Long Lake
Lake Management Plan

Polk County, Wisconsin
October 2013

Prepared By
Polk County Land and Water Resources Department
Harmony Environmental

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Purpose of the Study

Lakes are a product of the landscape they are situated in and of the actions that take place on the land which surrounds them. Due to this fact, lakes situated within feet of others can differ profoundly in the uses they support. Factors such as lake size, lake depth, water sources to a lake, and geology all cause inherent differences in lake quality.

Additionally, humans, by changing the landscape, can bring about changes in a lake. This arises because rain and melting snow may eventually end up in lakes and streams through surface runoff or groundwater infiltration. Rain and melting snow entering a lake is not inherently problematic. However, water has the ability to carry nutrients, bacteria, sediment, and chemicals into a lake. These inputs can impact aquatic organisms such as insects, fish, and wildlife and—especially in the case of the nutrient phosphorus—fuel problematic algae blooms.

The landscape can be divided into watersheds and subwatersheds, which define the land area that drains into a particular lake, stream, or river. Watersheds that preserve native vegetation and minimize impervious surfaces (cement, concrete, and other materials that water can't permeate) are less likely to cause negative impacts on lakes, rivers, and streams.

Lake studies often examine the underlying factors that impact a lake's health, such as lake size, depth, water sources, and the land use in a lake's watershed. Many forms of data can be collected and analyzed to gauge a lake's health including: physical data (oxygen, temperature, etc.), chemical data (including nutrients such a phosphorus and nitrogen), biological data (algae and zooplankton), and land use within a lake's watershed.

Lakes can be classified based on their nutrient status and clarity levels. Three categories commonly used are: oligotrophic, mesotrophic, and eutrophic.

- ✓ Oligotrophic lakes are generally clear, deep, and free of weeds and large algae blooms.
- ✓ Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have good fisheries and occasional algae blooms.
- ✓ Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms. Lakes can also be hypereutrophic. Hypereutrophic lakes are characterized by dense algae and plant communities and can experience heavy algal blooms throughout the summer.

Lake studies often identify strengths, opportunities, challenges, and threats to a lake's health. These studies can identify practices already being implemented by watershed residents to improve water quality and areas providing benefits to a lake's ecosystem. Additionally, these studies often quantify practices or areas on the landscape that have the potential to negatively impact the health of a lake.

The end product of a lake study is a Lake Management Plan which identifies goals, objectives, and action items to either maintain or improve the health of a lake. These goals should be realistic based on inherent lake characteristics (lake size, depth, etc.) and should align with watershed residents' goals.

Included in this document are the data and conclusions drawn from a 2012 lake study completed by the Polk County Land and Water Resources Department. This study collected and analyzed the following data to aid in the creation of a Lake Management Plan for Long Lake:

- ✓ Lake resident opinions
- ✓ Lake level and precipitation data
- ✓ In lake physical and chemical data
- ✓ Algae and zooplankton data
- ✓ Lake sediment chemistry
- ✓ Shoreline land use
- ✓ Lakefront property models results
- ✓ Lakeshore soil sampling results
- ✓ Tributary monitoring results (North and South Ditch)
- ✓ Watershed and subwatershed land use

This study also included a number of educational opportunities for members of the Long Lake District including:

- ✓ A series of four meetings to review the data collected and develop a Lake Management Plan

Whenever possible, past lake studies completed on Long Lake are used as a baseline comparison for this study. A summary of previous lake studies can be found on page 19.

Executive Summary

Long Lake is a 272 acre seepage lake located between the Villages of Balsam Lake and Centuria. The lake receives water from precipitation and snowmelt through ditches located on the north and south side of the lake. Long Lake responds greatly to rainfall events, with the lake level dropping over one foot during 2012 drought conditions.

One hundred six lake residents completed a survey regarding Long Lake. Algae growth, water clarity, invasive aquatic plant growth, algae toxins, and plants making it difficult to swim caused the greatest degree of negative impact on lake use. Three-fourths of respondents expressed interest in free information and site visits to address waterfront property runoff.

Citizen Lake Monitoring Data has been collected intermittently since 1992 and indicated that Long Lake is eutrophic (productive with frequent algae blooms). Data for 2012 indicated that Long Lake was hypereutrophic and characterized by heavy algae blooms and dense plant growth.

Blue green algae were the most abundant form of algae from 2010-2012. Blue green algae are of specific concern because they produce toxins at elevated concentrations.

In 2009 high algae toxin levels were likely the cause of a human skin rash and a large dog becoming violently ill and were confirmed as the cause of the death of a small dog. These unfortunate events prompted the Long Lake Board to work with the Polk County Land and Water Resources Department to monitor algae toxins on Long Lake from 2010-2012. Toxin samples were only taken when algae scums were present. Nearly 75% of the samples indicated a high probability of adverse health effects from the toxin microcystin LR, 17% had confirmed anatoxin-a present, and 75% of the 2012 samples tested positive for the toxin cylindrospermopsin.

From 1959 - 1981 chemical treatment for algae in Long Lake included literally tons of sodium arsenate and copper sulfate. As a result, copper in the sediments of Long Lake have built up to levels where harmful effects to the lake are likely to be observed.

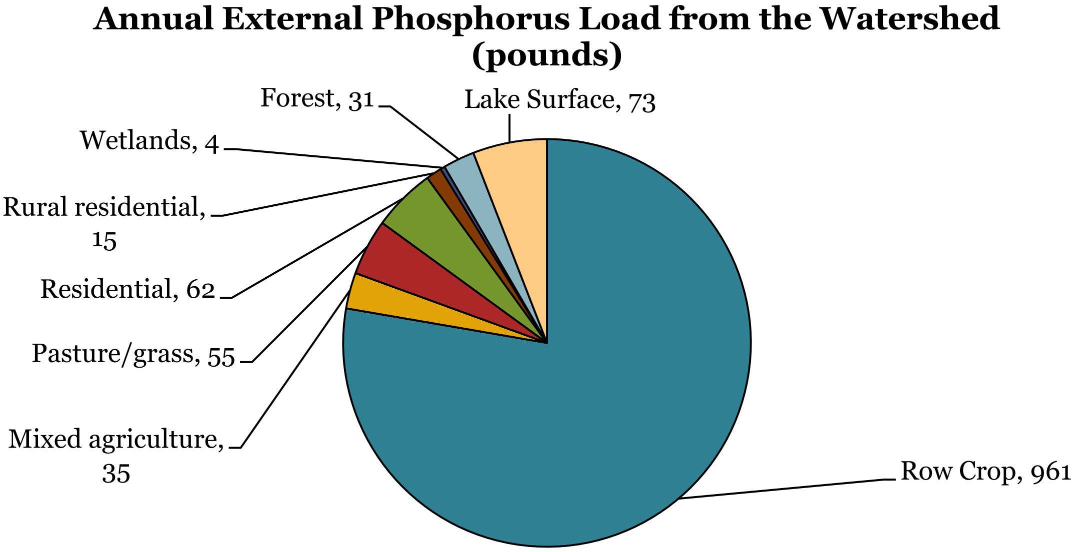
Most of the shoreline area on the lake is in a natural state (55%) or sand and rock (37%). The shoreline buffer area (35 feet upland from the water's edge) is equally split between a natural state (47%) and lawn (46%). An average lot on the Lake was estimated as mostly lawn (65%), followed by natural (21%), and impervious surface (15%).

The majority of lawns sampled on the lake (90%) tested over 25 ppm for phosphorus, indicating that phosphorus fertilizer is not needed.

The watershed area of Long Lake is approximately 2,343 acres. The lake itself is 272 acres and represents 6% of the total land use in the Long Lake Watershed. The largest land uses in the Long Lake Watershed are row crop (46%) followed by forest (17%). The majority of the shoreline of Long Lake is residential.

Modeling was used to estimate an annual phosphorus budget for Long Lake

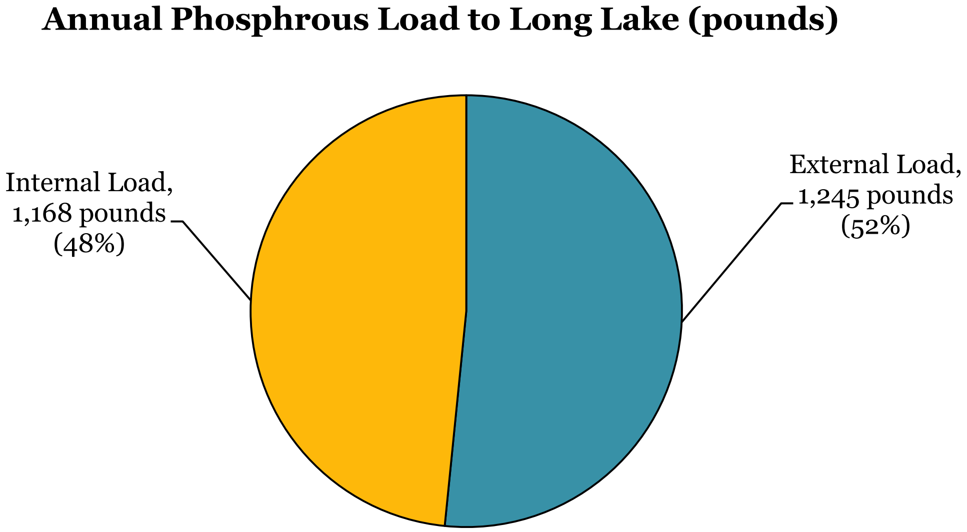
External load from the watershed: 1245 lbs phosphorous/year



Internal load from the lake sediments: 1168 pounds phosphorus/year

Load from curly-leaf pondweed die off: 52 pounds of phosphorus/year

Total load to Long Lake: 2,413 pounds of phosphorus/year



The following goals were developed through a series of four meetings by the Long Lake Water Quality Committee.

1. Minimize nutrients, sediment, and other pollutants that flow to the lake from its watershed.
2. Encourage lake processes which minimize the release of nutrients from within the lake.
3. Preserve and enhance lake and shoreline fish and wildlife habitat.
4. Lake residents and visitors understand the components of and the means to support a healthy lake.
5. Implement the goals of the Long Lake Aquatic Plant Management Plan.

Introduction to the Lake

Long Lake (WBIC 2478200) is located in central Polk County, Wisconsin in the Town of Balsam Lake (T.33N./R.17W./Sec 6, 7, 8).

The lake is classified as a seepage lake because it has no significant inlet or outlet. However, ditches on the north and south end flow to the lake during and after storm events.

The main boat landing is located on the northwest side of the lake and has a public fishing pier with handicap access. A second public access is located along Sunnyvale Lane.

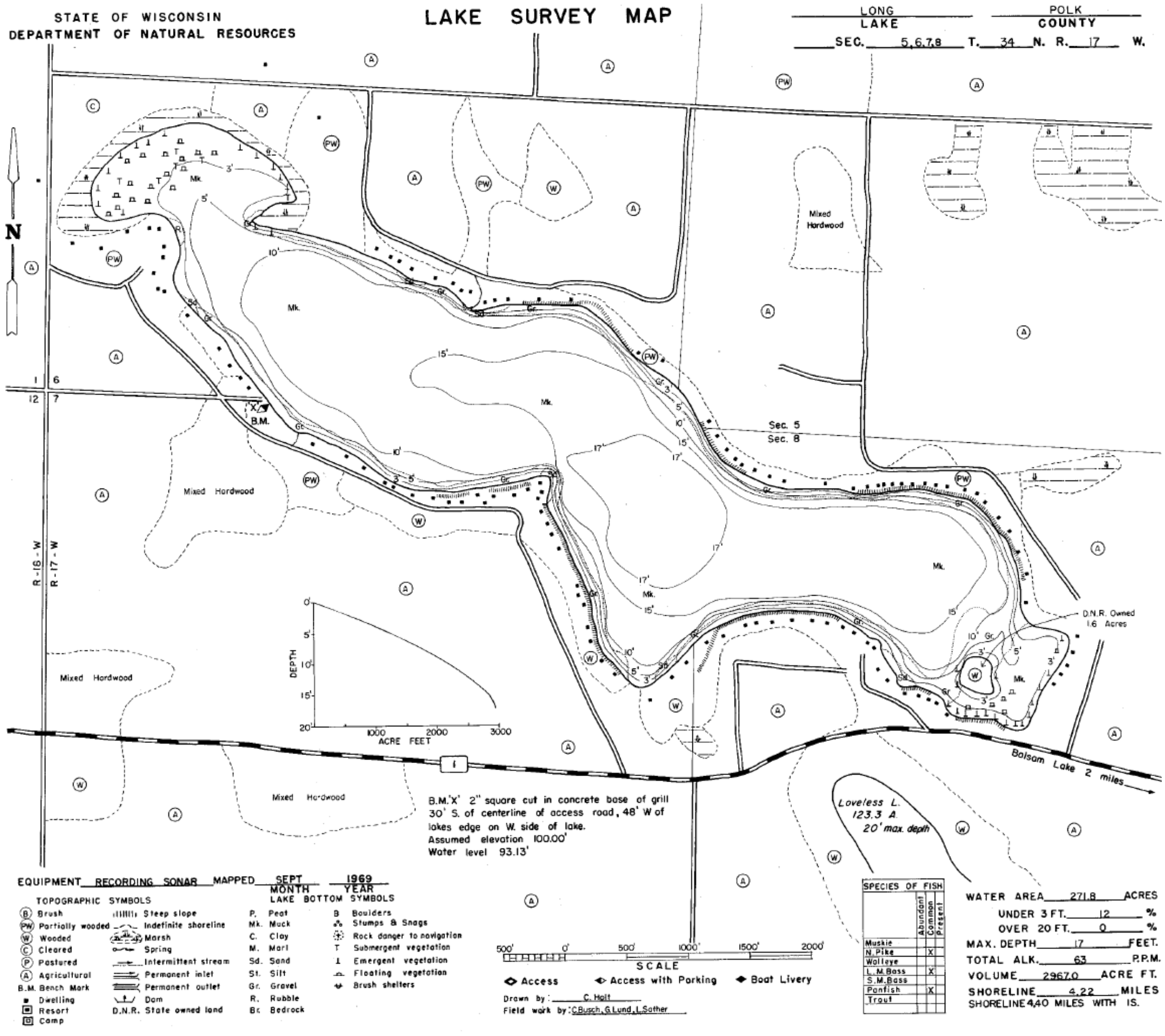
Long Lake is situated in pitted glacial outwash material approximately 100-150 feet thick which overlies sandstone bedrock. Areas of glacial drift containing isolated deposits of buried sand and gravel are located east and west of the lake. The soils surrounding Long Lake are fertile and composed of clay, sand, and organic matter (Wisconsin Department of Natural Resources Office of Inland Lake Renewal, 1981).

Lake Characteristics

Information from: (Wisconsin Department of Natural Resources)

Long Lake (WBIC: 2478200)
Area: 272 Acres
Maximum depth: 17 feet
Mean depth: 11 feet
Bottom: 40% sand, 0% gravel, 0% rock, and 60% muck
Hydrologic lake type: seepage
Total shoreline: 4.22 miles (4.40 miles including island)
WDNR owned island: 1.6 acres
Invasive species: curly leaf pondweed, Chinese mystery snail, banded mystery snail

Self Help Monitoring Data has been collected on Long Lake at the deep hole annually since 1992. Secchi depth has been recorded since 1992 and chlorophyll *a* and total phosphorus were recorded in 1993, 1996, 1997, 2000, and 2012. The Self Help Monitoring Data indicates that Long Lake is eutrophic.

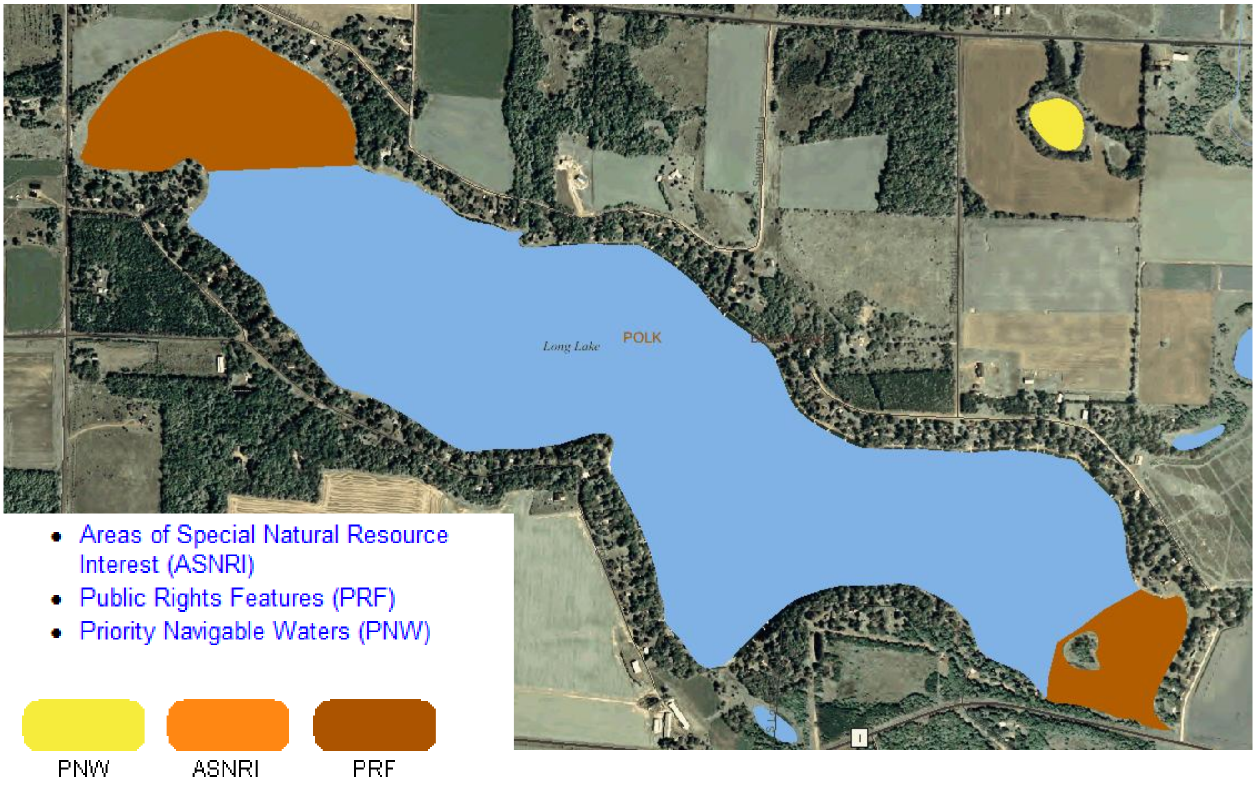

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES
LAKE SURVEY MAP
LONG LAKE
POLK COUNTY
SEC. 5,6,7,8 T. 34 N. R. 17 W.
N
Mixed Hardwood
Sec. 5
Sec. 8
D.N.R. Owned 1.6 Acres
R-16-W
R-17-W
B.M.
DEPTH
ACRE FEET
Balsam Lake 2 miles
Loveless L. 123.3 A. 20' max. depth
B.M.'X' 2" square cut in concrete base of grill 30' S. of centerline of access road, 48' W of lakes edge on W. side of lake.
Assumed elevation 100.00'
Water level 93.13'
EQUIPMENT RECORDING SONAR MAPPED SEPT MONTH 1969 YEAR
TOPOGRAPHIC SYMBOLS
Brush
Partially wooded
Wooded
Cleared
Pastured
Agricultural
B.M. Bench Mark
Dwelling
Resort
Camp
Steep slope
Indefinite shoreline
Marsh
Spring
Intermittent stream
Permanent inlet
Permanent outlet
Dam
D.N.R. State owned land
LAKE BOTTOM SYMBOLS
P. Peat
Mk. Muck
C. Clay
M. Marl
Sd. Sand
St. Silt
Gr. Gravel
R. Rubble
Br. Bedrock
B Boulders
Stumps & Snags
Rock danger to navigation
T Submergent vegetation
Emergent vegetation
Floating vegetation
Brush shelters
SCALE
Access
Access with Parking
Boat Livery
Drawn by: C. Holt
Field work by: C.Busch, G.Lund, L.Sather
SPECIES OF FISH
Abundant Common Present
Muskie
N. Pike X
Walleye
L. M. Bass X
S. M. Bass
Panfish X
Trout
WATER AREA 271.8 ACRES
UNDER 3 FT. 12 %
OVER 20 FT. 0 %
MAX. DEPTH 17 FEET.
TOTAL ALK. 63 P.P.M.
VOLUME 2967.0 ACRE FT.
SHORELINE 4.22 MILES
SHORELINE 4.40 MILES WITH IS.

Designated Waters

A designated water is a waterbody with special designations that affect permit requirements. Designations for Long Lake include:

- ✓ **Public Rights Feature** : identified as areas that merit special protection of aquatic habitat through lake sensitive area survey results
    - ○ 2 locations [1]

In 1989 a Sensitive Area Survey Report and Management Guidelines was prepared for Long Lake. Further information on the two Public Rights Features can be found in this report.



Please note that Areas of Special Natural Resource Interest (ASNRI) waters and Public Rights Features (PRF) waters are also considered Priority Navigable Waters (PNW).

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[1] "These areas of aquatic vegetation on Long Lake offer critical or unique fish and wildlife habitat. This habitat provides the necessary seasonal or life stage requirements of the associated fisheries while offering water quality or erosion control benefits to the body of water" (Wisconsin DNR).

Habitat Areas

Information directly from: (Harmony Environmental and Endangered Resource Services LLC, 2012).

The littoral, or plant supporting, zone of the lake provides critical habitat for fish, waterfowl, and other wildlife. It is found in a narrow band around Long Lake at depths up to 10 feet. More extensive littoral zones are found in the northwest and southeast bays.

The DNR sensitive area study (1989) identified two areas that merit special protection of aquatic habitat. "These areas of aquatic vegetation on Long Lake offer critical or unique fish and wildlife habitat. This habitat provides the necessary seasonal or life stage requirements of the associated fisheries while offering water quality or erosion control benefits to the body of water."

Resource Value of Area A
This area consists of the northwestern bay. It provides important habitat for bass and panfish and northern pike spawning and nursery areas. The area also provides important habitat for forage species. Wildlife also are reliant upon this area for habitat. Eagles, loons, herons, waterfowl, songbirds, furbearers, turtles, and amphibians benefit from this valuable habitat.

Resource Value of Area B
This area consists of the southeastern bay.
Values are the same as those described above for Area A.

Long Lake is located in the Town of Balsam Lake (T34N, R17W) in sections 6 and 7. Natural Heritage Inventory records are provided to the public by town and range rather than section, so there is no indication if the incidences of these species occur in and immediately surrounding Long Lake. Committee members report an active bald eagle nest east of the island on County Road I in 2012.

Species listed in the Town of Balsam Lake (T34N, R17W):

Bald Eagle	*Haliaeetus leucocephalus*	Special Concern

Fishery

Information directly from: (Harmony Environmental and Endangered Resource Services LLC, 2012).

Long Lake's fish community consists of northern pike, largemouth bass, and panfish. The Department of Natural Resources stocked northern pike in the lake most years from 1980 through 2010. In some years from 250,000 to 500,000 inch fry were stocked. In other years from 500 to 3,000 fingerlings (4 to 11 inches) were stocked.

The DNR last completed a night electro-fishing survey in October of 2006. The survey captured 13 black crappie (5-10.5 inches), 122 blue gill (3-8.5 inches), 376 largemouth bass (6-8.5 inches), and 38 northern pike (12-27.5 inches).

Fish spawning times are listed below:

Fish Species	**Spawning Temperature (°F)**	**Spawning Substrate/ Location**	**Comments**
Northern Pike	Upper 30s – mid 40s (right after ice-out)	Emergent vegetation 6-10 inches of water	Eggs are broadcast
Black Crappie	Upper 50s to lower 60s	Nests are built in 1-6 feet of water.	Nest builders
Largemouth Bass Bluegills	Mid 60s to lower 70s	Nests are built in water less than 3 feet deep.	

Lake Classification

Lake classification in Polk County is a relatively simple model that considers:

- ✓ lake surface area
- ✓ maximum depth
- ✓ lake type
- ✓ watershed area
- ✓ shoreline irregularity
- ✓ existing level of shoreline development

These parameters are then used to classify lakes as class one, class two, or class three lakes.

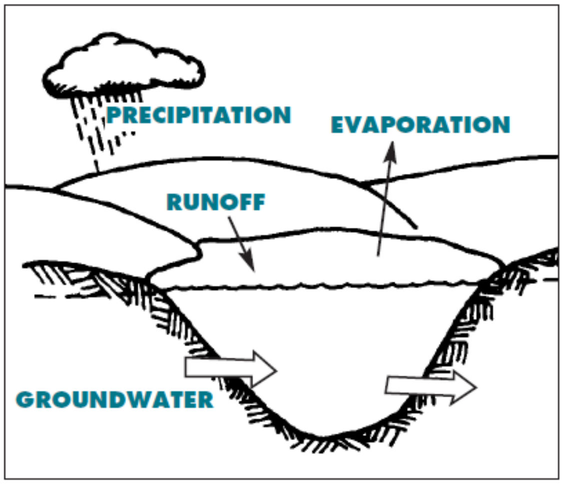
Class one lakes are large and highly developed.
Class two lakes are less developed and more sensitive to development pressure.
Class three lakes are usually small, have little or no development, and are very sensitive to development pressure.

(Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

Long Lake is classified as a class one lake (Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property, October 2002).

Lake Types

Lakes are commonly classified into four main types based on water source and type of outflow: seepage lakes, groundwater drainage lakes, drainage lakes, and impoundments. The Wisconsin DNR has classified Long Lake as a seepage lake. Seepage lakes do not have an outlet and are fed by precipitation, limited runoff, and groundwater. (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).



1. SEEPAGE LAKE—a natural lake fed by precipitation, limited runoff and groundwater. It does not have a stream outlet.

The groundwater entering Long Lake is relatively fertile, with soluble reactive phosphorus concentrations nearly twice that of groundwater entering other Polk County lakes.[2] (Wisconsin Department of Natural Resources Office of Inland Lake Renewal, 1981)

The drainage basin: lake area ratios (DB: LA) compares the size of a lake's watershed to the size of a lake. If a lake has a relatively large DB:LA then surface water inflow (containing nutrients and sediments) occurs from a large area of land relative to the area of the lake (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The DB: LA for Long Lake is approximately 9.5:1 (Wisconsin Department of Natural Resources Office of Inland Lake Renewal, 1981).

A study by Lillie and Mason (1983) found that in general seepage lakes have better water clarity and are less eutrophic as compared to drainage lakes. In this study the DB: LA for seepage lakes was smaller as compared to drainage lakes. This may explain why seepage lakes tend to have lower levels of nutrients.

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[2] Average soluble reactive phosphorus concentration of 0.052 mg/L for Long Lake as compared to an average of 0.02-0.03 mg/L for other lakes in Polk County.

Impaired Waters

Wisconsin lakes, rivers, and streams are managed to determine if their conditions are meeting state and federal water quality standards. Water samples are collected through monitoring studies and results are compared to guidelines designed to evaluate conditions as compared to set standards. General assessments can place waters in four different categories: poor, fair, good, and excellent. The results of assessments can be used to determine which actions will ensure that water quality standards are being met (anti-degradation, maintenance, or restoration).

If a waterbody does not meet water quality standards it is placed on Wisconsin's Impaired Waters List under the Federal Clean Water Act, Section 303(d). Every two years the State of Wisconsin is required to submit list updates to the United States Environmental Protection Agency for approval.

Waterbodies can be listed as impaired based on pollutants such as total phosphorus, total suspended solids, and metals.

The total phosphorus criteria for seepage lakes that do not stratify (i.e. Long Lake) is 0.040 mg/L. The average summer index period total phosphorus for Long Lake in 2012 was 0.146 mg/L. This indicates that the total phosphorus criteria was not meet in 2012.

Previous Lake Studies

Past studies that include Long Lake are:

- ✓ Office of Inland Lake Renewal Feasibility Study and Management Alternatives (1981)
- ✓ Nonpoint Source Control Plan for the Balsam Branch Priority Watershed Project (1995)
- ✓ Barr Engineering Long Lake Management Plan Phases I – IV (2001)
- ✓ Barr Engineering Long Lake Management Plan Phases V and VI (2003)
- ✓ Harmony Environmental and Endangered Resources Services Aquatic Plant Management Plan (2012)
- ✓ Polk County Land and Water Resources Department Cyanobacteria and Toxin Monitoring (2010-12)

Office of Inland Lake Renewal Feasibility Study and Management Alternatives

The earliest study on Long Lake was completed by the Office of Inland Lake Renewal in 1981.

This evaluation included:

- ✓ A nutrient budget for Long Lake
- ✓ Groundwater flow patterns
- ✓ Existing water quality determination
- ✓ Lake management alternatives

Some of the notable conclusions made from this study include:

- ✓ Groundwater entering Long Lake is relatively fertile with an average total soluble phosphorus concentration of 0.052 mg/L. Reasons for this elevated concentration are not known.
- ✓ Sewage ponds for Centuria were not contributing a signification amount of phosphorus to Long Lake.
- ✓ The greatest contributors to Long Lake's phosphorus budget were surface runoff (67%), followed by groundwater (13%), barnyard runoff (10%), atmospheric (8%), and septic system leachate (1%).
- ✓ TSI values for secchi depth and chlorophyll *a* indicate that Long Lake is eutrophic.
- ✓ Dominance of blue-green algae in Long Lake is not desirable.

Nonpoint Source Control Plan for the Balsam Branch Priority Watershed Project

This project quantifies land use in the Long Lake watershed. The Long Lake watershed is approximately 2,612 acres in size. Land use in the watershed is primarily agriculture (62%), followed by forest (18%), residential development (17%), and wetland (3%).

The main sources of phosphorus to the lake were identified as agricultural (52%) and groundwater (24%).

This project also established the following water management goals for Long Lake:

- ✓ Achieve an in-lake summer phosphorus concentration of 25 µg/L (0.025 mg/L)
- ✓ Enhance fish and wildlife habitat

Barr Engineering Long Lake Management Plan Phases I – IV

The most recent Lake Management Plan was completed by Barr Engineering as part of a six phase project.

The first four phases of the project included:

- ✓ Macrophyte surveys
- ✓ Inflow monitoring
- ✓ Water quality survey
- ✓ Lake level and precipitation monitoring
- ✓ Membership survey
- ✓ Total phosphorus budget

This study determined that Long Lake was hypereutrophic based on average summer total phosphorus and chlorophyll *a*, and eutrophic based on average summer secchi depth.

The annual hydrologic budget indicated that Long Lake receives the majority of its water from direct precipitation on the lake (55%), followed by watershed runoff (42%), and groundwater inflow (3%).

Long Lake's annual total phosphorus load was 593 kilograms (1307 pounds). Sources include: agricultural and developed areas within the tributary watershed (33%), die-off of curly leaf in late June (29%), internal load from sediments in mid-August (17%), atmospheric loading (10%), barnyards in the tributary watershed (6%), and septic systems around the lake (4%).

Barr Engineering Long Lake Management Plan Phases V and VI

The final two phases of the study suggested a management goal, evaluated scenarios to reach the goal, determined alum/lime slurry doses, and generated a lake management plan.

A management goal of 45 µg/L (0.045 mg/L) average summer total phosphorus for the upper surface water was generated. The study recommended a lime slurry/alum treatment to address phosphorus loads from lake sediments, early season herbicide treatments for curly leaf pondweed, and control of watershed phosphorus sources (stormwater ordinance, shoreland gardens, septic system ordinance, and best management practices).

Harmony Environmental and Endangered Resources Services Aquatic Plant Management Plan

This report provided an update on progress made towards the recommendations of the Barr Engineering study. The Long Lake District did not adopt the average summer total phosphorus water quality goal of 45 µg/L. Additionally, the District decided not to move forward with the lime slurry/alum treatment.

The District did formally adopt early season herbicide treatment of curly leaf pondweed through approval of a 2007 Aquatic Plant Management Plan. Additionally, best management practices such as nutrient management for farmers did occur through the Balsam Branch Priority Watershed Project in 1995-2005 and a stormwater ordinance was adopted by Polk County in 2005.

The current Aquatic Plant Management Plan goals developed for Long Lake include:

1. Improve water quality and clarity
2. Protect and restore healthy rooted native aquatic plant communities
3. Balance recreation and riparian needs with protection of native plants and the fishery
4. Prevent the introduction of Eurasian water milfoil and other invasive, non-native aquatic species
5. Rapidly respond to eliminate any newly introduced invasive, non-native aquatic plant species

Polk County Land and Water Resources Department Cyanobacteria and Toxin Monitoring

This study was prompted by the death of a dog in 2009 and other incidents suspected to be caused by cyanobacterial toxin exposure on Long Lake.

The following data was collected in 2010, 2011, and 2012 as part of this monitoring effort:

- ✓ In lake water quality data (dissolved oxygen, conductivity, pH, temperature, and secchi)
- ✓ Algae identification and quantity
- ✓ Algae toxins

Full results of this study can be found in the Algae Toxins section of this report.

Sociological Survey

A sociological survey was mailed to one hundred sixty nine residences of the Long Lake Protection and Rehabilitation District in early April 2012. The survey was designed to gather information from residents concerning property ownership, lake use, negative impacts on lake use, management practices for improvement of the lake, landscaping practices to improve lake water quality, and means of receiving information.

One hundred six surveys were returned (63% response rate) and data was entered and analyzed.

Property Ownership

Half of respondents (50%) have owned their property on Long Lake for more than 20 years and a quarter (25%) have owned their property for 10+ to 20 years. Eleven percent of respondents have owned their property for 5+ to 10 years and ten percent have owned their property for 2+ to 5 years. Only four percent of respondents have owned their property for less than 2 years.

The majority of respondents (60%) use their property during weekends, vacations, and/or holidays and another fourteen percent use their property seasonally (continued occupancy for months at a time). Approximately a quarter (25%) use their property as a full time residence. The 1995 Nonpoint Source Control Plan for the Balsam Branch Priority Watershed Project indicated that approximately 36% of residents on Long Lake occupy their property on a permanent basis. [3]

Lake Use

Respondents were asked to indicate their degree of participation (none, a little, some, quite a bit, or a great deal) in a list of activities.

A majority of respondents do not participate in scuba diving (97%), sail boating (94%), snowshoeing (93%), hunting (91%), winter skiing (83%), ice skating (83%), kayaking

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[3] Polk County tax roles were used to gather information.

(82%), jet skiing (73%), canoeing (72%), snowmobiling (71%), running (71%), and wakeboarding (69%). [4]

Many of the activities that a majority of respondents do not participate in are winter activities. The high degree of seasonal residency likely explains the lack of participation in winter activities on Long Lake. Since these activities receive no participation from the majority of survey respondents, management activities relating to these activities should receive the least priority.

The activities receiving the most participation include pontoon boating (59%), reading (53%), fishing (42%), swimming (41%), and nature/bird watching (41%). [5] Since these activities receive the greatest degree of participation, management activities for Long Lake relating to these activities should receive the greatest priority.

Negative Impacts on Lake Use

Survey participants were asked to indicate the level of negative impact (none present, no impact, unsure, a little, some, quite a bit, and a great deal) caused by a list of circumstances.

Circumstances causing the greatest degree of negative impact on lake use include algae growth (75%), water clarity (68%), invasive aquatic plant growth (65%), algae toxins (60%), and plants making it difficult to swim (56%). [6]

Since these activities are perceived as the circumstances causing the greatest degree of negative impact on lake use, management activities for Long Lake relating to improving these circumstances should receive the greatest priority. However, potential conflicts exist between water clarity and plants making it difficult to swim. Although the presence of plants may make it difficult to swim, plants also provide extensive benefits to water clarity.

Landscaping Practices to Improve Lake Water Quality

A list of landscaping practices designed to protect and improve lake water quality were provided on the survey. For each practice respondents were asked to indicate if they

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[4] Percentages were found by dividing the number of respondents that do not participate in each activity by the total number of responses for each activity. Percentages represent the number of respondents who do not participate in each activity.

[5] Responses for “quite a bit” and “a great deal” were clustered. Percentages were found by dividing the number of respondents that participate in each activity quite a bit/a great deal by the total number of responses for each activity. Percentages represent the number of respondents who participate in each activity quite a bit/a great deal.

[6] Responses for “quite a bit” and “a great deal” were clustered. Percentages were found by dividing the number of respondents that experience negative impacts quite a bit/a great deal by the total number of responses for each activity. Percentages represent circumstances that respondents perceive as causing “quite a bit” or “a great deal” of negative impact.

already used the practice, if they were familiar with but have not used the practice, or if they were unfamiliar with the practice.

Nearly half of respondents (46%) reported using shoreline buffer zones and native plants on their lake property and most (89%) reported either not fertilizing or using zero phosphorus fertilizer. The landscaping practices respondents are least familiar with include infiltration pits or trenches (50%), rain gardens (35%), and water diversions (32%).

For each practice (with the exception of infiltration pits or trenches) respondents were also asked if they would consider implementing the practice. If the respondent already used the practice they were also directed to check each practice. By comparing percentages for each practice that respondents already use with percentages respondents would consider/already use, it is possible to determine which practices respondents would be most likely to consider. These practices include rain barrels, rain gardens and water diversions.

Survey participants were asked if they would take advantage of free information/visits offered by the Lake District to address waterfront property runoff. Three quarters of respondents (73%) would be interested in the offer and over a quarter (27%) would not.

Landscaping Practices	Already use	Familiar but not used	Not familiar	Would consider or already use
Rain gardens	4%	46%	35%	26%
Rain barrels	6%	67%	15%	36%
Shoreline buffer zones	46%	32%	12%	48%
Native plants anywhere on lake property	46%	26%	14%	44%
Infiltration pits or trenches	5%	31%	50%	----
Water diversions	13%	39%	32%	35%
Not fertilizing or using zero phosphorus fertilizer	89%	7%	4%	72%

Means of Receiving Information

The majority of survey respondents would prefer to receive information from the Long Lake District through emails (59%) and special mailings (55%). Fewer respondents would prefer to receive information through annual meetings (41%) and newsletters (24%). Only 2% of respondents would prefer not to receive information from the Long Lake District.

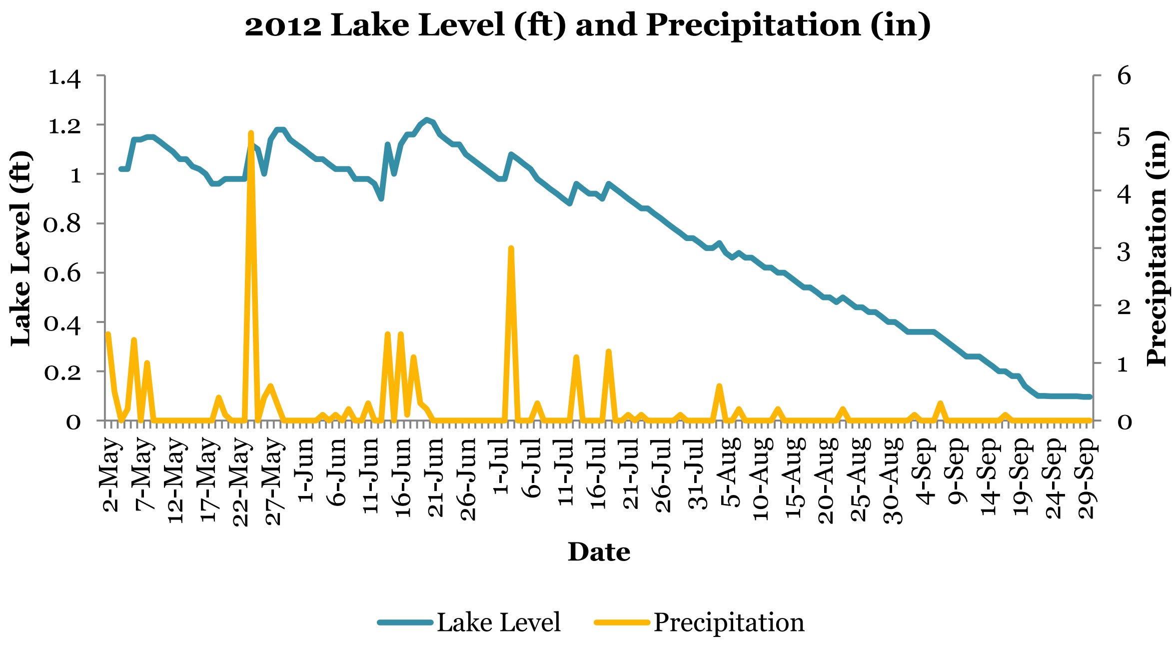
Lake Level and Precipitation Monitoring

Lake water-level fluctuations are important to lake managers, lakeshore property owners, developers, and persons using lakes for recreation. Lake level fluctuations can have significant effects on lake water quality and usability. Although lake levels naturally change from year to year, extreme high or low levels can present problems such as restricted water access, flooding, shoreline and structure damage, and changes in riparian (near shore) vegetation.

Records of lake water elevations can be very useful in understanding changes that may occur in lakes. While some lakes respond almost immediately to precipitation, other lakes do not reflect changes in precipitation until months later.

A volunteer monitored lake level and precipitation data for Long Lake. LWRD provided training regarding data collection and installed a staff and rain gauge. Staff gauges were set at an arbitrary height.

Monitoring began on May 4th, 2012 and continued through September 30th, 2012. Seasonal precipitation totaled 24.4 inches. Shortly following precipitation events lake levels increased. Over the course of the sampling season, the water level on Long Lake decreased by 1.1 feet.



Chemical and Physical Data Sampling Procedure

Physical and chemical data were collected at the deep hole of Long Lake from May 7th, 2012 through September 18th, 2012.

Surface and bottom samples were collected from the water column bi-weekly during May and June and weekly during July, August, and September. A Van Dorn Sampler was used to collect the surface sample (depth of 1 foot) and the bottom sample (1 foot above the lake bottom). Samples were analyzed at the State Lab of Hygiene for two types of phosphorus (total phosphorus and soluble reactive phosphorus), three types of nitrogen (nitrate/nitrite, ammonium, and total Kjeldahl nitrogen), and sulfate. Chlorophyll *a* was also analyzed for the surface sample.

Lake profile monitoring—which included dissolved oxygen, temperature, conductivity, pH, and Secchi depth—was conducted weekly at every meter within the water column using a YSI 85 multi-parameter probe. pH readings were recorded at every meter within the water column using a YSI 60 pH meter. During the third sampling set in July both YSI meters stopped working. Beginning with the July 24th sample, lake profile monitoring was collected using an HI 9828 multi-parameter probe.

Secchi depth was recorded using a secchi disk, which is an eight inch diameter round disk with alternating black and white quadrants. To record secchi depth, the secchi disk was lowered into the lake on the shady side of a boat until it just disappeared from sight. This depth was measured in feet and recorded as the secchi depth.

In most instances in this report, data is presented as an average over the **growing season**, which refers to data collected from May through September and excludes turnover data, collected in April and October. In some instances, data is averaged over the **summer index period**, which refers to data collected from July 15th through September 15th.

Lake Mixing and Stratification: Background Information

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Water quality is greatly affected by the degree to which the water in a lake mixes. Within a lake, mixing is most directly impacted by the temperature-density relationship of water. When comparing why certain lakes mix differently than others, lake area, depth, shape, and position in the landscape become important factors to consider.

Water reaches its greatest density at 3.9°C (39°F) and becomes less dense as temperatures increase and decrease. Compared to other liquids, the temperature-density relationship of water is unusual: liquid water is denser than water in its solid form (ice). As a result, ice floats on liquid water.

When ice melts in the early spring, the temperature and density of the water will be constant from the top to the bottom of a lake. This uniformity in density allows a lake to completely mix. As a result, oxygen is brought to the bottom of a lake, and nutrients are re-suspended from the sediments. This event is termed **spring overturn**.

As the sun's rays warm the surface waters in the spring, the water becomes less dense and remains at the surface. Warmer water is mixed deeper into the water column through wind and wave action. However, these forces can only mix water to a depth of approximately twenty to thirty feet. Generally, in a shallow lake, the water may remain mixed all summer. However, a deeper lake usually experiences layering called **stratification**.

During the summer, lakes have the potential to divide into three distinct zones: the **epilimnion**, **thermocline** or **metalimnion**, and the **hypolimnion**. The epilimnion describes the warmer surface layer of a lake; whereas the hypolimnion describes the cooler bottom area of a lake. The thermocline, or metalimnion, describes the transition area between the warmer surface layer and the cooler bottom layer.

As surface waters cool in the fall, they become denser and sink until the water temperature evens out from top to bottom. This process is called **fall overturn** and allows for a second mixing event to occur. Occasionally, fall algae blooms occur at fall overturn when nutrients from the hypolimnion are made available throughout the water column.

The variations in density arising from different water temperatures can prevent warmer water from mixing with cooler water. As a result, nutrients released from the sediments can become trapped in the hypolimnion of a lake that stratifies. Additionally, because mixing is one of the main ways oxygen is distributed throughout a lake, lakes that don't mix have the potential to have very low levels of oxygen in the hypolimnion.

The absence of oxygen in the hypolimnion can have adverse effects on fisheries. Species of cold water fishes, such as trout, require the cooler waters that result from stratification. Cold water holds more oxygen as compared to warm water. As a result, the cooler waters of the hypolimnion can provide a refuge for cold water fisheries in the summer as long as oxygen is present. Respiration by plants, animals, and bacteria is the primary means by which oxygen is removed from the hypolimnion. A large algae bloom can cause oxygen depletion in the hypolimnion as algae die, sink, and decay.

In the winter, stratification remains constant because ice cover prevents mixing by wind action.

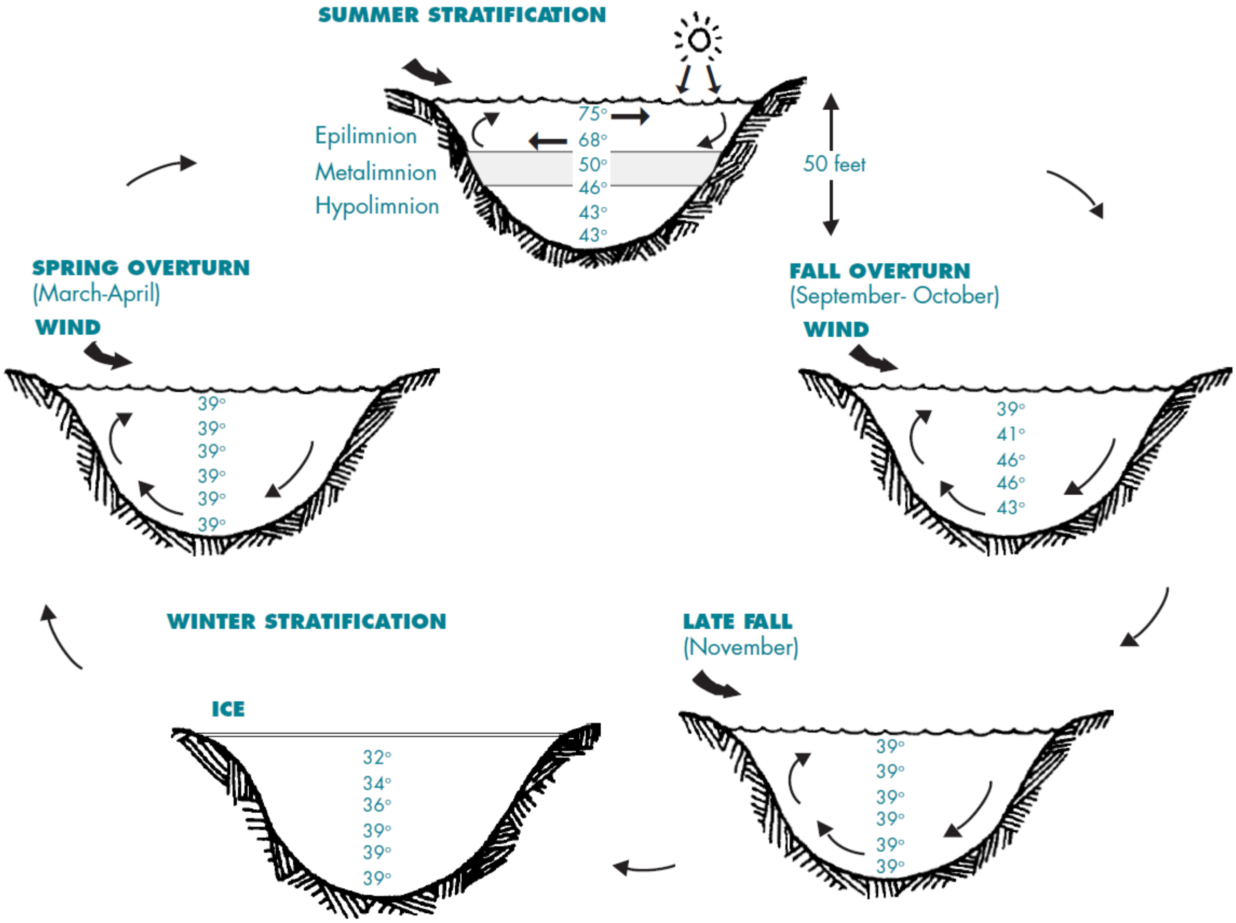


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Phosphorus

Phosphorus is an element present in lakes which is necessary for plant and algae growth. It occurs naturally in soil, rocks, and the atmosphere and can make its way into lakes through groundwater and soil erosion induced from construction site runoff or other human induced disturbances. Additional sources of phosphorus input into a lake can include fertilizer runoff from urban and agricultural settings and manure.

Phosphorus does not readily dissolve in water, instead it forms insoluble precipitates (particles) with calcium, iron, and aluminum. If oxygen is available, iron forms sediment particles that store phosphorus in the sediments. However, when lakes lose oxygen in the winter or when the hypolimnion becomes anoxic in the summer, these particles dissolve in the water. Strong wind action or turnover events can then re-distribute phosphorus throughout the water column.

While phosphorus is necessary for plant and animal growth, excessive amounts lead to an overabundance of growth which can decrease water clarity and lead to nutrient pollution in lakes. Phosphorus is present in lakes in several forms. This study measured two forms of phosphorus: total phosphorus and soluble reactive phosphorus.

Total phosphorus (TP) is a measure of all the phosphorus in a sample of water. In many cases total phosphorus is the preferred indicator of a lake's nutrient status because it remains more stable than other forms over an annual cycle.

Soluble reactive phosphorus (SRP) includes forms of phosphorus that are dissolved in the water and are readily available for uptake by algae and aquatic macrophytes (plants).

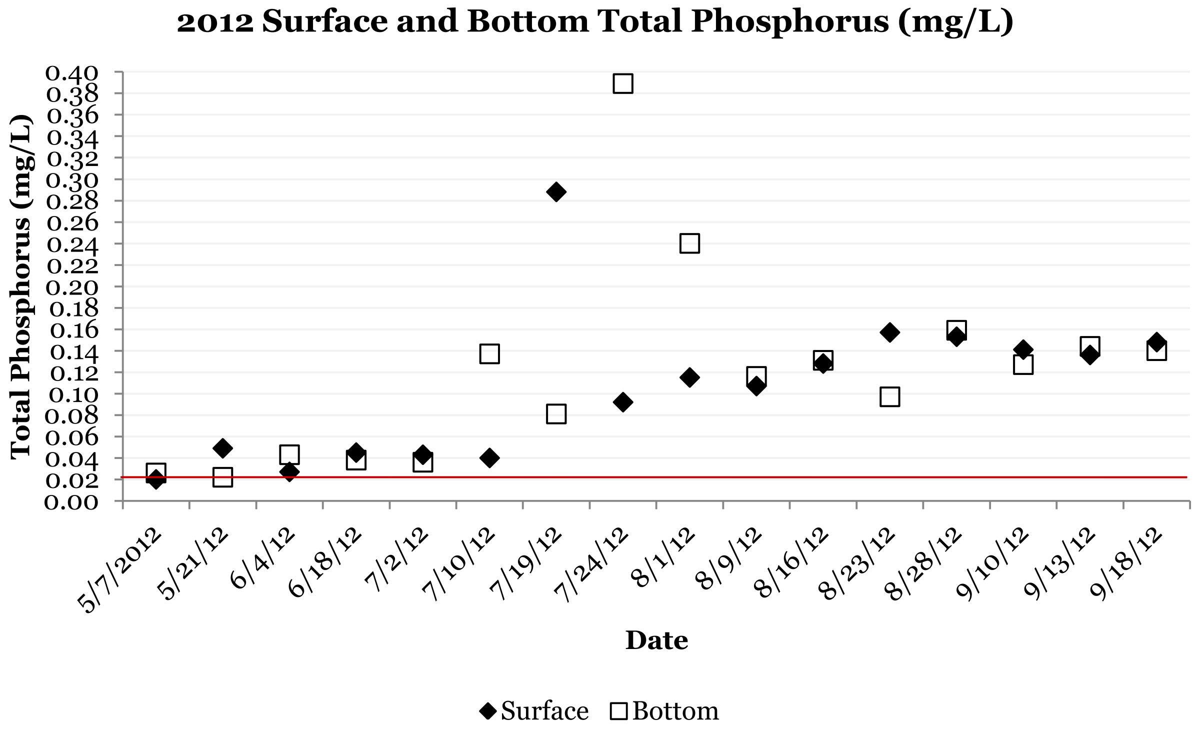
In lakes, a "healthy" limit of phosphorus is set at 0.02 mg/L total phosphorus and 0.01 mg/L soluble reactive phosphorus to prevent nuisance algae blooms. If a value is above the healthy limit it is more likely that a lake could support nuisance algae blooms. Additionally, the total phosphorus criteria for impairment listing for seepage lakes that do not stratify (i.e. Long Lake) is 0.040 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Total phosphorus was above the healthy limit at both the surface and bottom of Long Lake during the entire sampling season (May 7th through September 18th). The 2012 growing season average total phosphorus was well above the healthy limit at the surface of Long Lake (0.106 mg/L) and at the bottom of Long Lake (0.120 mg/L).

Average total phosphorus over the summer index period [7] was 0.146 mg/L at the surface of Long Lake and 0.165 at the bottom of Long Lake. These values are well above the total phosphorus criteria for seepage lakes that do not stratify.

The 2012 growing season average soluble reactive phosphorus was slightly above the healthy limit at the surface of Long Lake (0.011 mg/L) and above the healthy limit at the bottom of Long Lake (0.023 mg/L). The limit of detection for soluble reactive phosphorus is 0.002. Surface samples on May 7th, June 18th, and July 10th and bottom samples on July 2nd were below the limit of detection. Both surface and bottom samples were below the healthy limit early in the season through July 10th.



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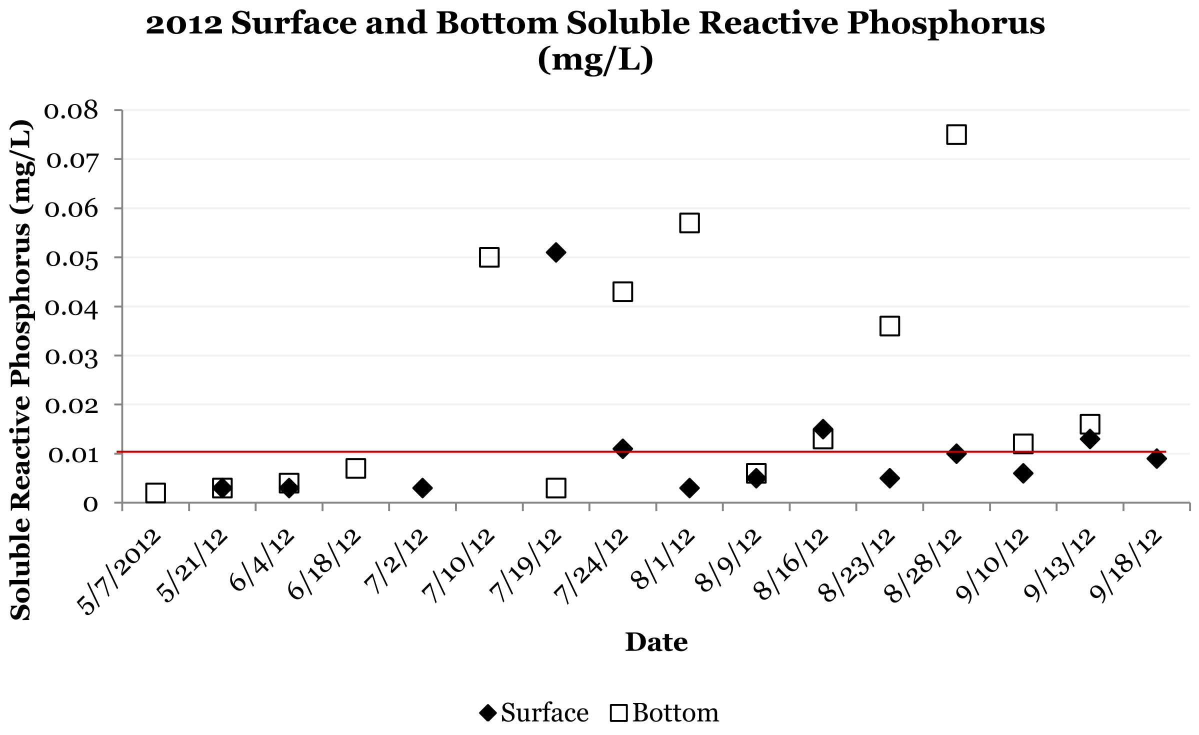
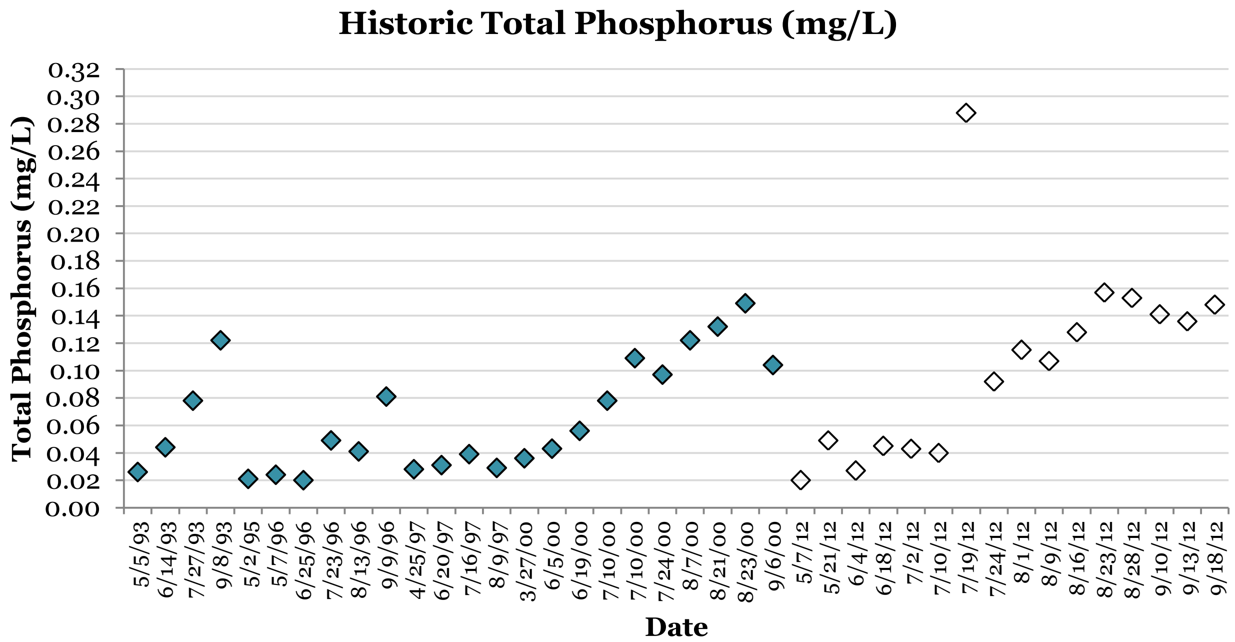
[7] The summer index period begins on July 15th and ends on September 15th.


2012 Surface and Bottom Soluble Reactive Phosphorus (mg/L)
Soluble Reactive Phosphorus (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5/7/2012
5/21/12
6/4/12
6/18/12
7/2/12
7/10/12
7/19/12
7/24/12
8/1/12
8/9/12
8/16/12
8/23/12
8/28/12
9/10/12
9/13/12
9/18/12
Date
◆ Surface
☐ Bottom


Historic Total Phosphorus (mg/L)
Total Phosphorus (mg/L)
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
5/5/93
6/14/93
7/27/93
9/8/93
5/2/95
5/7/96
6/25/96
7/23/96
8/13/96
9/9/96
4/25/97
6/20/97
7/16/97
8/9/97
3/27/00
6/5/00
6/19/00
7/10/00
7/10/00
7/24/00
8/7/00
8/21/00
8/23/00
9/6/00
5/7/12
5/21/12
6/4/12
6/18/12
7/2/12
7/10/12
7/19/12
7/24/12
8/1/12
8/9/12
8/16/12
8/23/12
8/28/12
9/10/12
9/13/12
9/18/12
Date

Nitrogen

Nitrogen, like phosphorus, is an element necessary for plant growth. Nitrogen sources in a lake can vary widely. Although nitrogen does not occur naturally in soil minerals, it is a major component of all plant and animal matter. The decomposition of plant and animal matter releases ammonia, which is converted to nitrate in the presence of oxygen. This reaction accelerates when water temperatures increase. Nitrogen can also be introduced to a lake through rainfall, in the form of nitrate and ammonium, and through groundwater in the form of nitrate.

Iin most instances, the amount of nitrogen in a lake corresponds to land use. Nitrogen can enter a lake from surface runoff or groundwater sources as a result of fertilization of lawns and agricultural fields, animal waste, or human waste from septic systems or sewage treatment plants. During spring and fall turnover events, nitrogen is recycled back into the water column which can cause spikes in ammonia levels. Under low oxygen conditions, nitrogen can be lost from a lake system, through a process called denitrification. Under these conditions nitrate is converted to nitrogen gas. Additionally, nitrogen can be lost through permanent sedimentation.

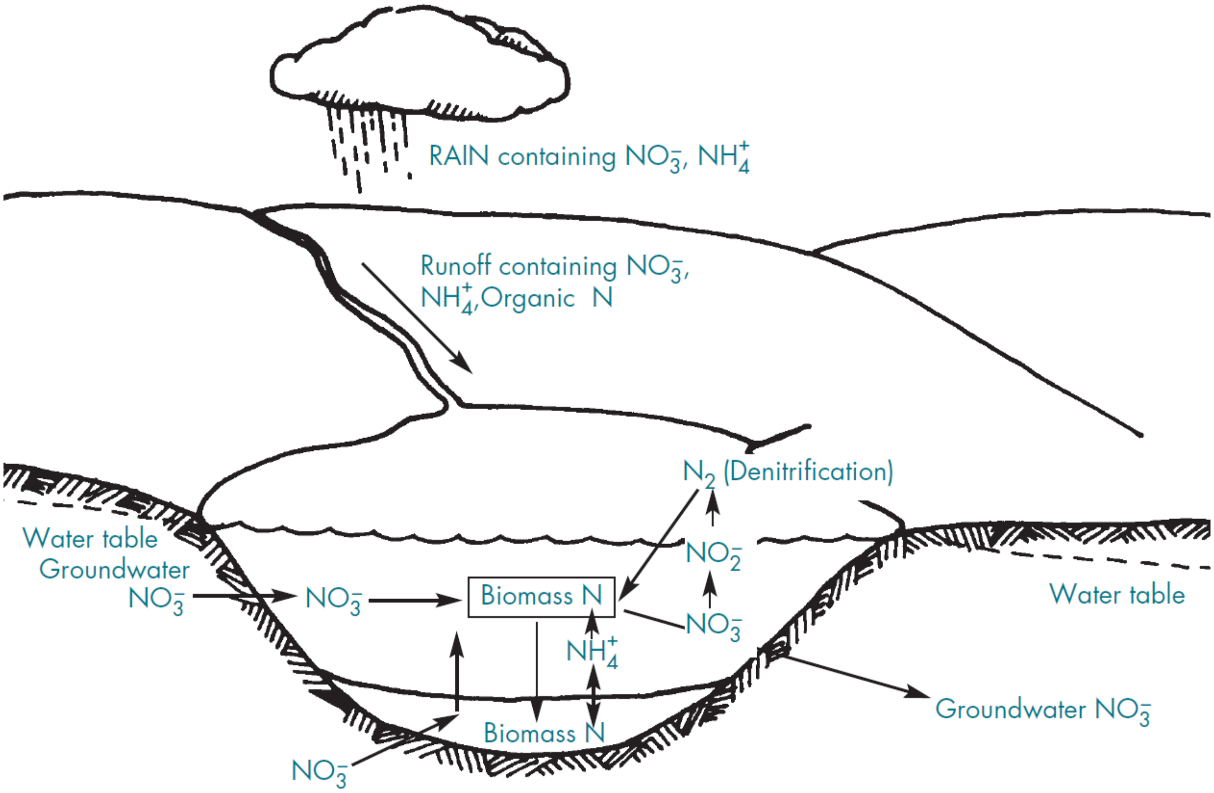


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Nitrogen comprises the majority (78%) of the gases in the Earth's atmosphere. As with other gases, nitrogen is more soluble in cooler water as compared to warmer water. Nitrogen gas is not readily available to most aquatic plants, with the exception of blue green algae.

Similar to phosphorus, nitrogen is divided into many components. In this study nitrate/nitrite (NO_3 and NO_2), ammonium (NH_4), and total Kjeldahl nitrogen (TKN) were analyzed.

Nitrate/nitrite and ammonium are all inorganic forms of nitrogen which can be used by aquatic plants and algae. Inorganic nitrogen concentrations above 0.3 mg/L can support summer algae blooms.

Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen plus ammonium. By subtracting the ammonium concentration from TKN, the organic nitrogen concentration found in plants and algal material can be found.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The limit of detection for nitrate/nitrite was 0.019 mg/L. In all bottom samples and all surface samples with the exception of September 13th (0.027 mg/L) nitrate/nitrite in Long Lake was below the limit of detection.

The limit of detection for ammonium is 0.015 mg/L. Surface samples were below the limit of detection for ammonia on May 7th, June 18th, August 1st, August 9th, September 10th, and September 18th. Bottom samples were below the limit of detection for ammonia on July 19th and August 9th.

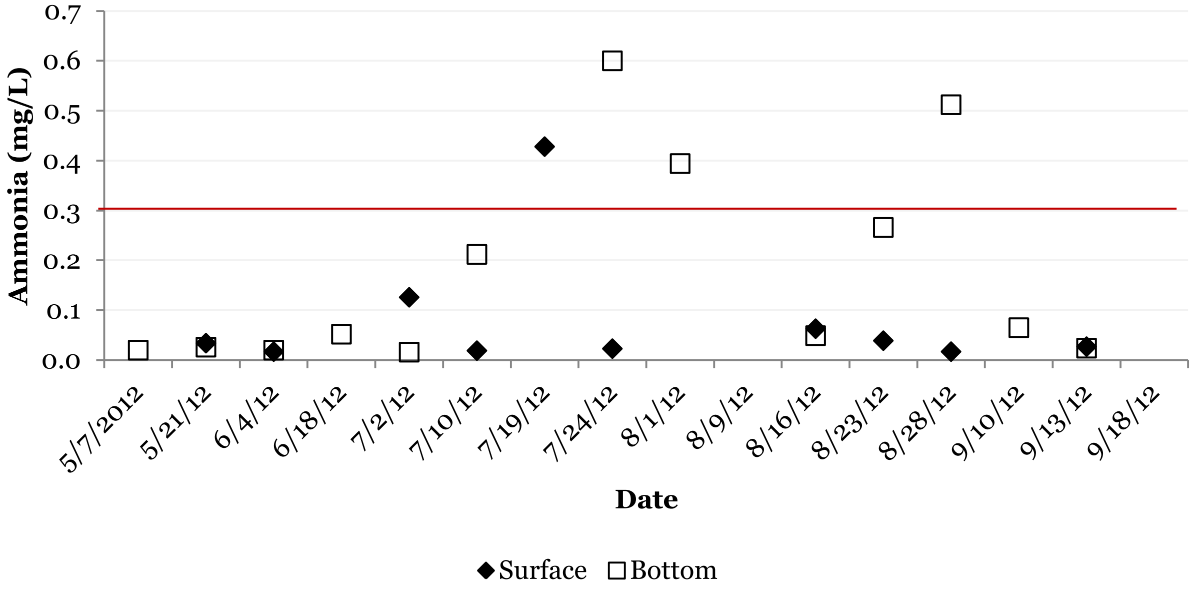
Nitrate/nitrite is typically added to ammonium to determine the concentration of inorganic nitrogen in a lake system. However, since nitrate/nitrite was nearly always below the limit of detection a graph of ammonia is used to represent inorganic nitrogen in Long Lake.

Average growing season ammonia was below the healthy limit at the surface (0.079 mg/L) and bottom (0.174 mg/L) of Long Lake. Surface ammonia was above the healthy limit on July 19th (0.428 mg/L) and bottom ammonia was above the healthy limit on July 24th (0.600 mg/L), August 1st (0.394 mg/L), and August 28th (0.512 mg/L).

Organic nitrogen, or the concentration of nitrogen found in plants and algae, increased over the growing season.

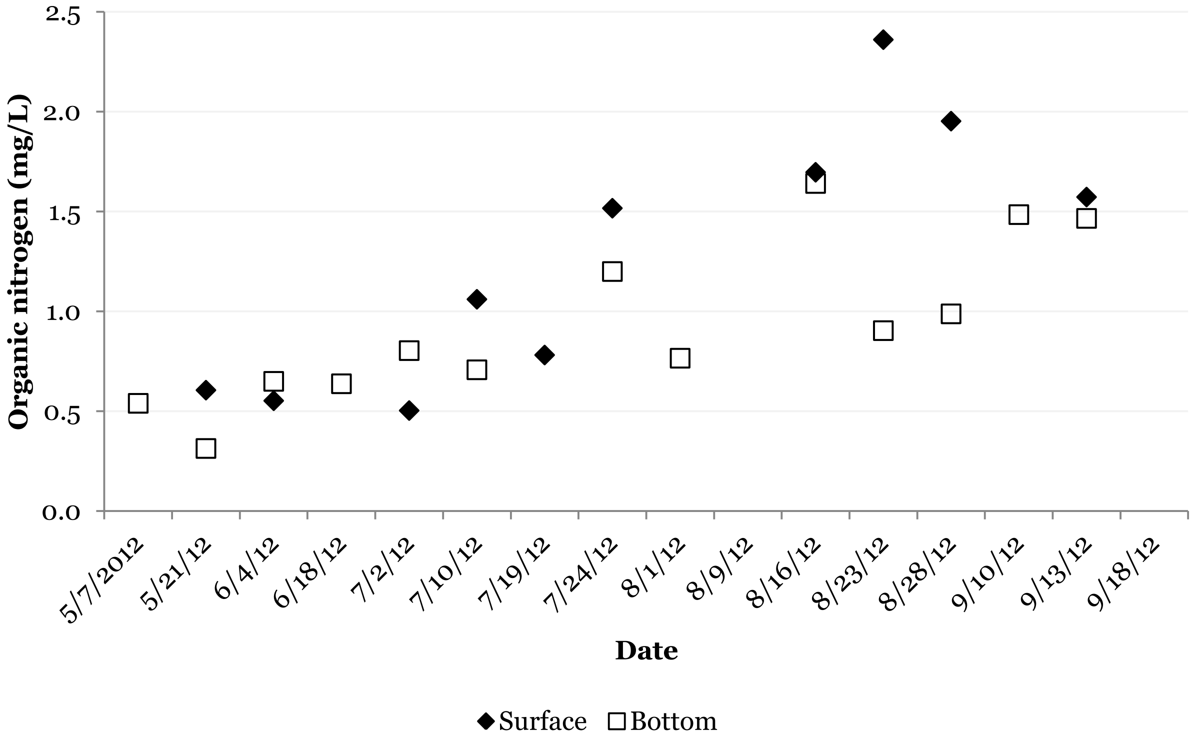
2012 Surface and Bottom Ammonia (mg/L)

** excludes samples where ammonia was below the limit of detection*



2012 Surface and Bottom Organic Nitrogen (mg/L)

** excludes samples where ammonia was below the limit of detection*

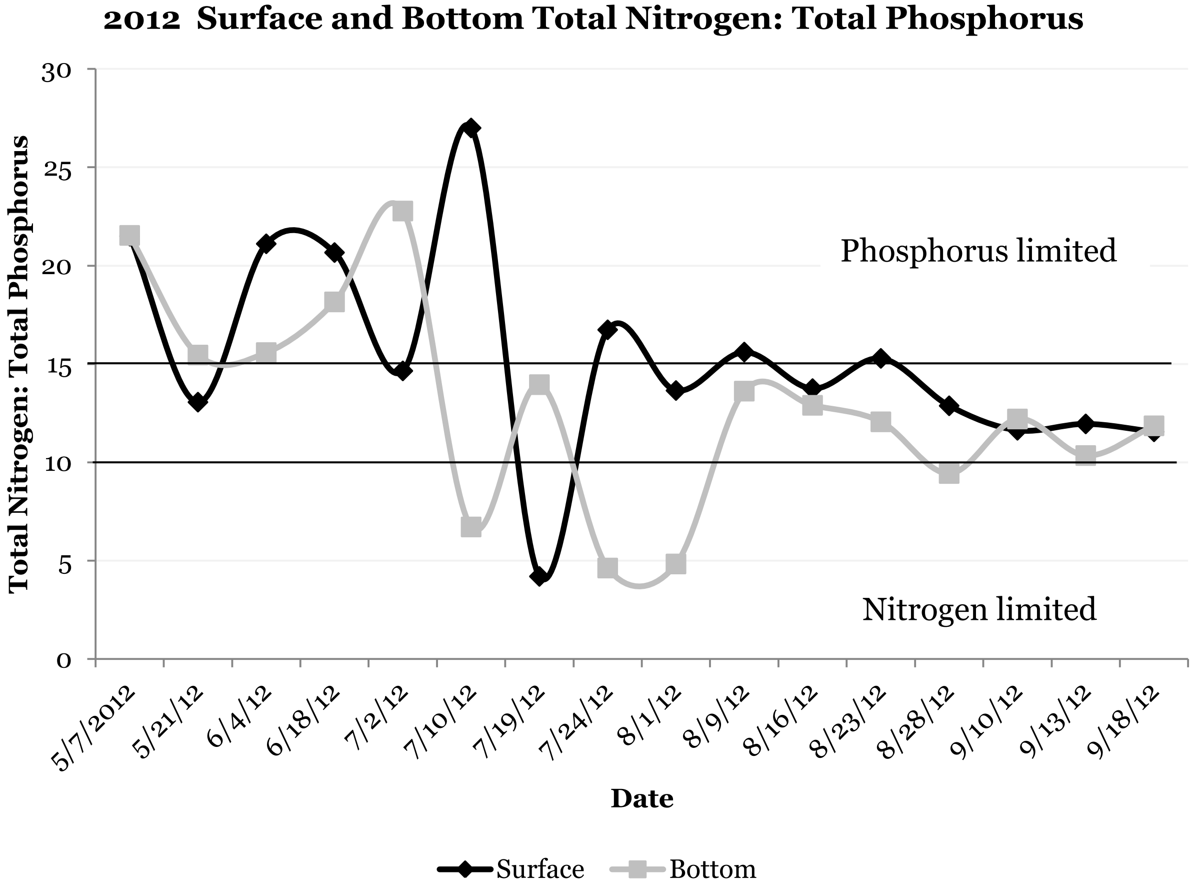


Total Nitrogen to Total Phosphorus Ratio

The total nitrogen to total phosphorus ratio (TN: TP) is a calculation that depicts which nutrient limits algae growth in a lake.

Lakes are considered nitrogen limited, or sensitive to the amount of nitrogen inputs into a lake, when TN: TP ratios are less than 10. Only about 10% of Wisconsin lakes are limited by nitrogen. In contrast, lakes are considered phosphorus limited, or sensitive to the amount of phosphorus inputs into a lake, when the TN: TP ratio is above 15. Lakes with values between 10 and 15 are considered transitional. In transitional lakes it is impossible to determine which nutrient, either nitrogen or phosphorus, is limiting algae growth (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Total nitrogen is found by adding nitrate/nitrite and total Kjeldahl nitrogen. A clear trend of nutrient limitation does not emerge for Long Lake. Early in the season (May and June), the majority of the top and bottom samples indicate phosphorus limitation. In July, the bottom samples indicate nitrogen limitation. Near the end of the season (August and September) the majority of samples indicate a transitional state.



Sulfate

Sulfate concentrations in lakes are most directly related to the types of minerals found in the watershed and to acid rain. Coal burning facilities that release sulfur compounds into the atmosphere can enter lakes via rainfall. In general, sulfate concentrations are higher in the southeastern portion of the state where mineral sources of sulfate and acid rain are more common.

In Polk County, sulfate concentrations are generally less than 10 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

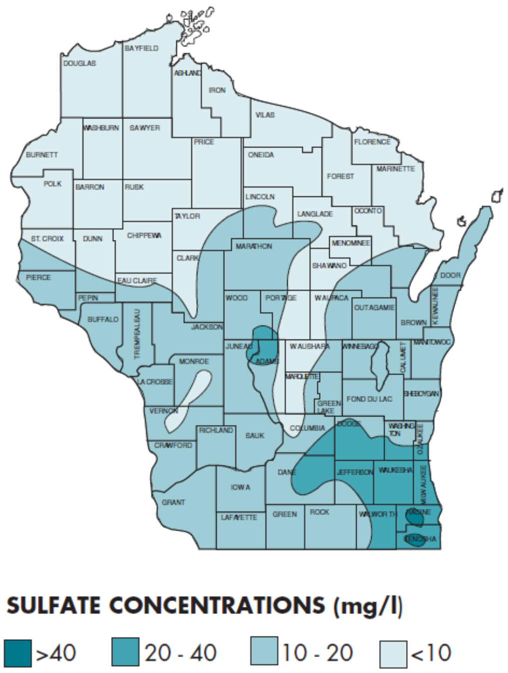
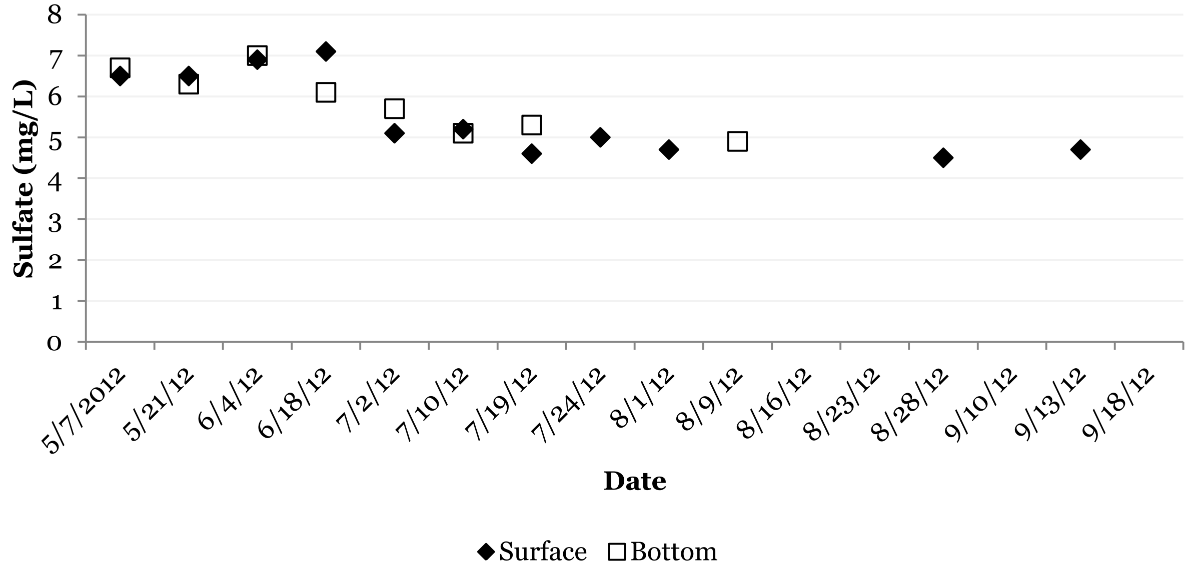


FIGURE 8. Generalized distribution gradients of sulfate in the surface waters of Wisconsin lakes. (*Adapted from Lillie and Mason, 1983.*)

Sulfate concentrations in Long Lake were under 10 mg/L over the entire growing season which fits with the general Polk County trend. The limit of detection for sulfate was 4.5 mg/L. Dates where sulfate concentrations were below the limit of detection are not shown graphically.

2012 Surface and Bottom Sulfate (mg/L)

** excludes samples where sulfate was below the limit of detection*



Dissolved Oxygen

Oxygen is required by all aquatic organisms for survival. The amount of oxygen dissolved in water depends on water temperature, the amount of wind mixing that brings water into contact with the atmosphere, the biological activity that consumes or produces oxygen within a lake, and the composition of groundwater and surface water entering a lake.

In a process called photosynthesis, plants use carbon dioxide, water, and the sun's energy to produce simple sugars and oxygen. Chlorophyll, the pigment in plants that captures the light energy necessary for photosynthesis, is the site where oxygen is produced. Since photosynthesis requires light, the oxygen producing process only occurs during the daylight hours and only at depths where sunlight can penetrate.

Plants and animals also use oxygen in a process called respiration. During respiration, sugar and oxygen are used by plants and animals to produce carbon dioxide and water.

Temperature °C	Temperature °F	Oxygen solubility (mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

Cold water is able to hold more oxygen as compared to warm water. However, although temperatures are coolest in the deepest part of a lake, these waters often do not contain the most oxygen. This arises because in the deepest parts of lakes, oxygen producing photosynthesis is not occurring, mixing is unable to introduce oxygen, and the only reaction occurring is oxygen consuming respiration. Therefore, it is not uncommon for oxygen depletion to occur in the hypolimnion.

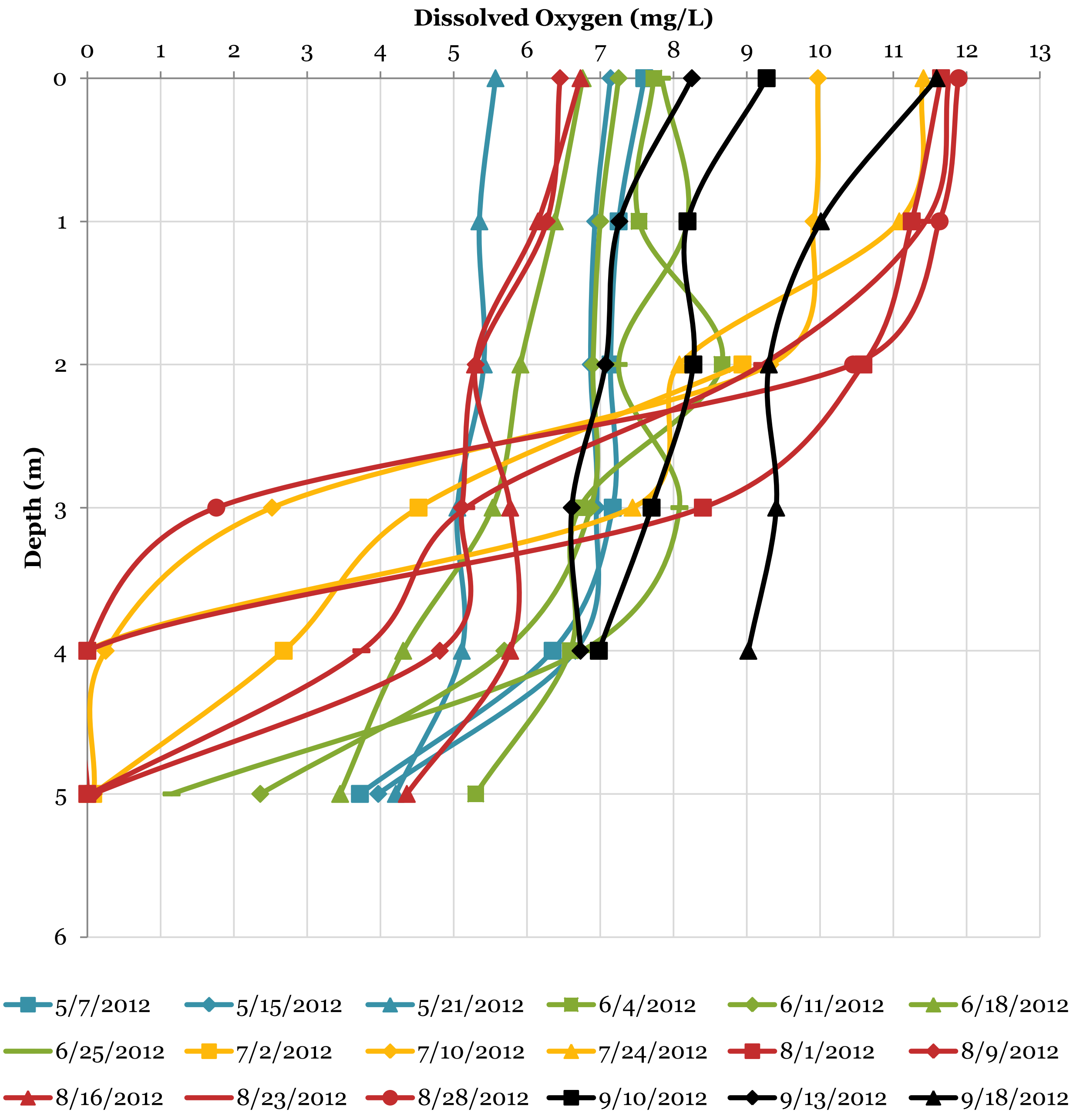
During the sunlight hours, when photosynthesis is occurring, dissolved oxygen levels at a lake's surface may exceed the oxygen solubility values. Conversely, at night or early in the morning (when photosynthesis is not occurring), the dissolved oxygen values can be expected to be lower.

A water quality standard for dissolved oxygen in warm water lakes and streams is set at 5 mg/L. This standard is based on the minimum amount of oxygen required by fish for survival and growth. For cold water lakes supporting trout, the standard is set even higher at 7 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

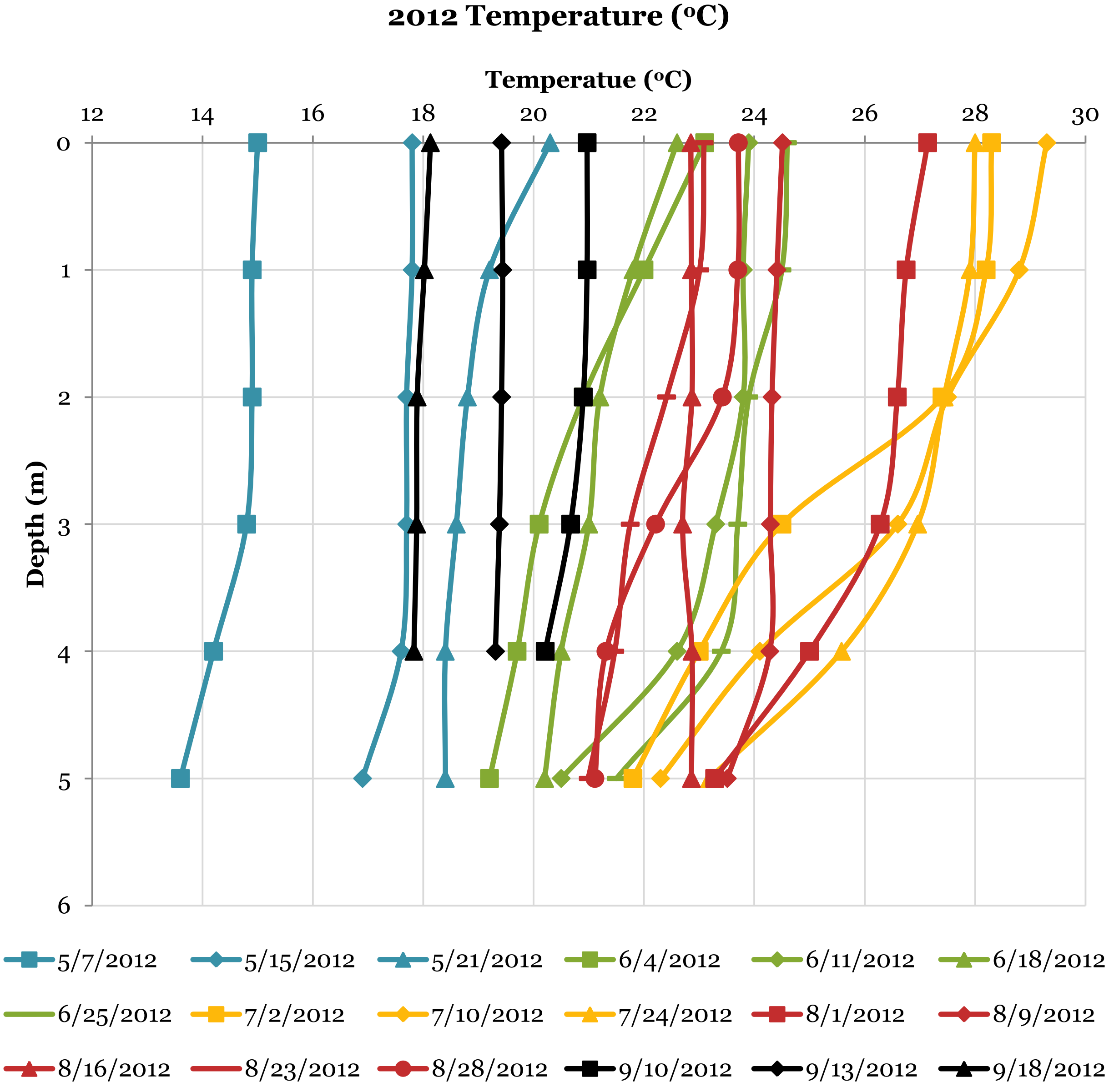
Dissolved oxygen levels began to fall below 5 mg/L at depths of three meters in late July and depths of four meters in late August. During the majority of the growing season, dissolved oxygen levels were below five mg/L at depths of 5 meters. The first two meters of the water column in Long Lake appear very well mixed based on dissolved oxygen.

2012 Dissolved Oxygen (mg/L)



Temperature

Long Lake reached its warmest surface temperature (~29°C) on July 10th, 2012. By examining the temperate profile, it is clear that in 2012 Long Lake did not stratify, or develop distinct layers over the majority of the growing season. Long Lake may have been slightly stratified in July, where the difference between surface and bottom temperatures was the greatest. [8]



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[8] On July 2nd, the difference between the surface and bottom temperature was 6.5 °C and on July 10th, the difference between the surface and bottom temperature was 7 °C.

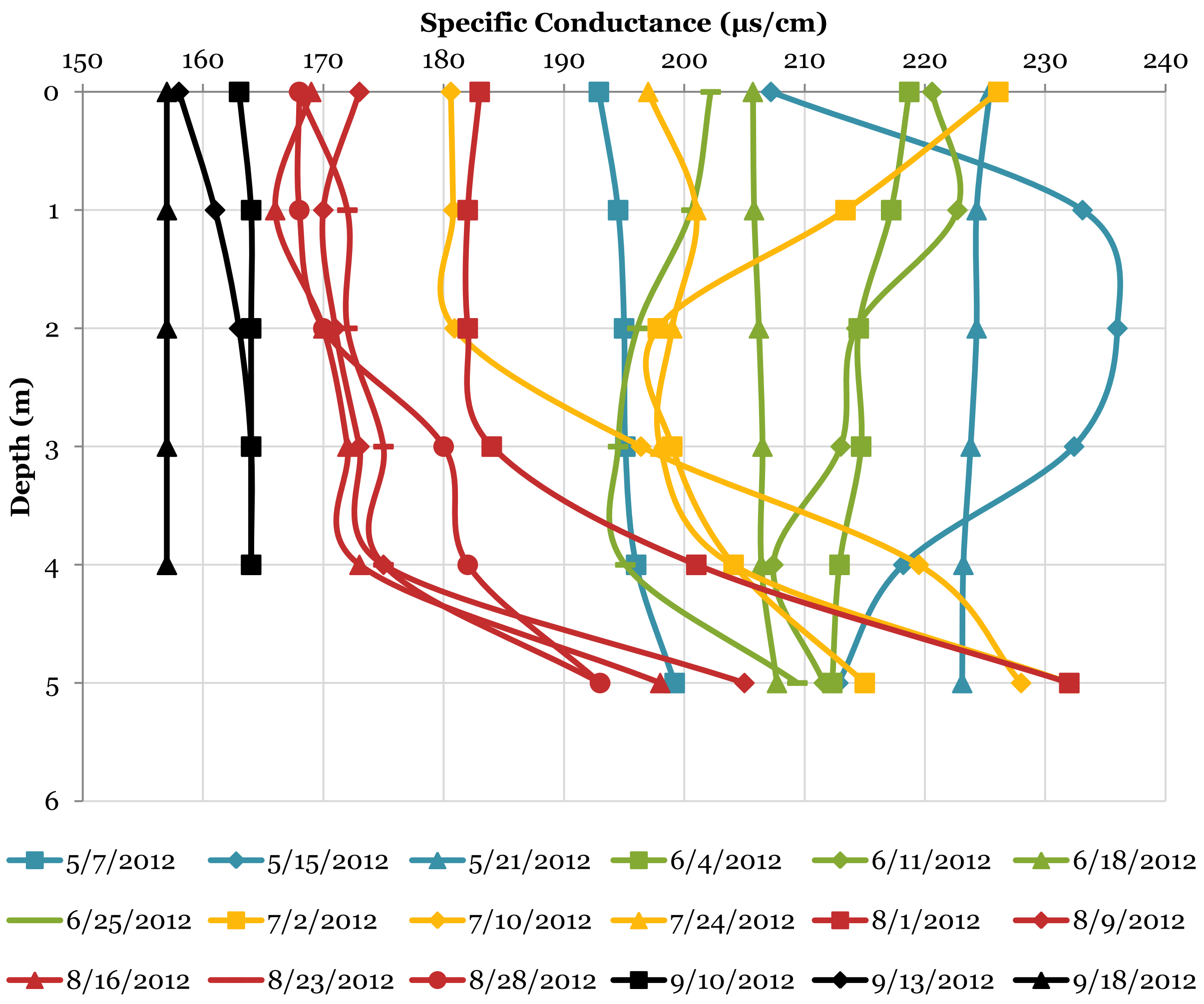
Conductivity (Specific Conductance)

Conductivity is the measure of the ability of water to conduct an electrical current and serves as an indicator of the concentration of total dissolved inorganic chemicals in the water. Since conductivity is temperature related, reported values are normalized at 25°C and termed specific conductance. Specific conductance increases as the concentration of dissolved minerals in a lake increase.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

In general, surface specific conductance was highest early in the spring and decreased over the growing season. In July and August specific conductance increased greatly with increasing depths as compared to other months.

2012 Specific Conductance (µs/cm)



pH

An indicator of acidity, pH is the negative logarithm of the hydrogen ion (H+) concentration. Low pH waters have more hydrogen ions and are more acidic, and high pH waters have less hydrogen ions and are less acidic.

A pH value of seven is considered neutral. Values less than seven indicate acidic conditions; whereas, values greater than seven indicate alkaline, or basic, conditions. A single pH unit change represents a tenfold change in the concentration of hydrogen ions. As a result, a lake with a pH value of eight is ten times less acidic than a lake with a pH value of seven.

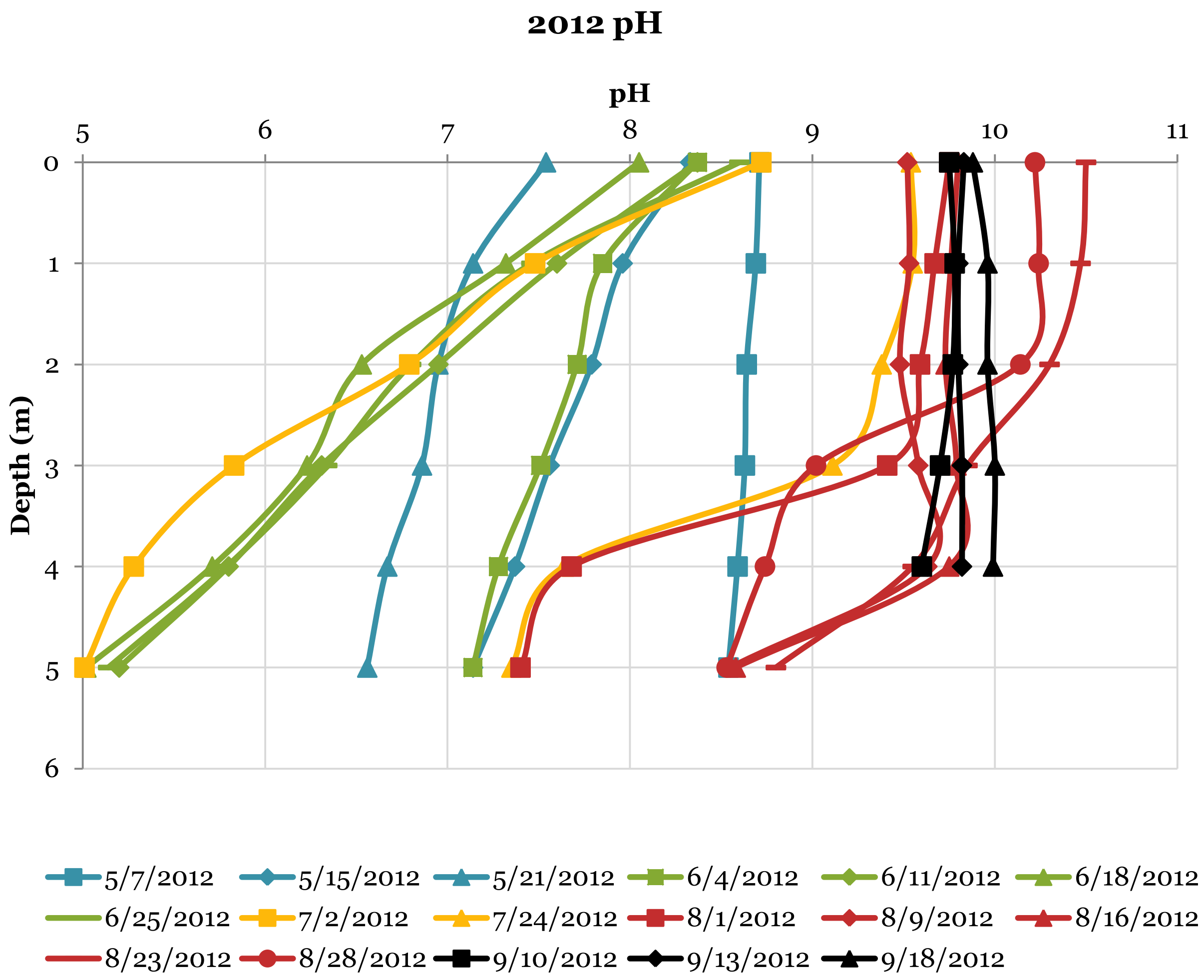
Across Wisconsin lakes, pH values can range from 4.5 (acid bog lakes) to 8.4 (hard water, marl lakes).

Through the removal of CO_2 from the water column, photosynthesis has the effect of increasing pH. As a result, pH generally increases during the day and decreases at night. Under conditions such as high temperature, high nutrients, and dense algae blooms, pH levels can increase.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Beginning on July 24th, pH values were an order of magnitude higher as compared to previous samples. Beginning on this date, data were collected with the HI 9828 multi-parameter probe; whereas prior to this date, data were collected using a YSI 60 pH meter. Although pH values do typically increase over the course of the summer, it is impossible to tell if the order of magnitude difference in pH is a result of the meters or a result of actual measured differences.

In general, pH was greater at the surface of Long Lake as compared to the bottom. Also, pH was the greatest in August and September as compared to earlier months.


2012 pH
pH
5
6
7
8
9
10
11
Depth (m)
0
1
2
3
4
5
6
5/7/2012
5/15/2012
5/21/2012
6/4/2012
6/11/2012
6/18/2012
6/25/2012
7/2/2012
7/24/2012
8/1/2012
8/9/2012
8/16/2012
8/23/2012
8/28/2012
9/10/2012
9/13/2012
9/18/2012

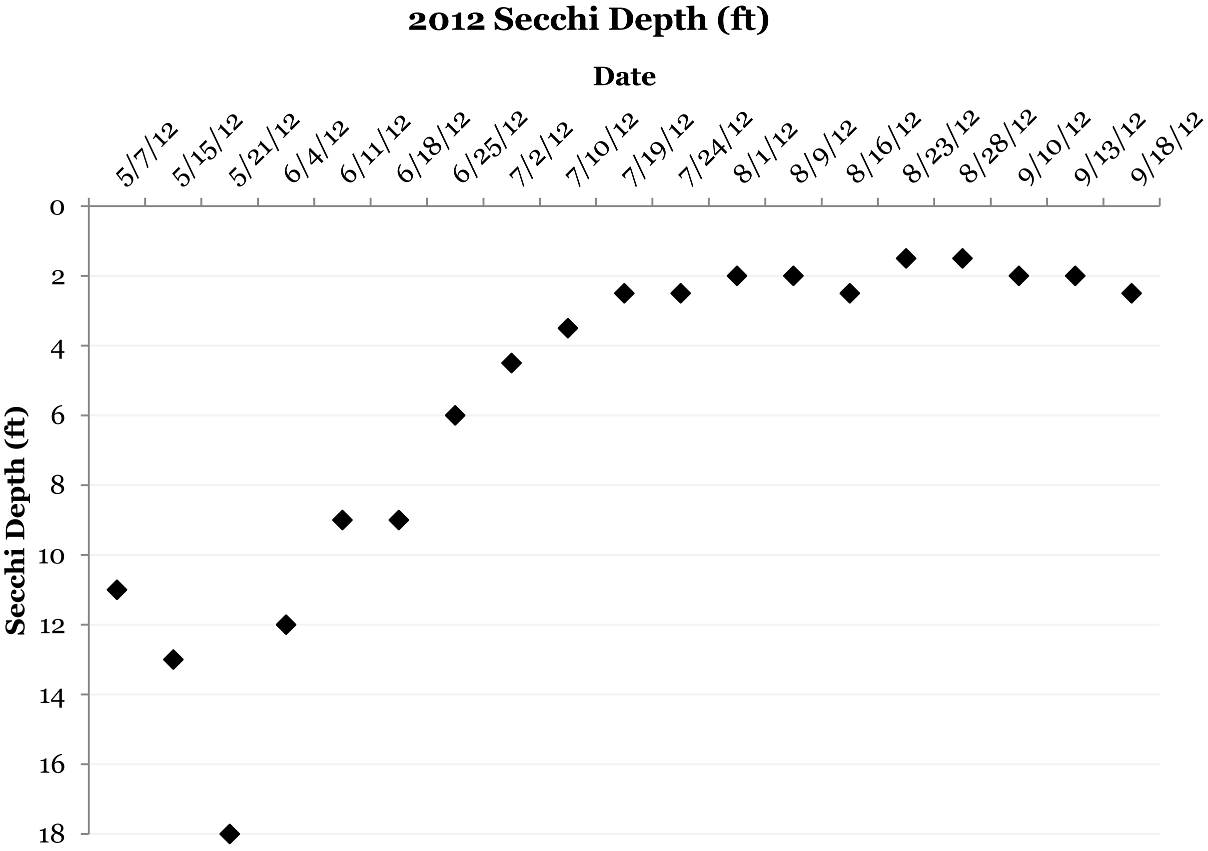
Secchi Depth

The depth to which light can penetrate into lakes is affected by suspended particles, dissolved pigments, and absorbance by water. Often, the ability of light to penetrate the water column is determined by the abundance of algae or other photosynthetic organisms in a lake.

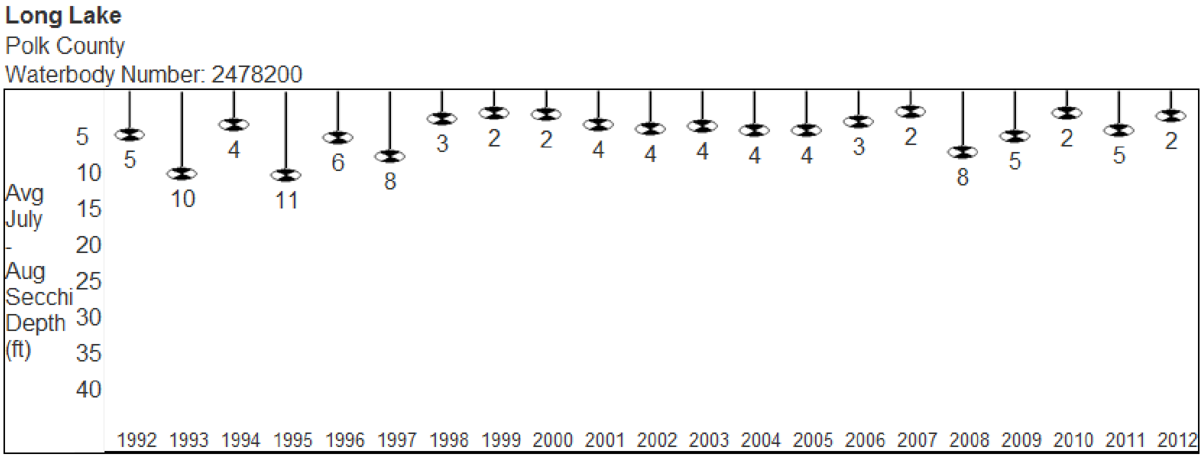
One method of measuring light penetration is with a secchi disk. A secchi disk is an eight inch diameter round disk with alternating black and white quadrants that is used to provide a rough estimate of water clarity. The depth at which the secchi disk is just visible is defined as the secchi depth. A greater secchi depth indicates greater water clarity.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The average growing season secchi depth for Long Lake was 5.6 feet and the average summer index period secchi depth was 2.1 feet. Secchi depth on Long Lake was the greatest on May 21st, where the secchi disk hit the bottom of the lake at 18 feet. On both August 23rd and 28th, secchi depth readings were only 1.5 feet.



The Wisconsin Department of Natural Resources provides historic secchi depth averages for the months of July and August only. This data exists for Long Lake from 1992 to present.



Past secchi averages in feet (July and August only).

Chlorophyll a

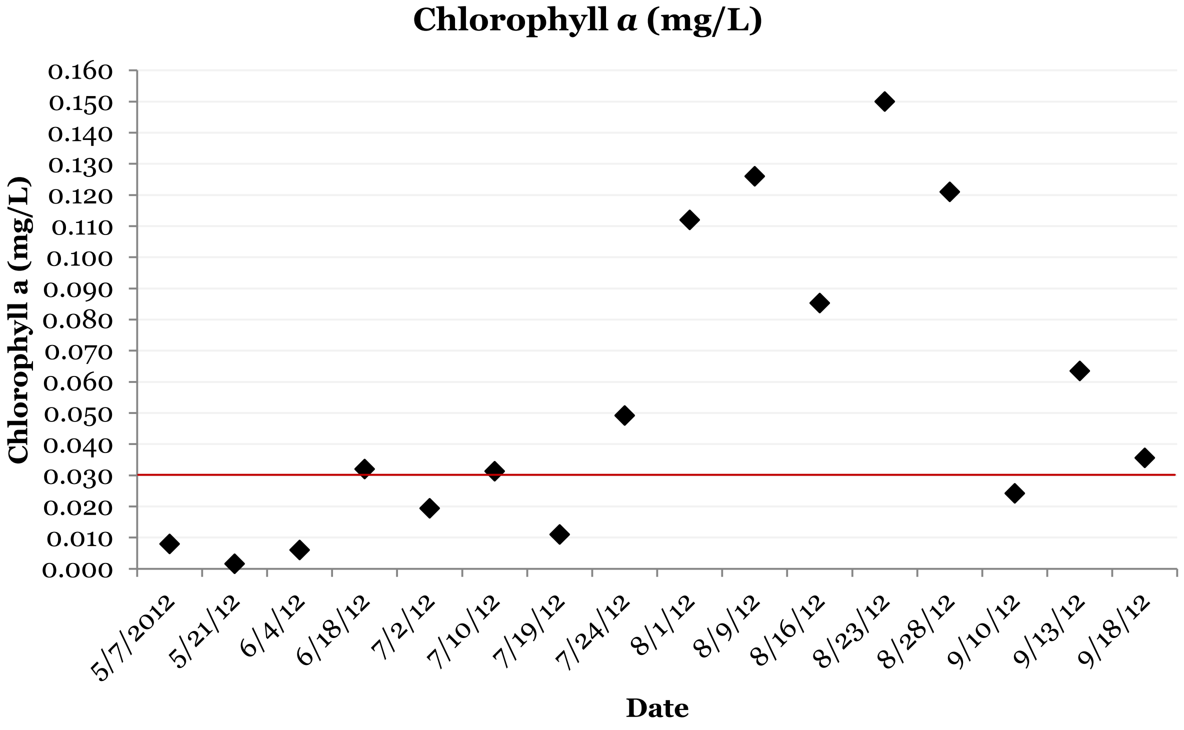
Chlorophyll *a* is a pigment in plants and algae that is necessary for photosynthesis and is an indicator of water quality in a lake. Chlorophyll *a* gives a general indication of the amount of algae growth in a lake, with greater values for chlorophyll *a* indicating greater amounts of algae. However, since chlorophyll *a* is present in sources other than algae—such as decaying plants— it does not serve as a direct indicator of algae biomass.

While chlorophyll *a* gives a general indication of the amount of algae growth in the water column, it is not directly correlated with algae biomass. Greater values for chlorophyll *a* do tend to indicate greater amounts of algae.

Chlorophyll *a* seems to have the greatest impact on water clarity when levels exceed 0.03 mg/L. Lakes which appear clear generally have chlorophyll *a* levels less than 0.015 mg/L.

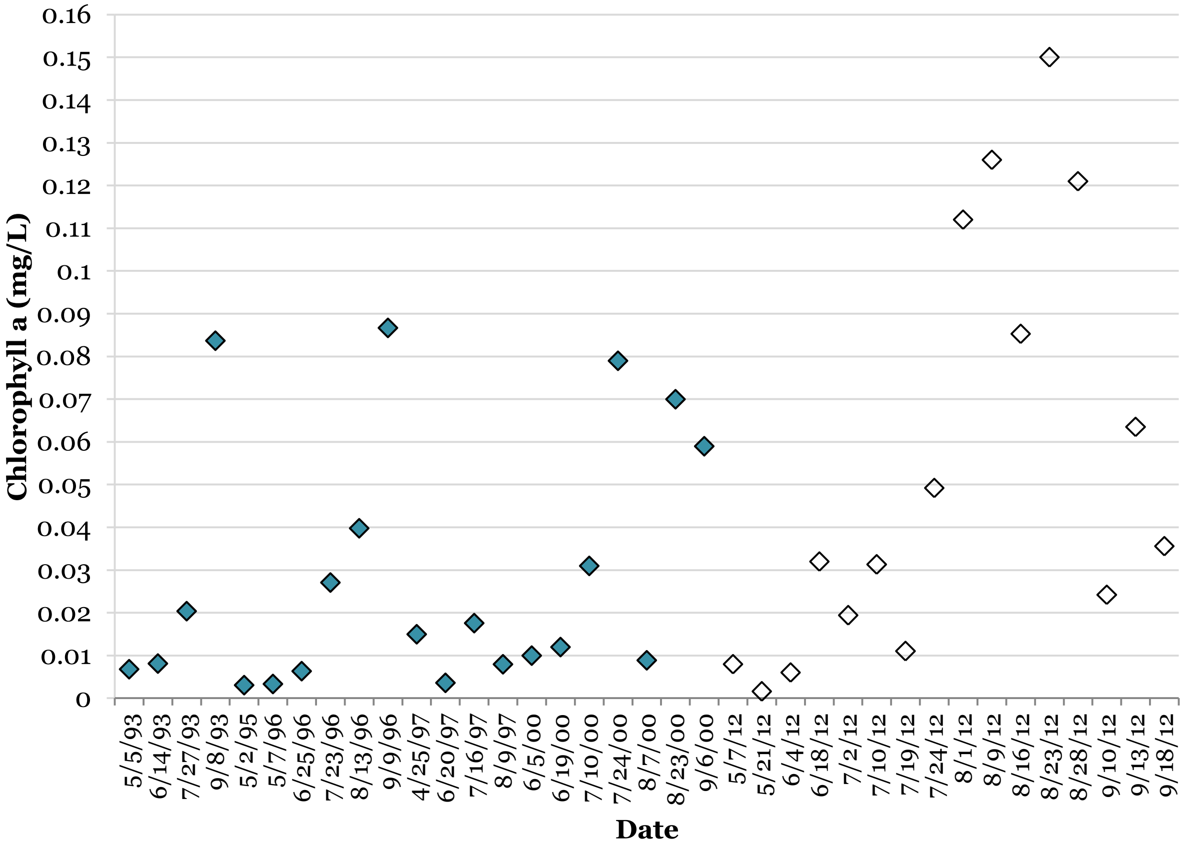
Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Chlorophyll *a* concentrations were well above the 0.03 mg/L level. The average growing season chlorophyll *a* concentration was 0.054 mg/L and the average summer index period chlorophyll *a* concentration was 0.082 mg/L.



It is difficult to compare historic chlorophyll *a* data due to the intermittency of the data collection. However, in 2012 chlorophyll *a* concentrations reached their highest historic recorded level.

Historic Chlorophyll *a* (mg/L)



Trophic State Index

Lakes are divided into three categories based on their trophic states: oligotrophic, eutrophic, and mesotrophic. These categories reflect a lake's nutrient and clarity level and serve as an indicator of water quality. Each category is designed to serve as an overall interpretation of a lake's primary productivity.

Oligotrophic lakes are generally clear, deep, and free of weeds and large algae blooms. These types of lakes are often poor in nutrients and are therefore unable to support large populations of fish. However, oligotrophic lakes can develop a food chain capable of supporting a desirable population of large game fish.

Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms. Eutrophic lakes often support large fish populations, but are susceptible to oxygen depletion. Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have good fisheries and occasional algae blooms.

All lakes experience a natural aging process which causes a change from an oligotrophic to a eutrophic state. Human influences which introduce nutrients into a lake (agriculture, lawn fertilizers, and septic systems) can accelerate the process by which lakes age and become eutrophic.

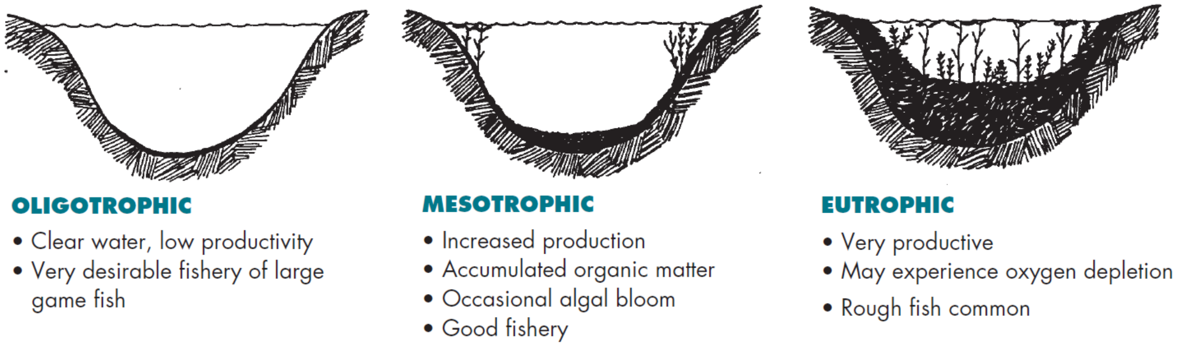


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

A common method of determining a lake's trophic state is to compare total phosphorus concentration (important for algae growth), chlorophyll *a* concentration (an indicator of the amount of algae present), and secchi disk readings (an indicator of water clarity). Although many factors influence these relationships, the link between phosphorus concentration, chlorophyll *a* concentration, and secchi disk readings is the basis of comparison for the Trophic State Index (TSI).

TSI is determined using a mathematic formula and ranges from 0 to 110. Lakes with the lowest numbers are oligotrophic and lakes with the highest values are eutrophic.

Three equations for summer index period TSI were examined for Long Lake.

TSI (P) = 14.42 * Ln [TP] + 4.15 (where TP is in µg/L)
TSI (C) = 30.6 + 9.81 Ln [Chlor-a] (where the chlorophyll *a* is in µg/L)
TSI (S) = 60-14.41 * Ln [Secchi] (where the secchi depth is in meters)
Equations from: (Carlson, 1977).

<u>Long Lake</u>

Average summer index period total phosphorus = 76
Average summer index period chlorophyll *a* = 74
Average summer index period secchi depth = 66
Average summer index period TSI = 72 = hypereutrophic

TSI	General Description
<30	Oligotrophic; clear water, high dissolved oxygen throughout the year/lake
30-40	Oligotrophic; clear water, possible periods of oxygen depletion in the lower depths of the lake
40-50	Mesotrophic; moderately clear water, increasing chance of anoxia near the bottom of the lake in summer, fully acceptable for all recreation/aesthetic uses
50-60	Mildly eutrophic; decreased water clarity, anoxic near the bottom, may have macrophyte problem, warm-water fisheries only
60-70	Eutrophic; blue-green algae dominance, scums possible, prolific aquatic plant growth, full body recreation may be decreased
70-80	Hypereutrophic; heavy algal blooms possible throughout the summer, dense algae and macrophytes
>80	Algal scums, summer fish kills, few aquatic plants due to algal shading, rough fish dominate

TSI data indicate that in 2012 Long Lake was eutrophic. Complete TSI data exists for 1993, 1996-97, 2000, and 2012. TSI secchi data exists for the past twenty years (1992-2012). The majority of the historic TSI data indicate a eutrophic state.

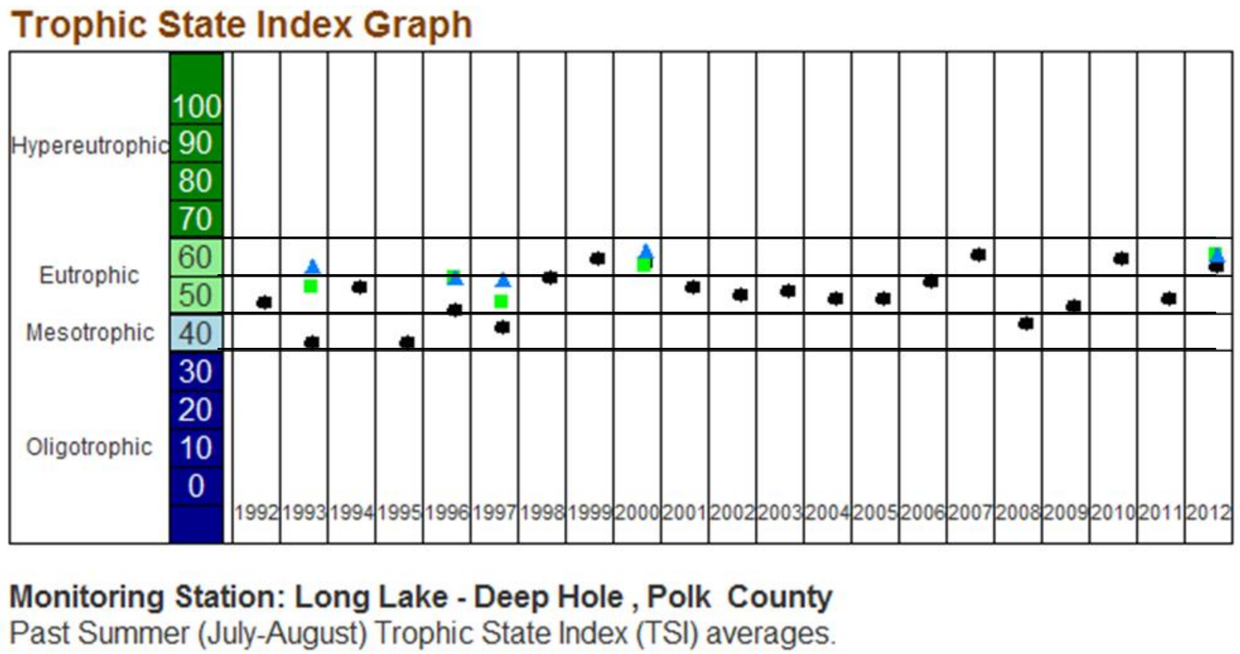
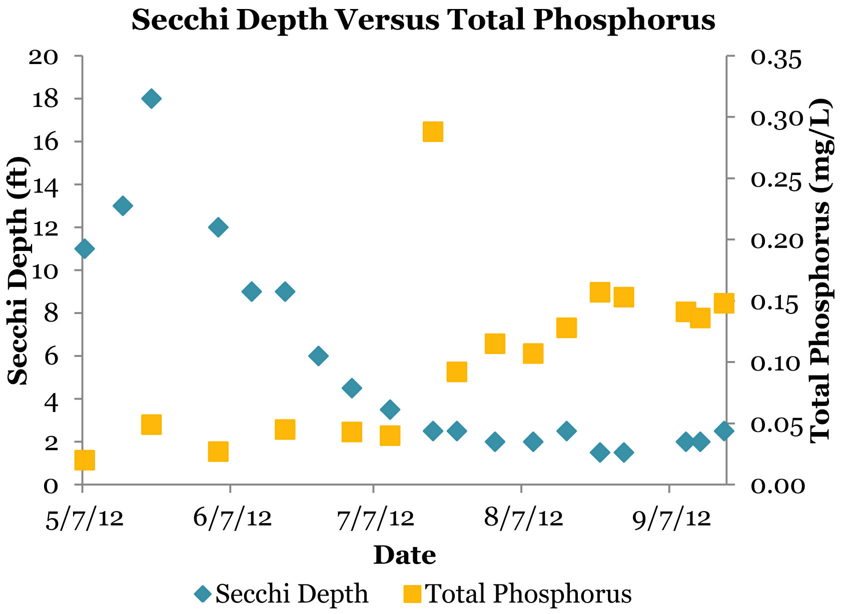
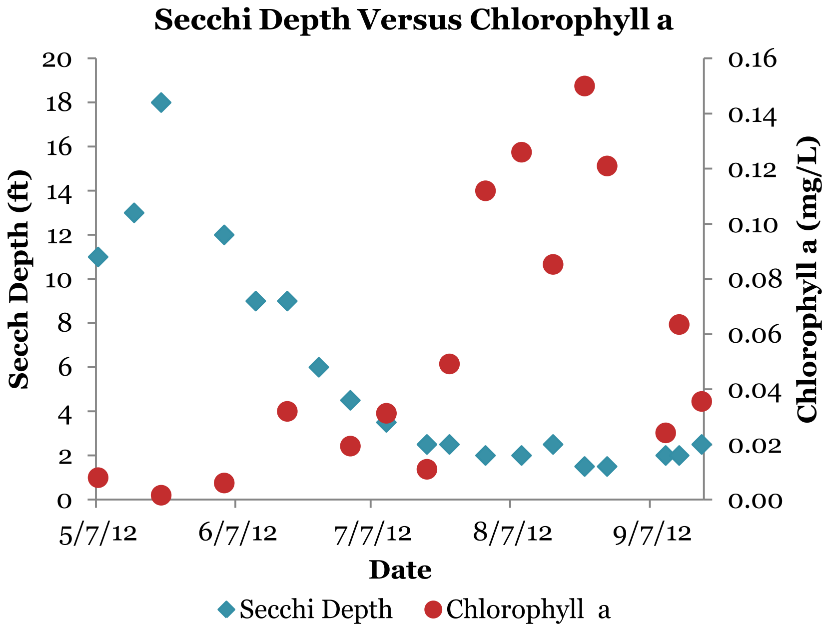
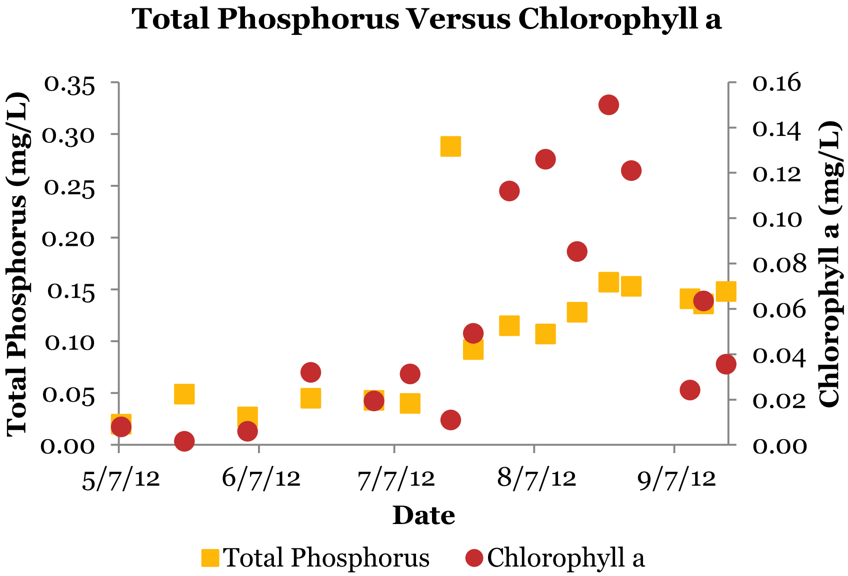


Figure from: (Wisconsin Department of Natural Resources).







2012 Trends

As total phosphorus concentrations in Long Lake increased, secchi depth (water clarity) decreased.

As chlorophyll a concentrations (an indicator of algae) in Long Lake increased, secchi depth (water clarity) decreased.

As total phosphorus concentrations in Long Lake increased, chlorophyll a concentrations (an indicator of algae) increased.

Historical Comparison

A Lake Management Plan for Long Lake was last completed in May 2003 (Barr Engineering, 2003). Water quality data was collected as part of this study in 2000 (Barr Engineering, 2001). Since this is the most recent comprehensive water quality study done on Long Lake, averages over the summer index period from 2000 are compared to averages over the summer index period in 2012.

A comparison of the 2000 to 2012 data show an increase in total phosphorus (0.117 mg/L to 0.146 mg/L), a decrease in secchi depth (2.7 feet to 2.1 feet), and an increase in chlorophyll *a* (0.049 mg/L to 0.082 mg/L).

	2000	2012
Total phosphorus (mg/L)	0.117	0.146
Secchi depth (ft)	2.7	2.1
Chlorophyll *a* (mg/L)	0.049	0.082

Phytoplankton

Algae, also called phytoplankton, are microscopic plants that convert sunlight and nutrients into biomass. They can live on bottom sediments and substrate, in the water column, and on plants and leaves. Algae are the primary producers in an aquatic ecosystem and can vary in form (filamentous, colonial, unicellular, etc). Zooplankton, are small aquatic organisms that feed on algae. The size and shape of algae determine which types of zooplankton—if any—can consume them.

Algae have short life cycles. As a result, changes in water quality are often reflected by changes in the algal community within a few days or weeks. The number and types of algae in a waterbody can provide useful information for environmental monitoring programs, impairment assessments, and the identification of best management strategies.

The types of algae in a lake will change over the course of a year. Typically, there is less algae in winter and spring because of ice cover and cold temperatures. As a lake warms up and sunlight increases, algae communities begin to increase. Their short life span quickly cycles the nutrients in a lake and affects nutrient dynamics.

The types of algae present in a lake are influenced by environmental factors like climate, phosphorus, nitrogen, silica and other nutrient content, carbon dioxide, grazing, substrate, and other factors in the lake. When high levels of nutrients are available, blue green algae often become predominant. Additionally, under nitrogen limited conditions (which did exist in 2012 on Long Lake) blue green algae have a competitive advantage over other algae because of their unique in their ability to fix nitrogen from the atmosphere.

Chlorophyll *a* is a pigment in plants and algae that is necessary for photosynthesis. Chlorophyll *a* gives a general indication of the amount of algae growth in the water column; however, it is not directly correlated with algae biomass. To obtain accurate algae data, composite samples from a two meter water column were collected monthly, preserved with glutaraldehyde, placed on ice, and sent to the State Lab of Hygiene for identification and enumeration of algae species. Sampling was conducted in 2010, 2011, and 2012.

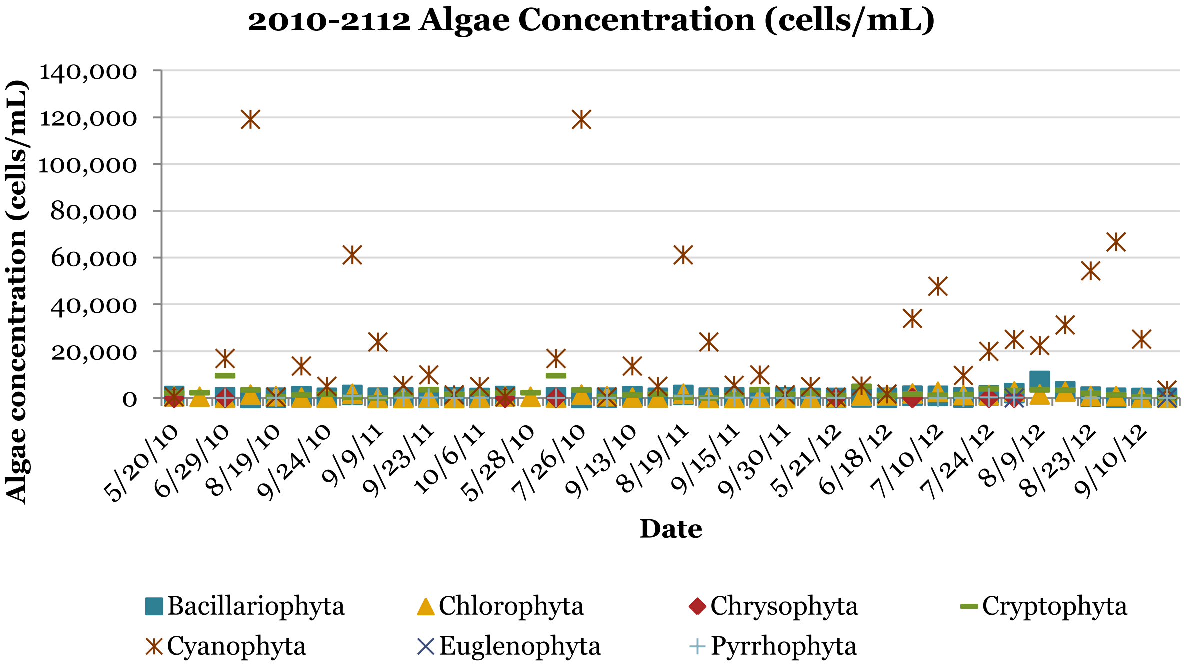
Algae were identified to genus, and a relative concentration and natural unit count was made to describe the algae community throughout the growing season. This method of sampling also allows the identification of any species of concern which might be present.

There are 12 divisions of algae found in typical lakes of Wisconsin. Seven divisions were found in Long Lake. The division Euglenophyta was only present in Long Lake in 2012.

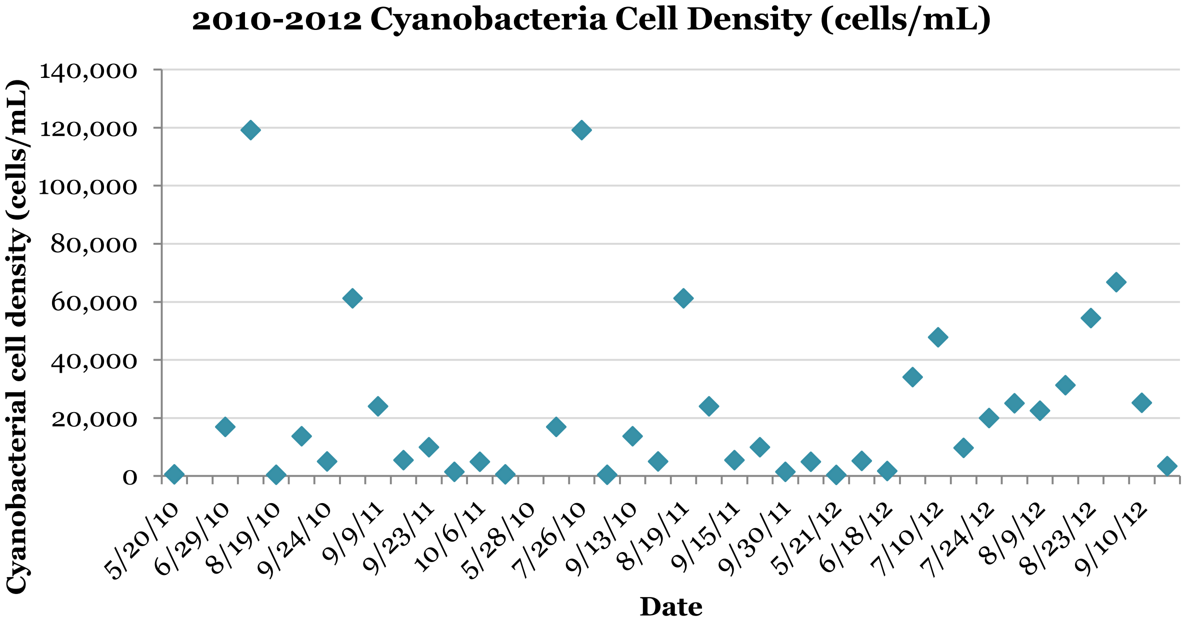
Algal Class	Common Name	Characteristics
Chlorophyta	Green algae	Provide high nutritional value to consumers. Can be filamentous and intermingle with macrophytes.
Bacillariophyta	Diatoms	Sensitive to chloride, pH, color, and total phosphorus (TP) in water. As TP increases, diatoms decrease. Generally larger in size. Tend to be highly present in spring and late spring.
Cryptophyta	Cryptomonads	Bloom forming, are not known to produce any toxins and are used to feed small zooplankton. Cryptomonads frequently dominate the phytoplankton assemblages of the Great Lakes.
Cyanophyta	Blue green algae	Prevail in nutrient-rich standing waters. Blooms can be toxic to zooplankton, fish, livestock, and humans. Can be unicellular, colonial, planktonic, or filamentous. Can live on almost any substrate. More prevalent in late to mid-summer.
Pyrrhophyta	Dinoflagellates	Have starch food reserves and serve as food for grazers.
Chrysophyta	Golden brown algae	A genus of single-celled algae in which the cells are ovoid. Contain chlorophyll a, c_1 and c_2, generally masked by abundant accessory pigment, fucoxanthin, imparting distinctive golden color to cells.
Euglenophyta	Euglenoids	Commonly found in freshwater that is rich in organic materials. Most are unicellular.

On the majority of the sampling dates, blue green algae (cyanophyta) were the most abundance division of algae in Long Lake.

Blue green algae have been around for billions of years and typically bloom during the summer months. However, blue-green algae blooms become more frequent as a result of increased nutrient concentrations. In addition to the negative aesthetics posed by algae, blue green algae are of specific concern because of their ability to produce toxins. Toxin monitoring data, in addition to algae concentration data, were collected in 2010, 2011, and 2012.



Cyanobacteria cell densities of less than 20,000 cells/mL are typically associated with low toxin risks, densities of 20,000-100,000 with moderate risks, and densities of greater than 100,000 with high risks. Based on cyanobacterial cell densities 63% of samples indicated a low risk, 32% indicated a moderate risk, and 5% indicated a high risk.



Algae Toxins

Blue green algae, technically known as cyanobacteria, are microscopic organisms that are naturally present in Wisconsin waterbodies at low levels. When conditions are favorable (usually in summer) the number of algae can increase dramatically, forming pea-soup blooms and scums on the water surface.

Some algal species produce toxins that when ingested or inhaled, can cause short and long term health effects. Effects range from tingling, burning, numbness, drowsiness, and dermatitis to liver or respiratory failure possibly leading to death. Not all cyanobacteria produce toxins, but the presence of blue green algae is a marker for a potential hazard.

On October 6th, 2009 a small dog died after exposure to algae toxins in Long Lake. Additional reports of a Labrador retriever becoming violently ill and a likely human skin rash from algae toxins occurred in 2009. These unfortunate events warranted a three year study to monitor harmful algae blooms on Long Lake. Funding for the three year study (2010-2012) was provided by the State Department of Health Services with support from the Center for Disease Control.

Federal guidelines for cyanobacterial cell densities and chlorophyll *a* concentrations do not exist. The Wisconsin Harmful Algal Bloom (HAB) Surveillance Program uses guidelines of the World Health Organization to determine risks from cyanobacteria:

Cyanobacterial cell density (cells/ml)	**Chlorophyll *a* (mg/L)**	**Risk**
Less than 20,000	Less than 0.01	Low
20,000 to 100,000	0.01 to 0.05	Moderate
Greater than 100,000	Greater than 0.05	High

However, in Long Lake in 2010-2012 the expected risk based on cyanobacterial cell density and chlorophyll a did not always correlate with the risk based on measured toxin production.

This study monitored the concentration of eight different toxins. Toxins marked with ** were not analyzed in 2010:

- ✓ Anatoxin A
- ✓ Homoanatoxin-a **
- ✓ Cylindrospermopsin **
- ✓ Deoxycylindrospermopsin **
- ✓ Microcystin LR
- ✓ Microcystin LA
- ✓ Microcystin YR
- ✓ Microcystin RR

Cyanobacterial toxins can be classified into two different types: neurotoxins and hepatotoxins. Anatoxins are examples of neurotoxins; whereas, microcystin and cylindrospermopsin are examples of hepatotoxins.

Neurotoxins cause result in muscle cramps, twitching, paralysis, and cardiac or respiratory failure. In comparison, hepatotoxins cause symptoms such as nausea, vomiting, and acute liver failure.

The recreational guidelines from the World Health Organization for microcystin LR are:

- ✓ Low risk of adverse health effects: Less than 10 µg/L
- ✓ Moderate risk of adverse health effects: 10-20 µg/L
- ✓ High probability of adverse health effects: Greater than 20 µg/L

Oregon, Vermont, and Washington have developed their own recreational guideline values which may take into account the higher risks that children and people with underlying health problems may experience from cyanobacterial toxins.

For microcystin LR the following recreational guidelines have been set:

- ✓ Washington and Vermont: 6 µg/L
- ✓ Oregon: 8 µg/L
- ✓ World Health Organization: 20 µg/L

Using the World Health Organization guidelines, twenty-five percent of the toxin samples from 2010 to 2012 indicated a low risk of adverse health effects due to the toxin microcystin LR, 4% indicated a moderate risk, and 71% indicated a high probability of adverse health effects.

For anatoxin-a, the following recreational guidelines have been set:

- ✓ Washington: 1 µg/L
- ✓ Vermont: 10 µg/L
- ✓ Oregon: 20 mg/L

From 2010 to 2012, 17% of the samples had confirmed anatoxin-a present. Concentrations ranged from a low of 2.5 µg/L to a high of 16 µg/L.

Cylindrospermopsin was not tested for in 2010, was tested for but not present in Long Lake in 2011, and was tested for and confirmed in 75% of the 2012 samples. The presence of this toxin in 2012 is the first confirmed case of cylindrospermopsin in Wisconsin.

Date	Anatoxin-a µg/L	Homoanatoxin-a µg/L	Cyclindro-spermopsin µg/L	Deoxycylindro-spermopsin µg/L	Microcystin LR µg/L	Microcystin LA µg/L	Microcystin YR µg/L	Microcystin RR µg/L
6/17/10	**	--	--	--	**	1.6	**	**
6/29/10	**	--	--	--	**	2.8	**	**
7/20/10	2.5	--	--	--	**	5.6	**	**
8/19/10	**	--	--	--	8.1	16	1.6	2.2
9/13/10	**	--	--	--	79	1,100	58	73
8/5/11	16	0.51	**	**	55	69	2.9	21
8/19/11	**	**	**	**	6.8	11	**	4.9
9/9/11	**	**	**	**	160	87	**	27
9/15/11	**	**	**	**	24	1.5	**	**
9/23/11	**	**	**	0.9	110	4.5	**	**
9/30/11	**	**	**	**	440	21	**	**
10/6/11	**	**	**	**	22	**	**	**
6/18/12	**	**	**	**	13	**	**	**
7/10/12	**	**	**	**	180	7.1	**	**
7/19/12	**	**	0.74	0.82	3,500	200	**	14
7/24/12	**	**	**	**	530	73	**	3.1
8/1/12	**	**	1.4	**	190	46	11	18
8/9/12	6.2	**	0.95	**	210	31	32	120
8/16/12	**	**	2	**	160	17	16	97
8/28/12	**	**	3.6	**	210	57	**	12
9/10/12	**	**	0.8	**	**	**	**	**
9/13/12	**	**	2.3	**	67	3.8	5.7	7.5
9/18/12	**	**	3.3	**	26	1.1	**	2.3
9/23/12	2.3	**	11	**	610	120	49	760

Concentration of eight algae toxins in Long Lake, 2010-2012
** indicates samples where toxins were below the limit of detection
-- indicates toxins that were not tested for

Date	Risk cyanobacterial cell density (WHO)	Risk chlorophyll a (WHO)	Risk toxin microcystin LR (WHO)	Toxin anatoxin-a present?	Toxin cyclindrospermopsin present?
5/20/10	Low	--	--	--	--
5/28/10	--	--	--	--	--
6/17/10	--	--	Low	No	--
6/29/10	Low	--	Low	No	--
7/26/10	High	--	Low	Yes	--
8/19/10	Low	--	Low	No	--
9/13/10	Low	--	High	No	--
9/24/10	Low	--	--	--	--
8/5/11	--	--	High	Yes	No
8/19/11	Moderate	--	Low	No	No
9/9/11	Moderate	--	High	No	No
9/15/11	Low	--	High	No	No
9/23/11	Low	--	High	No	No
9/30/11	Low	--	High	No	No
10/6/11	Low	--	High	No	No
5/7/12	--	Low	--	--	--
5/21/12	Low	Low	--	--	--
6/4/12	Low	Low	--	--	--
6/18/12	Low	Moderate	Moderate	No	No
7/2/12	Moderate	Moderate	--	--	--
7/10/12	Moderate	Moderate	High	No	No
7/19/12	Low	Moderate	High	No	Yes
7/24/12	Moderate	Moderate	High	No	No
8/1/12	Moderate	High	High	No	Yes
8/9/12	Moderate	High	High	Yes	Yes
8/16/12	Moderate	High	High	No	Yes
8/23/12	Moderate	High	--	--	--
8/28/12	Moderate	High	High	No	Yes
9/10/12	Moderate	Moderate	Low	No	Yes
9/13/12	Low	High	High	No	Yes
9/18/12	--	Moderate	High	No	Yes
9/23/12	--	--	High	Yes	Yes

2010-2012 Long Lake human health risk for algae toxins based on cell density, chlorophyll a, and concentration or presence of three toxins (microcystin LR, anatoxin-a and cylindrospermopsin
-- indicates no data available

Determining the risk associated with toxin production by cyanobacteria is difficult.

It is very costly to analyze samples for the production of toxins. As a result, guidelines exist to predict the risk from cyanobacteria based on the amount of cyanobacteria in a sample (cell density) and chlorophyll a. However, data from Long Lake indicate that caution should be exercised when using cyanobacteria cell densities and chlorophyll a to predict the risk from cyanobacteria (i.e. toxin production).

Another factor complicating the task of determining the risk associated with toxin production is the fact that federal and state guidelines do not exist to determine which level of toxins can be expected to cause adverse health effects. Although Vermont, Oregon, Washington, and the World Health Organization have guidelines for certain toxins, the guidelines vary widely by source. Additionally, some guidelines attempt to take into account the higher risks that children and people with underlying health problems may experience.

Additionally, there are many different types of toxins that can be produced by cyanobacteria. This study measured eight different toxins. For some toxins (such as cylindrospermopsin), there is no guideline to suggest which amount of the toxin will result in adverse health effects.

Zooplankton

Zooplankton are small aquatic animals that feed on algae and are eaten by fish. They are divided into three main components: rotifers, copepods, and cladocerans.

> **Rotifers** eat algae, other zooplankton, and sometimes each other. Due to their small size, rotifers are not capable of significantly reducing algal biomass although they are able to shift the algae community to favor larger species.
>
> **Copepods** feed on algae and other plankton. They are eaten by larger plankton and are preyed heavily upon by pan fish, minnows, and the fry of larger fish.
>
> **Cladocerans** are filter feeders that play an important part in the food web. Species of cladocerans (particularly Daphnia) are well known for their ability to reduce algal biomass and help maintain clear water in lake ecosystems.

Zooplankton are often overlooked as a component of aquatic systems, but their role in a lake is extremely important. Lake systems are valued primarily for water clarity, fishing, or other recreation, all of which are strongly linked to water quality and ecosystem health. Zooplankton are the primary link between the “bottom up” processes and “top down” processes of the lake ecosystem.

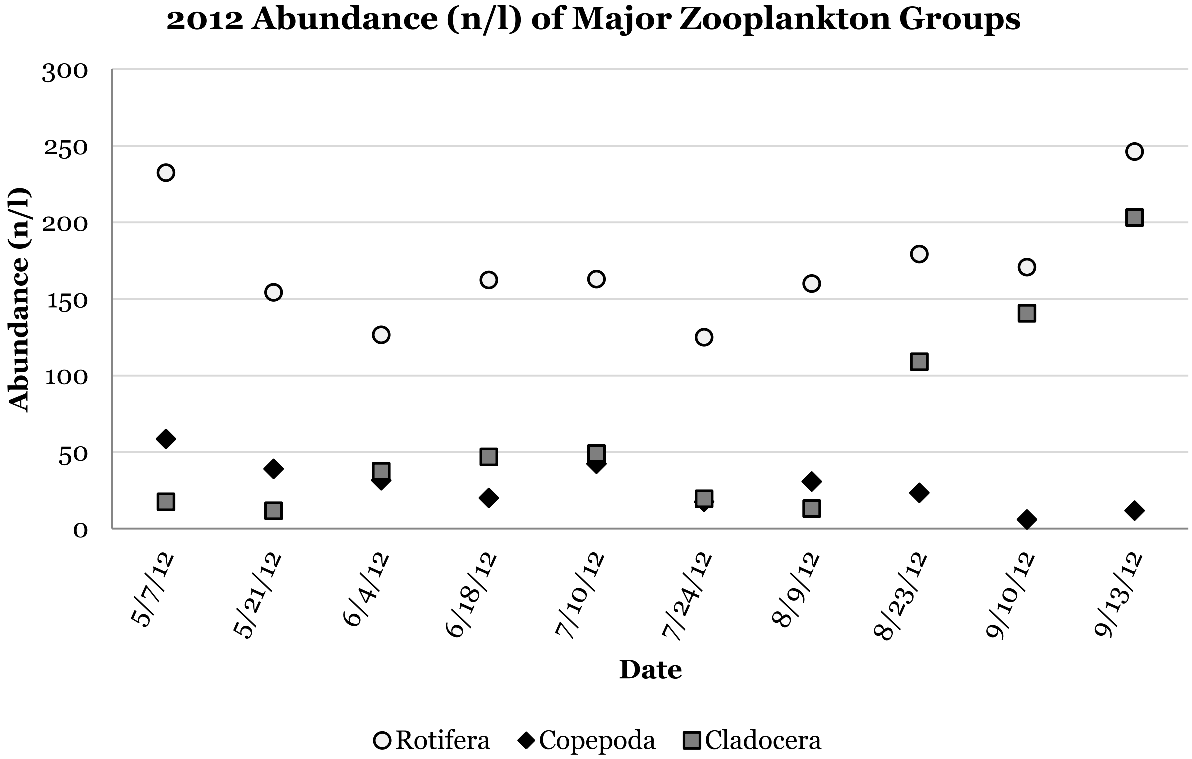
“Bottom up” processes include factors such as increased nutrients, which can cause noxious algal blooms. Zooplankton have the ability to mediate algae blooms by heavy grazing. Conversely, shifts in algal composition, which can be caused by increased nutrients, can change the composition of the zooplankton community. If the composition shifts to favor smaller species of zooplankton, for example, algal blooms can be intensified, planktivorous fish can become stressed, and the development of fry can be negatively impacted.

“Top down” processes include factors such as increased fish predation. Increases in planktivorous fishes (pan fish) can dramatically reduce zooplankton populations and lead to algal blooms. In some lakes, biomanipulation is utilized to manage this effect and improve water clarity. Piscivorous fish (fish that eat other fish) are used to reduce planktivorous fish. This in turn increases zooplankton populations and ultimately reduces algae populations.

Changes in the aquatic plant community and shoreland habitat can impact zooplankton populations. This occurs especially in shallow lakes where zooplankton are more likely to have the ability to migrate horizontally to avoid predation from fish and other invertebrates. In general, a diverse shoreland habitat (substrate, plant species, and woody debris) will support a diverse zooplankton community.

Composite samples from a two meter water column were collected monthly, preserved with denatured ethanol, placed on ice, and sent to the Northland College for identification and enumeration of zooplankton species. This analysis shows the abundance of the major zooplankton groups: cladocera, copepoda, and rotifer in Long Lake.

"Long lake shows a basic pattern, dominated by rotifers with (slightly) more crustacean plankton, but still lower than would be regionally expected (Lafrançois 2008, EOR 2009). The population explosion of cladocerans in late summer is primarily due to two groups. One, the chydoridae and particularly *Paralona pigra*, generally indicative of the presence of macrophytes and shallower waters. Large numbers of *Bosmina coregoni* are also responsible for this trend, ironically they are often characteristic of clearer open waters, although they can be littoral as well. The concurrent drop in copepod abundance to near zero suggests that release from predation could also be a factor" (Lafroncois, 2013).



Lake Sediments

On September 28th, 2012 a Petite Ponar® Grab Sampler was used to sample the surface sediments at five locations located on a transect/depth gradient. Samples were analyzed by the University of Wisconsin-Madison Soil Testing Laboratories for copper, zinc, sulfur, boron, manganese, iron, aluminum, sodium, organic matter, total nitrogen, phosphorus, potassium, calcium, and magnesium.

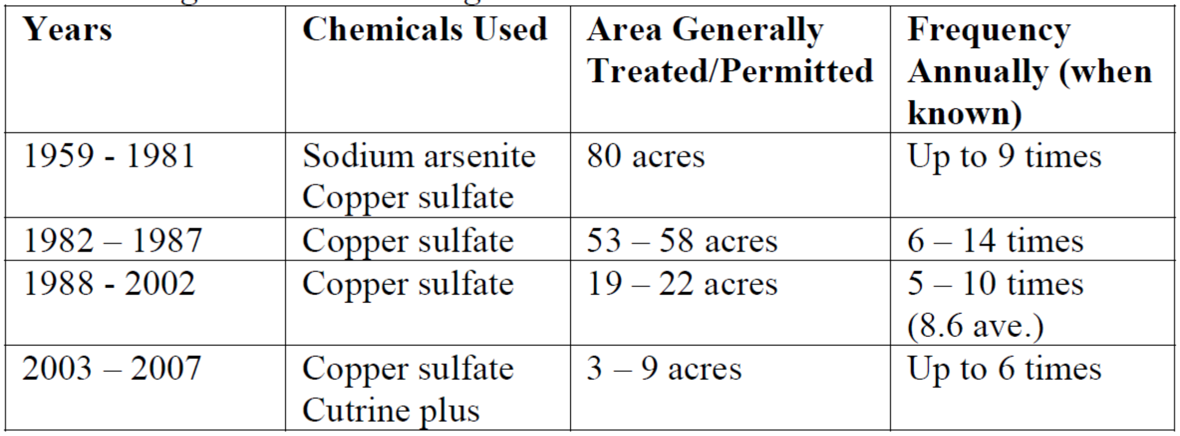
	Copper (mg/kg)	Zinc (mg/kg)	Sulfur (mg/kg)	Boron (mg/kg)	Manganese (mg/kg)	Iron (mg/kg)	Aluminum (mg/kg)	Sodium (mg/kg)
S1	215.54	49.66	5,500	7.22	192.37	14,268.30	13,211.40	213.00
S2	206.33	56.26	4,000	8.07	177.26	17,698.90	17,902.70	202.60
S3	184.10	58.32	3,800	9.34	192.78	19,015.20	16,933.00	235.40
S4	292.02	71.22	4,800	10.75	209.72	19,610.00	19,814.60	269.80
S5	158.89	61.74	4,000	9.66	223.66	18,905.30	17,426.50	286.80

	Organic matter (%)	Total nitrogen (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Calcium (mg/kg)	Magnesium (mg/kg)
S1	19.5	9,900	1,000	1,700	9,900	4,500
S2	18.0	9,700	800	2,200	5,900	4,300
S3	18.8	9,800	1,000	2,100	6,200	4,300
S4	21.7	10,700	1,100	2,500	7,100	5,100
S5	19.9	10,700	900	2,100	7,000	4,700

Lake Sediment Metals Copper and Zinc

Past aquatic plant management is documented in the 2012 Aquatic Plant Management Plan, Long Lake. According to this report the DNR reported that Long Lake has a history as being one of the most chemically treated lakes in the state for aquatic plant management. From 1959 through 1981 chemical treatment for algae in Long Lake included literally tons of sodium arsenate and copper sulfate, with about 80 acres of the lake generally being treated (Harmony Environmental and Endangered Resource Services LLC, 2012). Cutrine plus also contains copper.

Table 8. Algae Treatment along Lake Shoreline



Years	Chemicals Used	Area Generally Treated/Permitted	Frequency Annually (when known)
1959 - 1981	Sodium arsenite Copper sulfate	80 acres	Up to 9 times
1982 – 1987	Copper sulfate	53 – 58 acres	6 – 14 times
1988 - 2002	Copper sulfate	19 – 22 acres	5 – 10 times (8.6 ave.)
2003 – 2007	Copper sulfate Cutrine plus	3 – 9 acres	Up to 6 times

Figure from: (Harmony Environmental and Endangered Resource Services LLC, 2012).

Copper is an essential trace element that tends to accumulate in sediments and can be toxic to aquatic life at elevated concentrations (United States Environmental Protection Agency, June 2008).

A study completed by MacDonald et al. (2000) developed consensus based numerical sediment quality guidelines for metals in freshwater ecosystems. This study provides guidelines for metals in freshwater ecosystems that reflect threshold effect concentrations (TECs, below which harmful effects are unlikely to be observed) and probable effect concentrations (PECs, above which harmful effects are likely to be observed). The consensus based TEC for copper is 31.6 mg/kg and the consensus based PEC for copper is 149 mg/kg.

The sediments of Long Lake exceed the PEC for copper at all five sampling sites. The sediments at site 4, located at the southeast end of the lake, are nearly twice the PEC for copper. The copper concentrations in the sediments of Long Lake are likely causing harmful effects to the ecosystem. Adverse biological effects can include decreased benthic invertebrate diversity, reduced abundance, increased mortality, and behavioral changes.

Although copper sulfate is used in agriculture as a fungicide, the application of tons of copper sulfate to Long Lake for algae treatment since 1959 is likely responsible for the elevated copper concentrations in lake sediments.

Zinc is an additional essential trace element that can be toxic to aquatic life at elevated concentrations. The consensus based TEC for zinc is 121 mg/kg and the consensus based PEC for zinc is 315 mg/kg. The average zinc concentration in the sediments of Long Lake was 59.44 mg/kg. Zinc concentrations ranged from a low of 49.66 mg/kg to a high to 71.22 mg/kg. All sediment samples had zinc concentrations well below the TEC, or the concentration below which harmful effects are unlikely to be observed.

Lake Sediment Nutrients

In shallow lakes there is intense interaction at the water sediment interface. Therefore, understanding sediment water interactions is crucial to understanding the nutrient dynamics of shallow lakes such as Long Lake (Scheffer, 1998). An analysis of the sediments of Long Lake could have many implications for best management actions.

Nitrogen occurs in lakes in many different forms: dissolved nitrogen, ammonia, nitrite, nitrate, and a large number of organic compounds. Sources of nitrogen to lake systems include precipitation, nitrogen fixation in the water and sediment (in eutrophic lakes such as Long Lake this can account for >80% of the nitrogen input), and inputs from the watershed. Losses occur by outflow, reduction of nitrate to nitrogen gas (which escapes to the atmosphere), and permanent sedimentation loss of organic and inorganic nitrogen compounds (Wetzel, 2001).

Ammonia is a common end product of the decomposition of organic matter. In the sediment of healthy lakes, a large portion of ammonia is adsorbed on sediment particles. As a lake becomes anoxic (devoid of oxygen), the ability of sediment to adsorb ammonia is greatly reduced. In this situation (which occurred in 2012 in Long Lake) a large amount of ammonia is released into the water column. Under anoxic conditions in eutrophic lakes nitrate is also reduced to nitrite.

Rooted aquatic plants can absorb large amounts of nitrogen from the sediments by incorporating it into their roots and foliage. In some cases, plants can absorb so much nitrogen that water column nitrate levels fall below detectable limits (Wetzel, 2001). This illustrates the importance of a healthy aquatic plant community. Healthy aquatic plant communities can be a primary storage site for nitrogen and their senescing tissues become a very important component of nutrient burial and assimilation into the sediment. The total nitrogen content of the sediment samples was analyzed on Long Lake, so the different nitrogen species are unknown.

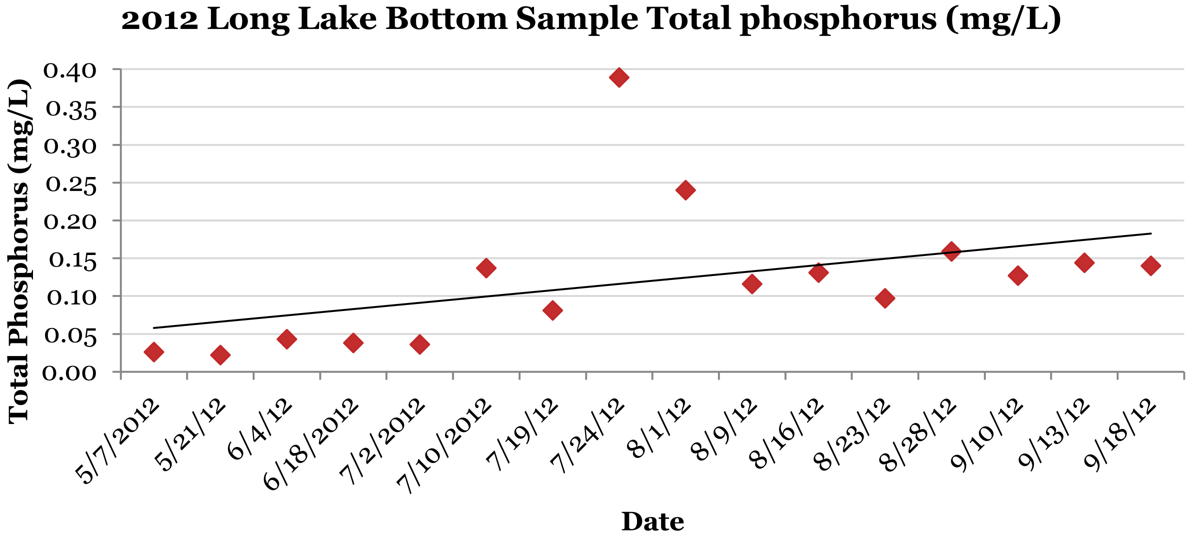
In contrast to nitrogen, which has many forms in lakes, the most significant form of inorganic phosphorus is orthophosphate. Much emphasis has been placed on the evaluation of the nutrient phosphorus because of its fundamental importance in lakes systems. The types of phosphorus commonly evaluated are soluble reactive phosphorus, soluble unreactive phosphorus, particulate reactive phosphorus, and particulate unreactive phosphorus (Wetzel, 2001). Often analysis is done for total phosphorus.

A substantial source of available phosphorus in shallow lakes, such as Long Lake, is the sediment. Release of phosphorus from the sediment into the water column depends on the composition of the sediment and the concentration of the phosphorus in the water column. Phosphorus release can vary strongly depending on the conditions at the sediment water interface (Scheffer, 1998) (Kaiserli, A., Voutsa, D., and Samara, C., 2002) (Gonsiorczyk, T., Casper, P., and Koschel, R., 1998).

Phosphorus in the sediments of lakes is often precipitated with clays, aluminum, and iron compounds. Work on Wisconsin lake sediments and the Great Lakes sediments indicate that phosphorus in the sediments is predominately apatites (phosphate minerals), organic phosphorus, and orthophosphate bonded to iron compounds. However, as the oxygen content near the sediment declines there is a release of phosphorus, iron, and manganese to the water column (Wetzel, 2001).

The concentration of phosphorus in the water column tends to correlate well with the ratio between phosphorus and iron concentrations (P:Fe) in the sediment. It has been found that where the P:Fe ratio is less than two, phosphorus is more readily released from the sediment into the water column (Rene Gachter and Beat Muller, 2003). The P:Fe ratio on Long Lake is approximately 0.05, indicating a strong release of phosphorus from the sediments. The mobilization of recently deposited phosphorus seems to be the driving force behind phosphorus release from the sediments (i.e. internal loading) in eutrophic lakes such as Long Lake (Gonsiorczyk, T., Casper, P., and Koschel, R., 1998). However there is a limited amount of knowledge of the mechanisms behind internal loading in shallow lakes (Sondergaard, M., Jensen, J.P., Jeppesen, E., 2001).

In 2012, water samples analyzed from near the water-sediment interface on Long Lake show an increase in phosphorus over the open water season, indicating a release of phosphorus from the sediments.



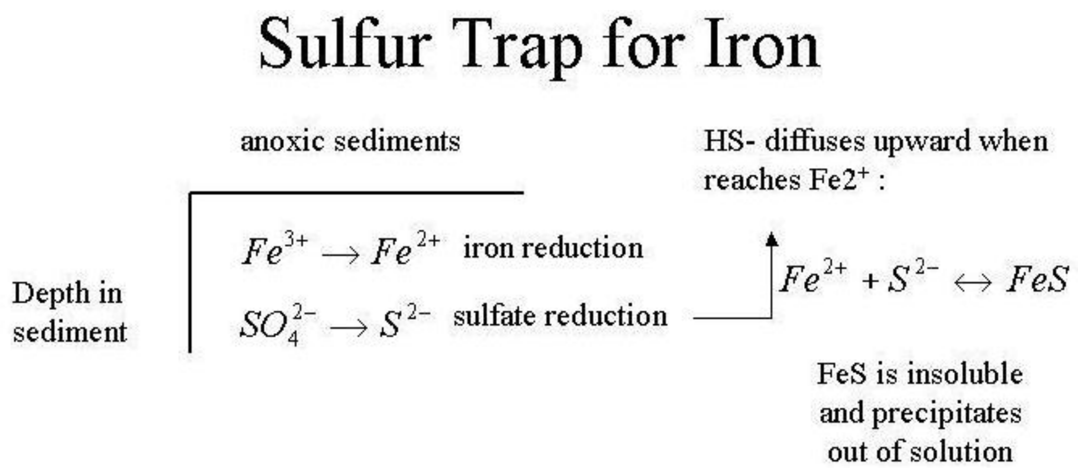
Internal phosphorus loading may delay the recovery of a lake once external phosphorus loading sources are reduced. Therefore, it is important that the fraction of available phosphorus (iron and manganese bound) is evaluated as a means to predict internal phosphorus loading. The major factors controlling sediment phosphorus release are dissolved oxygen, nitrates, sulfates, and pH (Kaiserli, A., Voutsa, D., and Samara, C., 2002). The University of Wisconsin Soil and Plant Analysis Lab uses the Bray-Kurtz method which analyzes plant available phosphorus (i.e. bound to Fe). This fraction is considered to be the potentially mobile pool of phosphorus available to algae and does not include phosphorus bound to other molecules such as organic matter. Therefore, the sediment phosphorus concentrations may be undervalued and there is potential for an ever greater release of phosphorus from the sediment of Long Lake.

Concentrations of nutrient binding elements, such as iron, depend greatly on the redox potential of the sediment. A redox reaction is the flow of electrons between an oxidized and reduced state (for example iron moving from Fe^{3+} to Fe^{2+} and vice versa). The state of these elements is very important for the ability to bind to nutrients, particularly phosphorus.

There are many similarities in the behavior of iron and manganese, so they can be discussed together, although much more is known about the cycling of iron in aquatic ecosystems. A very strong interaction between iron and sulfur also exists. The fluxes of iron and manganese reflect the variations in physical chemistry at the sediment water interface (Wetzel, 2001).

Iron is a very important micronutrient in aquatic systems. It is essential for aquatic organisms in many ways including: electron transport in oxidation-reduction systems of photosynthesis and respiration, enzyme activation, and as an oxygen carrier in nitrogen fixation.

Iron exists in solution in two different forms; either ferrous (Fe^{2+}) or ferric (Fe^{3+}). The amounts of iron in solution in lakes and the rate of oxidation of Fe^{2+} to Fe^{3+} in oxygenated water are dependent on pH, reduction potential, and temperature. Ferrous iron tends to be more soluble than ferric. In productive lakes (such as Long Lake), under anaerobic conditions with low redox potential, bacteria often reduce sulfate to sulfide. This reaction decreases the concentration of Fe^{2+} through the formation of insoluble FeS. The resulting reduction in abundance of iron compounds that can complex to phosphorus can promote the release of phosphorus from the sediment (Wetzel, 2001). If enough FeS precipitates and enough Fe is removed from the system, the result is iron poor water which makes phosphorus more available for algae uptake. This is sometimes called the Sulfur Trap for Iron.



Iron bonds (complexes) with many organic compounds (e.g. detritus), which greatly alters its solubility and availability to organisms. Under anoxic conditions in the surface sediment and overlying water these complexes are reduced and phosphorus is released, with the release rate from sediments doubling if the sediments are disturbed (i.e. through activities such as power boating) (Wetzel, 2001). Aquatic plants become especially important in productive waters such as Long Lake. Oxygen loss from the roots oxidize iron, and iron deposition can result in appreciable retention of iron and consequently phosphorus in the vegetated sediments (Sondergaard, M., Jensen, J.P., Jeppesen, E., 2001) (Wetzel, 2001).

Manganese is responsible for many cellular activities in organisms (i.e. electron transport reactions) and enzyme activation. Manganese (Mn) occurs in several states. Mn^{3+} is unstable under normal conditions in water and Mn^{4+} is insoluble at most pH values that would be found in natural lakes. As with ferrous iron, Mn^{2+} exists at low redox potentials and pH. Manganese also reacts relatively rapidly with other anions and precipitates to the sediment. Unlike iron, whose concentrations can be controlled by precipitation of FeS, manganese is usually under-saturated so MnS (manganous sulfide) is usually not precipitated. Even so, MnS is much more soluble and formation of MnS has little effect on the Mn^{2+} concentrations (Wetzel, 2001).

Sulfur is utilized by all living organisms in both inorganic and organic forms. Sources of sulfur compounds to natural waters include solubilization from rock, fertilizers, precipitation and dry deposition. Most (about 90%) of the total sulfur content in lakes is found in the organic matter of mineral soil. Therefore, much of the loading of sulfur compounds to lakes is in the form of sulfate and soluble organic sulfur compounds (Wetzel, 2001).

The cycling of sulfur entails the different sulfur chemical species under various conditions, the biotic influences, and sulfur transport within the lake. The predominant form of sulfur in water is sulfate; nearly all assimilation of sulfur is as sulfate.

Sulfur that reacts with metals to form metal sulfides are extremely insoluble, so when Fe^{+2} is released from the sediment, it reacts vigorously with S to form FeS. Since FeS is so insoluble, iron is not available to bind with phosphorus under these conditions (Wetzel, 2001).

All data collection and modeling indicates that the internal loading component of the nutrient budget for Long Lake is very significant. The senescence (dying back) of *Potamogeton crispus* (curly leaf pondweed) may contribute slightly to the internal load, but likely the main release mechanism is the release of phosphorus bound to iron due to changes in redox potential at the sediment water interface and sediment resuspension. Sediment amendments such as Alum would likely not be very effective because the sediment is organically rich and there are major shifts in pH and redox potential at the sediment water interface. Therefore ALP would not stay bonded very well and phosphorus would be released.

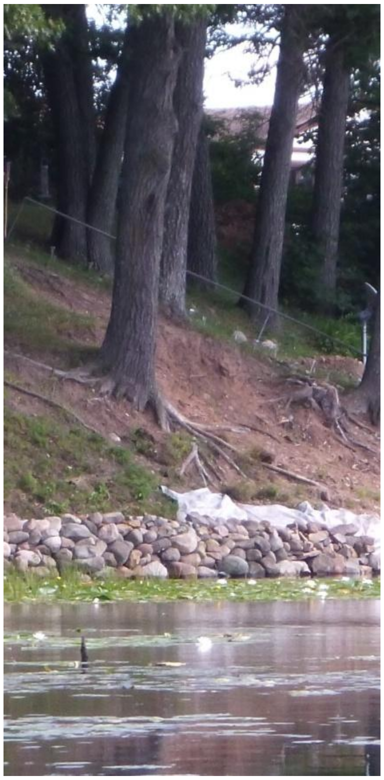
Establishment of a robust, rooted aquatic macrophyte community could reduce the internal load if the macrophyte community extended deep enough. Radial oxygen loss from plant root tissues can maintain iron-bound phosphorus in the surrounding sediment. The epiphytic and epipelic algae associated with macrophyte stands utilize phosphorus from the water column, released from the sediment, and excreted by the macrophytes themselves. In addition, plants and algae that can use bicarbonate as a carbon source for photosynthesis can create free calcium ions that can co-precipitate phosphorus with calcite. This can be an important self-cleaning mechanism in eutrophic lakes and can lead to the permanent burial of phosphorus within the sediments (Gonsiorczyk, T., Casper, P., and Koschel, R., 1998).

Because of the importance of the sediment phosphorus pool in Long Lake, further study of sediment release is warranted. *In situ* sediment release rates should be measured with benthic flux chambers over a series of years in several locations to accurately calculate actual phosphorus release from the sediment. In addition, sediment cores should be collected and species of phosphorus should be fractioned using sequential extractions (Engstrom, D.R., and Wright, H.E., 1984), and water column phosphorus should be reconstructed along with aquatic macrophyte community reconstruction.

Land Use and Water Quality

Information summarized from: (Carrol L. Henderson, Carolyn J. Dindorf, and Fred J. Rozumalski) and (Lynn Markham and Ross Dudzik, 2012).

The health of our water resources depends largely on the decisions that landowners make on their properties. When waterfront lots are developed, a shift from native plants and trees to impervious surfaces and lawn often occurs. Impervious surfaces are defined as hard, man-made surfaces that make it impossible for rain to infiltrate into the ground. Examples of impervious surfaces include rooftops, paved driveways, and concrete patios.



By making it impossible for rainwater to infiltrate into the soil, impervious surfaces increase the amount of rainwater that washes over the soil surface and feeds directly into lakes and streams. This rainwater runoff can carry pollutants such as sediment, lawn fertilizers, and car oils directly into a lake. Native vegetation can slow the speed of rainwater, giving it time to soak into the soil where it is filtered by soil microbes. Median surface runoff estimates from wooded areas are an order of magnitude less than those from lawn areas.

In extreme precipitation events erosion and gullies can result, causing loss of property as soil is carried to the lake. The signs of erosion are unattractive and can cause decreases in property values. Additionally, sediment can have negative impacts on aquatic life. For example, fish eggs will die when covered with sediment, and sediment influxes to a lake can cause decreases in water clarity making it difficult for predator fish species to locate food.

Increases in impervious surfaces can also cause other negative impacts to fisheries. A study of 164 Wisconsin lakes conducted in 2008 found that the amount of impervious surfaces surrounding lakes can cause shifts in fisheries species assemblages. Certain species such as smallmouth and rock bass, blackchin and blacknose shiners, and mottled sculpin become less common with increasing amounts of impervious surfaces. Many of the smaller species affected are an essential food source for common game fish species such as walleye, northern pike, and smallmouth bass.

Increases in impervious surfaces and lawns also cause a loss of habitat for birds and other wildlife. Over ninety percent of all lake life is born, raised, and fed in the area where land and water meet. Overdeveloped shorelines remove critical habitat which species such as loons, frogs, songbirds, ducks, otters, and mink depend on. Impervious surfaces and lawns can be thought of as biological desserts which lack food and shelter for birds and wildlife. Additionally, nuisance species such as Canada geese favor lawns over taller native grasses and flowers. Lawns provide geese with a ready food source (grass) and a sense of security from predators (open views).

Additionally, fish species depend on the area where land and water meet for spawning. The removal of coarse woody habitat, or trees and braches that fall into a lake, causes decreases in fisheries habitat.

Lawns in and of themselves are not particularly harmful and can provide an area for families to recreate. However, problems arise when lawns are not property maintained, over-fertilized, located in areas important to wildlife habitat, or located on steep slopes.

Common lawn species, such as Kentucky bluegrass, are often dependent on chemical fertilizers and require mowing. Excess chemical fertilizers are washed directly into the adjacent water during precipitation events. The phosphorus and other nutrients in fertilizers, which produce lush vegetative growth on land, are the same nutrients which fuel algae blooms and decrease water clarity in a lake. Additionally, since common lawn species have very shallow root systems, when lawns are located on steep slopes, the impacts of erosion can be intensified.

Avoiding establishing lawns on steep slopes and at the water land-interface can provide direct positive impacts on lake water quality. The creation of a buffer zone of native grasses, wildflowers, shrubs, and trees where the land meets the water can provide numerous benefits for water quality and restore valuable bird and wildlife habitat.

In Polk County, all new constructions on lakeshore properties require that a shoreland protection area (undisturbed area) be in place. A shoreland protection area is required to be 35 feet in depth as measured from the ordinary high water mark, which is defined as the point on the bank or shore up to which the water leaves a distinct mark (erosion, change in vegetation, etc.).

These rules are in place largely to protect water quality and also provide benefits in terms of natural beauty, and bird and wildlife viewing opportunities. Additionally, shoreline protection areas allow for a 30 foot maximum viewing corridor (or 30% of the width of the lot, whichever is less), which can be established as lawn (Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property, October 2002) and (Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

Shoreline Inventory

On Tuesday, September 18th four resident volunteers were trained by Polk County Land and Water Resources Department staff to conduct a shoreline inventory for Long Lake. The shoreline inventory followed the protocol first developed for Bone Lake by Harmony Environmental (Harmony Environmental, Polk County Land and Water Resources Department, and Ecological Integrity Services, 2009).

Volunteers were provided with maps for Long Lake and sheets for data collection. Parcel shoreline feet were estimated in the field because Long Lake, unlike the majority of Polk County, is not parcel mapped.

Land use for each parcel was categorized for the shoreline (linear feet at the ordinary high water mark) and for the shoreline buffer area (area upland thirty-five feet from the ordinary high water mark). Additionally, the presence or absence of coarse woody habitat was determined at each parcel.

The shoreline (linear feet) was categorized as:

- ✓ Rip rap
- ✓ Structure
- ✓ Lawn
- ✓ Sand
- ✓ Natural

The shoreline buffer area (square feet) was categorized as:

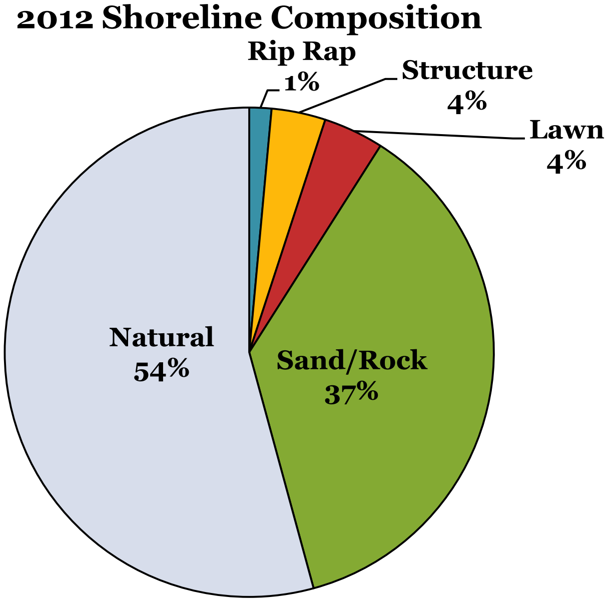
- ✓ Hard surface
- ✓ Landscaping
- ✓ Lawn
- ✓ Bare soil
- ✓ Natural

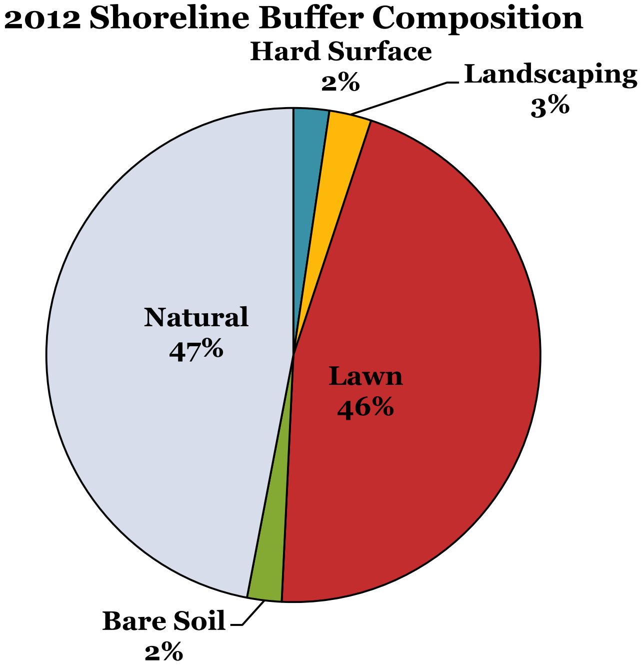
It should be noted that at the time of the shoreline inventory lake levels were close to a foot below the average ordinary high water mark. With decreased water levels, parcel owners may refrain from mowing areas that would otherwise be categorized as lawn because newly exposed soil may be too saturated to support people and/or equipment.

Volunteers categorized a total of 3.7 linear miles of shoreline and 0.025 square miles of buffer area beginning on September 18th through September 25th.

A characterization of Long Lake shoreline composition shows that the greatest land use is natural (55%), followed by sand/rock (37%), lawn (4%), structure (4%), and riprap (1%). A characterization of Long Lake shoreline buffer composition shows that the greatest land use is natural (47%), followed by lawn (46%), landscaping (3%), bare soil (2%), and hard surface (2%).

Out of a total of one hundred sixty-five sites, only two had coarse woody habitat present.





Lakefront Property Models

The Virginia Runoff Reduction Method Worksheet was used to model runoff results for eight lots on Long Lake. At each lot the percent impervious surface, turf grass, and native vegetation was calculated.

An average lot on Long Lake was 20.9% native vegetation, 64.5% turf grass, and 14.5% impervious surface. The model predicted the average phosphorus runoff per lot was 0.225 pounds of total phosphorus per year and 1.824 pounds of total nitrogen.

The ring of residential development along the shoreline of Long Lake totals 137.9 acres in size. Average values from the eight lots were extrapolated to the entire residential development area to determine total nutrient load from the residential lots directly adjacent to Long Lake.

The lots directly adjacent to Long Lake contribute an estimated 58.53 pounds of total phosphorus per year and 418.73 pounds of total annual nitrogen per year.

Soil Sampling

Long Lake is positioned in pitted glacial outwash material (100-150 feet thick) layered over sandstone bedrock. The soils surrounding Long Lake are composed mostly of clay, sand, and organic matter and are considered fertile (Wisconsin Department of Natural Resources Office of Inland Lake Renewal, 1981).

Volunteers collected soil samples from twenty lakefront properties using the methodology detailed by the University of Wisconsin Extension (J.B. Peters, K.A. Kelling, and L.G. Bundy, 2002). Samples were analyzed by the University of Wisconsin-Madison Soil Testing Laboratories for total nitrogen, phosphorus, potassium, calcium, magnesium, organic matter, and pH.

The Soil Testing Laboratory maintains soil test summary data from 1995-2009 by County (University of Wisconsin-Madison Soil Testing Laboratories).[9] Although this data represents soil samples submitted for routine farm soil analysis it can still be used as a reference point when exploring the soil testing data from Long Lake home lawn samples.

	Long Lake Low	**Long Lake High**	**Long Lake Average**	**Polk average 1995-2009[10]**
pH	5.3	6.6	6	6.4
Organic matter %	1.2	4	3	2.6
Phosphorus (ppm)	19	89	46	43
Potassium (ppm)	44	127	80	125
Calcium (ppm)	680	1660	1220	1936
Magnesium (ppm)	100	270	188	300
Total nitrogen (ppm)	778	2415	1644	---

The University of Wisconsin provides recommendations for fertilizer application of phosphorus for established lawns based on soil tests. According to these recommendations zero pounds of phosphorus should be applied to lawns where soil tests indicate phosphorus levels of over 25 ppm.

The majority of lawns sampled on Long Lake (90%) tested over 25 ppm for phosphorus, indicating that phosphorus fertilizer should not be applied to the majority of soils on Long Lake. Two soils (10%) tested between 11 and 25 ppm. Recommendations would allow 0.5 pounds of phosphate per 1000 square feet to be applied to these soils

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[9] The number of soil samples submitted varies in any one year and the frequency of sampling and the number of samples submitted for any given site may vary over time. http://uwlab.soils.wisc.edu/soilsummary/

[10] (University of Wisconsin-Madison Soil Testing Laboratories)

(Minnesota Department of Agriculture, Minnesota Office of Environmental Assistance, Minnesota Pollution Control Agency, and University of Minnesota Extension Service, August 2004).

When fertilizers are applied to lawns there is no guarantee that they will stay there. If nutrient levels in fertilizers exceed the needs of plants, fertilizer nutrients will remain available on the landscape. Many times the nutrients in fertilizers are carried into lakes and rivers with melting snow and rain water. The same nutrients in fertilizers that are used to promote lush lawn growth can fuel plant and algae growth in lakes.

The main nutrient that drives excessive plant and algae growth in lakes is phosphorus. When purchasing fertilizers be aware of the nutrient content. The three common macronutrients in fertilizers are nitrogen, phosphorus, and potassium. The amount of each nutrient will be represented on bags of fertilizer as a set of three numbers. The first represents the amount of nitrogen, the second the amount of phosphorus, and the third the amount of potassium. When buying fertilizers, choose those where the second number is zero (for example: 8-0-8).

According to the Polk County Shoreland Protection Zoning Ordinance the use of phosphate fertilizers within shoreland areas is prohibited. The shoreland area is defined as the lands within one thousand feet of the ordinary high water mark [11] of any navigable lake, pond, or flowage and those lands within three hundred feet of the ordinary high water mark of any navigable river or stream, or to the landward side of the flood plain, whichever is greater (Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

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[11] The ordinary high water mark is defined as the point on the bank or shore up to which the presence and action of surface water is so continuous as to leave a distinctive mark such as by erosion, destruction or prevention of terrestrial vegetation, predominance of aquatic vegetation, or other easily recognized characteristics (Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

Tributaries

Grab samples were collected by a resident volunteer after rainfall events on the north and south ditches which divert water to Long Lake. These samples were analyzed at the State Lab of Hygiene for two types of phosphorus (total phosphorus and soluble reactive phosphorus) and three types of nitrogen (nitrate/nitrite, ammonium, and total Kjeldahl nitrogen).

The phosphorus data collected is specific to date and location and can be used to theoretically determine how much phosphorus is entering the lake. Values for phosphorus influxes are established by multiplying the phosphorus concentration at a specific location by the volume of water that moves through a specific location, or the discharge in cubic feet per second. To determine the average instantaneous load of phosphorus (in mg/s), the average phosphorus concentration is multiplied by the average season discharge. Units are then converted and expressed as lb/yr.

In this study it was impossible to measure the volume of water that moved through each ditch because flow was not constant and only occurred during and after significant rainfall events. As a result, a series of models were used to determine the volume of runoff moving through each ditch. WinTR-55 was used to determine the peak flow rate, or amount of runoff that is expected from the north ditch subwatershed and south ditch subwatershed. Peak flow rates were then translated into P8 to determine an annual volume and quantity of runoff.

On an annual basis the north ditch is contributing 83 pounds of phosphorus to Long Lake and the south ditch is contributing 22 pounds of phosphorus to Long Lake.

Land Use and Nutrient Loading in the Long Lake Watershed

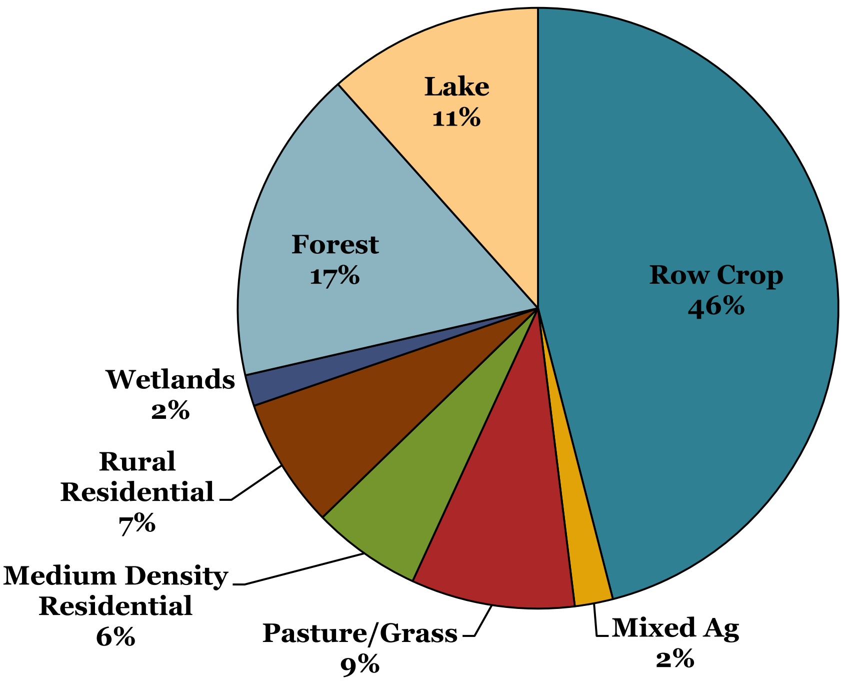
The area of land that drains towards a lake is called a watershed. The watershed area of Long Lake, including the lake, is approximately 2,343 acres. The lake itself is 272 acres and represents 6% of the total land use in the Long Lake Watershed.

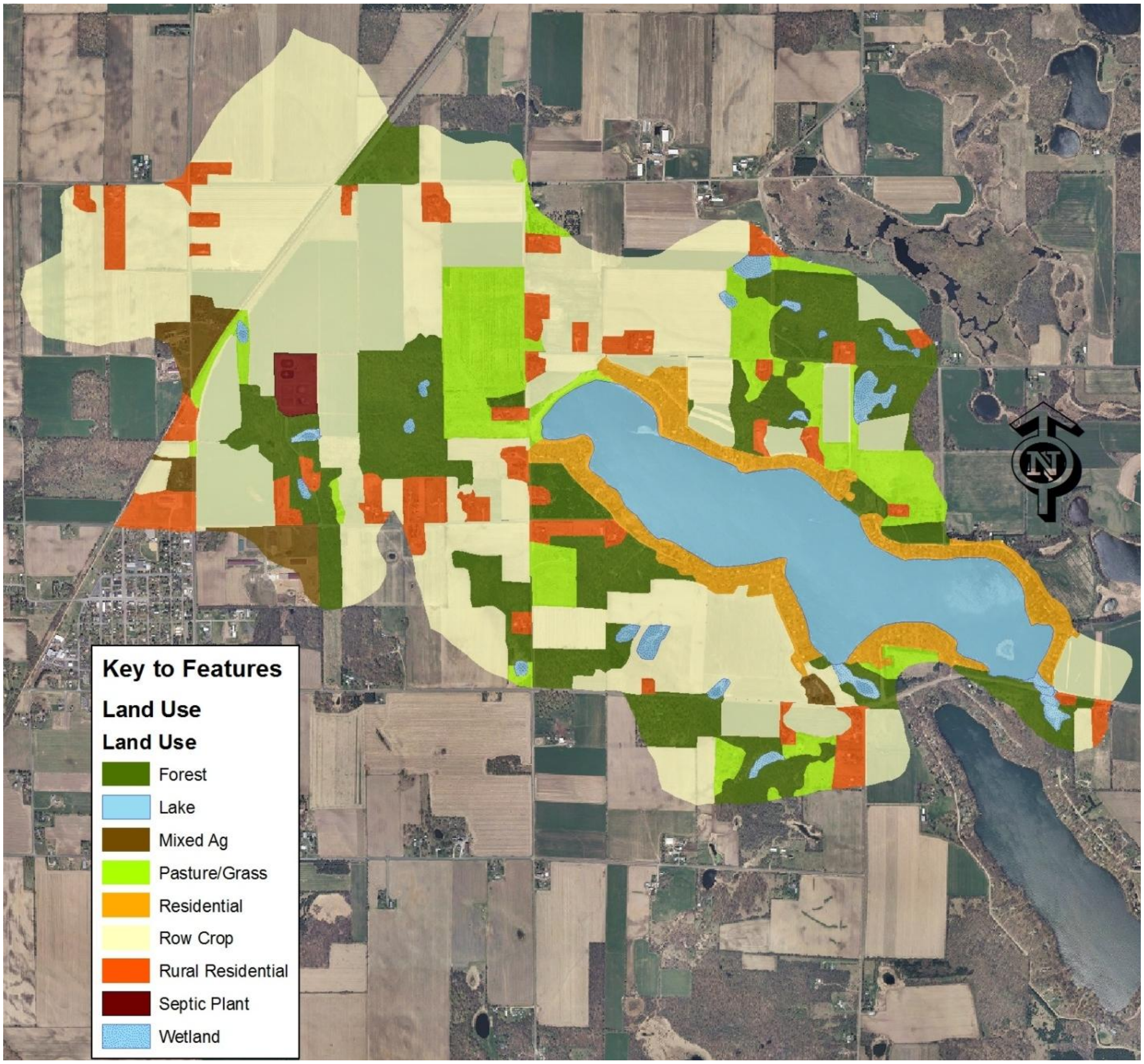
The largest land uses in the Long Lake Watershed are row crop (46%) followed by forest (17%). The remaining land use is pasture/grass (9%), rural residential (more than 1 acre/person, 7%), medium density residential (1/4 acre/person, 6%), mixed agriculture (2%), and wetlands (2%).

The majority of the shoreline of Long Lake is medium density residential.

Land Use	Acres	Percent Acreage
Row crop	1077.6	45.99%
Mixed agriculture	48.2	2.06%
Pasture/Grass	206.6	8.82%
Medium density residential	137.9	5.88%
Rural residential	163.9	6.99%
Wetlands	39.3	1.68%
Forest	397.8	16.98%
Long lake	272.0	11.61%

Land Use in the Long Lake Watershed



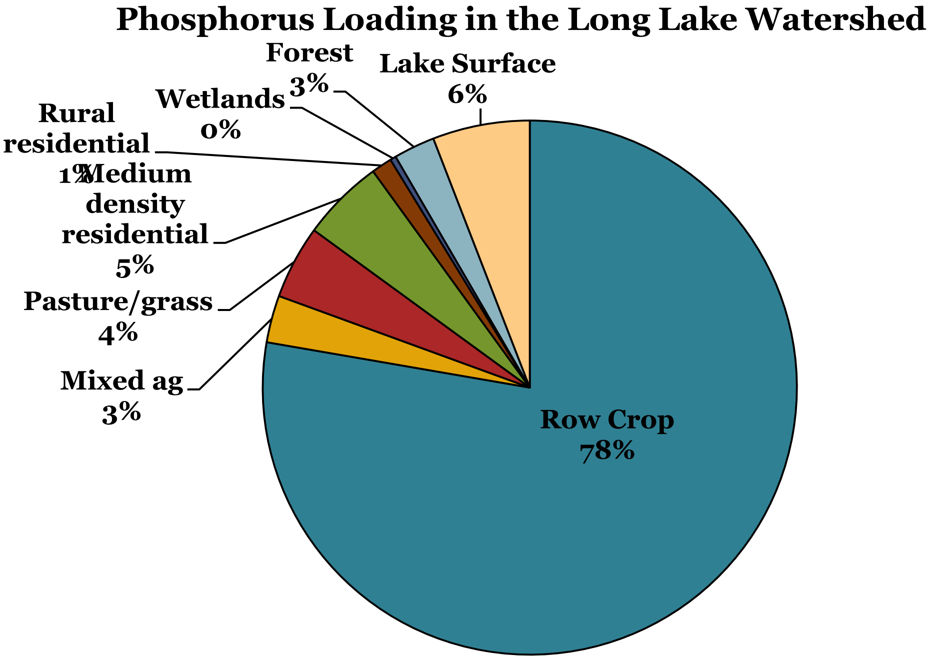

Key to Features
Land Use
Land Use
Forest
Lake
Mixed Ag
Pasture/Grass
Residential
Row Crop
Rural Residential
Septic Plant
Wetland
N

The Wisconsin Lakes Modeling Suite (WiLMS) was used to model current conditions for Long Lake, verify monitoring, and estimate land use nutrient loading for the watershed. Phosphorus is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes.

According to WiLMS, row crop—making up nearly half of the total land use in the watershed—contributes over three quarters (78%) of the phosphorus loading to Long Lake.

The lake itself contributes 6% of the total loading, medium density residential contributes 5%, pasture/grass contribute 4%, mixed agriculture and forest each contribute 3%, rural residential contributes 1%, and wetlands contribute less than 1%.

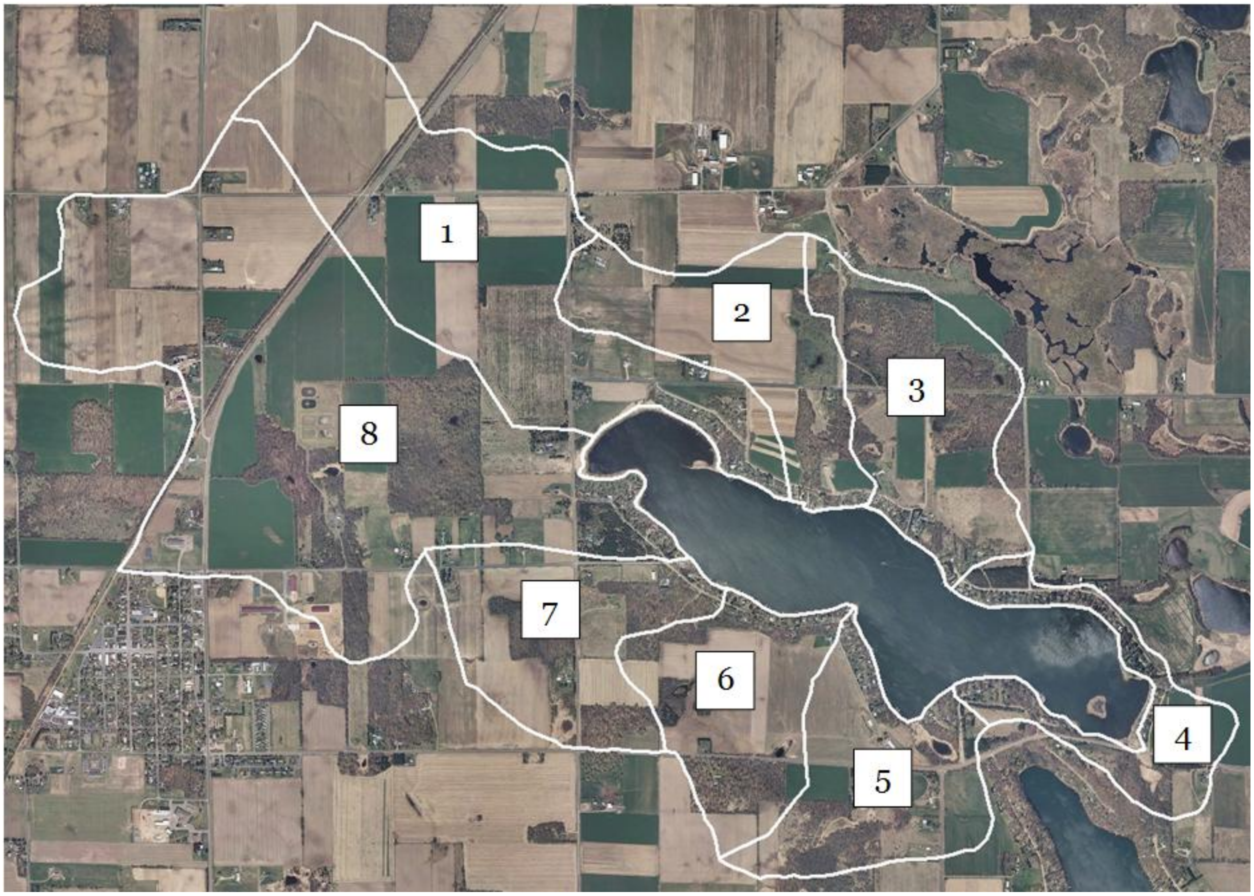
Land Use	**Total acres**	**Percent acres**	**Loading (lb/yr)**	**Percent Loading**
Row Crop	1077.6	45.99%	961.21	77.72%
Mixed agriculture	48.2	2.06%	35.27	2.85%
Pasture/grass	206.6	8.82%	55.12	4.46%
Medium density residential	137.9	5.88%	61.73	4.99%
Rural residential	163.9	6.99%	15.43	1.25%
Wetlands	39.3	1.68%	4.41	0.36%
Forest	397.8	16.98%	30.86	2.50%
Lake Surface	272.0	11.61%	72.75	5.88%



WiLMS estimated annual phosphorus loading from medium density residential as 61.73 pounds. This estimate is comparable with the annual phosphorus loading from the Lakefront Property Model (58.53 pounds).

Land Use and Nutrient Loading in the Long Lake Subwatersheds

Eight subwatersheds for Long Lake were delineated using USGS topographic maps.



WiLMS was used to model current conditions for Long Lake, verify monitoring, and estimate land use nutrient loading for each of the eight subwatersheds. Phosphorus is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes.

This data can be used to determine which subwatersheds are contributing the greatest amount of phosphorus to Long Lake and which best management practices will have the greatest impact for improving water quality for Long Lake.

The total phosphorus load (pounds/year) was calculated for each subwatershed. Overall, subwatershed eight is contributing the greatest amount of phosphorus to Long Lake (421 pounds), followed by subwatershed one (267 pounds).

In an effort to take into account the differing size of the subwatersheds, the total phosphorus load per acre was calculated.

On a per acre basis, subwatershed one contributes the greatest amount of phosphorus loading to Long Lake (0.68 lb P/acre/year), followed by subwatershed two (0.66 lb P /acre/year), subwatershed eight (0.60 lb P /acre/year), and subwatershed six (0.57 lb P /acre/year). Subwatershed five and seven both contribute 0.51 lb P /acre/year. The subwatersheds contributing the least amount of phosphorus to Long Lake on a per acre basis are three (0.29 lb P /acre/year) and four (0.42 lb P /acre/year).

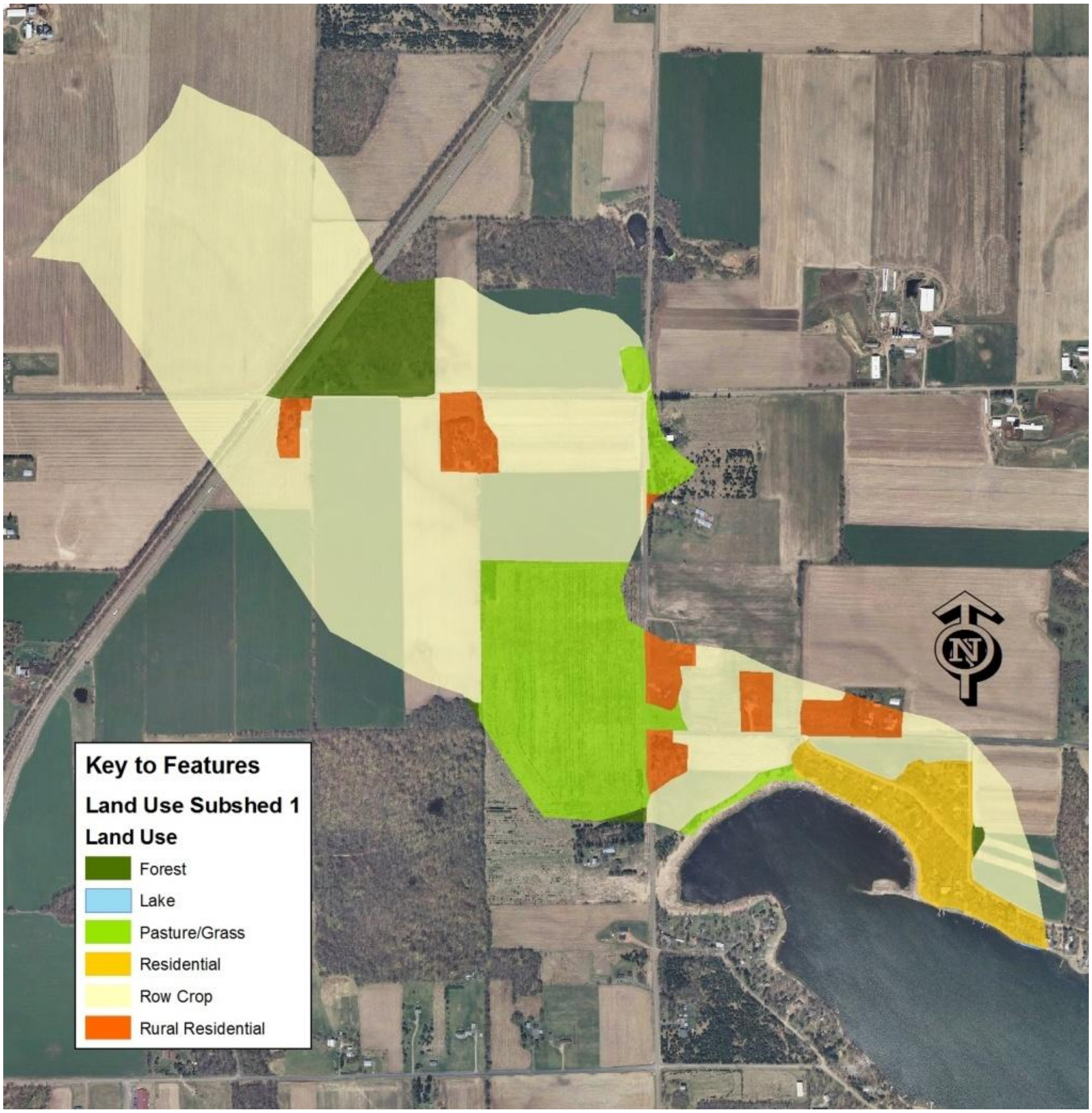
The north and south ditches that drain to Long Lake are located in subwatersheds two and seven, respectively. The total phosphorus data collected in-field estimates that the north ditch is contributing 83 pounds of phosphorus per year and the south ditch is contributing 22 pounds of phosphorus per year. Since these values were determined using field collected tributary phosphorus monitoring data, these values are likely more accurate than the WiLMS model output values (115 pounds south ditch; 112 north ditch).

Subwatershed	Acres	Total loading (lb/yr)	Total load (lb/acre/yr)
1	391.15	266.76	0.68
2 *(north ditch)*	171.26	112.43	0.66
3	196.00	57.32	0.29
4	104.46	44.09	0.42
5	164.55	83.77	0.51
6	155.10	88.18	0.57
7 *(south ditch)*	223.36	114.64	0.51
8	697.76	421.08	0.60

Subwatershed 1 is the second largest subwatershed for Long Lake (391 acres).

Row crop makes up the largest land use in the subwatershed (67%) and contributes the majority of the phosphorus load (88%).

Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	263.93	67.48%	235.89	88.43%
Pasture/grass	61.08	15.62%	15.43	5.79%
Medium density residential	22.48	5.75%	11.02	4.13%
Rural residential	22.17	5.67%	2.20	0.83%
Forest	21.50	5.50%	2.20	0.83%

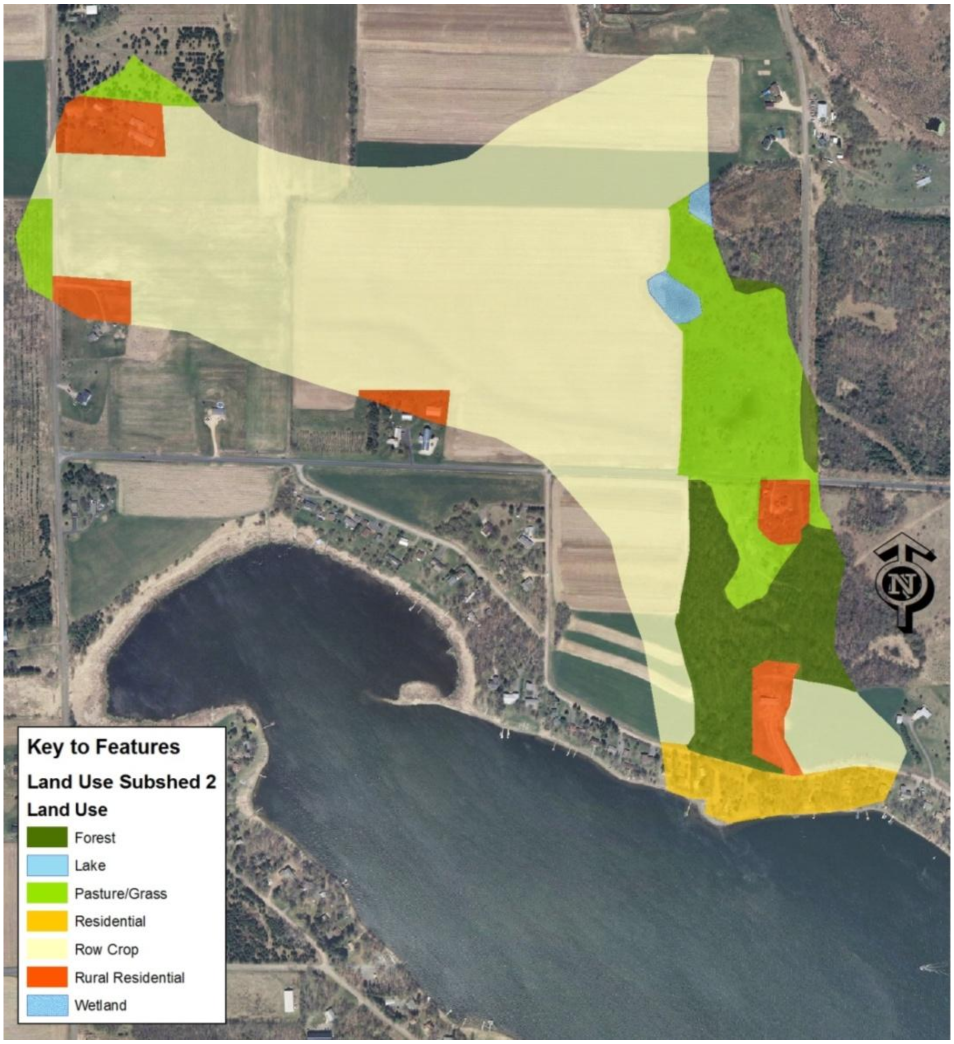


Subwatershed 2 is 171 acres in size.

Row crop makes up the largest land use in the subwatershed (67%) and contributes the majority of the phosphorus load (90%).

In this subwatershed forest makes up nearly 17% of the land use but contribute less than 2% of the phosphorus load to Long Lake.

Land Use	**Total acres**	**Percent acres**	**Loading (lb/yr)**	**Percent Loading**
Row Crop	114.18	66.67%	101.41	90.20%
Pasture/grass	22.13	12.92%	6.61	5.88%
Medium density residential	6.25	3.65%	2.20	1.96%
Rural residential	10.57	6.17%	0.00	0.00%
Wetlands	1.46	0.85%	0.00	0.00%
Forest	16.68	9.74%	2.20	1.96%



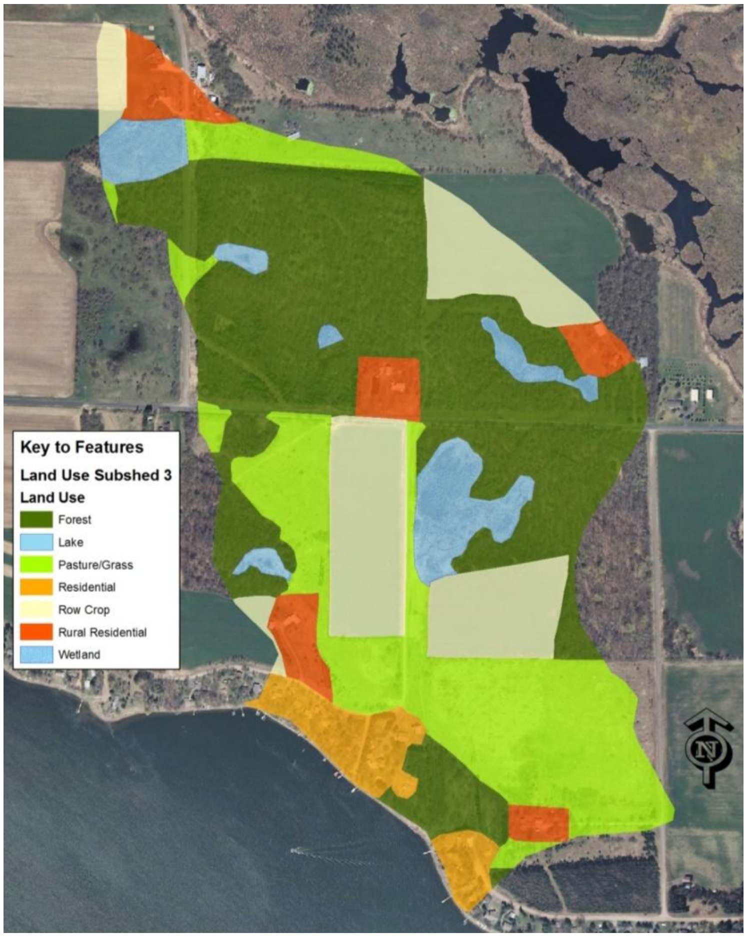
Subwatershed 3 is 196 acres in size.

Forest makes up the largest land use in the subwatershed (41%) but contributes only 12% of the phosphorus load to Long Lake.

Row crop makes up only 16% of the land use in the subwatershed but contributes 50% of the phosphorus load to Long Lake.

Pasture and grass contribute a quarter (23%) of the subwatershed phosphorus load.

Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	32.25	16.45%	28.66	50.00%
Pasture/grass	45.80	23.37%	13.23	23.08%
Medium density residential	9.63	4.91%	4.41	7.69%
Rural residential	13.19	6.73%	2.20	3.85%
Wetlands	13.95	7.12%	2.20	3.85%
Forest	81.17	41.41%	6.61	11.54%

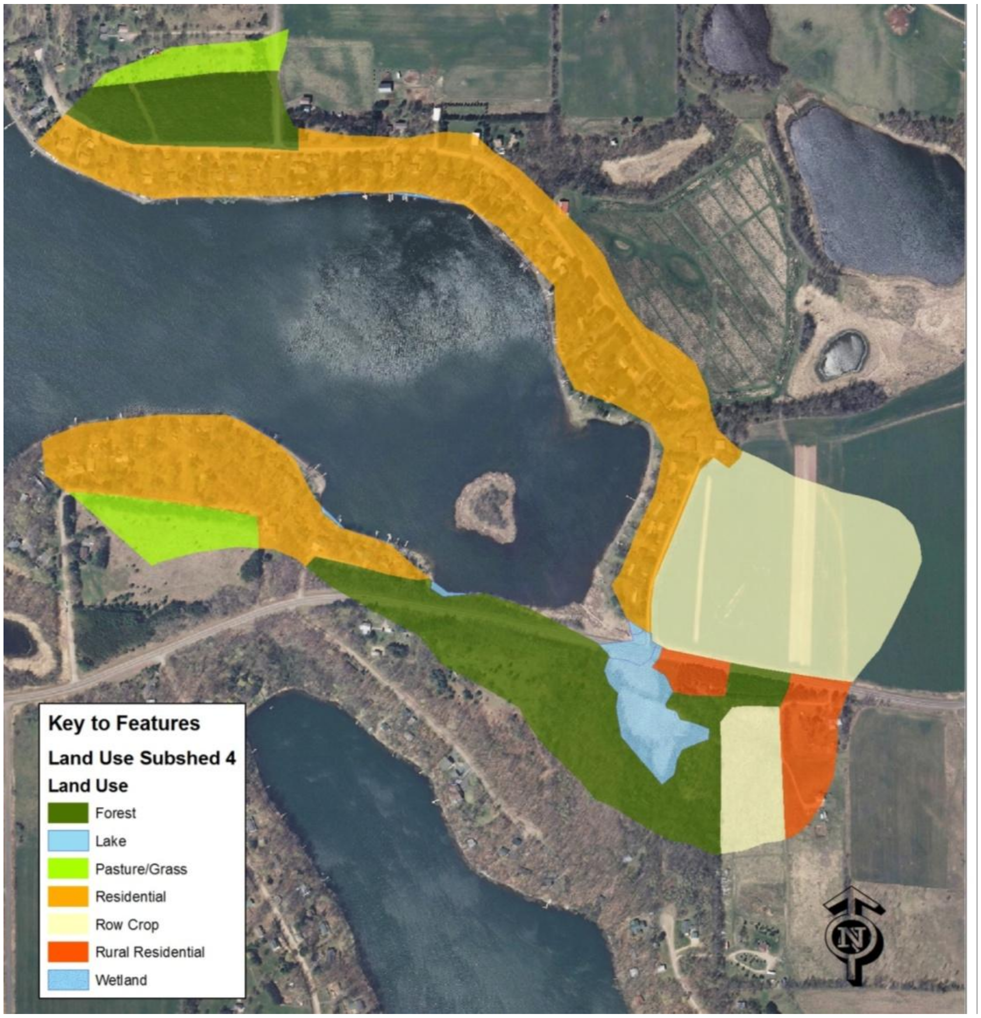


Subwatershed 4 is the smallest subwatershed for Long Lake (104 acres).

Medium density residential makes up the largest land use in the subwatershed (37%) and contributes 40% of the phosphorus load to Long Lake.

Row crop and forest both make up a quarter (24%) of the land use. However, row crop contributes 50% of the phosphorus load to Long Lake; whereas forest contributes only 5% of the load.

Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	25.56	24.47%	22.05	50.00%
Pasture/grass	6.09	5.83%	2.20	5.00%
Medium density residential	39.06	37.39%	17.64	40.00%
Rural residential	4.99	4.78%	0.00	0.00%
Wetlands	3.79	3.63%	0.00	0.00%
Forest	24.97	23.91%	2.20	5.00%

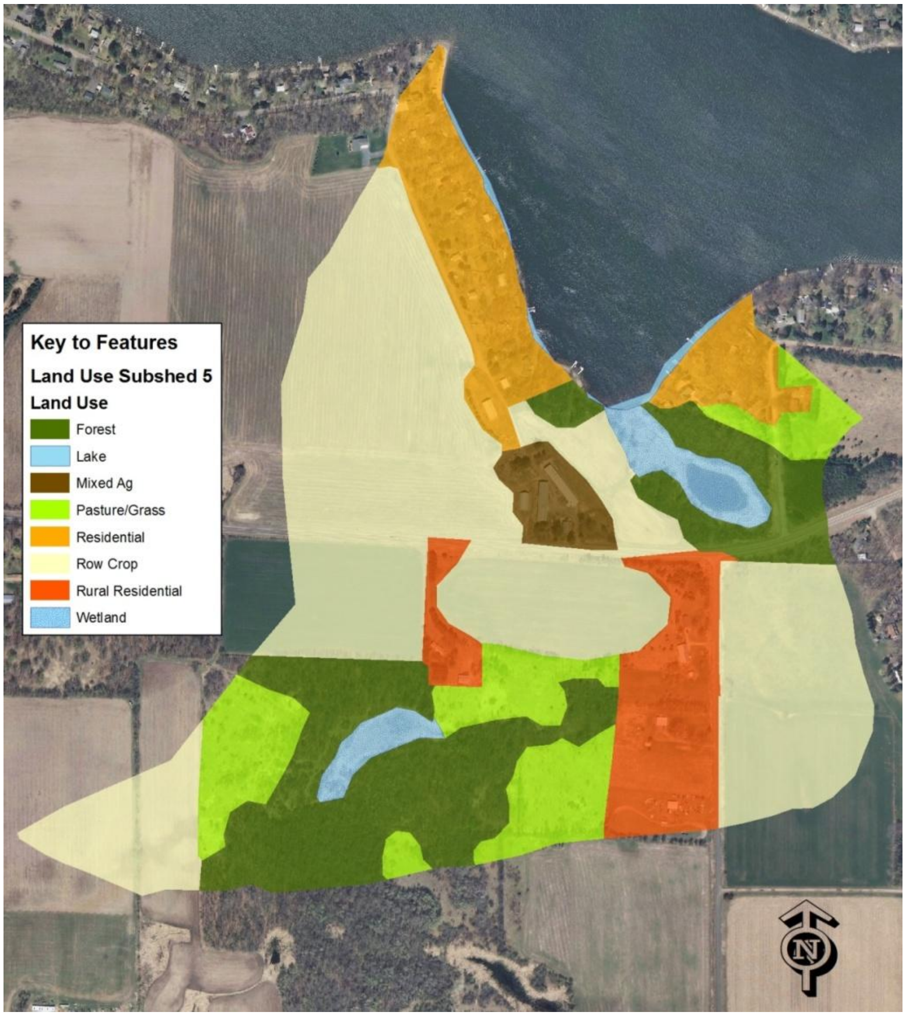


Subwatershed 5 is 165 acres in size.

Row crop makes up the largest land use in the subwatershed (45%) and contributes the majority of the phosphorus load to Long Lake (79%).

Forest makes up 19% of the land use and contributes only 3% of the phosphorus load to Long Lake.

Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	73.65	44.76%	66.14	78.95%
Mixed agriculture	4.02	2.44%	2.20	2.63%
Pasture/grass	18.66	11.34%	4.41	5.26%
Medium density residential	17.00	10.33%	6.61	7.89%
Rural residential	14.60	8.87%	2.20	2.63%
Wetlands	5.80	3.53%	0.00	0.00%
Forest	30.83	18.73%	2.20	2.63%

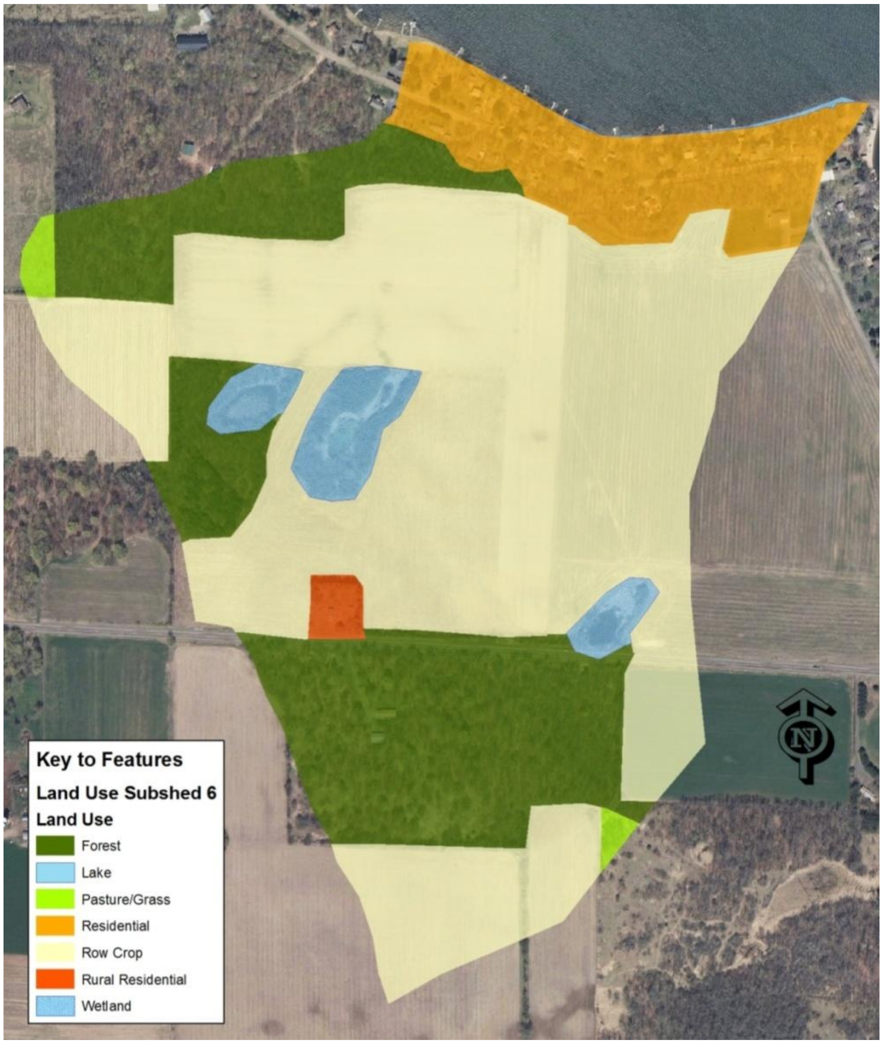


Subwatershed 6 is 155 acres in size.

Row crop makes up the majority of the land use in the subwatershed (57%) and contributes 90% of the phosphorus load to Long Lake.

Forest, making up a quarter (26%) of the land use, contributes only 2.5% of the phosphorus load to Long Lake.

Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	88.90	57.32%	79.37	90.00%
Pasture/grass	1.30	0.84%	0.00	0.00%
Medium density residential	16.30	10.51%	6.61	7.50%
Rural residential	1.20	0.77%	0.00	0.00%
Wetlands	6.80	4.38%	0.00	0.00%
Forest	40.60	26.18%	2.20	2.50%

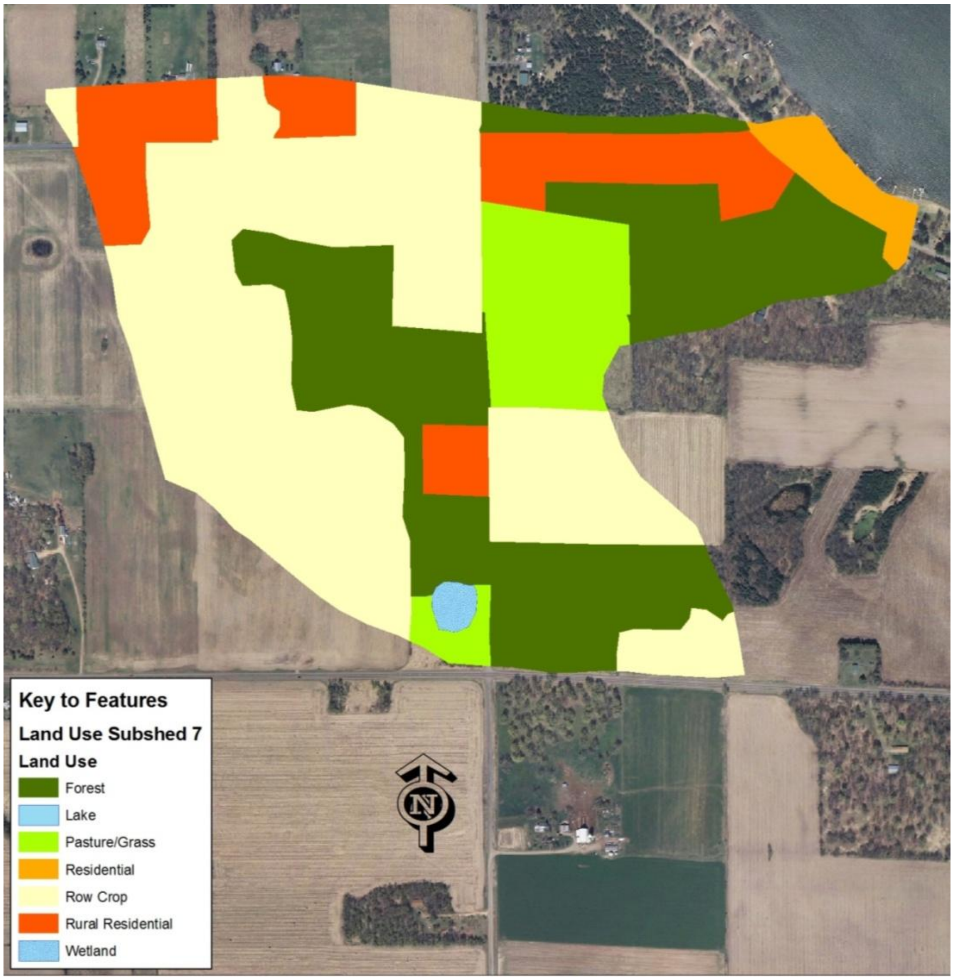


Subwatershed 7 is 223 acres in size.

Row crop makes up the largest land use in the subwatershed (35%) and contributes 62% of the phosphorus load to Long Lake. Mixed agriculture makes up 20% of the land use and contributes 27% of the phosphorus load to Long Lake.

Forest makes up a quarter (25%) of the land use and contributes only 4% of the phosphorus load to Long Lake.

Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	78.82	35.29%	70.55	61.54%
Mixed agriculture	44.20	19.79%	30.86	26.92%
Pasture/grass	16.81	7.53%	4.41	3.85%
Medium density residential	4.64	2.08%	2.20	1.92%
Rural residential	23.14	10.36%	2.20	1.92%
Wetlands	1.03	0.46%	0.00	0.00%
Forest	54.72	24.50%	4.41	3.85%

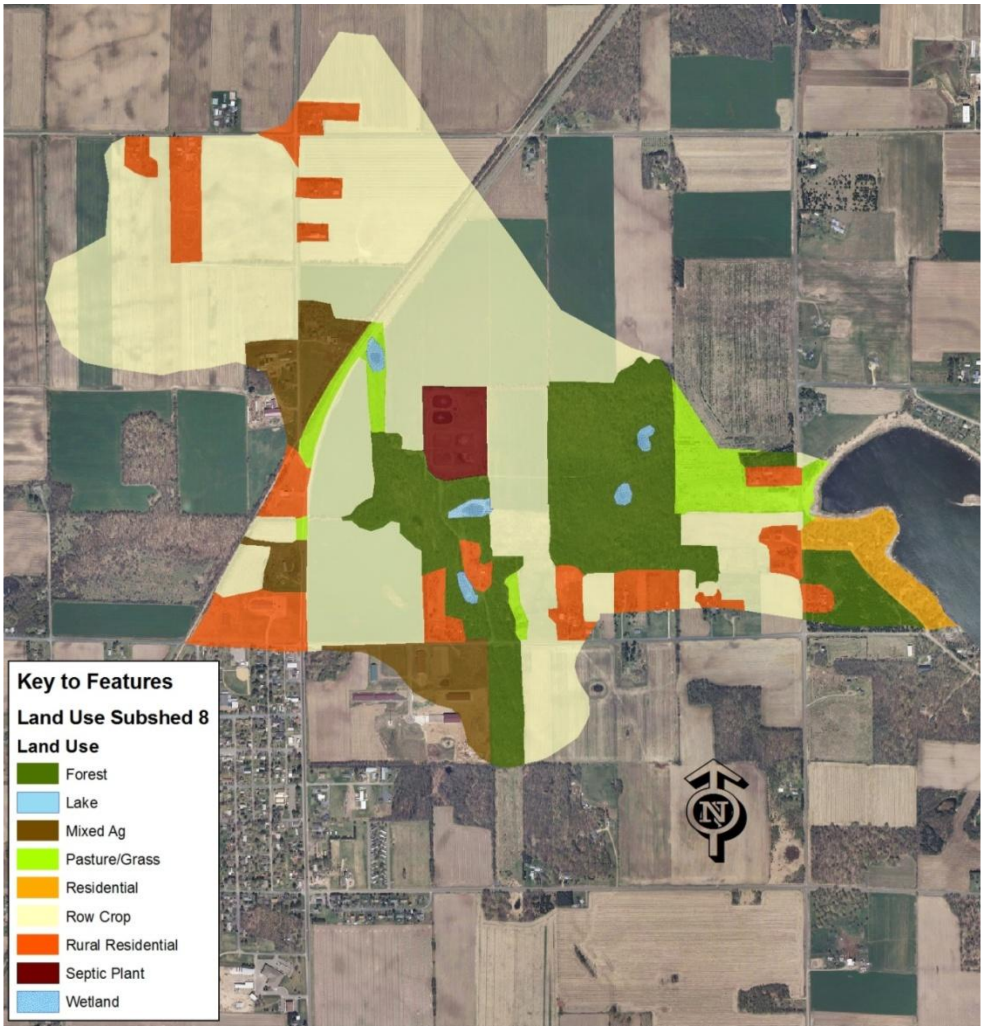


Subwatershed 8 is the largest subwatershed for Long Lake (698 acres).

Row crop makes up the majority of the land use in the subwatershed (57%) and contributes 85% of the phosphorus load to Long Lake.

Forest makes up 18% of the land use and contributes only 3% of the phosphorus load to Long Lake.

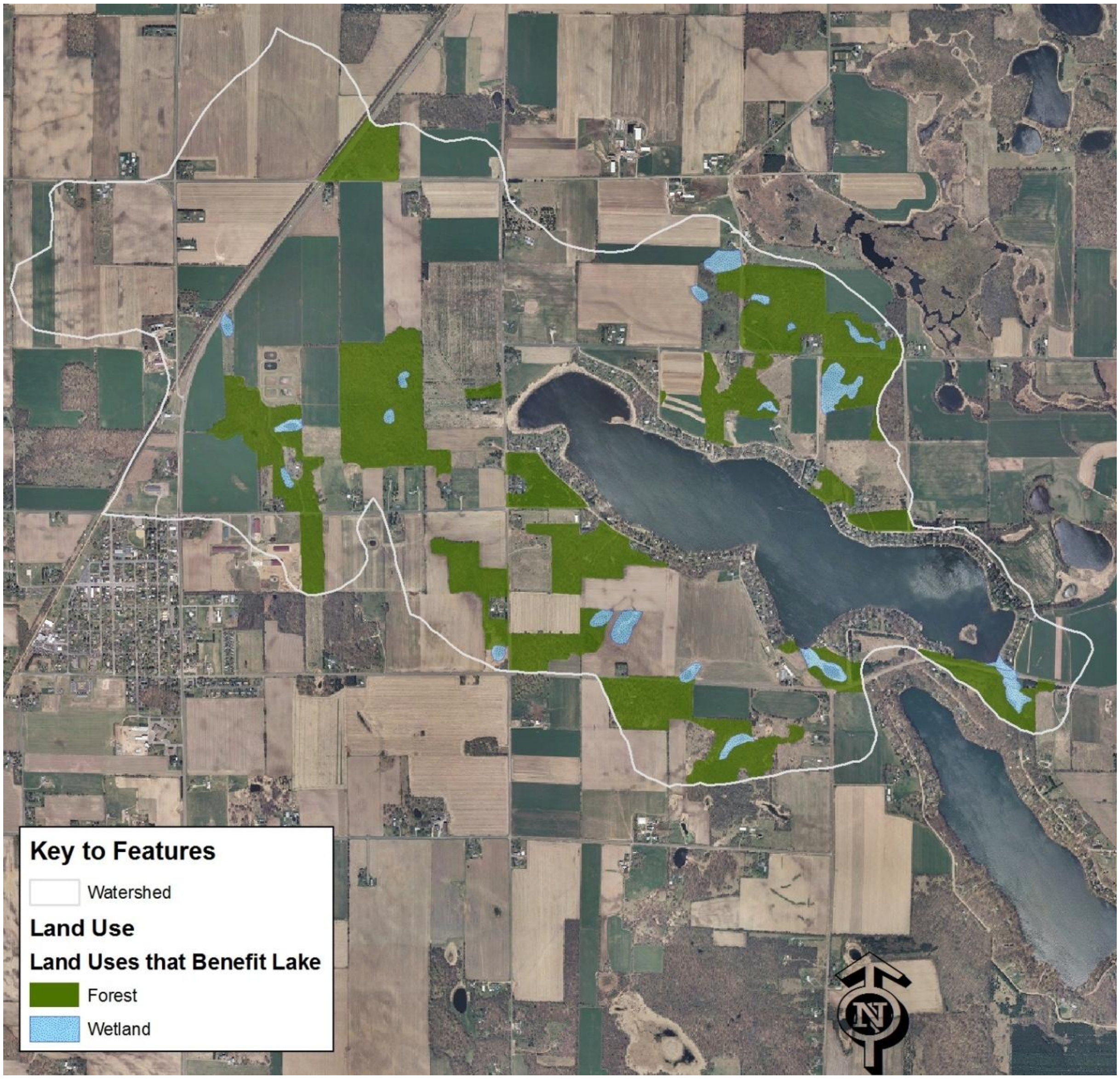
Land Use	Total acres	Percent acres	Loading (lb/yr)	Percent Loading
Row Crop	400.31	57.37%	357.15	84.82%
Mixed agriculture	44.17	6.33%	30.86	7.33%
Pasture/grass	31.83	4.56%	8.82	2.09%
Medium density residential	15.23	2.18%	6.61	1.57%
Rural residential	74.07	10.62%	6.61	1.57%
Wetlands	5.30	0.76%	0.00	0.00%
Forest	126.85	18.18%	11.02	2.62%



Areas Providing Water Quality Benefits to Long Lake

Natural areas such as forests and wetlands allow for more infiltration of precipitation when compared with row cropped fields and developed residential sites containing lawns, rooftops, sidewalks, and driveways. This occurs because dense vegetation lessens the impact of raindrops on the soil surface, thereby reducing erosion and allowing for greater infiltration of water. Additionally, wetlands provide extensive benefits through their ability to filter nutrients and allow sediments to settle out before reaching lakes and rivers.

The wetlands and forests of the Long Lake watershed should be considered sensitive areas and preserved for the benefits they provide to Long Lake. Wetlands make up only 2% of the land use in the Long Lake Watershed and forests make up 17% of the land use.



Watershed Modeling

WiLMS was used to model current conditions for the Long Lake Watershed and eight Long Lake Subwatersheds, verify monitoring, and estimate nutrient loading. Phosphorous is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes.

Watershed modeling can be used to estimate the external (or land based) inputs of phosphorus to a lake and the internal (or lake based) sediment inputs of phosphorus to a lake. However, because models can only make estimates, the outputs from modeling scenarios need to be compared with actual in-lake water quality data.

Based on average evaporation, precipitation, and runoff coefficients for Polk County soils and land use, the annual external non-point source load to Long Lake was calculated to be 1244.8 pounds of phosphorous. With the current economic conditions favoring the conversion of grass, pasture, and woods to corn and other row crops, the external loading in 2012 may be higher than in previous years.

Four different methods were used to estimate internal phosphorus loading for Long Lake using 2012 in-situ (in-lake) water quality data:

1. The first method completed a total phosphorus mass budget and estimated the annual internal load as 128 pounds of phosphorus.

2. The second method used in-situ phosphorus increases and estimated the annual internal load as 237 pounds of phosphorus, with a daily sediment phosphorus release rate of 4.9 mg/m^2.

3. The third method used in-situ phosphorus increases in the fall and estimated the annual load as 1168 pounds of phosphorus, with a daily sediment phosphorus release rate of 229.5 mg/m^2.

4. The fourth method used the average of the calculated phosphorus release rates and anoxic sediment area and estimated the annual internal load to be 208 pounds of phosphorus.

The data generated from the four different methods can be used to model the likely phosphorus content of a lakes water column.

The data was used to select the Vollenweider 1982 shallow lake and reservoir model: [12]

$$P = 1.02\left[\frac{LT_w/z}{1+\sqrt{T_w}}\right]^{0.88}$$

This model was used to estimate the total phosphorus content of the water column under many different scenarios.

The first modeling scenario used land use phosphorus coefficients and did not take into account internal loading. In this scenario the Vollenweider model calculated the total phosphorus concentration as 0.07381 mg/L. This scenario is obviously not accurate because there is intense interaction at the sediment water interface, especially in shallow lakes.

The second modeling scenario used the land use phosphorus coefficients and the internal loads estimated in the four methods described earlier. In this scenario the Vollenweider model calculated the total phosphorus concentration as four different values.

1. Using the first method (internal load estimated using a total phosphorus mass budget) the model estimated water column phosphorus as 0.07625 mg/L.

2. Using the second method (internal load estimated using in-situ phosphorus increases) the model estimated water column phosphorus as 0.07675 mg/L.

3. Using the third method (internal loading estimated using in-situ phosphorus increases in the fall) the model estimated water column phosphorus as 0.10402 mg/L.

4. Using the fourth method (internal load estimated using in-situ phosphorus release rates and anoxic sediments area) the model estimated water column phosphorus as 0.07774 mg/L.

The 2012 annual average total water column phosphorus concentration for Long Lake was 0.106 mg/L.

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[12] Where P = the predicted mixed lake total phosphorus concentration
L = the areal total phosphorus load (mg/m^2-yr.)
T_w = the lakes hydraulic retention time
z = the lakes mean depth

The third method, which estimated water column phosphorus as 0.10402 mg/L, was less than 2 percent different from the actual observed water column phosphorus concentration of 0.106 mg/L. Indeed the actual phosphorus content near the water sediment interface increased throughout the growing season and into the fall. This strongly implies that internal loading is a major component of Long Lake's phosphorus budget and needs to be addressed through management strategies.

The WiLMS output using the in-situ increases of phosphorus in the fall suggests that the internal load contributes 48.8% of the estimated phosphorus load.

When the Nurnberg total phosphorus model[13] and the Osgood Lake mixing index are taken into account, the predicted internal loading is predicted to be over 36% of the estimated phosphorus load.

$$P = \frac{L_{Ext}}{q_s}(1-R) + \frac{L_{Int}}{q_s} \text{ where } R = \frac{15}{18+q_s} \qquad OI = z/\sqrt{km^2}$$

Models can be used to predict many different scenarios and can be useful to guide management decisions. The Vollenweider model predicts that if the internal load of phosphorus to Long Lake was completely eliminated (which is not likely possible) and the external load of phosphorus to Long Lake was reduced by 60% that the resulting water column total phosphorus concentration would be 0.03577 mg/L which indicates a eutrophic state in Carlson's Trophic State Index (Carlson, March 1977. Volume 22(2)).

Modeling clearly indicates that internal loading is a major contributor to the total phosphorus budget for Long Lake (up to almost 50%). As a result, it will be necessary to manage for water quality on Long Lake using alternative in-lake management efforts in addition to watershed best management practices. Productivity in Long Lake may not be able to be suppressed or eliminated; however, productivity may be able to be shifted or displaced to other organisms (i.e. from algae to rooted submerged macrophytes) (Wetzel, 2001).

In order for such management to take place, a clear understanding of Long Lake's current and past ecosystem functions has to be achieved. Activities such as aquatic macrophyte surveys, continued water column monitoring, detailed in situ sediment nutrient release and REDOX conditions, and paleolimnoligical techniques should be employed to further the understanding of the Long Lake ecosystem.

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[13] Where P = the predicted mixed lake total phosphorus concentration
L_{ext} = external loading
L_{int} = internal loading
qs = areal water loading or surface overflow rate
z = the lakes mean depth

Nutrient Budget Summary

Modeling was used to estimate an annual phosphorus budget for Long Lake for external (watershed) and internal (in-lake) sources of phosphorus.

EXTERNAL LOAD

Non-point source load estimated with WiLMS: 1245 lbs phosphorous/year

Divided by land use:

- ✓ Row crow: 961 pounds
- ✓ Lake surface: 73 pounds
- ✓ Medium density residential: 62 pounds
- ✓ Pasture/grass: 55 pounds
- ✓ Mixed agriculture: 35 pounds
- ✓ Forest: 31 pounds
- ✓ Rural residential: 15 pounds
- ✓ Wetlands: 4 pounds

Divided by subwatershed:

- ✓ Subwatershed 8: 421 pounds
- ✓ Subwatershed 1: 267 pounds
- ✓ Subwatershed 7 (south ditch): 115 pounds
- ✓ Subwatershed 2 (north ditch): 112 pounds
- ✓ Subwatershed 6: 88 pounds
- ✓ Subwatershed 5: 83 pounds
- ✓ Subwatershed 3: 57 pounds
- ✓ Subwatershed 4: 44 pounds

Tributary load using field collected phosphorus data: 106 pounds of phosphorus/year

- ✓ North ditch: 83 pounds
- ✓ South ditch: 22 pounds

Waterfront property load estimated with Virginia Runoff Reduction Method Worksheet: 59 pounds of phosphorus [14]

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[14] This value is comparable to the annual medium density residential value of 61.73 pounds of phosphorus.

INTERNAL LOAD

Load from sediments/detritus (dead or decaying matter): 1168 pounds phosphorus/year

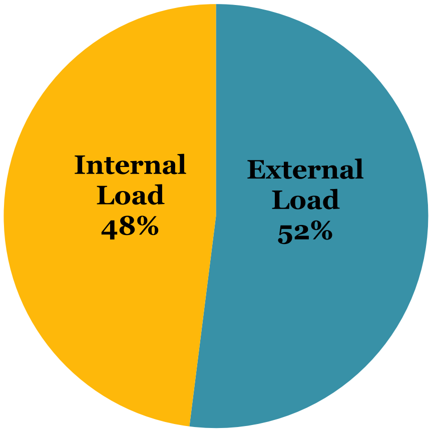
Load from curly-leaf pondweed die off: 52 pounds of phosphorus [15]

Note: The internal load from curly leaf die off is already taken into account in the non-point source load estimate.

ANNUAL TOTAL LOAD TO LONG LAKE: 2,413 POUNDS OF PHOSPHORUS

- ✓ 52% of the total is from external loading
- ✓ 48% of the total is from internal loading

Annual Total Phosphrous Load to Long Lake



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[15] The 2001 Barr Engineering report estimated the phosphorus contribution from CLP die off in late June as 384 pounds, which was associated with an estimated CLP coverage of 103 acres. By 2010 and 2011, CLP had been reduced to approximately 60 acres. Ratios would suggest that 60 acres of CLP would release 224 pounds of phosphorus at die off.

To determine the pounds of phosphorus associated with CLP die off, the Barr Engineering study analyzed dried curly leaf pondweed samples for total phosphorus content. However, a 2010 study by Schieffer and Clemens determined that only 21.3% of the total phosphorus in CLP was released into the water column during CLP die off.

When applying this percentage to the estimated pounds of phosphorus released at die off (224 pounds), it can be suggested that 52 pounds of phosphorus are being released into the water column as a result of CLP die off.

In 2012, the TSI (phosphorus) for Long Lake was 76, which would indicate a hypereutrophic state characterized by heavy algal blooms throughout the summer and dense algae and macrophytes.

Modeling can be used to predict the changes in water quality that would result from reductions in external and internal sources of phosphorus to a lake. Scenarios for 20%, 40%, and 60% reductions of external loading and 0%, 50%, and 100% reductions of internal loading were modeled. For each combination of reductions, water column phosphorus (mg/L) and TSI (phosphorus) were estimated.

	20% external reduction		40% external reduction		60% external reduction	
	Phosphorus (mg/L)	TSI (P)	Phosphorus (mg/L)	TSI (P)	Phosphorus (mg/L)	TSI (P)
0% internal reduction	0.121	73	0.109	72	0.098	70
50% internal reduction	0.092	69	0.080	67	0.068	65
100% internal reduction	0.062	64	0.048	60	0.036	56

Modeling predicts that current water column phosphorus (with no reductions in internal or external loading) would be 0.132 mg/L with a TSI (phosphorus) value of 75.

For each combination of reductions, water column chlorophyll a (mg/L) and TSI (chlorophyll a) were estimated.

	20% external reduction		40% external reduction		60% external reduction	
	Chlor a (mg/L)	TSI(Chlor a)	Chlor a (mg/L)	TSI(Chlor a)	Chlor a (mg/L)	TSI(Chlor a)
0% internal reduction	0.057	70	0.052	69	0.047	68
50% internal reduction	0.045	68	0.040	67	0.035	65
100% internal reduction	0.032	65	0.026	63	0.020	60

Modeling predicts that current water column chlorophyll a (with no reductions in internal or external loading) would be 0.062 mg/L with a TSI (chlorophyll a) value of 71.

The pounds of phosphorus that must be removed to achieve each reduction is show below.

External load reductions

- ✓ 20% = 249 pounds of phosphorus
- ✓ 40% = 498 pounds of phosphorus
- ✓ 60% = 747 pounds of phosphorus

Internal load reductions

- ✓ 50% = 584 pounds of phosphorus
- ✓ 100% = 1,168 pounds of phosphorus

Lake Management Alternatives

To choose from the many management options that are available, it is important to do the following:

- Set clear goals and objectives
- Understand potential results
- Prioritize activities
- Consider social and political feasibility
- Investigate funding possibilities
- Seek available assistance

A range of management activities are available to address water quality and habitat concerns. Categories for consideration include the following:

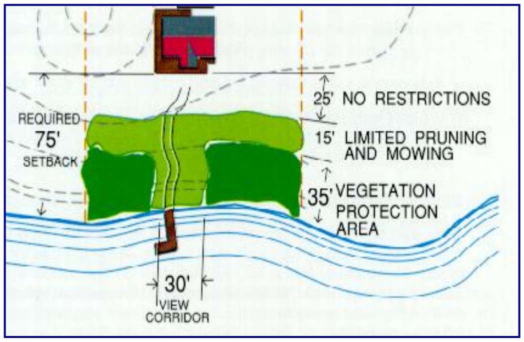
- Information and Education
- Incentives
- Conservation Practices
- Land Preservation
- Enforcement/Land Use Planning
- Lake Studies/Evaluation
- In-Lake Management

Information and Education

Providing information and education to lake residents, visitors, and policymakers is an important component of any lake management program. There is an abundance of printed and web information to help explain lake ecology and management methods. The University of Wisconsin Extension (http://learningstore.uwex.edu) and the Wisconsin Department of Natural Resources (http://dnr.wi.gov/lakes/publications) have many resources available. Lake organizations also develop informational materials specific to their lake and management program.

Information can be distributed using a variety of methods including:

- Packets of information for new homeowners
- Notebooks with pertinent information
- Brochures
- Web sites
- Newsletters
- Newspapers
- Workshops and training sessions



Long Lake residents report that they prefer to get information in the following ways: email (59%), special mailings (55%), annual meeting (41%), and newsletters (24%). The Long Lake Association uses an email list to distribute information to lake residents.

Distributing information can certainly increase knowledge. A key consideration is that sometimes people have the knowledge of lake concerns, but still don't make desired behavioral changes. It is important to identify the specific behaviors to be changed and the barriers to those behavioral changes, then to design programs that overcome these barriers. For example, concerns about native vegetation blocking views to water where children are swimming can be a barrier to the installation of shoreland buffers. To address this concern, information about shoreland buffers can emphasize planting lower growing plants and maintaining viewing corridors so the waterfront is still visible.

Incentives

Incentives are frequently provided along with information and education to encourage behavior changes. Examples of incentives include payments, tax credits, and recognition.

The Burnett County Shoreland Incentive Program uses cost sharing, an annual property tax rebate, participation shirts and hats, and shoreline signs as incentives to encourage participation. Enrollment in the program involves signing a perpetual covenant to restore and maintain a shoreland buffer on a waterfront property in Burnett County.

Conservation Practices

Conservation practices, frequently called best management practices, are installed to reduce pollutants. For lake management, conservation practices tend to focus on reducing erosion, slowing water flow, and encouraging infiltration. Many times these practices use native vegetation to accomplish pollutant reduction objectives. For the most effective installation of conservation practices, the most likely participants where significant sources of pollution can be addressed are targeted.

Installation of conservation practices is likely to require some form of technical assistance. For simple practices, this assistance might be in the form of a guidebook. Many practices will require on-site visits with designs prepared by technicians. More complicated practices may require design by professional engineers.

Large scale practices and multiple small scale practices are likely to require significant funding for design and installation. Some lake organizations provide direct financial and technical assistance. It is more common for lake organizations to work together with a county and/or another nonprofit organization. DNR Lake Protection Grants are available for both small and large-scale practices with Comprehensive Lake Management Plan approval.

Because of watershed land use and pollutant load identification, conservation practices for Long Lake are likely to focus on reducing runoff and pollutant loading from agricultural crop fields and/or waterfront property.

Agricultural Best Management Practices

Large-scale best management practices might involve changing tillage practices, implementing nutrient management plans, converting a crop fields to a more permanent vegetative cover, restoring wetlands, and/or constructing sedimentation basins. A list of potential agricultural best management practices is include: conservation tillage, crop rotation, cover crops, detention/sedimentation basins, grassed waterways, integrated pest management, livestock fencing, and nutrient management planning.

Practice	Description
Conservation Tillage	Any tillage or planting system that maintains at least 30% of the soil surface covered by residue after planting to reduce soil erosion by water. Examples of conservation tillage include no-till, strip-till, or vertical-tillage.
Crop Rotation	Reduces soil erosion and nutrient applications by alternating row crops with forage crops such as alfalfa.
Cover Crops	Reduces soil erosion and improves soil tilth and structure by providing vegetative cover on fields in the fall after harvest and before spring planting.
Detention/Sedimentation Basin	Reduces the flood peak, sediment, nutrient and contaminant loading by retaining runoff and letting soil particles and attached nutrients and contaminants settle out in the basin.
Grassed Waterways	Reduces erosion, nutrient, and contaminant loading by having runoff flow over a grassy area as it moves toward a waterbody. Soil is protected and grass helps utilize nutrients and trap contaminants.
Integrated Pest Management	Reduces pesticide applications, improves effectiveness of application, and uses more pest-resistant cultivars.
Livestock Fencing	Livestock exclusion from concentrated flow areas and other surface waters to eliminate erosion and provide vegetated buffer areas to intercept nutrient laden surface runoff before it enters flow areas or surface water.
Nutrient Management Planning	Reduces nutrient loading by managing proper timing, amount, and form of fertilizer and manure application to fields.

Promoting nutrient management is recommended within the Long Lake watershed. Nutrient management planning helps to manage the amount, source, placement, form, and timing of the application of nutrients and soil amendments. All nutrient sources, including soil reserves, commercial fertilizer, manure, organic byproducts, legume crops, and crop residues are accounted for and properly utilized. These criteria are intended to minimize nutrient entry into surface water, groundwater, and atmospheric resources while maintaining and improving the physical, chemical, and biological condition of the soil.

A detention/sedimentation basin can be an effective way to treat agricultural and urban pollutants when treatment near the source is not possible. Sedimentation basins were used in nearby Deer Lake subwatersheds both to settle out sediment from farm fields and to reduce the flow rate in intermittent streams where erosion was occurring.

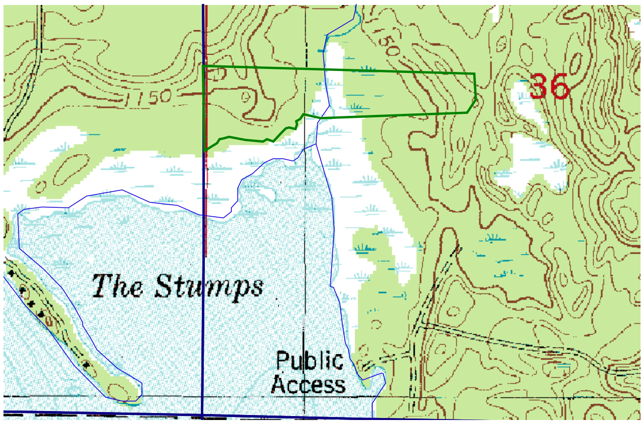
Funding for agricultural best management practices may be available through the Polk County Land and Water Resources Department which receives funding from the Department of Agriculture, Trade and Consumer Protection. Federal funding sources include the Farm Services Agency and Natural Resources Conservation Service. A DNR Lake Protection Grant or Targeted Runoff Management Grant may also fund some agricultural projects. Local tax revenue could also be used for agricultural projects.

Waterfront Runoff Practices

Waterfront runoff practices include rock pits or trenches, rain gardens, and shoreline buffers. It may be appropriate for Long Lake to consider offering design assistance and cost sharing for these practices. Nearby Deer Lake, Balsam Lake, and Burnett County offer programs and education materials to encourage waterfront runoff practices. These programs could be used as examples, and educational materials developed for these programs could be used on Long Lake.

Land Preservation

Land preservation involves purchasing land or putting land in conservation easements to preserve natural areas or to ensure that conservation practices will remain in place. A conservation easement is a voluntary legal agreement that restricts some land uses to protect important conservation values.



There are several nearby examples of land preservation purchases and conservation easements. The Balsam Lake Protection and Rehabilitation District purchased over fifty acres on the north side of the lake to preserve and prevent development in the Stump Bay area - an important wildlife area. To ensure that conservation practices remain in place, the Deer Lake Conservancy has easements or owns land where the practices are installed. In some cases, the Deer Lake Conservancy purchased highly erodible crop lands planted to row crops and converted the fields to native prairie. The Half Moon Lake Conservancy accepted donation of forty acres of natural area along Harder Creek, the largest tributary flowing into the lake.

Enforcement / Planning

Lake District involvement in enforcement of state and local regulations and planning activities can help to protect lakes. Local regulations and plans are summarized in the Related Plans, Regulations, and Ordinances Section of this report. Lake District members can report potential violations of regulations and ordinances to assist with appropriate enforcement. However, it is important to note that the Lake District cannot establish or enforce laws (except for boating laws under certain circumstances). Involvement in planning activities can help to ensure that land uses that protect the lake are in place in the watershed. Plans might be developed at the town, county, or state level.

In-Lake Management[16]

There are many options for in-lake management. Aeration, alum treatment, and dredging are just a few. These techniques generally require in-depth study, detailed permits, and significant funding.

Algaecides

Algaecides such as copper sulfate can kill algae and result in clearer water. Copper sulfate treatment is less effective in alkaline water, so liquid, chelated forms such as Cutrine plus (which also contains copper) are sometimes used. Copper usually destroys many green and blue-green algae. However, some planktonic forms many not be affected by copper including certain species or strains of filamentous blue-green algae *Aphanizomenon*, *Oscillatoria*, *Phormidium*, and *Anabaena*. Matted algae may also be resistant to treatment. Because of this resistance, copper treatment may eventually cause greater algal problems by not affecting these forms. Algaecides can also release toxins contained in blue-green algae cells by breaking the cell membrane. Repeated copper sulfate treatments in Long Lake have resulted in elevated sediment copper levels and may have shifted the composition of algae in the lake to favor toxin-producing blue-green algae.

Aeration

Aeration is used to add oxygen to bottom waters when a lake stratifies. Low oxygen levels release phosphorus from lake sediments. Aeration is also used in shallow lakes to prevent low oxygen levels which may kill fish. There are various types of aeration systems available.

Cedar Lake, located in southern Polk and northern St. Croix Counties, had an aeration system in place from 1991 to 2008. The purpose of the system was to prevent low oxygen levels near the lake bottom. The system was expensive to maintain, with high power costs (about $13,000 per year[17]). The system was recently removed because it was found that while the aeration system didn’t keep the lake bottom oxygen levels consistently high, it did cause mixing of the lake and re-suspension of nutrients into the water column. It was determined that the aeration system probably made lake water quality worse by allowing more regular mixing[18], which may increase phosphorus loading from the sediments by 20-30 times.

Alum Treatment/Phosphorus Inactivation

A phosphorus inactivation method such as an alum treatment controls algae by limiting

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[16] Adapted from Managing Lakes and Reservoirs. North American Lake Management Society, 2001.

[17] Personal communication Stuart Nelson, Cedar Lake P&R District Treasurer, April 2013.

[18] Effects of Summer Aeration System Operation on Water Quality Conditions in Cedar Lake Wisconsin: 2011. William F. James. U.S. Army Corps of Engineers.

phosphorus in the water column in the short-term and preventing release of phosphorus from bottom sediments on a longer-term basis. Alum, or aluminum sulfate, binds phosphorus under a wide range of conditions, but pH influences the process. Alum lowers the pH when it is applied, so a buffer such as sodium aluminate, lime, and sodium hydroxide may be added before treatment occurs. Long Lake tends to have high pH, especially later in the summer.

When alum is added to the water column, aggregates of aluminum hydroxide form and settle to the lake bottom. This aggregate, or floc, carries phosphorus and bits of particulate matter resulting in very clear water. If enough alum is added, a layer of aluminum hydroxide will cover the sediments and retard the release of phosphorus into the water column. If there is minimal external load from the watersheds, alum can be effective for many years.

Good candidate lakes for alum treatment include those with low external and high internal phosphorus loads. High alkalinity is also desirable to balance the pH when alum is used. Appropriate dosing of alum is critical. In Lake Wapogassett, a 2001 alum treated resulted in significantly clearer water for only a few months. Two explanations for this lack of success are a low aluminum to iron ratio (Al:Fe) in the lake and soft sediments.

As a rule of thumb, if the Al:Fe is greater than 1.0, the effectiveness of the alum is much greater. With this ratio, phosphorus will tend to bind to aluminum instead of iron. If bound to aluminum, phosphorus is less likely to be released under low oxygen levels. On the other hand, iron bound phosphorus releases quite readily with low oxygen levels. The Al:Fe averaged 0.95 in five lake sediment samples from Long Lake. The Al:Fe was very low in Wapogasset (0.30) and Bear Trap (.27) Lakes, even after the alum treatment.[19]

Wapogasset and Bear Trap Lakes also had very low levels of calcium in the sediments. Under low calcium conditions, phosphorus binds with iron instead of calcium. When bound with iron, phosphorus is released much more readily. In contrast, phosphorus bound to calcium complexes tends to be very stable and can be considered permanently buried.

Another consideration for potential alum treatment is the characteristics of lake sediments. The bottom substrate of Long Lake (where plants were sampled) is composed of muck (75%), rock (13%) or sand (11%). (Berg, 2011) Wapogasset and Bear Trap sediments were analyzed to assess where the aluminum from the alum treatment ended up. It seems that not all aluminum was retained in the lake

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[19] An evaluation of the alum treatment of Wapogasset and Bear Trap Lakes, Polk Co. Paul Garrison WDNR. November 2001.

sediments. Where it was present, it was surprisingly deep. In Wapogasset the added alum appears to reach a depth of 22 cm with a peak at 10-12 cm. This is much deeper than expected. The depth is attributed to large lake size and soft sediments. The conclusion is that Wapogasset is not a good candidate for alum. In Bear Trap, the added alum is in the upper 8 cm of the lake sediments. The conclusion is that Bear Trap is a better candidate for alum.[20]

Dredging

Removing sediment from a lake can lower in-lake nutrient concentrations and algae production by preventing the release of nutrients from the sediment. Dredging also removes the accumulated resting cysts deposited by a variety of algae. Although algae recolonization would probably be rapid, algal composition could change. Even where incoming nutrient loads are high, dredging can reduce the formation of benthic mats (formed at the lake bottom) and related problems with filamentous green and blue-green algae that depend on these substrates for nutrition.

Lake dredging is most frequently used to deepen a lake, control accumulations of toxic substances, or control aquatic plants. Dredging is generally not used for algae control because it is very expensive. Other negative side effects include turbid, nutrient rich water that is suspended during dredging, difficulty in finding dredge disposal locations (especially for contaminated sediment), and impacts to aquatic habitat. Because of these impacts, dredging is not commonly permitted for algae management on Wisconsin’s inland lakes.

While a repeated alum application at a higher recommended dose for Lake Wapogasset was estimated to cost 0.75 to $1.5 million, a dredging project to remove the top fourteen inches of nutrient-rich sediment was estimated to cost $5 to $7 million (Osgood 2007).[21]

Lake Studies/Evaluation

The water quality study completed in preparation for this plan is one example of a lake study. It is common for studies to identify further work that is needed to better understand a lake. It is important to understand why data is being collected before taking the time and spending the money to do it. In-lake management options are likely to require further study prior to implementation.

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[20] *Further Update on Wapogasset and Bear Trap Lakes*. Paul Garrison (author assumed). WDNR. 2002.

[21] *Wapogasset - Bear Trap Lake & Watershed Analysis with Alum Dose Recommendations*. Osgood Consulting. March 2007.

Related Plans, Regulations, and Ordinances

As described previously, knowledge of and involvement in development and implementation of local plans and ordinances can assist the Long Lake Protection and Rehabilitation District in achieving the goals of this Lake Management Plan.

Comprehensive Land Use Planning

The Polk County Comprehensive Land Use Plan was adopted in 2009. The plan includes an analysis of population, economy, housing, transportation, recreation, and land use trends. It also reports the physical features of Polk County. The purpose of the land use plan is to provide general guidance to achieve the desired future development of the county and direction for development decisions. The lakes classification outlines restriction on development according to lake features. Plan information is available online at http://www.co.polk.wi.us/landinfo/PlanningCompPlan.asp

Town, City and Village Comprehensive Plans are available at:
http://www.co.polk.wi.us/landinfo/PlanningCompPlans.asp

Smart growth is a state mandated planning requirement to guide land use decisions and facilitate communication between municipalities. Wisconsin's Comprehensive Planning Law (Statute 66.1001, Wis. Stats.) was passed as part of the 1999 Budget Act. The law requires that if a local government engages in zoning, subdivision regulations, or official mapping, those local land use regulations must be consistent with that unit of local government's comprehensive plan beginning on January 1, 2010. The law defines a comprehensive plan as having at least the following nine elements:

- ✓ Issues and opportunities
- ✓ Housing
- ✓ Transportation
- ✓ Utilities and community facilities
- ✓ Agricultural, natural, and cultural resources
- ✓ Economic development
- ✓ Intergovernmental cooperation
- ✓ Land use
- ✓ Implementation
- ✓ Polk County added "Energy and Sustainability"

Polk County Comprehensive Land Use Ordinance

The Polk County Comprehensive Land Use Ordinance, more commonly known as the Zoning Ordinance, is currently being updated due to the passage of the Comprehensive Plan. 17 of Polk County's 24 Towns have adopted county zoning, including: the Towns

of Alden, Apple River, Beaver, Black Brook, Clam Falls, Clayton, Clear Lake, Eureka, Georgetown, Johnstown, Lincoln, Lorain, Luck, McKinley, Milltown, Osceola, and West Sweden. The Towns of Farmington, Garfield, and St Croix Falls have adopted Town Zoning and the Towns of Balsam Lake, Bone Lake, Laketown, and Sterling have no town or county zoning other than the state-mandated shoreland zoning. Land use regulations in the zoning ordinance include building height requirements, lot sizes, permitted uses, and setbacks among other provisions. The current Comprehensive Zoning Ordinance is available at:
http://www.co.polk.wi.us/landinfo/pdfs/Ordinances/ComprehensiveLandUse.pdf

Shoreland Protection Zoning Ordinance

The State of Wisconsin's Administrative Rule NR115 dictates that counties must regulate lands within 1,000 feet of a lake, pond or flowage and 300 feet of a river or stream. The Shoreland Protection Zoning Ordinance is also currently being rewritten due to the Comprehensive Plan and the State of Wisconsin passing a new version of NR 115 in 2010. Polk County passed an update of the current Shoreland Ordinance in 2002 and again in 2008. These updates put in place standards for impervious surfaces, a phosphorus fertilizer ban for shoreland property, and lakes classification and setback standards. The current ordinance is available online at:
http://www.co.polk.wi.us/landinfo/pdfs/Ordinances/ShorelandOrdinance.pdf

Updates to the Shoreland Protection Ordinance and the Comprehensive Land Use Ordinance will be completed in 2013. The old and new version of the ordinances will be available at: http://www.co.polk.wi.us/landinfo/ordinances.asp

Subdivision Ordinance

The subdivision ordinance, adopted in 1996 and updated in 2005, requires a recorded certified survey map for any parcel less than 19 acres. The ordinance requires most new plats to incorporate storm water management practices with no net increase in runoff from development. The ordinance is available online at:
http://www.co.polk.wi.us/landinfo/PDFs/Ordinances/Subdivision%20Ordinance%202005-07-01.pdf

Animal Waste

The Polk County Manure and Water Quality Management Ordinance was revised in January 2000. A policy manual established minimum standards and specifications for animal waste storage facilities, feedlots, degraded pastures, and active livestock operations greater than 300 animal units for livestock producers regulated by the ordinances. The Land and Water Resource Department's objective was to have countywide compliance with the ordinance by 2006. The ordinance is available online at: http://www.co.polk.wi.us/landwater/MANUR21A.htm.

Storm Water and Erosion Control

The ordinance, passed in December 2005, establishes planning and permitting requirements for erosion control on disturbed sites greater than 3,000 square feet, where more than 400 cubic yards of material is cut or filled, or where channels are used for 300 feet more of utility installation (with some exceptions). Storm water plans and implementation of best management practices are required for subdivisions, survey plats, and roads where more than ½ acre of impervious surface will result. The Polk County Land and Water Resources Department administers the ordinance. The ordinance is a local mechanism to implement the Wisconsin Non-agricultural Runoff Performance Standards found in NR 151.

WI Non-Agricultural Performance Standards (NR 151)

Construction Sites >1 acre – must control 80% of sediment load from sites

Storm water management plans (>1 acre)
- Total Suspended Solids
- Peak Discharge Rate
- Infiltration
- Buffers around water

Developed urban areas (>1000 persons/square mile)
- Public education
- Yard waste management
- Nutrient management
- Reduction of suspended solids

Polk County Land and Water Resources Management Plan

The Polk County Land and Water Resources Management Plan describes the strategy the Land and Water Resources Department (LWRD) will employ from 2010-2018 to address agriculture and non-agriculture runoff management, stormwater discharge, shoreline management, soil conservation, invasive species and other environmental degradation that affects the natural resources of Polk County. The plan specifies how the LWRD will implement NR 151 (Runoff Management). It involves identifying critical sites, offering cost-share and other programs, identifying BMP's monitoring and evaluating projects for compliance, conducting enforcement activities, tracking progress, and providing information and education.

Polk County has local shoreland protection, zoning, subdivision, animal waste, and non-metallic mining ordinances. Enforcing these rules and assisting other agencies with programs are part of LWRD's ongoing activities. Other activities to implement the NR

151 Standards include information and education strategies, write nutrient management plans, provide technical assistance to landowners and lakeshore owners, perform lake studies, collaborate with other agencies, work on a rivers classification system, set up demonstration sites of proper BMP's, control invasive species, and revise ordinances to offer better protection of resources.

WI Agricultural Performance Standards (NR 151)

For farmers who grow agricultural crops
- ✓ Meet "T" on cropped fields
- ✓ Starting in 2005 for high priority areas such as impaired or exceptional waters, and 2008 for all other areas, follow a nutrient management plan designed to limit entry of nutrients into waters of the state

For farmers who raise, feed, or house livestock
- ✓ No direct runoff from feedlots or stored manure into state waters
- ✓ No unlimited livestock access to waters of the state where high concentrations of animals prevent the maintenance of adequate or self sustaining sod cover
- ✓ Starting in 2005 for high priority areas, and 2008 for all other areas, follow a nutrient management plan when applying or contracting to apply manure to limit entry of nutrients into waters of the state

For farmers who have or plan to build a manure storage structure
- ✓ Maintain a structure to prevent overflow, leakage, and structural failure
- ✓ Repair or upgrade a failing or leaking structure that poses an imminent health threat or violates groundwater standards
- ✓ Close a structure according to accepted standards
- ✓ Meet technical standards for a newly constructed or substantially-altered structure

For farmers with land in a water quality management area (defined as 300 feet from a stream, or 1,000 feet from a lake or areas susceptible to groundwater contamination)
- ✓ Do not stack manure in unconfined piles
- ✓ Divert clean water away from feedlots, manure storage areas, and barnyards located within this area

Boating Regulations

The Department of Natural Resources regulates boating in the state of Wisconsin.[22] Wisconsin conservation wardens enforce boating regulations. A few highlights of boating regulations are found below.

- ✓ Personal watercrafts (PWCs) may not operate from sunset to sunrise.
- ✓ PWC operators must be at least 12 years old.
- ✓ There are 100-foot restrictions between boats or PWCs and water skiers, towropes, and boats towing skiers.
- ✓ It is unlawful to operate within 100 feet of shore or of any dock, raft, pier, or buoyed restricted area at a speed in excess of "slow-no-wake." Boats have specific lighting requirements after dark.
- ✓ Speed must be reasonable and prudent under existing conditions to avoid colliding with any object or person.

A town or village may delegate the authority to adopt lake use regulations to a lake district. These may include regulation of boating equipment, use, or operation; aircraft; and travel on ice-bound lakes.[23] Local ordinances may now extend the slow-no-wake zone to within 200 feet of shore with passage of WI Act 31.

Dredging Regulations (Sec 30.20 Wis. Stats.)[24]

A general permit or an individual permit is required to dredge material from the bed of a navigable waterway. Local zoning permits and U.S. Army Corps of Engineers permits may also be required.

District Involvement in Planning and Zoning

The Long Lake Protection and Rehabilitation District has two seats on the board of directors for representatives appointed by the Polk County Board of Supervisors and the Town of Balsam Lake. These individuals help to bring concerns related to local planning and zoning to the Lake District board. As concerns are identified, commissioners may attend related meetings and hearings to express concerns and gather information.

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[22] Boating regulations may be found online at www.dnr.wi.us/org/es/enforcement/docs/boating regs.pdf.
[23] Chapter 33. Wisconsin State Statutes.
[24] Information from http://dnr.wi.gov.org/water/fhp/waterway/dredging.

Lake Management Plan

Lake Management Plans help protect natural resources by encouraging partnerships between concerned citizens, lakeshore residents, watershed residents, agency staff, and diverse organizations. Lake Management Plans identify concerns of importance and set realistic goals, objectives, and action items to address concerns of importance. Additionally, Lake Management Plans identify roles and responsibilities for meeting each goal and provide a timeline for implementation.

Lake Management Plans are living documents that are under constant review and adjustment depending on the condition of a lake, available funding, level of volunteer commitments, and the needs of lake stakeholders.

The implementation plan presented below was created through collaborative efforts and takes into account current and past water quality data, a 2012 sociological survey regarding the needs of Long Lake Protection and Rehabilitation District members, and a series of four meetings by the Long Lake Water Quality Committee.

On May 22nd and May 29th a notice was posted in the Inter-County Leader, directing the public to review and comment on the plan.

Long Lake Plan Vision, Goals, Objectives, and Actions

2014-2023

Plan Long Term Vision

Long Lake is a healthy, recreational lake with clean water and diverse native fish, wildlife, and plants.

Guiding Principles for Plan Implementation

1. *Understanding of lake and watershed processes drives lake management.*
2. *Lake management activities are conducted in a manner that will limit unintended environmental impacts (Do good – Do no harm).*
3. *Lake residents and users are provided information to understand the ever evolving nature of lake management, the complexity of issues, the status of projects and activities, the costs and benefits of remedial actions, and the opportunity and techniques to reduce or prevent any negative consequences of lake use and lakeside living.*
4. *Communication regarding plan goals, objectives, and actions is clear, concise, and frequent.*
5. *The agricultural community is engaged as a partner in reaching the Long Lake Plan vision.*
6. *All major decisions that impact the lake or have a financial burden on Lake District residents are reviewed and voted on by Lake District members. Any budget item of $5,000 or more must be reviewed and voted on by members.*

Plan Goals and Objectives

<u>Water quality goal.</u> Achieve and maintain a growing season mean total phosphorus concentration of .065 mg/L (65 ug/L) with plan implementation.

> *The long term goal will be to meet the State of Wisconsin standard for total phosphorus for nonstratified seepage lakes of 40 ug/L (ppm). The progress towards achieving this goal will be assessed following full plan implementation.*
>
> *Phosphorus leads to algae blooms in Long Lake. Total phosphorus concentration at this level will mean that the lake will stay clear longer and there will be less risk from algae toxins. This goal is achievable only if both the internal load from lake sediments and the external load from the watershed are controlled. In 2012 the total phosphorus was .146 mg/L.*

> *The results of water quality modeling are described on page 99 of this plan. In order to reach a predicted 62 ug/L total phosphorus, the internal load would need to be reduced by 100% and the external load by 20%. The committee agreed that 65 ug/L was a reasonable mid-term goal given this information.*

Water clarity goal. Extend the number of weeks that secchi depths exceed 4 feet and 2 ½ feet by 2 weeks.

> *Secchi depth is a measure of water clarity. It records the depth at which a black and white disk is no longer visible as it is lowered into the lake. A secchi depth of 4 feet is the threshold where algae growth increases greatly. The chlorophyll a level (a measure of algae growth) increases above .03 mg/L at this point. This transition occurred early in July in 2012. A secchi depth of 2 ½ feet corresponds to a chlorophyll a level of about .05 – the threshold from moderate to high risk for algae toxin production. This transition occurred in early August in 2012.*

Evaluation:

1. Participate in DNR Expanded Self-Help Monitoring measuring total phosphorus, chlorophyll a, temperature and oxygen profiles in addition to secchi depth.
2. Continue algal toxin measurements and algae assessment.
3. Consider conducting a sediment core study to establish a baseline of lake conditions, magnitude of changes, and progress with plan implementation.

Goal 1. Minimize nutrients, sediment, and other pollutants that flow to the lake from its watershed.

Objective A. Engage and support agricultural producers in reducing runoff to Long Lake.

Actions

1. Invite agricultural producers to special lake meetings and develop other means to reach out to farmers in a positive manner.
2. Inventory crop fields and other agricultural land uses to identify positive practices and where priority improvements could be made.
3. Share information about positive agricultural and residential practices with lake owners and agricultural producers.

4. Pay for soil tests to measure phosphorus levels in crop fields.

5. Consider financially supporting the installation of priority best management practices including sediment basins.

6. Consider purchasing land or easements to allow installation of priority best management practices including sediment basins.

7. Evaluate to track improvements made and determine next steps.

Objective B. At least 50 percent of Long Lake owners carry out best management practices to reduce runoff to the lake.

Actions

1. Provide information about residential best management practices in meetings, personal visits, newsletters, and emails.

2. Teach residents about residential best management practices at workshops, demonstrations, and tours.

3. Provide free design assistance for water quality landscaping and habitat improvements to lake residents if funds are available from the LLPRD, grants, and other sources.

4. Assemble and train volunteers and provide volunteer support for project installation.

5. Share in the cost of project installation if funds are available from the LLPRD, grants, and other sources.

6. Provide recognition in the form of a sign or dock marker to raise interest, and/or consider a special listing in the homeowner's directory with permission from the landowner.

7. Evaluate to track best management practices implemented and determine next steps.

Goal 2. Encourage lake processes which minimize the release of nutrients from within the lake.

Objective A. Investigate/pursue in-lake management techniques including alum treatment and aeration.

Actions

1. Conduct an alum dosage study to determine appropriate alum application rates and cost.

2. Measure soluble and total iron in the hypolimnion (near lake bottom) to assess potential efficacy of an aeration system.

Objective B. Reduce internal loading from lake sediments by 90 percent.

Actions

1. Develop financing and install the recommended in- management technique(s).

2. Repeat selected treatment as needed.

Objective C. Reduce phosphorus loading from curly leaf pondweed by reducing beds to less than 20 acres and preventing CLP spread (from Aquatic Plant Management Plan).

Objective D. Increase native aquatic plant rooting depth (from Aquatic Plant Management Plan).

Actions for Objectives C and D are described in the Long Lake Aquatic Plant Management Plan.

Goal 3. Preserve and enhance lake and shoreline fish and wildlife habitat.

Objective A. Encourage installation of residential best management practices, such as native plantings and woody habitat, which improve habitat.

Actions are described under Goal 1, Objective B.

Goal 4. Lake residents and visitors understand the components of and the means to support a healthy lake.

Objective A. Lake residents understand the rationale behind the plan actions and have enough information to make sound decisions.

Objective B. Lake residents take action to improve lake water quality and habitat.

Messages to convey:

- Messages should be simple, and they should be repeated. Recipients can be directed to more in-depth information if interested.

- Celebrate the progress made with aquatic plant and lake management so far.
- Explain plan goals and actions.
- There is an urgency to lake water quality improvements. Algae toxins are a threat to the safety and well-being our families, visitors, and pets and wildlife.
- Describe conditions when algae toxins are a likely concern.

Educational methods:

- LLPRD and Long Lake Association newsletters
- Handouts/brochures (alum handout is one example)
- Presentations (annual meeting, seminars) – encourage new owners to attend, bring in credible experts such as Bill James, use testimonials from owners, include food
- Website: http://longlakepolk.ning.com/
- Email list
- Lake Association welcome packets for new lake residents – add water quality and plan information
- Articles for the Lake News edition of the Ledger Newspaper
- Letter from the LLPRD president, include on web site
- Additional educational methods are described under Plan Goal 1.

Goal . Implement the goals of the Long Lake Aquatic Plant Management Plan.

See the Long Lake Aquatic Plant Management Plan for Implementation Actions.

Long Lake Aquatic Plant Management Plan Goals

1) Improve water quality and clarity.

2) Protect and restore healthy rooted native aquatic plant communities.

3) Balance recreation and riparian needs with protection of native plants and the fishery.

4) Prevent the introduction of Eurasian water milfoil and other invasive, non-native aquatic species.

5) Rapidly respond to eliminate any newly introduced invasive, non-native aquatic plant species.

Plan Implementation

The implementation charts on following pages list potential funding sources for plan implementation. The implementation plan and funding sources will be reviewed each year prior to the LLPRD annual meeting.

While grants are available for most plan activities, the LLPRD may choose to move forward in some instances without DNR grant funding secured. DNR and other permits may be required for some activities, but activities do not need to be funded by grants.

Grant Sources

The main sources of implementation funds are LLPRD revenues and Department of Natural Resources grants. The DNR Lake Management Grant Program has two main types of lake management grants: planning and lake protection grants. Lake planning grants are available at two scales – large scale up to $25,000 and small scale up to $3,000. These applications are accepted twice each year on February 1 and August 1. DNR lake protection grants for plan implementation have a maximum grant amount of $200,000. These grants are due each year by May 1. Plan activities will be eligible for lake protection grant funds following approval by the DNR.

The Department of Natural Resources also manages Targeted Runoff Management (TRM) grants for urban and agricultural practices as described in the state runoff rule: NR151. Cities, villages, towns, counties, regional planning commissions, tribal governments, and special purpose districts such as lake, sewerage, and sanitary districts are eligible to apply for TRM grants.

DNR Lake Planning Grants (up to 67% state share)

Large scale – up to $25,000
Small scale – up to $3,000
Applications due February 1 and August 1
These grant applications could proceed without final plan approval.

DNR Lake Protection Grants (up to 75% state share)

Up to $200,000
Requires DNR approval of tasks in the comprehensive plan (allow 60 days)
Applications due May 1

DNR Targeted Runoff Management (up to 70% state share)

Small Scale: Up to $150,000 (only land purchase and structural practices)

Large Scale: Typically $500,000 to $1 million (cropping practices and staffing costs also eligible)
Agricultural activities in this plan may be eligible. Projects must address state agricultural performance standards.
Application due April 15th

<u>Water quality goal.</u> Achieve a growing season mean total phosphorus concentration of 0.65 mg/L.

Actions[1]	**Timeline**	**$ Estimate (annually)**	**Vol. Hours (annually)**	**Responsible Parties**[2]	**Funding Sources**
Participate in Expanded Self-Help Monitoring measuring total phosphorus, chlorophyll a, temperature and oxygen profiles in addition to secchi depth.	Ongoing	$0	120	LLPRD	WDNR
Continue algal toxin measurements and algae assessment.	Ongoing	$4,100	0	LWRD	WI Dept. of Health Centers for Disease Control
Consider conducting a sediment core study to establish a baseline of lake conditions, magnitude of changes, and progress with implementation.	TBD	$15,000 to $30,000 (1X)	0	LWRD	WDNR Lakes Planning Grant
SUBTOTAL WQ EVALUATION					

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[1] See previous pages for action item detail. Estimates are for annual budgets once implementation begins.

[2]LLPRD = Long Lake Protection and Rehabilitation District
LWRD = Land and Water Resources Department
WDNR = Wisconsin Department of Natural Resources

<u>Goal 1.</u> Minimize nutrients, sediment, and other pollutants that flow to the lake from its watershed.

<u>Objective A.</u> Engage and support agricultural producers in reducing runoff to Long Lake.

Actions[3]	**Timeline**	**$ Estimate**	**Vol. Hours**	**Responsible Parties**[4]	**Funding Sources**
1. Reach out to farmers through special meetings and other activities	2014-2018	$300	40	LLPRD	Lakes Planning Grant (08/01/13)
2. Inventory crop fields to ID positive practices and potential improvements	2014	$5,000	0	LWRD (contract)	Lakes Planning Grant (08/01/13)
3. Share information from inventory above	2015	$100	20	LLPRD LWRD	Lakes Planning Grant (08/01/13)
4. Pay for crop field soil tests	2014	$2,350	0	LWRD (contract)	Lakes Planning Grant (08/01/13)
5. Consider supporting recommended Best Management Practices	2015	TBD	0		
5a. further investigate sediment basin options: contact landowners, preliminary engineering	2014	$2,000		LWRD (contract)	Lakes Planning Grant (08/01/13)
6. Consider purchasing land or easements to allow installation	2015	TBD		LLPRD	Lake Protection Grant
7. Evaluate to track improvements	2018	TBD		LLPRD LWRD	Lakes Planning Grant LLPRD
Grant writing	2013 – 2015	$1,200		LLPRD	LLPRD

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[3] See previous pages for action item detail. Estimates are for annual budgets once implementation begins.

[4] LLPRD = Long Lake Protection and Rehabilitation District
LWRD = Land and Water Resources Department
WDNR = Wisconsin Department of Natural Resources

Goal 1. Minimize nutrients, sediment, and other pollutants that flow to the lake from its watershed.
Objective A. Engage and support agricultural producers in reducing runoff to Long Lake.

Actions[3]	**Timeline**	**$ Estimate**	**Vol. Hours**	**Responsible Parties**[4]	**Funding Sources**
				Consultant	
SUBTOTAL GOAL 1A					

Goal 1. Minimize nutrients, sediment, and other pollutants that flow to the lake from its watershed.

Objective B. At least 50 percent of Long Lake owners carry out best management practices to reduce runoff to the lake.

Goal 3. Preserve and enhance lake and shoreline fish and wildlife habitat.

Objective A. Encourage installation of residential best management practices, such as native plantings and woody habitat, which improve habitat.

Actions[5]	**Timeline**	**$ Estimate**[6] **(annually)**	**Vol. Hours**	**Responsible Parties**[7]	**Funding Sources**
1. Provide information about residential best management practices	2013-2018	$200	20	LLPRD LWRD	Lakes Planning Grant (08/01/13)
2. Teach residents about best management practices			40-80	LLPRD LWRD	Lakes Planning Grant (08/01/13)
2a. workshops	2014 – 2018	$200			
2b. demonstrations and tours	2015-2018	$200			
3. Provide free design assistance to residents	2013 (5 properties) TBD	TBD		LWRD Consultant	Lakes Planning Grant (08/01/13)
4. Assemble and train volunteers for project installation	2014	$200	80	LLPRD LWRD	Lakes Planning Grant (08/01/13)
5. Cost share project installation	2014- 2018	TBD		LWRD LLPRD Landowners	Lake Protection Grant (05/01/14)

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[5] See previous pages for action item detail.

[6] Additional costs if staffing covered under grant (instead of or in addition to volunteer time).

[7] LLPRD = Long Lake Protection and Rehabilitation District
LWRD = Land and Water Resources Department
WDNR = Wisconsin Department of Natural Resources

Goal 1. Minimize nutrients, sediment, and other pollutants that flow to the lake from its watershed.

Objective B. At least 50 percent of Long Lake owners carry out best management practices to reduce runoff to the lake.

Goal 3. Preserve and enhance lake and shoreline fish and wildlife habitat.

Objective A. Encourage installation of residential best management practices, such as native plantings and woody habitat, which improve habitat.

Actions[5]	**Timeline**	**$ Estimate**[6] **(annually)**	**Vol. Hours**	**Responsible Parties**[7]	**Funding Sources**
				Landscapers	
6. Provide recognition for installation 6a. develop program 6b. Implement recognition	2013 – 2018	$500	40	LLPRD Volunteer	Lakes Planning Grant (08/01/13)
7. Evaluate to track BMPs and determine next steps	Ongoing		20	LLPRD LWRD	Lakes Planning Grant (08/01/13)
Grant writing	Ongoing	$1,200	10	LLPRD Consultant	LLPRD
Consultant assistance/coordination	Ongoing	?		LLPRD	Lakes Planning Grant (08/01/13)
SUBTOTAL GOAL 1B/3					

<u>Goal 2.</u> Encourage lake processes which minimize the release of nutrients from within the lake.

<u>Objective A.</u> Investigate/pursue in-lake management techniques including alum treatment and aeration.

Actions[8]	**Timeline**	**$ Estimate**	**Vol. Hours**	**Responsible Parties**[9]	**Funding Sources**
Conduct an alum dosage study	2013	$6,000	10	LLPRD James	LLPRD Small Scale Lakes Planning Grant (08/01/13)
Measure iron etc.	2013	$200	0	LWRD	LWRD LLPRD
Ongoing consulting	Ongoing	$1,500	0	James (?)	Lakes Planning Grant (08/01/13)
SUBTOTAL GOAL 2A					

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[8] See previous pages for action item detail.

[9] LLPRD = Long Lake Protection and Rehabilitation District
LWRD = Land and Water Resources Department
WDNR = Wisconsin Department of Natural Resources

Goal 2. Encourage lake processes which minimize the release of nutrients from within the lake.

Objective B. Reduce internal loading from lake sediments by 90 percent.

Actions[10]	**Timeline**	**$ Estimate**	**Vol. Hours**	**Responsible Parties**[11]	**Funding Sources**
Provide detailed implementation plans	2014 and 2016	$2,000	40	LLPRD Consultant	Lakes Planning Grant (08/01/13)
Develop financing	2014	$2,000	40	LLPRD Consultant (grants)	
In-lake treatments	TBD	TBD	40	LLPRD WDNR	DNR Lake Protection Grant
Write grants	TBD	$2,000 - $2,500	10	LLPRD Consultant	LLPRD
SUBTOTAL GOAL 2B					

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[10] See previous pages for action item detail.

[11] LLPRD = Long Lake Protection and Rehabilitation District

LWRD = Land and Water Resources Department

WDNR = Wisconsin Department of Natural Resources

Goal 4. Lake residents and visitors understand the components of and the means to support a healthy lake.

Objective A. Lake users are aware of the potential threats from algae toxins and are notified when threats are likely present.

Objective B. Lake residents understand the rationale behind the plan actions and have enough information to make sound decisions.

Actions[12]	**Timeline**	**$ Estimate (annually)**	**Vol. Hours (annually)**	**Responsible Parties**[13]	**Funding Sources**
Newsletters/letter from President	May each year	$600	10	LLPRD LLA	LLPRD
Handout/brochures: (Plan contents, Alum, etc.) e.g., In LLA Welcome Packets	2013 2014	$400	20	LLPRD LWRD Consultant LLA	Lakes Planning Grant (08/01/13)
Presentations: Plan seminars	2013	$500		LLPRD TOPIC EXPERTS	Lakes Planning Grant (08/01/13)
Website upgrades	Ongoing	$300	20	LLA LLPRD	Lakes Planning Grant (08/01/13)
Email list	Ongoing	$0	20	LLA LLPRD	Lakes Planning Grant (08/01/13)
Articles for other publications	Ongoing	$0	20	LLPRD LWRD Consultant	Lakes Planning Grant (08/01/13)
SUBTOTAL GOAL 4					

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[12] See previous pages for action item detail.

[13] LLA = Long Lake Association, LLPRD = Long Lake Protection and Rehabilitation District, LWRD = Land and Water Resources Department, WDNR = Wisconsin Department of Natural Resources

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