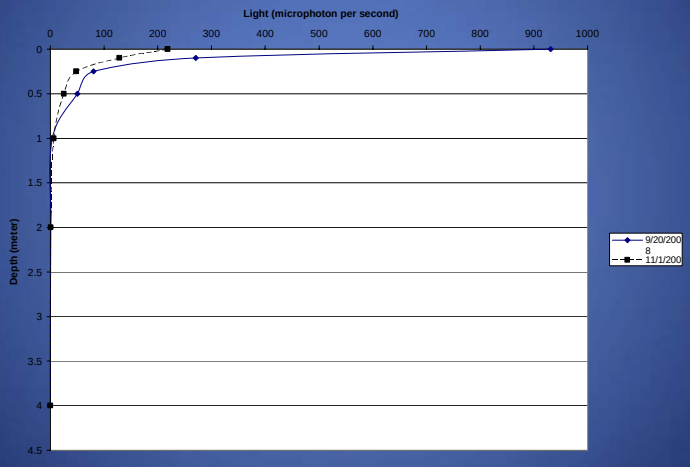
Turbidity Profile



Light Transmissivity

- Indicator of water quality
- Measures how much light penetrates water column
- Essential for photosynthesis
- Light is scattered by algae and other suspended particles
- Light can reach depths of tens of meters deep in clear lakes
- Light in North Lake dramatically declined after just a few centimeters
- Due primarily to lake's cyanobacteria bloom present at sampling time

Light Profile



Phosphorus and Nitrogen

- Main “pollutants” of lake
- Major nutrients of algae and macrophytes
- External and Internal loading
  - External sources include septic leachate, sewer effluent, dish detergent (soaps), run-off and precipitation
  - Internal loading from decomposition and sediments
- Nitrate/Nitrogen to total Phosphorus ratio (N:P)found to be 0.44. This low value suggests that the cause is from septic leachate

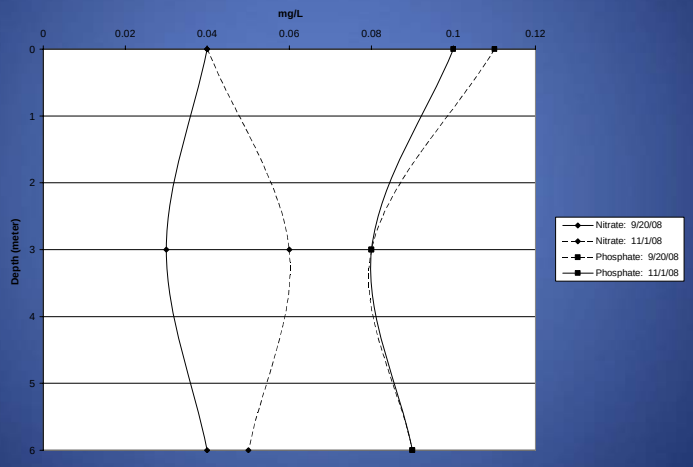
Phosphorus

- Typically a limiting factor on algal production in freshwater lakes in this region
- Essential nutrient to all living species
- Normal range 0.01 to 0.03 mg/L
- Values below 0.01 indicate oligotrophic (nutrient poor) conditions; greater than 0.03 is eutrophic (nutrient rich), and in between, mesotrophic
- Oligotrophic, little productivity
- Mesotrophic, medium productivity
- Eutrophic, high productivity
- North Lake registered a high of 0.11 and mean value of 0.09 mg/L
- This is more than 3 times the expected phosphorus for a eutrophic lake
- North Lake is probably“Hyper-Eutrophic”, exhibiting excessive productivity

Nitrogen

- Nitrogen cycle is complex
- Nitrogen can exist as oxidized forms such as nitrate (NO_3^-), nitrite (NO_2^-), or reduced forms such as nitrite (NO_2^-) and Ammonia (NH_3)
- Ammonia is most commonly found near bottom
- The form of nitrogen depends upon dissolved oxygen concentrations

Phosphorus/Nitrogen Profile



North Lake Biology

Phytoplankton

- Photosynthetic organisms that float freely
- Adapted for life of suspension
- Dependent upon wind and water currents for transportation
- Cyanobacteria (blue-green algae) are in this group

Zooplankton

- "Animal-like" organisms that exist in plankton community
- 4 major groups: protozoa, rotifers and 2 subclasses of Crustacea—Copepods and Cladocerans

Phytoplankton

- Cyanobacteria: (Blue-Green Algae) *Anabaena* and *Microcystis* dominate at North Lake
- They are responsible for obnoxious green surface scums
- Their excessive presence is the result of abnormally high concentrations of P and N
- Generally not grazed upon by zooplankton

Schindler trap used for collection of plankton

North Lake Biology

- 1978 study found 35 species of plankton compared to 2008 study of only 15 species of plankton
- This was a 43% loss of diversity!
- Cyanobacteria, or blue-green algae was the dominant species in current study
- Cyanobacteria are the most undesirable form and responsible for obnoxious green surface scums, wind swept "green mats", and foul odors
- Highly adaptable species
- Can fixate its own N; therefore the overabundance of P provides a huge growth potential
- If P loads are reduced, cyanobacteria levels will drop
- *Microcystis* accounted for over 87% of the 15 species and is responsible for DEP's decision to close the lake recently
- Contains a toxin called microcystin which can cause numerous allergic reactions and health problems in humans and pets

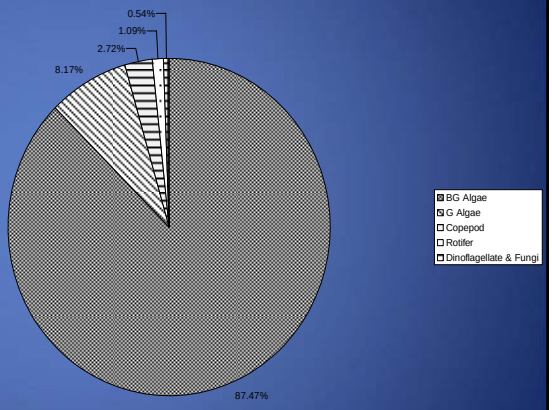
Zooplankton

- Animal-like organisms
- Cladocerans dominant
- *Chydorus sphaericus*
- Small crustaceans commonly referred to as "water fleas"
- Feeds upon small algae and bacteria
- Does *not* feed upon toxic cyanobacteria
- Observed grazing phytoplankton, but excreting waste at high rate
- Did not appear to have noticeable impact on biomass

Chydorus sphaericus

North Lake Biodiversity

- 43% loss of diversity since 1978!
- 1978 study found green algae dominant
- 2008 study found blue-green algae dominant



Plankton Sampling

- Wisconsin Tow (vertical)
- Used to collect plankton samples of various sizes
- Consists of a fine mesh net which is volumetrically calibrated
- This can be used to calculate the lake's biomass density

Wisconsin net

Bottom Sediments

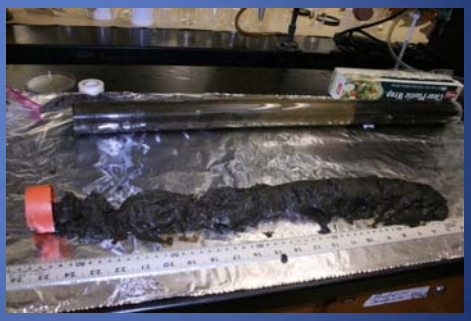
- Accumulate lake's nutrients and acts as a repository
- Can add nutrients into water (internal loading)
- Can "date" the lake and reveal history of development
- D.O. meter revealed anoxic conditions present at water/sediment interface
- Core sample obtained and used for determining loss on ignition (LOI)

Bottom Core Sampling

- Core sample taken at deepest point (22.1 ft)
- 63.5 cm L X 49 mm W
- Core was darker colored on top than bottom, suggesting increased amounts of organic matter introduced more recently in time
- LOI was conducted to verify this

North Lake's core sample

Bottom Core Sample (continued)



Bottom Core Sample (continued)

Loss on Ignition

- Laboratory test used to determine amount of organic matter is in substance
- Core sample broken down into 6 sections
- Sample closest to top represents present time and sample near bottom represents a few hundred years ago
- Dried samples were burned in a 525°C furnace, then re-weighed to determine LOI
- Important test: showed how North lake's productivity changed over time
- More organic matter "burned off" translates to more organic matter that was present
- Data given as % organic matter lost

Loss on Ignition (continued)

- Clearly shows more organic matter at present time
- % lost declines throughout time
- Core age at 50-60cm mark hundreds of years old
- Significant find since lake has never been this productive until recently
- Human impact is most likely cause

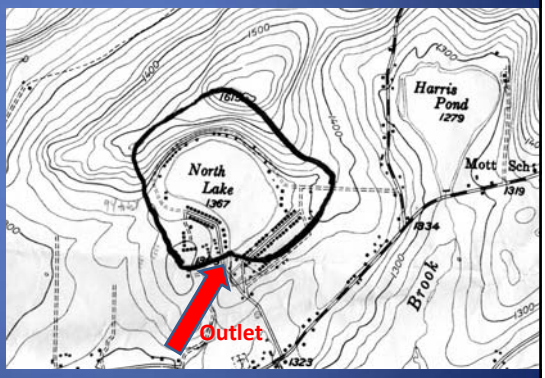
Sediment Depth (cm)	Loss on Ignition (%)
0-10	38.9
10-20	38.8
20-30	31.2
30-40	27.7
40-50	28.1
50-60	24.3

Theoretical Flush rate

- Calculating “real” flush rate was beyond scope of study without a detailed knowledge of groundwater inputs
- Flushing rate has direct impact on water residence time (amount of time water stays in a system)
- A short residence time will benefit lake since it will flush “old” water out and replace with “new” water
- Residence time is affected by the water budget of a lake and watershed area
- Theoretical value will yield highest possible flush rate lake can achieve
- “Real” flush rate will be somewhat lower
- Calculated by determining long term average annual precipitation multiplied by watershed area
- Value then multiplied by a runoff coefficient to give the amount of water entering the lake annually
- Annual input of water to lake is then divided by the lake’s volume

North Lake’s Watershed Area

- 137 acres
- An extremely small watershed area
- Long-term average annual precipitation for WB/Scranton 0.91m
- Theoretical flush rate determined to be 1.6 times/year
- Moderate value
- Positive attribute for lake



Map courtesy: USGS ; Area by Joel Antolik

The CLEAN-FLO System and Artificial Circulation

- Artificial circulation (AC) and de-stratification are main objectives of this system
- Theoretically achieved by pumps, pipes, and bubbled air from diffusers resting just above bottom sediments
- Expected lake water quality improvements include aeration (increase in dissolved oxygen and expansion of suitable habitat
- AC *may* also reduce *internal* loading of P by subjecting algal cells to higher hydrostatic pressures
- AC intended to mix the entire water column, therefore decreasing amount of time algae has in photic zone for photosynthesis; however, North Lake may not be deep enough for this to occur
- In some cases phytoplankton may increase following AC

The CLEAN-FLO System and Artificial Circulation (cont)

ADVANTAGES

- Increases dissolved oxygen concentrations at nearly all depths
- Increases suitable habitat for all organisms and fish
- Remediation tool to reduce phytoplankton biomass by light limitation

DISADVANTAGES

- Increases water temperature
- For treatment of internal loading of P only
- Costly to operate/maintain
- Pipes & diffusers must be properly placed to avoid disturbance of bottom sediments rich in phosphorus and nitrogen (requires visual inspection)

Conclusions

- Overall, water quality at North Lake has declined sharply since the first 1978 study by Wilkes College
- Recent CLEAN-FLO system has increased D.O. levels for some fish and zooplankton species.
- Nevertheless, North Lake exhibits dramatic losses in biodiversity in the past 30 years consistent with increasing eutrophication.
- Internal loading may have increased because of diffuser aeration and disturbance of bottom sediments
- Flush rate of 1.6 times/yr provides "hope" for lake ***if*** external P is taken care of first

Recommendations

- Before any attempt to halt internal loading , external loading *must* be stopped--a sewer system is desperately needed and is most likely the ultimate solution
- If funds cannot be made available, every attempt to upgrade and maintain the existing septic system is recommended
- Lawn fertilizers should not be used within the the watershed area
- Any detergents used should be "phosphorus-free"
- Some observed properties have steep embankments which are not vegetated; Plant trees, shrubs, or grass on such embankments
- Mud and silt naturally carry P into the water and can account for modest increases of P, therefore, all properties should participate in Best Management Practices for erosion control
- The dirt road traversing around the lake should be paved
- In some case studies, a reduction in external loading was sufficient to restore the water body
- Another form of remediation tool that may provide temporary relief is nutrient inactivation

Recommendations (continued)
Nutrient Inactivation

- Involves addition of alum (aluminum salts) which binds P (coagulation) and settles it to the bottom
- Forms 1-2" layer of "floc" on bottom
- Prevents P from being re-distributed in water column
- Works well in little or no oxygenated water
- If internal loading is high, it can reduce P enough to limit algal growth, or at least shift a blue-green dominant algae to one dominated by green algae and diatoms

Recommendations (continued)
Nutrient Inactivation

ADVANTAGES

- Very effective in reduction of internal P
- Long lasting (> 8 years)
- Virtually maintenance-free
- Does not directly kill phytoplankton, such as copper sulfate treatments of the past (those treatments rupture algal cells and release additional nutrients)
- Cost effective

DISADVANTAGES

- External P must be stopped and will not work if it is too high
- Decreases pH levels
- Aluminum toxicity by decreasing pH values
- Boat motors may disturb sequestered P

Recommendations (cont)
Nutrient Inactivation

- North Lake is a "borderline" candidate for this remediation tool
- pH is good but alkalinity may need to be increased
- Lake's pH and alkalinity must constantly be monitored and managed
- Chance for aluminum toxicity is low
- Sufficient depth of lake makes it questionable

Review of Final Recommendations

- External P must be stopped first before any other remediation effort
- Sewer system must be installed
- Maintain/upgrade existing septic systems
- The use of Lawn Fertilizers are strongly discouraged
- Buy only "Phosphate-Free" laundry detergents
- Limit the amount of "grey water" entering watershed area
- Residents should take proper erosion control measures around their properties
- Dirt road around lake should be paved

Final Recommendations

1. Connect to sewer system
2. Visually inspect CLEAN-FLO system under operational conditions to determine impact on bottom sediments.
3. Explore possiblity of alum treatment.
4. Enact horsepower restrictions on motorboats.

End of Presentation

- I would like to thank everyone for their time and participation
- Special thanks to Mr. J.D. and Neil Paternoster, Mr. Carl Steinbrenner, Mr. Fred Frey, and The North Lake Association
- Questions will now be taken