Big Blake Lake Aquatic Plant and Lake Management Plan, 2016-2021

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Funded by
Wisconsin Department of Natural Resources Lake Planning Grant
Big Blake Lake Protection and Rehabilitation District

We would like to thank the following for their contributions to this project. Asterisks indicate members of the Lake Planning Committee.

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Purpose of the Study

In 2012, the Big Blake Lake Protection and Rehabilitation District applied for a Wisconsin Department of Natural Resources Aquatic Invasive Species Education, Prevention, and Planning Grant. The grant was awarded and data collection occurred in 2013, 2014, and 2015.

The main purpose of the grant was to address the following problems: aquatic invasive species, nuisance aquatic plant growth, algae blooms, impaired water clarity, and a lack of education and data.

Methods and activities completed through this grant award include:

- ✓ Lake resident survey
- ✓ In-lake physical and chemical monitoring
- ✓ Tributary monitoring
- ✓ Phytoplankton
- ✓ Zooplankton
- ✓ Aquatic plant point intercept surveys
- ✓ Curly-leaf pondweed biomass and turion monitoring
- ✓ Watershed delineation, land use determination, and modeling
- ✓ Participation in aquatic invasive species statewide programs: Citizen Lake Monitoring Network for AIS and Water Quality, Bait Dealer Initiative, and Clean Boats, Clean Waters
- ✓ Communication of information: the Blake Lake Bugle Newsletter, pontoon classrooms, and distribution of AIS flyers
- ✓ Development of Aquatic Plant Management Plan

In 2013, the Big Blake Lake Protection and Rehabilitation District applied for a Wisconsin Department of Natural Resources Large Scale Lake Management Planning Grant to collect a sediment core on Big Blake Lake.

Methods and activities completed through this grant award include:

- ✓ Sediment core collection
- ✓ Sediment phosphorus
- ✓ Diatom analysis
- ✓ Macrofossils
- ✓ Zooplankton
- ✓ Pigments
- ✓ Biogenic silica analysis
- ✓ Historical land use determination and modeling
- ✓ Development of a Lake Management Plan

The following report details the methods and activities completed through both grant awards.

Background Information on Lakes, Studies, and Management Plans

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

A landscape can be divided into watersheds and subwatersheds. These areas define the land that drains to a particular lake, flowage, 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. This arises because rain and melting snow eventually end up in lakes and streams through surface runoff or groundwater infiltration. Rain and melting snow entering a waterbody is not inherently problematic. However, water has the ability to carry nutrients, bacteria, sediments, and chemicals into a waterbody. 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.

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, zooplankton, and aquatic plants), and land use within a lake's watershed. Additionally, sediment cores can be used to determine how a lake has changed over the course of hundreds of years

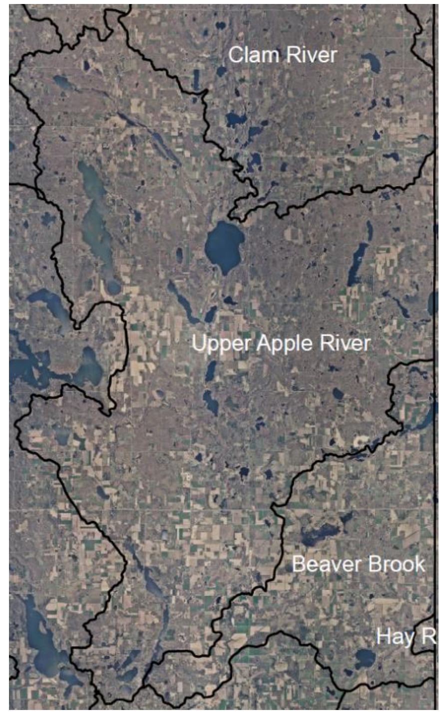
Lake studies identify challenges and threats to a lake's health along with opportunities for improvement. These studies identify practices already being implemented by watershed residents to improve water quality and areas providing benefits to a lake's ecosystem. Additionally, these studies quantify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

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 the goals of watershed residents.

An **Aquatic Plant Management Plan** is similar to a Lake Management Plan, although the goals, objectives, and action items pertain specifically to aquatic plants.

Both types of management plans are designed to be working documents that are used to guide the actions which take place to manage a specific lake.

Introduction to Big Blake Lake



Big Blake Lake[1] is a 208 acre lake located in the Town of Georgetown[2] in Polk County, Wisconsin, approximately 80 miles northeast of the Twin Cities metropolitan area. The area of land that drains to a lake is called a watershed. Big Blake Lake is situated within the Upper Apple River Watershed, which is part of the St. Croix River Basin. The Upper Apple River Watershed is the largest watershed in Polk County, totaling approximately 125,074 acres in size.

On a smaller scale, the area of land that drains to Big Blake Lake, or the Big Blake Lake watershed, is 15,369 acres in size. The drainage basin: lake area ratio (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. The DB: LA for Big Blake Lake is approximately 61:1.[3]

The main inlet for Big Blake Lake is a channel flowing directly from Little Blake Lake on the southeast end of the lake. Additionally, Big Blake Lake receives water from an inlet located on the north side of the lake. This tributary flows from Lost Lake and is called Lost Creek. The lake's outlet is located on the northwest side of Big Blake Lake and flows to the Apple River via Fox Creek.

Lakes are classified according to their primary source of water and how that water enters and leaves the system. Big Blake Lake is defined as a drainage lake, or a lake with an inlet and an outlet. Drainage lakes receive most of their water from the surrounding watershed in the form of stream drainage, have a prominent inlet and outlet that move water through the system, and commonly have high nutrient levels due to inputs from the watershed.

The residence time is the average amount of time water remains in a body of water. The residence time for Big Blake Lake is 0.10 year, meaning that water is replaced approximately every 36 days.[4]

There are two ramp public access sites on Big Blake Lake located on the northeast and southwest sides of the lake.

The Big Blake Lake Protection and Rehabilitation District was formed in 1976 in response to concerns about algae blooms and aquatic plant problems. The District includes two hundred twenty-two residences. The majority of the shoreline property on Big Blake Lake is parceled into 100 foot lots, although a moderate tract of forested land remains on the east side of the lake.

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[1] Waterbody ID (WBIC) 2627000
[2] T35N, R16 W, Sec. 22, 26, 27
[3] Blake Lake Polk County Feasibility Study Results: Management Alternatives; Wisconsin Department of Natural Resources Office of Inland Lakes Renewal, 1981
[4] Ibid

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 used to classify lakes as class one, class two, or class three lakes. Big Blake Lake is classified as a class one lake.

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.

Big Blake Lake Characteristics

Big Blake Lake [5]

Area: 208 Acres
Maximum depth: 14 feet
Mean depth: 9 feet
Bottom: 55% sand, 0% gravel, 0% rock, and 45% muck
Hydrologic lake type: Drainage [6]
Total shoreline: 6.65 miles
Invasive species: Curly-leaf pondweed, Chinese mystery snail, and banded mystery snail
Fish: Musky, panfish, largemouth bass, northern pike, and walleye
Boat landings: 2
Trophic Status: Eutrophic

Oligotrophic lakes are generally clear, deep, and free of plants and large algae blooms.

Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have productive fisheries, healthy plant life, 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 communities and can experience heavy blooms throughout the summer.

[5] http://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2627000&page=more
[6] A drainage lake is fed by streams, groundwater, precipitation, and runoff and drained by a stream

Designated Waters and Sensitive Areas

A designated water is a waterbody with special designations that affect permit requirements.

Big Blake Lake is designated as an Area of Special Natural Resource Interest (ASNRI) Endangered, Threatened, or Special Concern Lake. The Natural Heritage Inventory Program identifies waters or portions of waters inhabited by any endangered, threatened, special concern species, or unique ecological community identified in the Natural Heritage Inventory.

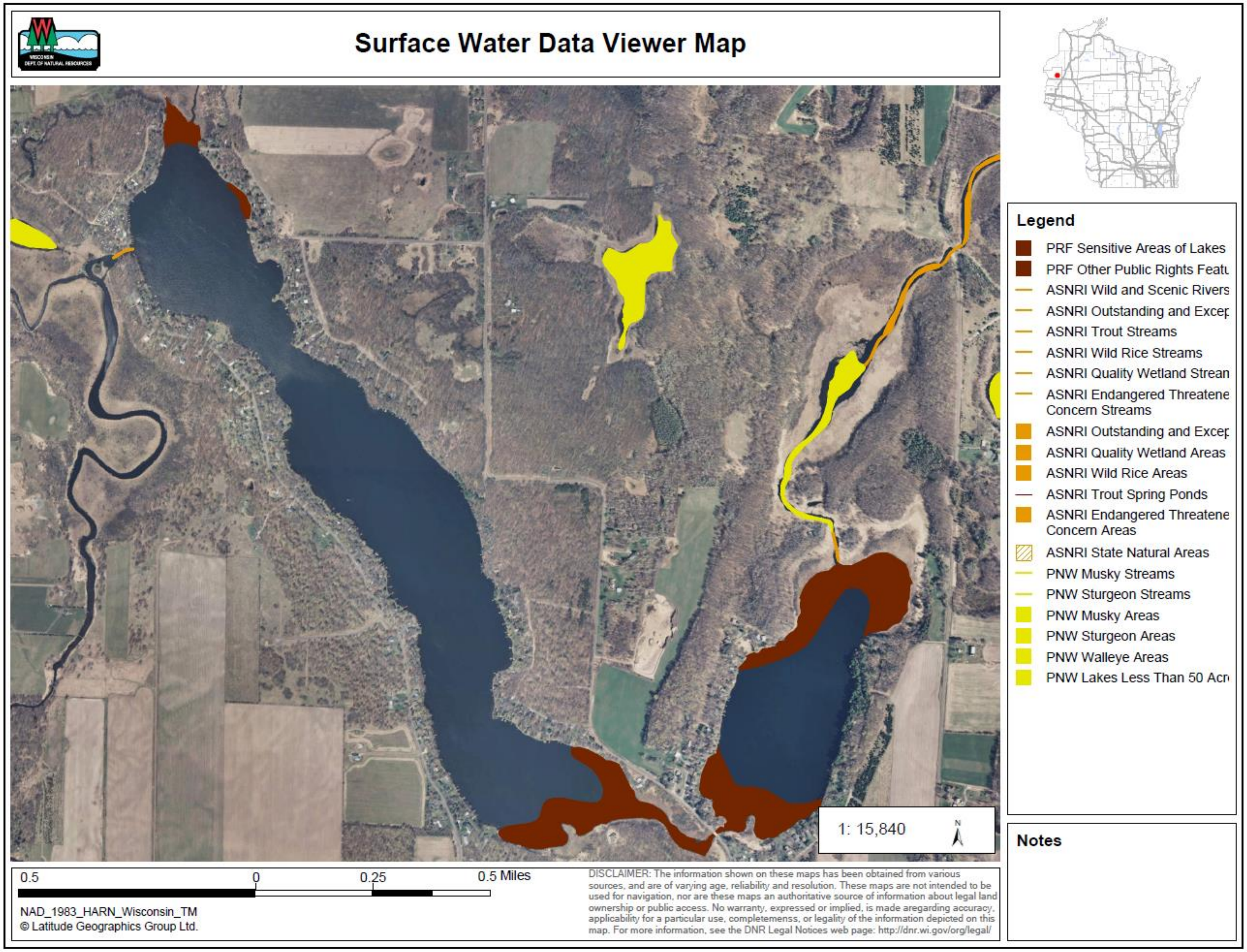
An Integrated Sensitive Area Survey Report was completed for Big Blake Lake in August, 2000. This survey identified three areas of Big Blake Lake that merit special protection of aquatic habitat. Sensitive area A is located on the northern end of Big Blake Lake and covers approximately 400 feet of shoreline and extends out as far as 100 feet, sensitive area B is located at the northeastern end of Big Blake Lake and covers approximately 400 feet of shoreline and extends out as far as 150 feet, and sensitive area C is located at the southeastern end of Big Blake Lake and the southwestern end of Little Blake Lake and encompasses the channel between the two lakes. [7]

Wild rice was documented in sensitive areas A and C. Big Blake Lake is recognized as a wild rice water in the Wisconsin Ceded Territory.[8]

Wild rice, white water lily, and yellow water lily in sensitive area A

[7] Blake and Little Blake Lake Sensitive Area Survey Report and Management Guidelines, Wisconsin Department of Natural Resources, 2000

[8] Wisconsin Ceded Territory Manoomin Inventory, GLIFWC Project Report, Peter David, 2010



Surface Water Data Viewer Map
Legend
PRF Sensitive Areas of Lakes
PRF Other Public Rights Featu
ASNRI Wild and Scenic Rivers
ASNRI Outstanding and Excep
ASNRI Trout Streams
ASNRI Wild Rice Streams
ASNRI Quality Wetland Strean
ASNRI Endangered Threatene Concern Streams
ASNRI Outstanding and Excep
ASNRI Quality Wetland Areas
ASNRI Wild Rice Areas
ASNRI Trout Spring Ponds
ASNRI Endangered Threatene Concern Areas
ASNRI State Natural Areas
PNW Musky Streams
PNW Sturgeon Streams
PNW Musky Areas
PNW Sturgeon Areas
PNW Walleye Areas
PNW Lakes Less Than 50 Acr
Notes
1: 15,840
N
0.5 0 0.25 0.5 Miles
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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 state standards. General assessments 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. Wisconsin waters are each assigned four uses (fish and aquatic life, recreation, public health and welfare, and wildlife) that carry with them a set of goals.

Impairment thresholds vary for each use and vary based on lake characteristics such as whether a waterbody is shallow versus deep and whether a waterbody is a drainage lake versus a seepage lake. Big Blake Lake is classified as a shallow drainage lake that does not stratify.[9]

Big Blake Lake was assessed during the 2016 listing cycle and proposed for listing for the pollutant total phosphorus and the impairment of excess algal growth. The general condition is suspected poor.

Total phosphorus sample data exceeded the 2016 Wisconsin's Consolidated Assessment and Listing Methodology (WisCALM) listing thresholds for recreation use (40 µg/L) but not for fish and aquatic life use (100 µg/L). Chlorophyll sample data exceeded the 2016 WisCALM listing thresholds for recreation use (30% of days in the sampling season have nuisance algal blooms with chlorophyll values greater than 20 µg/L) and fish and aquatic life use (60 µg/L).[10]

[9] Listing thresholds can be found in: Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM) Clean Water Act Section 305(b), 314, and 303(d) Integrated Reporting, Wisconsin Department of Natural Resources, September 2013

[10] http://dnr.wi.gov/water/waterDetail.aspx?key=16558

Previous Lake Studies

Past studies on Big Blake Lake include:

- ✓ Blake Lake Polk County Feasibility Study Results: Management Alternatives, Wisconsin Department of Natural Resources Office of Inland Lake Renewal, 1981
- ✓ Blake Lake Macrophyte Surveys and Management Plan, Barr Engineering, 1998
- ✓ Blake and Little Blake Lake Sensitive Area Survey Report and Management Guidelines, Wisconsin Department of Natural Resources, 2000
- ✓ 2004 Big Blake Lake Water Quality and Technical Report, Aquatic Engineering, Inc., 2005
- ✓ 2004 Big Blake Lake Aquatic Plant Survey Technical Report and Management Plan, Aquatic Engineering, Inc., 2005
- ✓ Aquatic Macrophyte Surveys, Polk County Land and Water Resources Department, 2006-2012

Blake Lake Polk County Feasibility Study Results: Management Alternatives, 1981

Office of Inland Lake Renewal, Wisconsin Department of Natural Resources

The Big Blake Lake Protection and Rehabilitation District was formed in 1976. In response, a study of Big Blake Lake and its watershed was initiated by the Office of Inland Lake Renewal, Wisconsin Department of Natural Resources (November 1978-October 1979).

The three main objectives of this study were to: define a nutrient budget, define a water budget, and characterize in-lake chemistry and biological processes for Big Blake Lake.

The following sources of phosphorus loading were identified and used to develop a nutrient budget:

- ✓ Surface runoff: 1,190 kg/yr, 90%
    - *Approximately 70% of this loading originated from the Straight River Watershed*
- ✓ Groundwater: 72 kg/yr, 5%
- ✓ Septic system leachate: 38 kg/yr, 3%
- ✓ Atmospheric deposition: 30 kg/yr, 2%

Additionally, the study determined that the net release of phosphorus from sediments was 149 kg during the study period. Data indicated that Big Blake Lake was over half full of sediment, with a maximum sediment thickness of 25 feet.

The study classified Big Blake Lake as a productive, eutrophic body of water based on total phosphorus, secchi depth, and chlorophyll a. Dissolved oxygen remained adequate throughout the winter months and thermal stratification was not recorded during the summer months. The nitrogen to phosphorus ratio was 13:1, indicating that phosphorus is the most important nutrient for limiting algae populations.

At the time of this study, Big Blake Lake contained a diverse group of macrophytes including eight submerged species, three emergent species, and six floating leaf species. With the exception of dense curly-leaf pondweed in the northwest portion of the lake, macrophyte densities were light to moderate through June. However, by August macrophyte densities were elevated in many areas of the lake with curly-leaf pondweed beds being replaced with coontail. Approximately 10% (25 acres) of Big Blake Lake was covered with aquatic macrophytes during the study.

Management alternatives suggested in this study include: improving the water quality of Big Round Lake, chemically removing phosphorus from the Straight River, diverting the Straight River south to White Ash Lake, controlling weeds with herbicides or harvesting, and dredging.

Blake Lake Macrophyte Surveys and Management Plan, 1998

Barr Engineering

In 1996 the Big Blake Lake District approached the Wisconsin DNR to discuss options for plant management. In response, the DNR suggested that the District complete a macrophyte survey and a macrophyte management plan for the lake. As a result, Barr Engineering completed macrophyte surveys during June and July 1997.

Macrophytes were surveyed using a series of 29 transects at approximately 500 foot intervals along the shoreline. Each transect was divided into depth categories of 0-1.5 feet, 1.5-5 feet, and 5-10 feet (or the maximum rooting depth), with four rake samples taken at each depth category.

The study determined that the total area of macrophyte growth was 122 acres (49% of the lake surface area) in June and 120 acres (49% of the lake surface area) in July. This compares with macrophyte growth covering only 25 acres (10% of the lake surface area) in 1979. In the 18 years between the two surveys, macrophyte coverage in Big Blake Lake increased by nearly 100 acres.

A total of 21 species were found in Big Blake Lake with approximately 8-9 species being found in each transect. In general, each plant had a low individual density, but because there were a large number of species found at each site, overall plant growth was moderate to high. The study determined that diversity was similar when comparing 1979 and 1997 data. In both June and July 1997, the diversity index was 0.89.

Curly-leaf pondweed, the only invasive plant located in the survey, was found in approximately 52% of the sample transects during June and approximately 48% of the sample transects during July. In general, densities remained low, although occasionally curly-leaf pondweed was found at higher densities. The study indicated that native species were relatively successful in competing with curly-leaf pondweed.

Barr Engineering also surveyed members of the Big Blake Lake District to determine: resident understanding of functions and values of aquatic plants, uses of the lake, perceived impairment of lake uses by aquatic plants, and aquatic plant management preferences. Seventy-seven responses were received (31% response rate).

The primary uses for Big Blake Lake were fishing (94%), viewing (82%), swimming (70%), powerboating (47%), and canoeing (43%). The primary use impairments caused by plants were swimming (62%) and fishing (60%). Over half of respondents (56%) had removed or attempted to remove plants around their docks or along their shorelines. More respondents were opposed to the use of chemicals to remove aquatic plants from the lake (39%) as compared to mechanical harvesting of plants (23%). Over half of respondents (57%) indicated that the District should not own and operate a weed harvester. Most respondents (88%) recognized that aquatic plants have value, with high levels of importance for fish shelter and high to medium levels of importance for fish food.

The six aquatic plant management goals developed for Blake Lake included:

- Improve navigation within the lake through areas containing dense plant beds
- Remove or limit current exotic plants (i.e. curly-leaf pondweed)
- Preserve native species and prevent introduction of additional exotic species
- Preserve and/or improve fish and wildlife habitat
- Protect and/or improve quality of the resources for all to enjoy (i.e., people, fish, wildlife)
- Minimize disturbance of sensitive areas (i.e. fish and wildlife)

The management plan developed for Big Blake Lake was based upon the need to: provide reasonable access to the lake for residents living adjacent to very dense plant growth, control curly-leaf pondweed growth, preserve the current macrophyte community, and prevent the introduction of additional invasive species to Big Blake Lake.

The resulting management plan included:

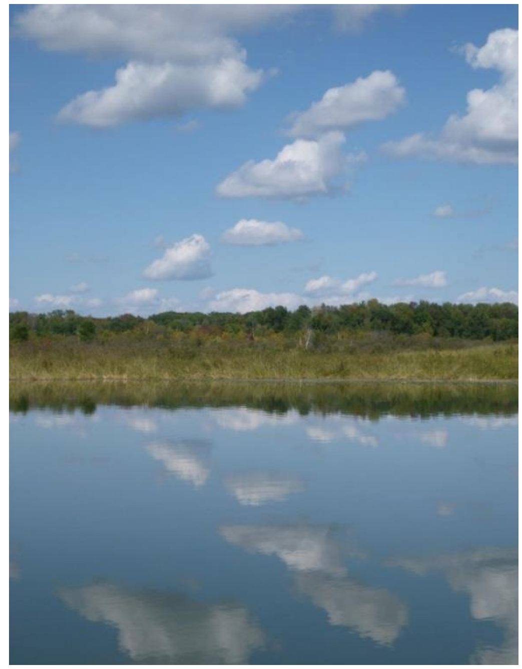
- A harvesting plan for approximately 5 acres, with channel width restricted to 20 feet
- Herbicide treatment for approximately 60 acres of curly-leaf pondweed
- Education programs to increase understanding of the function and roles of native plant communities and the threat that invasive species pose
- A plan to control the introduction of invasive species including: boat inspections; littoral area inspections; informational meetings; and boat launch signage, bulletin boards and brochures with educational information
- Evaluation program to monitor the effectiveness of the plan and resurvey the plant community every five years

Blake and Little Blake Lake Sensitive Area Survey Report and Management Guidelines, 2000
Wisconsin Department of Natural Resources
A lake sensitive area survey was completed on Big Blake Lake on August 17th, 2000. The report indicated three sensitive areas in Big Blake Lake.

Sensitive area A is located at the northern end of Big Blake Lake and covers approximately 400 feet of shoreline and extends out as far as 100 feet. The area encompasses the alder thicket and open/shallow water wetland area north of the boat launch. The majority of the shoreline in this area is considered "wild" with little or no development and high scenic beauty.

Sensitive area B is located at the northeastern end of Big Blake Lake and covers approximately 400 feet of shoreline and extends out as far as 150 feet. The majority of the length is dominated by a shallow or open water wetland which has protected the area from the negative impacts of improperly developed shorelines.

Sensitive area C is located at the southeastern end of Big Blake Lake and the southwestern end of Little Blake Lake and encompasses the channel between the two lakes. The majority of the length is dominated by deep marsh and shallow or open water wetland which has protected the area from the negative impacts of improperly developed shorelines. However, some developed shorelines with minimal buffers do exist in the area. It is recommended that these shorelines should create suitable vegetative buffers for approximately 35 feet.


Sensitive Area A, north end of Big Blake Lake

All three sensitive areas provide important habitat for bass, panfish, and northern pike spawning and nursery areas; forage species; and wildlife. Additionally, loons, herons, waterfowl, songbirds, furbearers, turtles, and amphibians benefit from the valuable habitat in these sensitive areas.

Wild rice was documented in sensitive areas A and C and should be allowed to proliferate.

The report recommended that chemical treatment and mechanical harvesting not be allowed in sensitive area A, and that these actions be limited to navigational channels in sensitive areas B and C.

2004 Big Blake Lake Water Quality and Technical Report, 2005
Aquatic Engineering, Inc.
In 2004, the District received a WDNR grant to collect physical and chemical water quality data, algae data, zooplankton data, and develop a phosphorus budget for Big Blake Lake. The final report was prepared by Aquatic Engineering, Inc.

Data indicated that Big Blake Lake was eutrophic and did not thermally stratify. The TN:TP ratio was approximately 12.5:1. In July and September the most common algae division was cyanophyta, or blue green algae. In August and September the zooplankton community was dominated by rotifers.

The Big Blake Lake watershed was determined as 798.37 acres and summed for each functional category. This study determined the largest land uses in the Big Blake Lake Watershed as forest (385.8 acres) and grassland (144.6 acres).[11]

Using the Wisconsin Lake Modeling Suite (WiLMS), it was determined that the most likely total annual phosphorus load to Big Blake Lake was 808 kg. This value includes 712 kg/year as point source load and 96 kg/year as non-point source load, but does not include internal loading or groundwater interactions. The study determined that the single largest load in 2004 came from the Straight River (85% of the total load or 703.7 kg/year).

[11] This study indicated that the Big Blake Lake Watershed was 798.37 acres in size. However, when all the land uses in the watershed are added the total equals 895.3 acres. Removing the lake surface area of 230 acres does not alleviate the discrepancy in acreage.

To improve the water quality of Big Blake Lake, the study recommended: public education and implementation of buffer strips and shoreline restoration, creating a committee to improve the Straight River Watershed, working with Polk County and towns as they create land use and zoning regulations, collecting in-lake data, reducing curly-leaf pondweed biomass, and adopting and implementing the 2005 Aquatic Plant Management Plan goals and recommendations.

2004 Big Blake Lake Aquatic Plant Survey Technical Report and Management Plan, 2005
Aquatic Engineering, Inc.
A second grant was awarded to the District to assess aquatic macrophytes and macroinvertebrates in conjunction with the water quality study. Project activities included an assessment of riparian land use, a lake resident survey, and updates to the current Lake Management Plan. The final report was prepared by Aquatic Engineering, Inc.

Macrophytes were surveyed in spring and summer using a series of thirty-four transects along the shoreline. Each transect was divided into depth categories of 0-1.5 feet, 1.5-5 feet, 5-10 feet, and 10 feet to the maximum rooting depth. Each sample area was divided into quadrants and sampled with a rake.

Seventeen species were identified in Big Blake Lake with 14 present in the spring and 12 present in the summer. The most common species found in the spring were curly-leaf pondweed (56.9%), coontail (16.9%), and flat stemmed pondweed (12.1%). The most common species in the summer were coontail (32%), flat stemmed pondweed (20.3%), and najas (13.1%).[12] The diversity value was 62.82 in the spring and 81.2 in the summer.

Curly-leaf pondweed was found at 87% of the sites sampled in the spring and 20% of the sites sampled in the summer.

Macroinvertebrates were collected in June and July at three different site conditions: curly-leaf pondweed dominated communities, moderate curly-leaf pondweed communities, and native plant communities. In general, diversity and richness did not differ significantly across sites.

At each point where the macrophyte transect intersected the shoreline, the riparian area was classified as natural or disturbed. Approximately three-fourths (79%) of the shoreline was classified as disturbed as compared to natural (21%).

A survey was distributed to all members of the District in the spring of 2005 to engage public participation and determine resident opinions and concerns. The survey had a 40% response rate (87 surveys completed out of 218). Over two-thirds of respondents (69%) were seasonal/part time residents. Respondents most frequently described their property immediately adjacent to the lake as mowed lawn leading to a pier. Over half (60%) of respondents felt that fertilizers and weed killer were not necessary to maintain lawns around the lake. Clear water received the most rankings as the issue of greatest importance. In the time since respondents have lived on Big Blake Lake, over half perceived the

[12] Percentages for frequency of occurrence, relative percent

following conditions to have worsened: nuisance weed growth, algae growth, noise, personal watercraft traffic, motor boat traffic, and muckiness of lake bottom.

The vast majority of respondents felt that overall there were too many plants in Big Blake Lake (87%), that there are areas in the lake where aquatic plants became especially problematic (86%), and that the current weed management program was not effectively controlling nuisance plant growth (89%).

Over half of respondents believed that recreational activities and lake uses were occurring that were seriously jeopardizing the health and safety of Big Blake Lake (52%) and were in favor of expanding slow-no-wake times and/or locations to promote safety and protect sensitive habitat areas (56%).

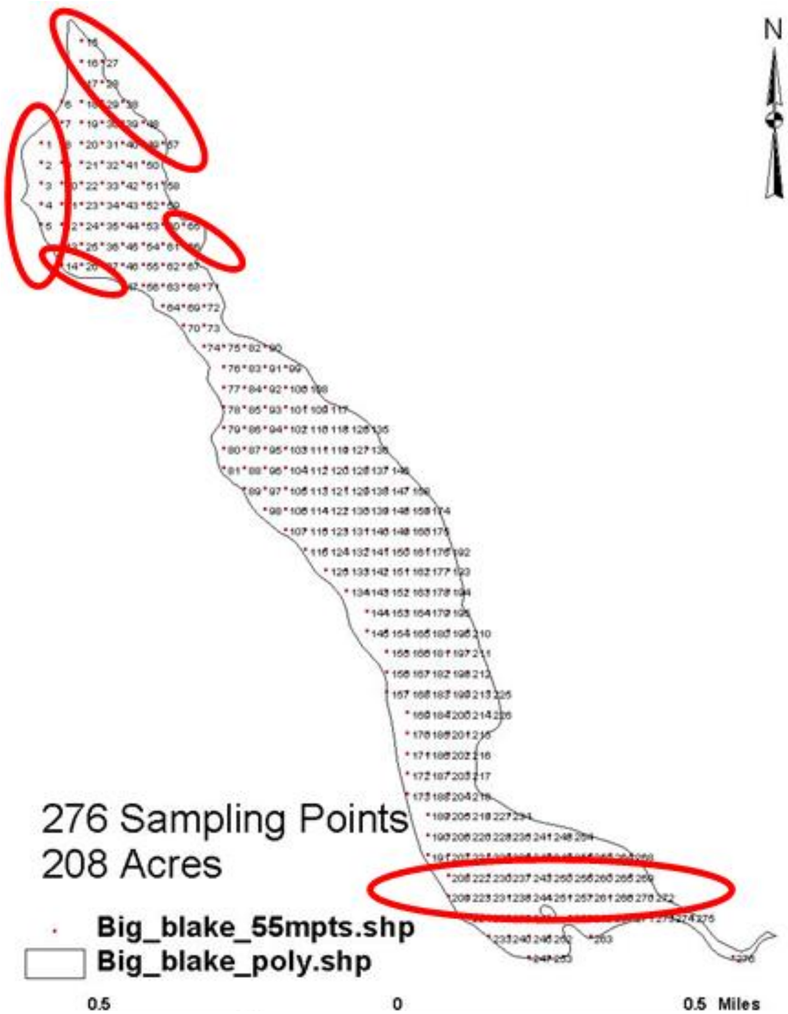
The study outlined an implementation plan for Big Blake Lake with immediate, short range, and long-range actions. Immediate actions included education campaigns to inform residents about the value of aquatic plants and what they can do to help improve water quality. Short-range actions included harvesting curly-leaf pondweed throughout the lake in the spring and native plants in designated navigational channels in the summer. Long range actions included improving water quality by implementing best management practices in the Straight River Watershed and promoting the growth of native plants in sensitive areas.

Aquatic Macrophyte Surveys, 2006-2012
Polk County Land and Water Resources Department
The Polk County Land and Water Resources Department has completed aquatic plant surveys on Big Blake Lake since 2006. The surveys completed in 2006 sampled 40 points with early establishment of curly-leaf pondweed and the surveys completed in 2008-2010 occurred in two intensive management areas. Full spring and fall point intercept surveys were completed in 2007, 2011, and 2012 with data being summarized in the "Point Intercept Aquatic Macrophyte Surveys" section of this report.

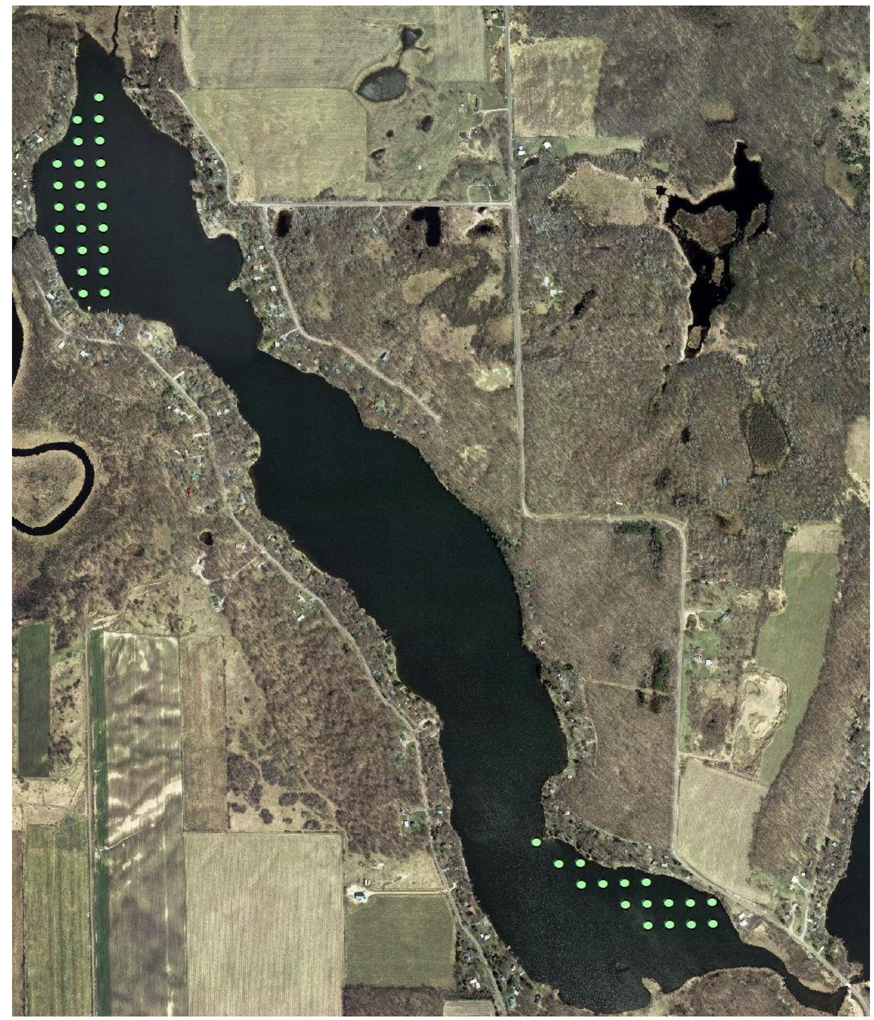

May 2008 plant survey, rake shows curly leaf pondweed and coontail

In 2006, 2008, 2009, and 2010 curly-leaf pondweed was the dominant species in the spring being found at 98%, 100%, 95%, and 88% (respectively) of the sites sampled. Coontail was the only other common species found in all three years. Flat stem pondweed was fairly common in spring and fall 2006 and small pondweed was fairly common in spring 2010. The dominance of curly-leaf pondweed is not surprising given that the sampling points were chosen based on the presence of this species.

From 2008-2010, the Simpsons Diversity Index ranged from a high of 0.79 in October 2009 to a low of 0.53 in August 2008. Species richness, or the number of species found (including visuals), ranged from a high of 14 species in June 2010 to a low of 6 species in June 2009.



2006 sampling points



2008-2010 sampling points

Fisheries

The most recent fisheries survey on Big Blake Lake was completed in 2009 and included netting and shocking surveys.

Over a time period of 13 net nights, the total catch was highest for bluegill (103 fish, average length of 6.86 inches) followed by pumpkinseed (31 fish, average length of 7.25 inches). Fewer numbers of black crappie (13 fish, average length of 6.90 inches), northern pike (11 fish, average length of 22.34 inches), muskellunge (8 fish, average length of 37.31 inches), walleye (4 fish, average length of 23.13 inches), largemouth bass (3 fish, average length of 11.75 inches), and yellow perch (2 fish, average length of 6.50 inches) were caught.

Electroshocking occurred over one mile of shoreline on Big Blake Lake. The total catch was highest for bluegill (394 fish, average length of 6.36 inches) and largemouth bass (254 fish, average length of 11.53 inches). Fewer numbers of pumpkinseed (38 fish, average length of 7.24 inches), black crappie (8 fish, average length of 8.88 inches), northern pike (8 fish, average length of 23.63 inches), green sunfish (7 fish, average length of 6.68 inches), muskellunge (2 fish, average length of 35.00 inches), and yellow perch (1 fish, average length of 8.75 inches) were shocked.

Lake Resident Survey

A Wisconsin Department of Natural Resources approved survey was mailed to two hundred seventeen property owners on Big Blake Lake in May 2014. One hundred twenty-six surveys were returned (58% response rate) and data was entered by volunteers and analyzed.

Survey respondents have owned their property on Big Blake Lake for an average of 21 years. One third of survey respondents (33%) use their property as a year-round residence. The majority of respondents use their property part time, either as a weekend, vacation, and/or holiday residence (56%) or as a seasonal residence (continued occupancy months at a time) (10%). On average, properties on Big Blake Lake are used 148 days per year and occupied by 3.6 people.

The survey asked respondents to describe the area measuring 35 feet inland (beginning at the water's edge, shoreland towards the road). Survey respondents indicated that the vast majority of properties (91%) on Big Blake Lake contain mowed lawn in the 35 foot buffer area. Fewer respondents indicated that this area of their property contained shrubs/trees (44%), un-mowed vegetation (38%), and undisturbed woods (15%). A small minority of property owners have installed best management practices such as shoreline restorations (9%) and rain gardens (3%) in this area. Around half of respondents indicated their property has a dock/pier (48%) and stabilizing rock/rip rap (42%).

The survey asked respondents which activities they enjoy on Big Blake Lake. Activities enjoyed by over three-fourths of respondents include: enjoying peace and tranquility (93%), enjoying the scenic view (89%), open water fishing (83%), motorized boating (80%), and observing birds and wildlife (79%). Swimming is enjoyed by nearly three-fourths of respondents (70%), non-motorized boating (canoe/kayak) and ice fishing are enjoyed by around half of respondents (47% and 45%, respectively), and jet skiing/wakeboarding/waterskiing are enjoyed by one-fourth of respondents (27%). Fewer respondents enjoy cross country skiing/snowshoeing (17%), snowmobiling (16%), hunting/trapping (8%), and sailing/wind surfing (1%).

Most respondents keep watercraft on their property for use on Big Blake Lake, with only 7% of respondents noting that they do not have watercraft. Most survey respondents keep motorboats/pontoons on their property for use on Big Blake Lake. Nearly half of respondents keep motorboats/pontoons that are 21-50 HP (46%), approximately one-third keep motorboats/pontoons that are more than 50 HP (36%), and approximately one-fourth keep motorboats/pontoons that are 1-21 HP (26%). Nearly half of survey respondents keep canoes/kayaks and paddleboats/rowboats on their property (46% and 44% respectively). Fewer respondents keep jet skis (12%) and sailboats (3%) on their property for use on Big Blake Lake.

In an effort to quantify risk of spreading aquatic invasive species, survey respondents were asked if the watercrafts they use on Big Blake Lake are used on other waterbodies. Approximately one-fourth (23%) of boats kept on Big Blake Lake are used on other waterbodies.

Respondents were asked to rank their degree of concern with fifteen issues as high, medium, low, issue exists but isn't a concern, and issue doesn't exist. Responses for this question were analyzed using a point system. Each issue ranked as high received 4 points, as medium received 3 points, as low received 2 points, as exists but not a concern 1 point, and as not an issue received 0 points. Total points were averaged to determine a final rank.

Issues with a final ranking of medium concern included: excessive aquatic plant growth, expansion of current invasive species (curly-leaf pondweed), excessive algae blooms, decrease in overall lake health, lack of water clarity or quality, new invasive species entering the lake, and increased nutrient pollution. The remaining issues ranked as low concerns.

What is your degree of concern with each issue listed below?	**Rank**
Excessive aquatic plant growth	3.4
Expansion of current invasive species (curly-leaf pondweed)	3.4
Excessive algae blooms	3.4
Decrease in overall lake health	3.3
Lack of water clarity or quality	3.3
New invasive species entering the lake	3.3
Increased nutrient pollution	3.2
Decreased property values	2.9
Decreased fisheries	2.7
Unsafe use of motorized water craft	2.6
Loss of natural scenery/beauty	2.5
Disregard for slow-no-wake zones	2.4
Increased development	2.3
Decreased wildlife populations	2.2
Excessive noise level on the lake	2.1

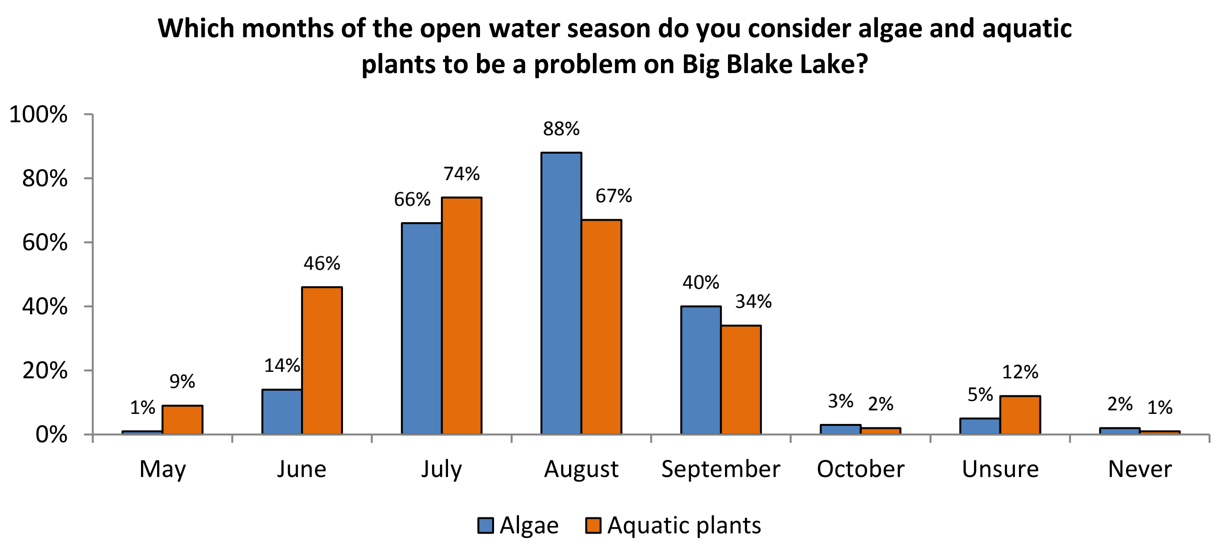
The survey was mailed out to members of the Big Blake Lake Protection and Rehabilitation District just after the dam on the outlet blew out in May 2014. As a result, when the survey was mailed out water levels on Big Blake Lake were below average. Not surprisingly, at the time of the survey the majority of respondents (81%) described the lake level as too low.

Over half of respondents described the current water quality of Big Blake Lake as fair (54%). More respondents described the current water quality as good (26%) compared to poor (14%). Respondents were more divided in describing how the water quality has changed since they've lived on Big Blake Lake. In general, more respondents described water quality as degrading in the time they'd lived on the lake (42%) as compared to improving (27%). However, approximately one-third of respondents (31%) were unsure how to describe the change or described the lake as unchanged.

The survey also asked a variety of questions regarding algae and aquatic plants. Respondents were asked to describe the amount of aquatic plants in Big Blake Lake, what months during the open water season algae and aquatic plants are a problem, and what uses are impaired as a result of algae and aquatic plants.

Algae are considered problematic by over three-fourths of respondents in August (88%), by two-thirds of respondents in July (66%), and by less than half of respondents in September (40%). A large majority of respondents indicated that swimming (92%) and overall enjoyment of the lake (84%) are limited by algae. Around half of respondents indicated that fishing (57%), boating (52%), and dogs/animals using the water (46%) were limited by algae.

The majority of respondents described the amount of aquatic plants as too many (69%). Fewer respondents described a healthy amount of plants (29%) and too few plants (2%). Aquatic plants are considered problematic by three-fourths of respondents in July (74%), by two-thirds of respondents in August (67%), by half of respondents in June (46%), and by one-third of respondents in September (34%). Approximately three-fourths of respondents indicated that swimming (83%), overall enjoyment of the lake (72%), and boating (71%) were limited by aquatic plants. Fewer respondents felt that fishing (63%) and navigation (43%) were limited.



Curly-leaf pondweed is an invasive species that creates nuisance conditions in Big Blake Lake by forming dense beds of vegetation that interfere with lake uses in the spring. Nearly half of respondents (49%) indicated that they would definitely recognize this invasive species and nearly one-fourth of respondents (20%) indicated that they would probably recognize this species.

Survey respondents were divided in describing if the current aquatic plant management program is effectively controlling nuisance aquatic plant growth (not including algae). More respondents felt that the program was effective (40%) as compared to ineffective (27%), although a third of respondents (33%) weren't sure how to describe the program. In a related question, the survey asked how satisfied residents were with the current aquatic plant harvesting program. Nearly two-thirds of respondents were satisfied with the program (63%), one-fourth of respondents were unsure or neutral (25%), and a minority were dissatisfied with the program (12%).

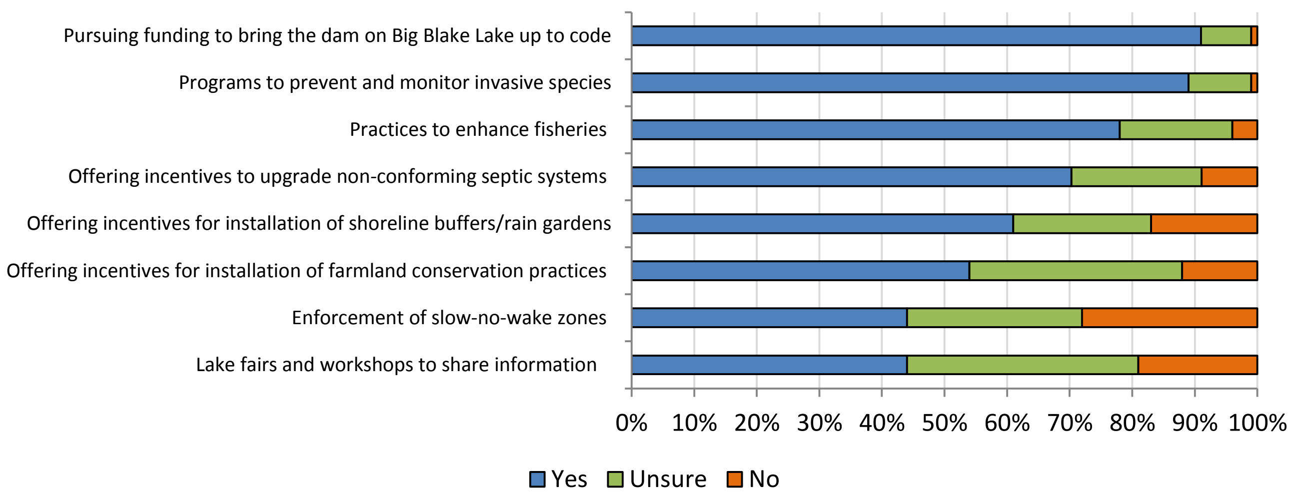
Earlier in the survey, 91% of respondents indicated that the area 35 feet back from their shoreline contained mowed lawn. Later, the survey asked respondents to describe the current amount of mowed lawn across the entire shoreline of Big Blake Lake. Nearly half of respondents described the amount of lawn as just right (47%), one-fourth described the amount of lawn as too much (24%), and another one-fourth were unsure (27%). Only 2% of respondents described the amount of lawn as not enough.

Overall the majority of respondents felt that shoreline buffers, rain gardens, and native plants were very important (37%) or somewhat important (34%) to the water quality of Big Blake Lake. A minority described them as not too important (10%) and not at all important (7%). However, earlier in the survey it was indicated that very few shoreline property owners had installed shoreline restorations and rain gardens (9% and 3%, respectively).

On a positive note, over half of respondents do not use fertilizer on their property (60%) and another one-third use zero phosphorus fertilizer (38%). A very small minority of respondents use fertilizer but are unsure of its phosphorus content (2%) or use multiple types of fertilizer that contain varying amounts of phosphorus (1%).

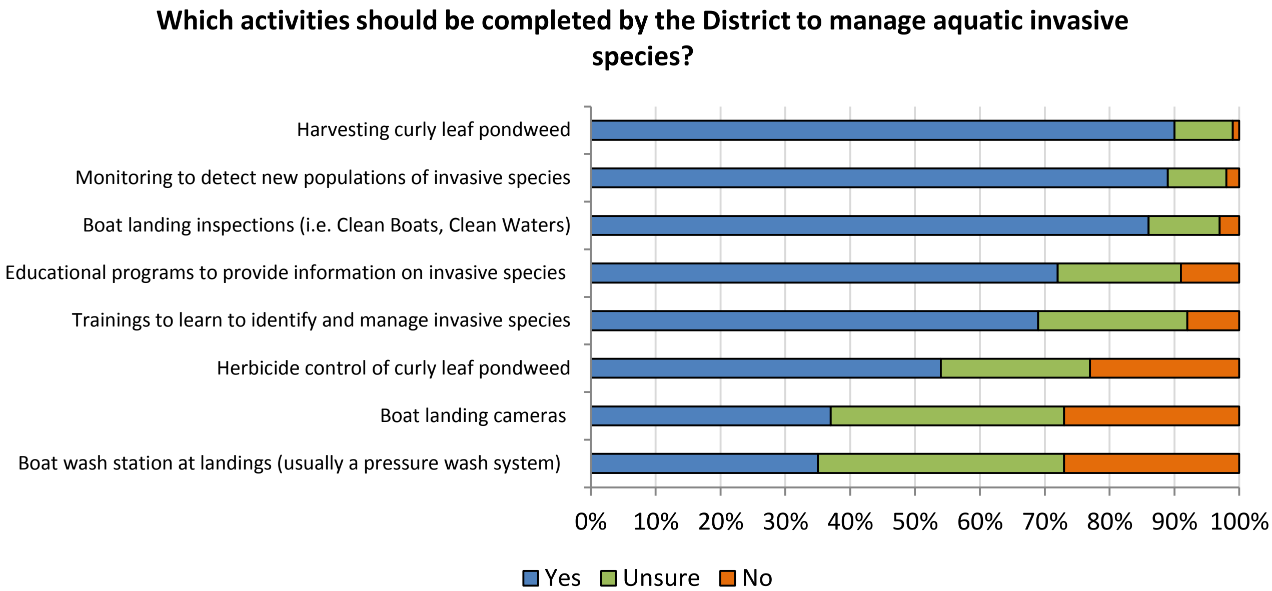
The survey asked respondents to indicate which actions should be completed by the District to manage Big Blake Lake. Over three-fourths of respondents supported: pursuing funding to bring the dam on Big Blake Lake up to code (91%), programs to prevent and monitor invasive species (89%), and practices to enhance fisheries (78%). Over half of respondents supported offering incentives for: upgrades to non-conforming septic systems (71%), installation of shoreline buffers/rain gardens (61%), and installation of farmland conservation practices (54%). Fewer respondents supported the enforcement of slow-no-wake-zones (44%) and lake fairs and workshops to share information (44%).

Which activities should be completed by the District to manage Big Blake Lake?



The survey also asked respondents to indicate which actions should be completed by the District to manage aquatic invasive species. Over three-fourths of respondents supported: harvesting curly-leaf pondweed (90%), monitoring to detect new populations of invasive species (89%), and boat landing inspections (86%). Over half of respondents supported: educational programs to provide information on invasive species (72%), trainings to learn to identify and manage invasive species (69%), and herbicide control of curly-leaf pondweed (54%).

Fewer respondents supported boat landing cameras (37%) and boat wash stations at landings (35%). However, over one-third of respondents were unsure if the District should pursue these opportunities, indicating a potential need for information and education regarding these management practices.



Survey respondents were asked how they prefer to receive information from the Big Blake Lake District. Respondents indicated that the most preferred method of communication was the newsletter (85%), followed by email (51%), and the annual meeting (40%). Only one-fourth of respondents preferred to receive information through websites (24%) and a small minority preferred Facebook (6%).

Over half of survey respondents were not aware of the Big Blake Lake District Facebook page (55%) and one-third of respondents never visit the page (32%). Fewer respondents rarely (9%), and sometimes (4%) visit the page.

The survey asked respondents which activities they were interested in participating in to improve Big Blake Lake. Around one-third of respondents were interested in learning to identify invasive species (36%), installing a shoreline buffer on their property (32%), and learning how to monitor for aquatic invasive species (29%). Approximately one-fourth of respondents were interested in learning how to monitor water quality (28%) and installing a rain garden on their property (28%). Fewer respondents were interested in serving on a committee to develop an action plan for improving Big Blake Lake (12%).

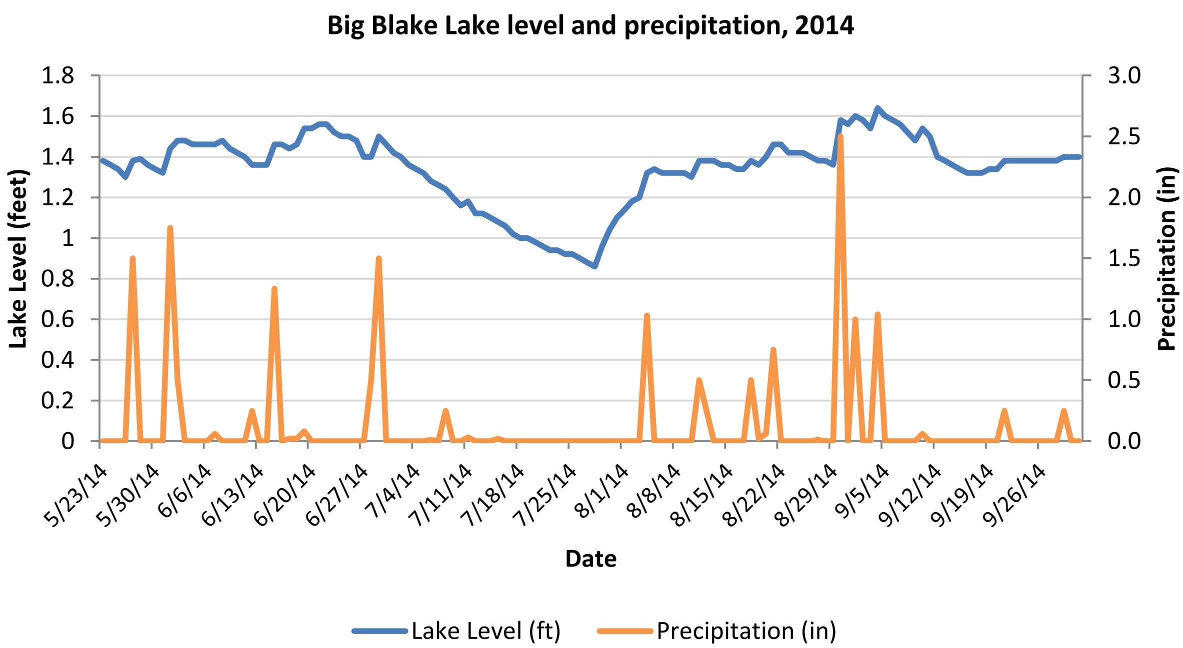
Lake Level and Precipitation Monitoring

Lake water-level fluctuations are important to lake managers, lakeshore property owners, developers, and recreational users because they can have significant impacts 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 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.

Volunteers monitored lake level and precipitation on Big Blake Lake in 2014 in response to the dam failure. Polk County Land and Water Resources Department provided training on data collection methods and installed staff and rain gauges. Monitoring began on May 23rd and continued through October 10th.

Seasonal precipitation on Big Blake Lake totaled 17.71 inches. Lake level did respond to precipitation events, with levels increasing following rainfall events. Lake levels were lowest on July 28th and highest on September 4th, with a variation of 0.78 feet.



Lake Mixing and Stratification: Background Information

Water quality is 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^{o}C (39^{o}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 more dense 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 the 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 turnover**.

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 based on temperature differences, called **stratification**.

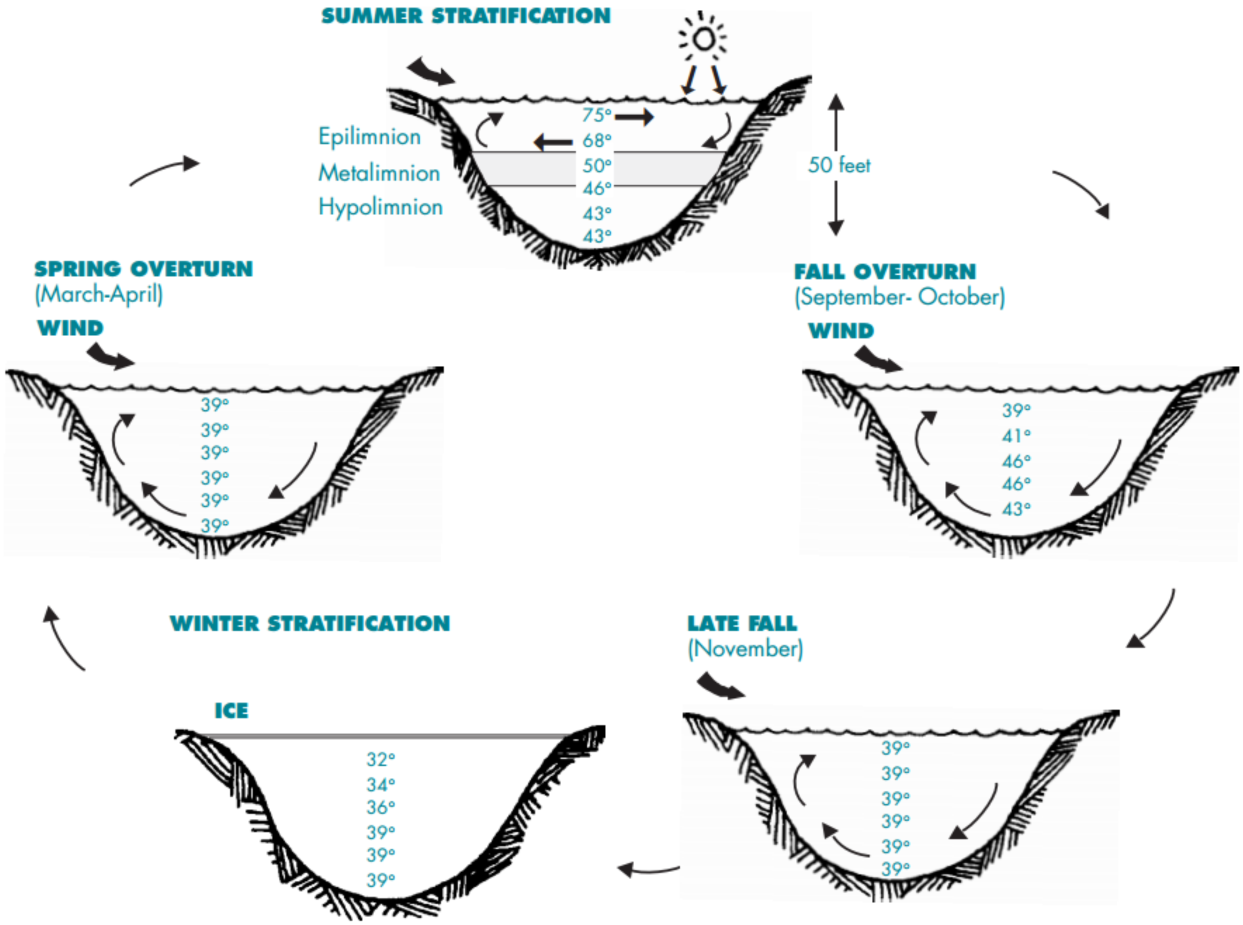
During the summer, lakes have the potential to divide into three distinct zones: the **epilimnion**, **thermocline** or **metalimnion**, and the **hypolimnion**. The epilimnion describes the warmer surface layer of a lake and the hypolimnion describes the cooler bottom area of a lake. The thermocline,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

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

Variations in density arising from differences in 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, since 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 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 especially bacteria is the primary way 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.



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[13] Figure from Understanding Lake Data (G3582), UW-Extension, Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004

Deep Hole Sampling Procedure

In-lake data were collected by the Polk County Land and Water Resources Department at the deep hole of Big Blake Lake at spring and fall turnover events and bi-weekly between the months of May through September from 2013-2015.

Lake profile monitoring

Dissolved oxygen, temperature, conductivity, specific conductance, and pH were recorded at meter increments with a Hanna Instruments 9828 multi-parameter probe.

Secchi depth

Secchi depth was recorded with an eight inch diameter round disk with alternating black and white quadrants called a secchi disk. To record secchi depth, the disk was lowered into the lake on the shady side of a boat until just before it disappeared from sight. This depth was measured in feet and recorded as the secchi depth. Data were collected biweekly to correspond with lake profile monitoring readings.

Chemistry and chlorophyll a

Top and bottom samples were collected once monthly with a Van Dorn sampler and analyzed at the Wisconsin State Lab of Hygiene. Top samples were analyzed for total phosphorus, soluble reactive phosphorus, nitrate/nitrite, ammonium, total Kjeldahl nitrogen, sulfate, total suspended solids, and chlorophyll a. Bottom samples were analyzed for total phosphorus and soluble reactive phosphorus.

Dissolved Oxygen

Oxygen is required by all aquatic organisms for survival. The amount of oxygen dissolved in water depends on 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.

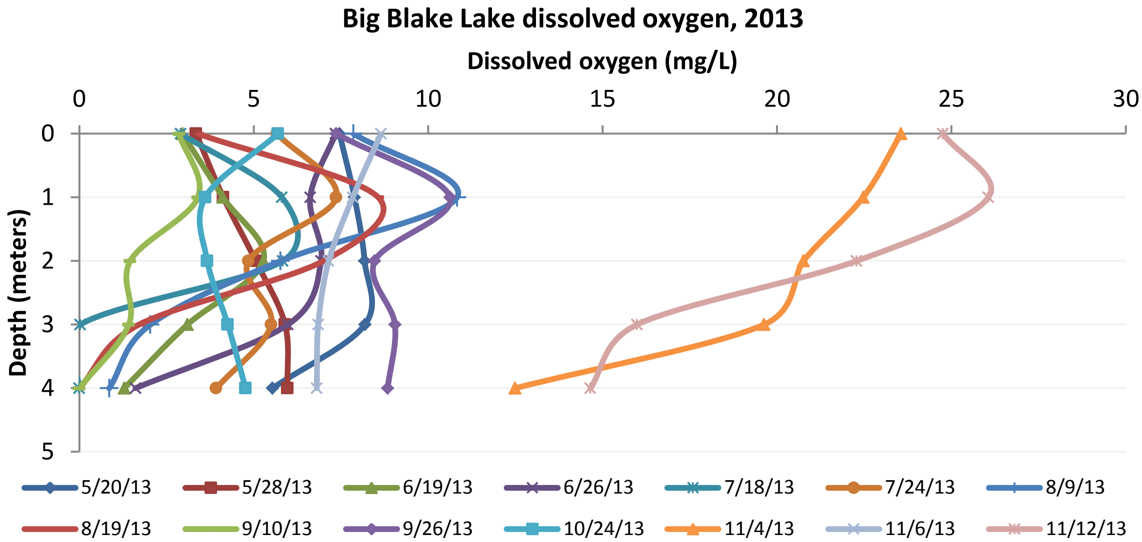
In a process called photosynthesis, plants use carbon, water, and the sun's energy to produce simple sugars and oxygen. Chlorophyll, the pigment in plants that captures the light energy necessary for photosynthesis, is the site where oxygen is produced. Since photosynthesis requires light, the oxygen 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.

Cold water has a higher capacity for oxygen than 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 be quite high. 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.

Dissolved oxygen levels at the surface of Big Blake Lake were below 5 mg/L on 15 of the 37 days data was collected. Dissolved oxygen levels at the surface were below 5 mg/L in July and July in 2013, 2014, and 2015.



Big Blake Lake dissolved oxygen, 2013
Dissolved oxygen (mg/L)
0
5
10
15
20
25
30
Depth (meters)
0
1
2
3
4
5
5/20/13
5/28/13
6/19/13
6/26/13
7/18/13
7/24/13
8/9/13
8/19/13
9/10/13
9/26/13
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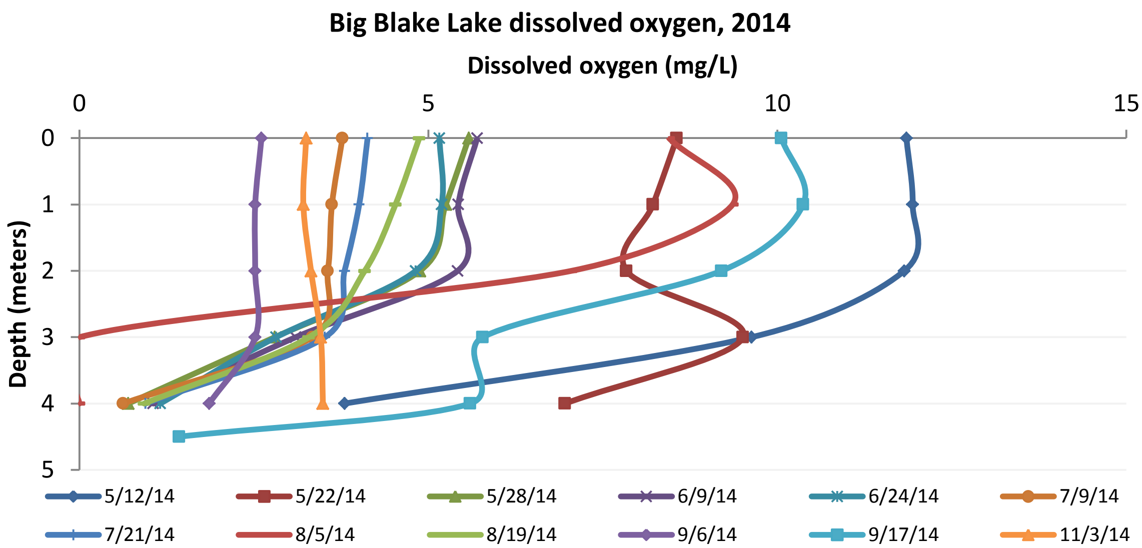
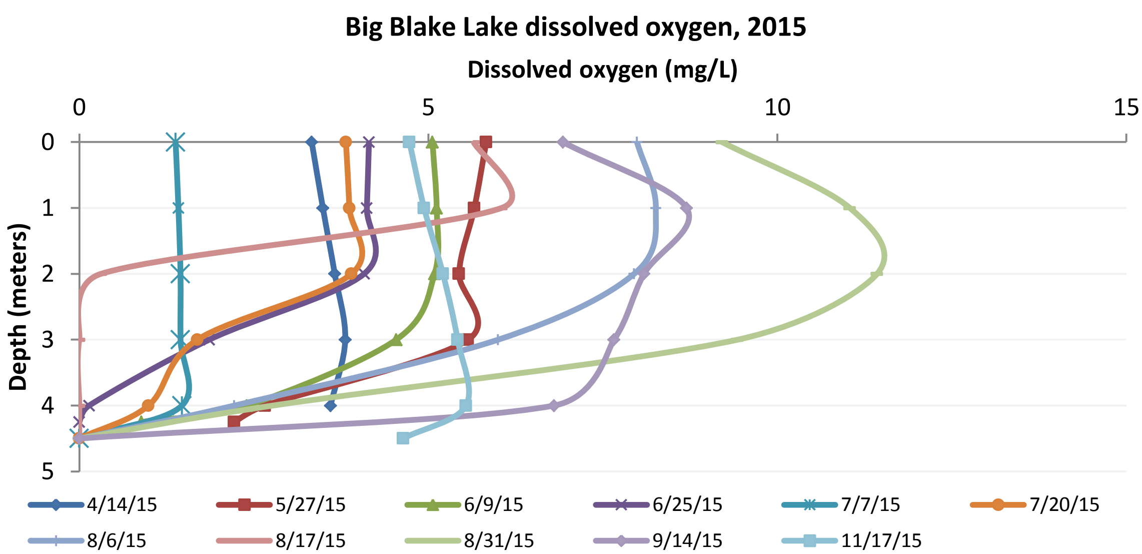
11/4/13
11/6/13
11/12/13



Big Blake Lake dissolved oxygen, 2014
Dissolved oxygen (mg/L)
0
5
10
15
Depth (meters)
0
1
2
3
4
5
5/12/14
5/22/14
5/28/14
6/9/14
6/24/14
7/9/14
7/21/14
8/5/14
8/19/14
9/6/14
9/17/14
11/3/14

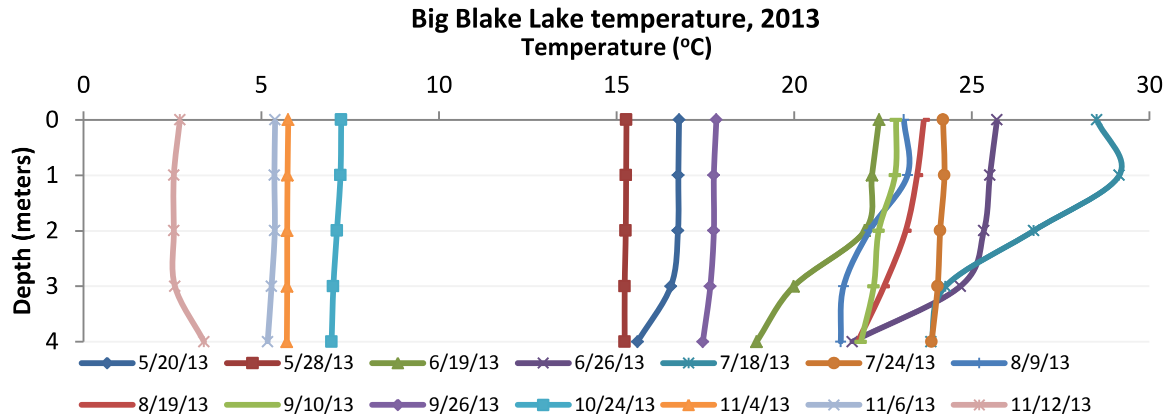


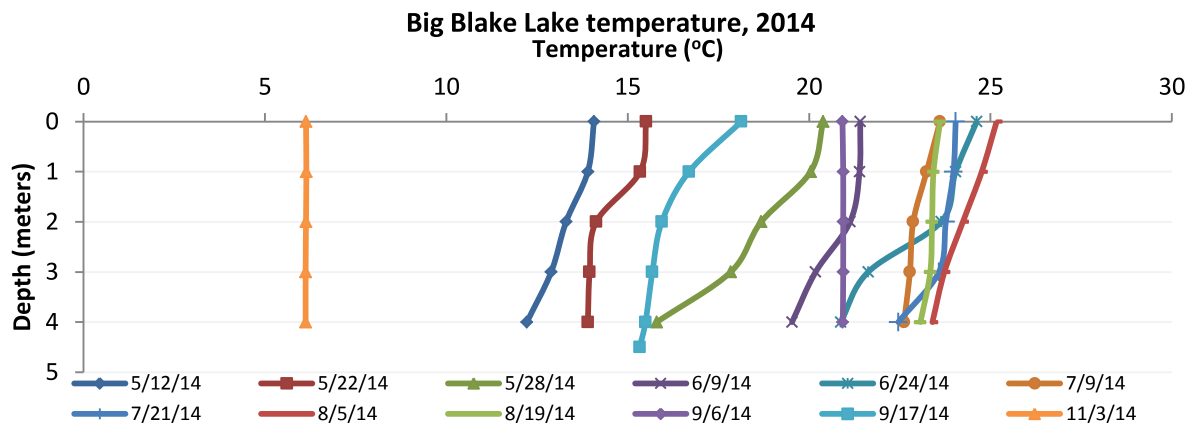
Big Blake Lake dissolved oxygen, 2015
Dissolved oxygen (mg/L)
0
5
10
15
Depth (meters)
0
1
2
3
4
5
4/14/15
5/27/15
6/9/15
6/25/15
7/7/15
7/20/15
8/6/15
8/17/15
8/31/15
9/14/15
11/17/15

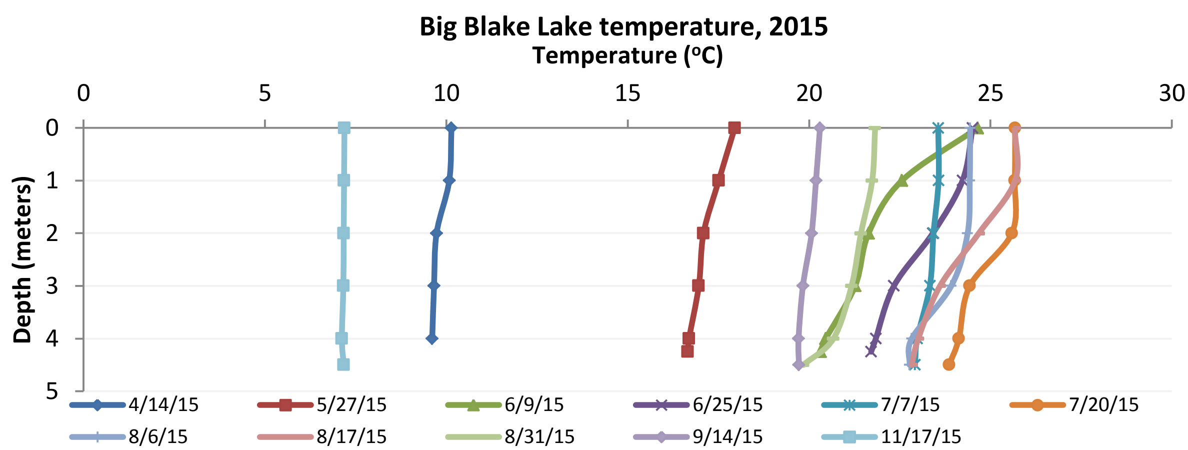
Temperature

Big Blake Lake reached its warmest surface temperature (28.52°C) on July 18th, 2013. In 2014, the warmest surface temperature recorded was 25.17°C on August 5th and in 2015 the warmest surface temperature recorded was 25.68°C on July 20th.

Big Blake Lake did weakly stratify, or set up density dependent layers, in all three sampling years. Generally stratification occurred in May, June, and July.



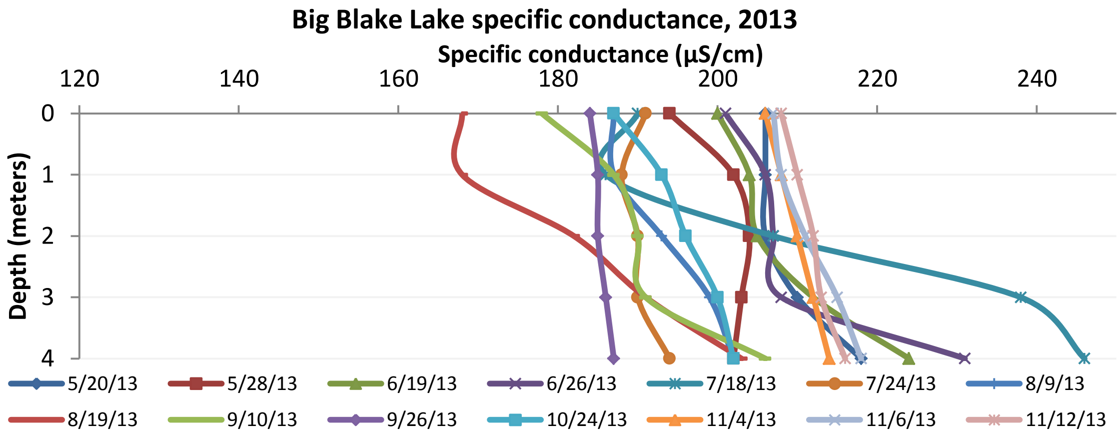


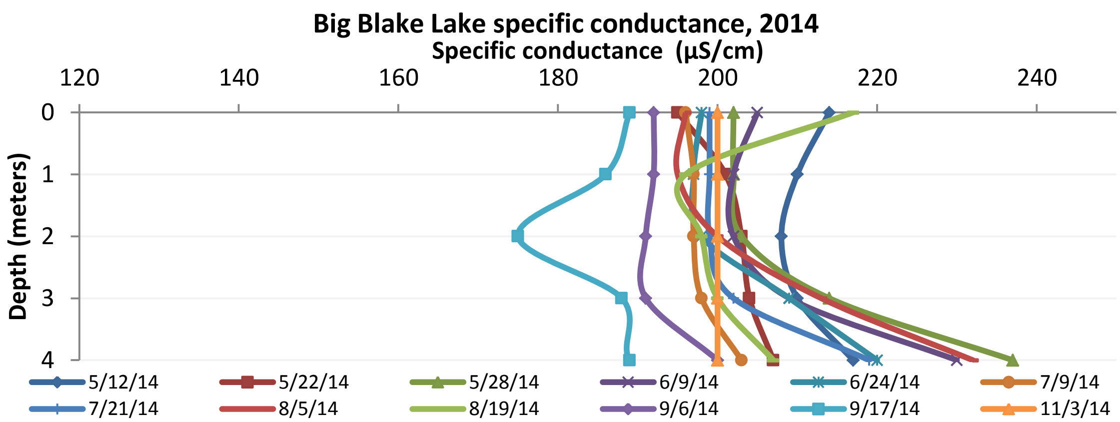


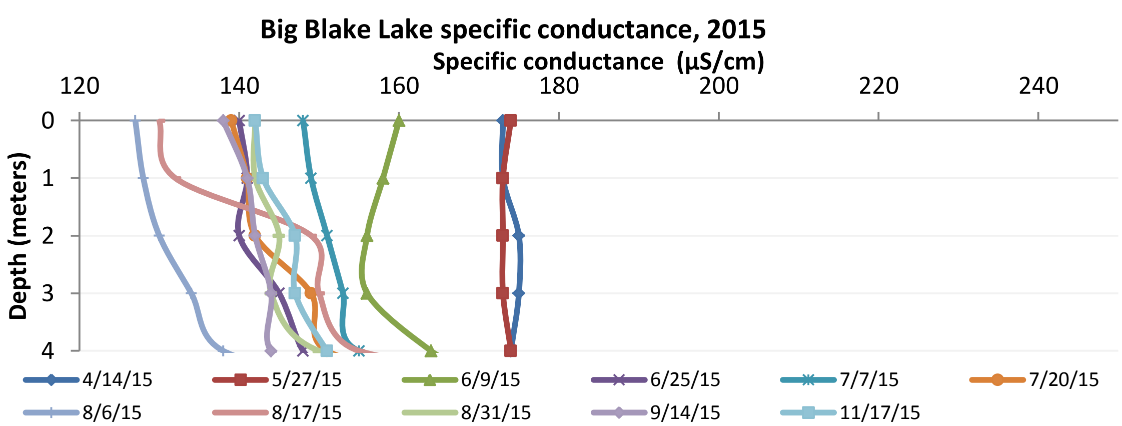
Specific Conductance (Conductivity)

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.

In general, specific conductance values were between 160 and 240 µS/cm in 2013 and 2014. However, in 2015 specific conductance values were much lower, falling between 130 and 180 µS/cm. Values generally increased towards the bottom of the lake and were highest in the spring/early summer.







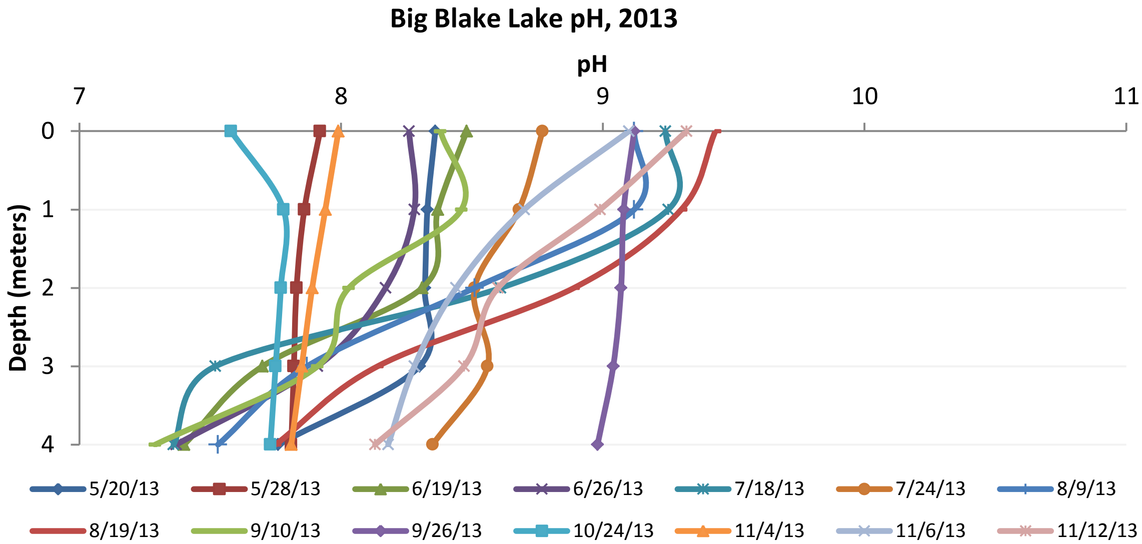
pH

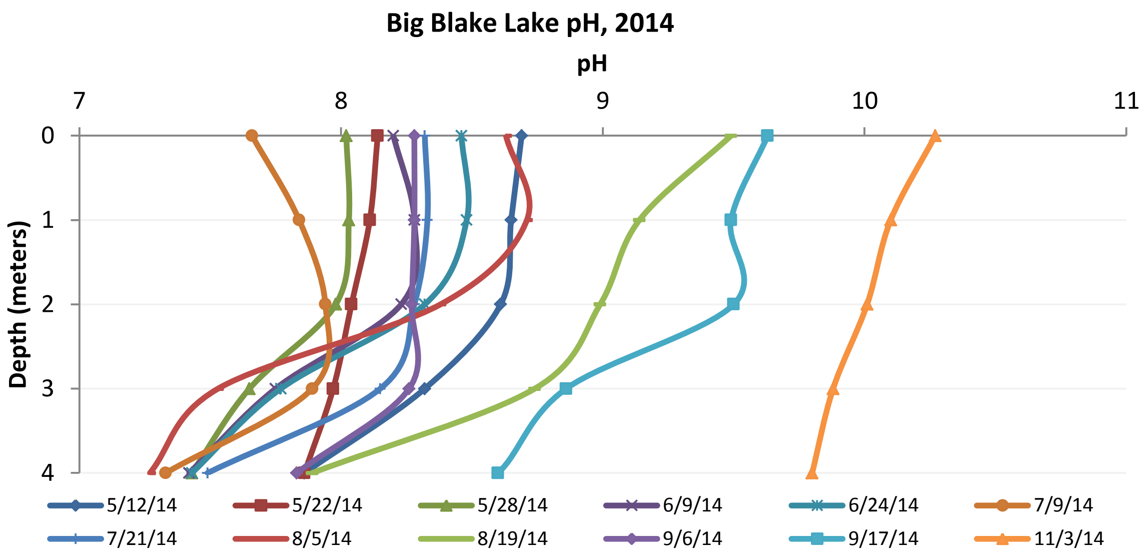
An indicator of acidity, pH is the negative logarithm of the hydrogen ion (H+) concentration. Lower pH waters have more hydrogen ions and are more acidic, and high pH waters have less hydrogen ions and are less acidic.

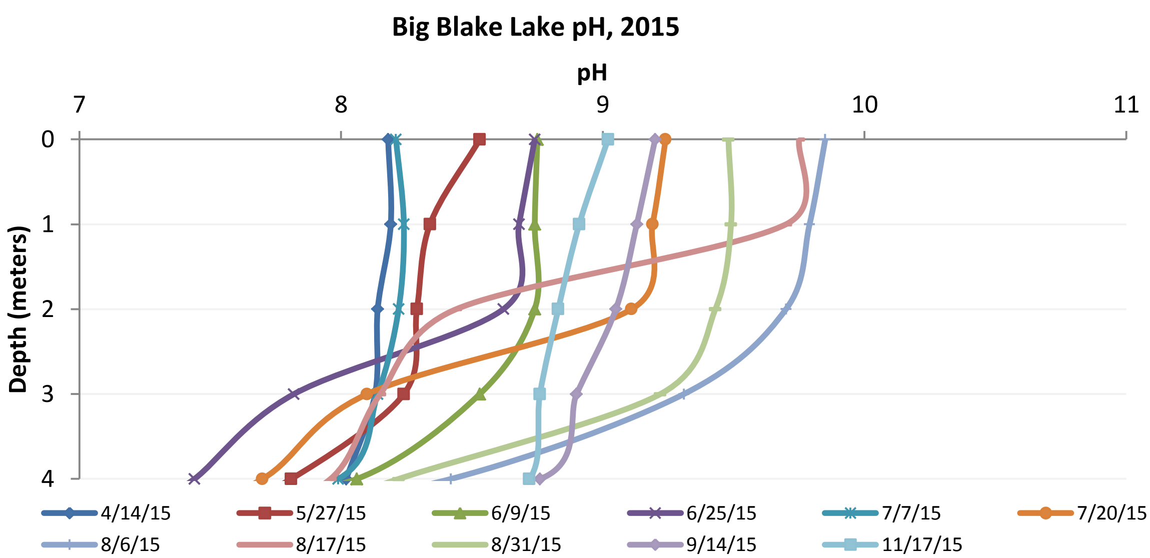
A pH value of seven is considered neutral. Values less than seven indicate acidic conditions; whereas, values greater than seven indicate alkaline conditions. A single pH unit change represents a tenfold change in the concentration of hydrogen ions. As a result, a lake with a pH value of eight is ten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

In general pH levels on Big Blake Lake were between 8 and 10, with values decreasing towards the bottom of the lake. Values for pH were highest in the late summer and early fall.


Big Blake Lake pH, 2013
pH
7
8
9
10
11
0
1
2
3
4
Depth (meters)
5/20/13
5/28/13
6/19/13
6/26/13
7/18/13
7/24/13
8/9/13
8/19/13
9/10/13
9/26/13
10/24/13
11/4/13
11/6/13
11/12/13


Big Blake Lake pH, 2014
pH
7
8
9
10
11
0
1
2
3
4
Depth (meters)
5/12/14
5/22/14
5/28/14
6/9/14
6/24/14
7/9/14
7/21/14
8/5/14
8/19/14
9/6/14
9/17/14
11/3/14


Big Blake Lake pH, 2015
pH
7
8
9
10
11
0
1
2
3
4
Depth (meters)
4/14/15
5/27/15
6/9/15
6/25/15
7/7/15
7/20/15
8/6/15
8/17/15
8/31/15
9/14/15
11/17/15

Secchi Depth

The depth 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.

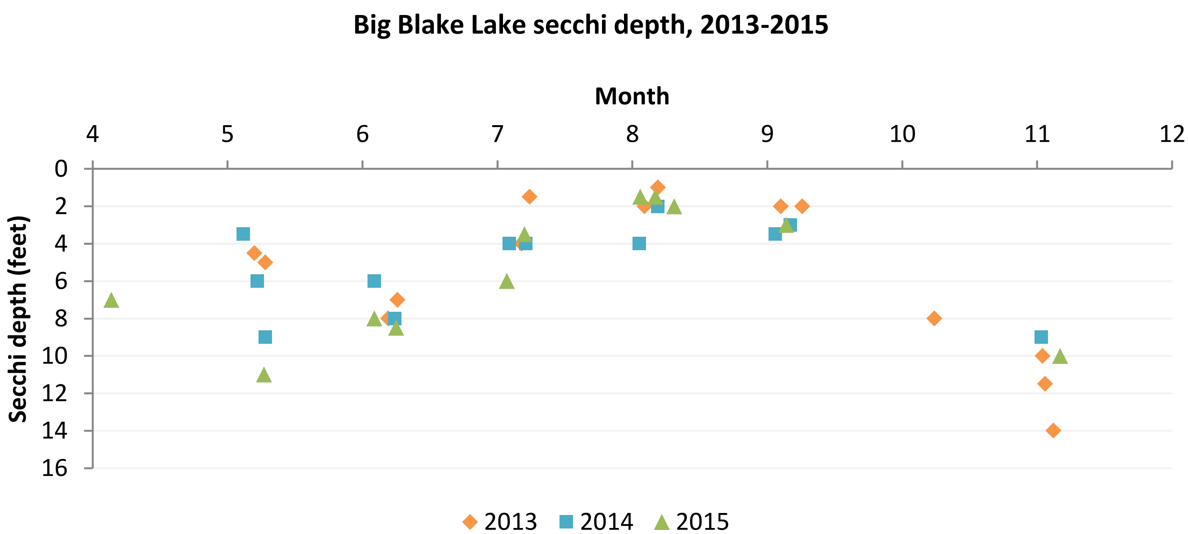
One method of measuring light penetration is with a secchi disk. A secchi disk is an eight inch diameter round disk with alternating black and white quadrants that is used to provide a rough estimate of water clarity. The depth at which the secchi disk is just visible is defined as the secchi depth.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

For the majority of the summer months (July through September) secchi depth was below 4 feet.

Secchi depth ranged from a low of one foot on August 19th, 2013 to a high of fourteen feet on November 12th, 2013.

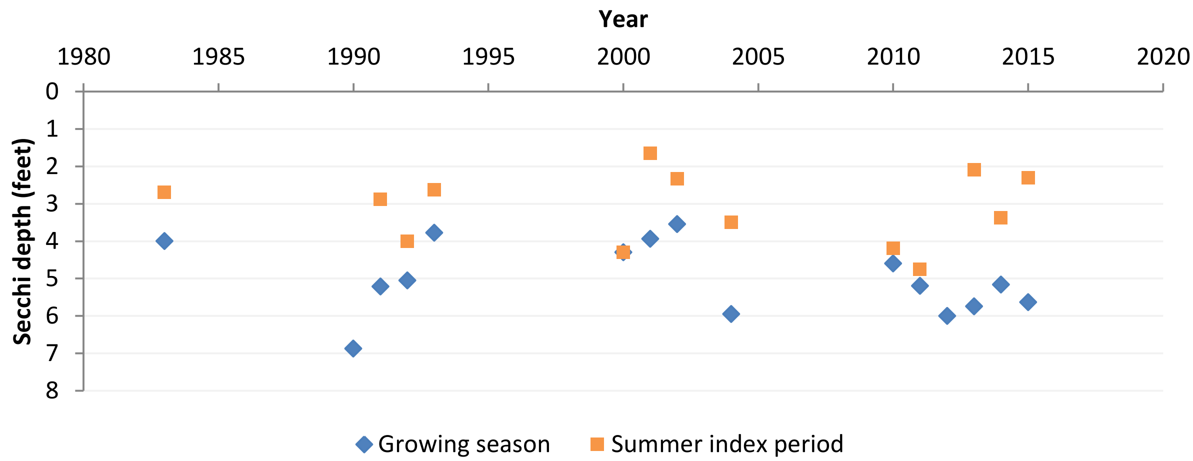
Growing season average secchi depth (April-November) was between five and six feet in all three sampling years (6 feet in 2013, 5 feet in 2014, and 6 feet in 2015).

Summer index period average secchi depth (July 15-September 15) ranged from two to three feet in all three sampling years (2 feet in 2013, 3 feet in 2014, and 2 feet in 2015).

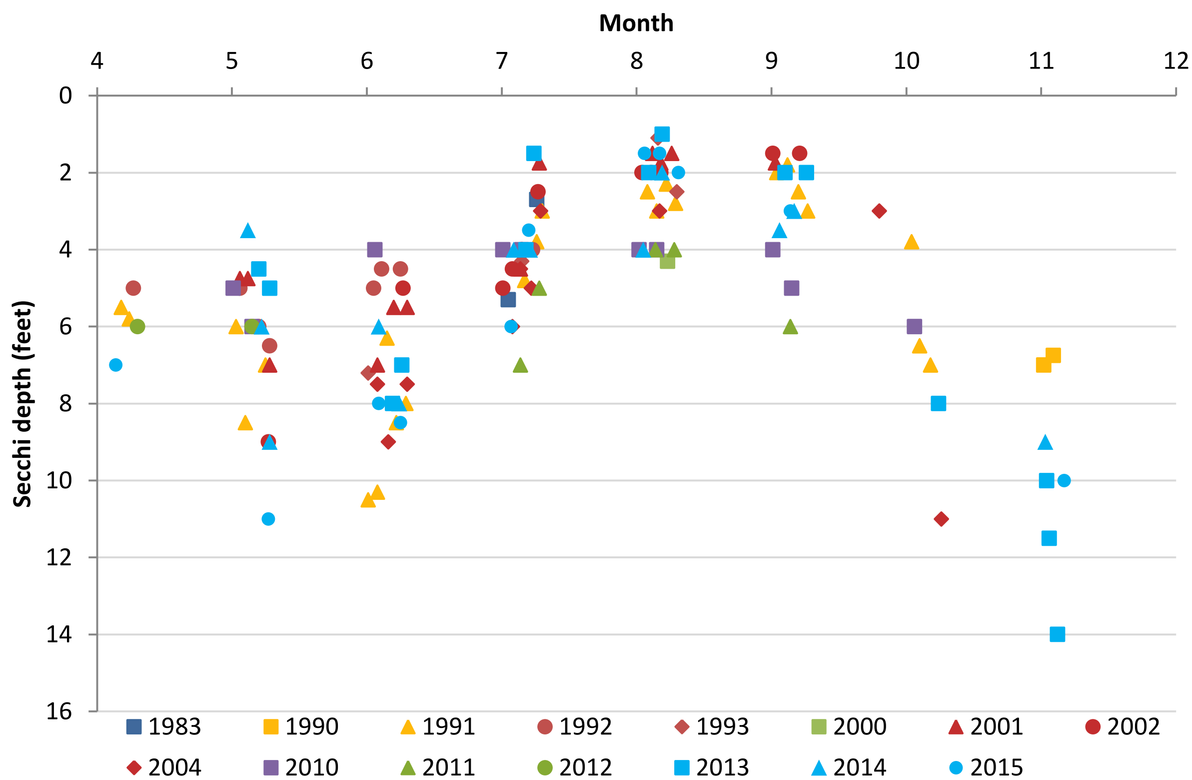


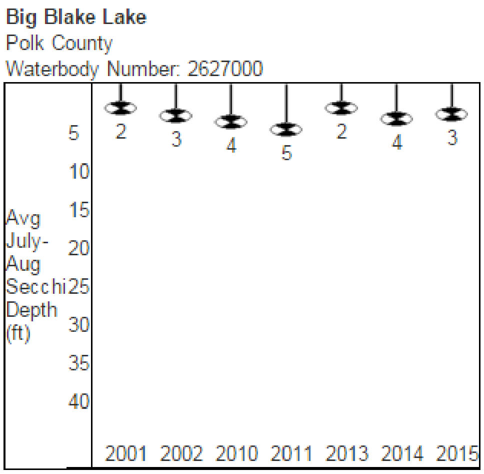
Average growing season and summer index period secchi depth has varied since 1983. In most years, the summer index period secchi depth was less than four feet. Over this same time period, secchi depth has been lowest in the months of July, August, and September.

Big Blake Lake average secchi depth, 1983-2015



Big Blake Lake secchi depth, 1983-2015





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

Year	Secchi Mean	Secchi Min	Secchi Max	Secchi Count
2001	2.2	1.5	4.5	5
2002	3.14	2	5	7
2010	4	4	4	4
2011	5	4	7	4
2013	2.13	1	4	4
2014	3.5	2	4	4
2015	2.9	1.5	6	5

The Wisconsin Department of Natural Resources website provides historic secchi depth averages for the months of July and August. This data exists for Big Blake Lake for 2001, 2002, and 2010-2015. Averages over this time period range from a low of 2 feet to a high of 5 feet.

Over the three years this study took place, average summer secchi depth (July-August) was 2.1 feet in 2013, 3.5 feet in 2014, and 2.9 feet in 2015.

The average summer secchi depth (July and August) for the Northwest geo-region was 8.6 feet in 2013, 8.5 feet in 2014, and 8.4 feet in 2015.

In all three years, secchi depth for Big Blake Lake was well below the Northwest georegion average.

Phosphorus

Phosphorus is an element present in lakes which is necessary for plant and algae growth. It occurs naturally in soil and rocks and in the atmosphere in the form of dust. Phosphorus can make its way into lakes through groundwater and human induced disturbances such as soil erosion. Additional sources of phosphorus inputs into a lake can include external sources such as fertilizer runoff from urban and agricultural settings and internal sources such as release from lake bottom sediments.

Phosphorus does not readily dissolve in water, instead it forms insoluble precipitates with calcium, iron, manganese, sulfur, and aluminum. If oxygen is available in the hypolimnion, 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 and phosphorus is redistributed throughout the water column with strong wind action or turnover events.

Phosphorus is necessary for plant and animal growth. Excessive amounts can lead to an overabundance of growth which can decrease water clarity and lead to nutrient pollution in lakes.

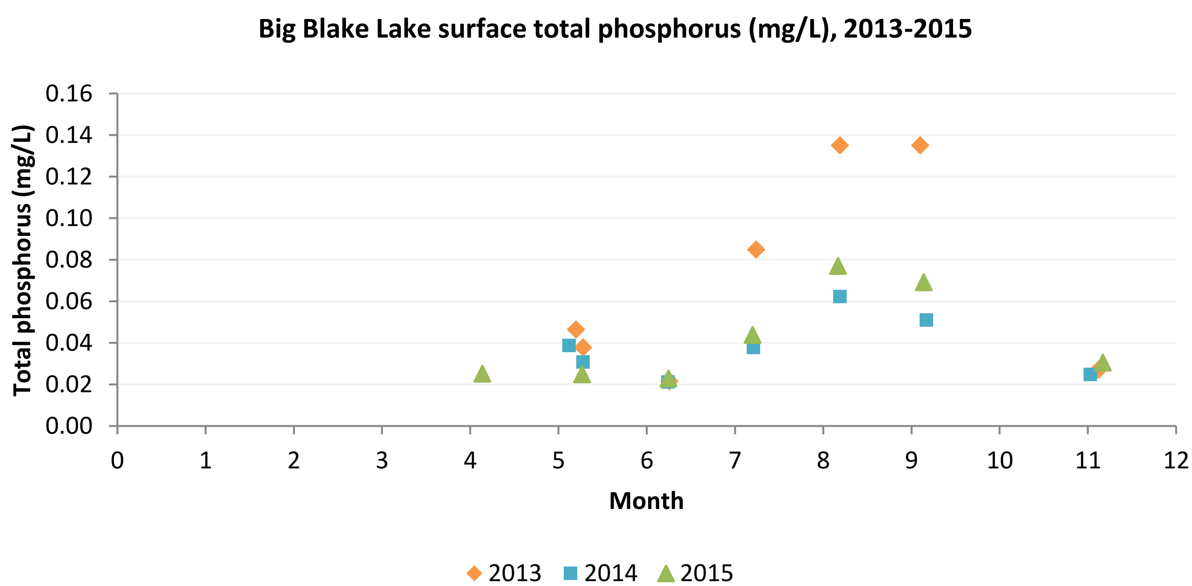
Total phosphorus (TP) is a measure of all the phosphorus in a sample of water. In many cases total phosphorus is the preferred indicator of a lake's nutrient status because it remains more stable than other forms over an annual cycle.

In lakes, a "healthy" limit of total phosphorus is set at 0.02 mg/L. If a value is above the healthy limit it is more likely that a lake could support nuisance algae blooms. Total phosphorus concentrations were above 0.02 mg/L on all twenty-one sampling dates.

Growing season average[14] surface total phosphorus exceeded the healthy limit in 2013 (0.08 mg/L), 2014 (0.04mg/L), and 2015 (0.05mg/L).

Summer index period average surface total phosphorus (July 15-September 15) exceeded the healthy limit in 2013 (0.12 mg/L), 2014 (0.05 mg/L), and 2015 (0.06mg/L).

Surface total phosphorus concentrations were approximately twice as high in 2013 as compared to 2014 and 2015. As the growing season progressed, a general trend of increasing phosphorus was evident through September. By November (fall turnover), total phosphorus levels had returned to what they had been in April/May (spring turnover). However, in 2013 and 2014 total phosphorus levels exhibited a slight decrease in June as compared to May, which would align with the time that harvesting of curly-leaf pondweed occurred. With warmers temperatures in 2015, harvesting began earlier (May) which may explain why total phosphorus levels remained fairly constant from April through June.

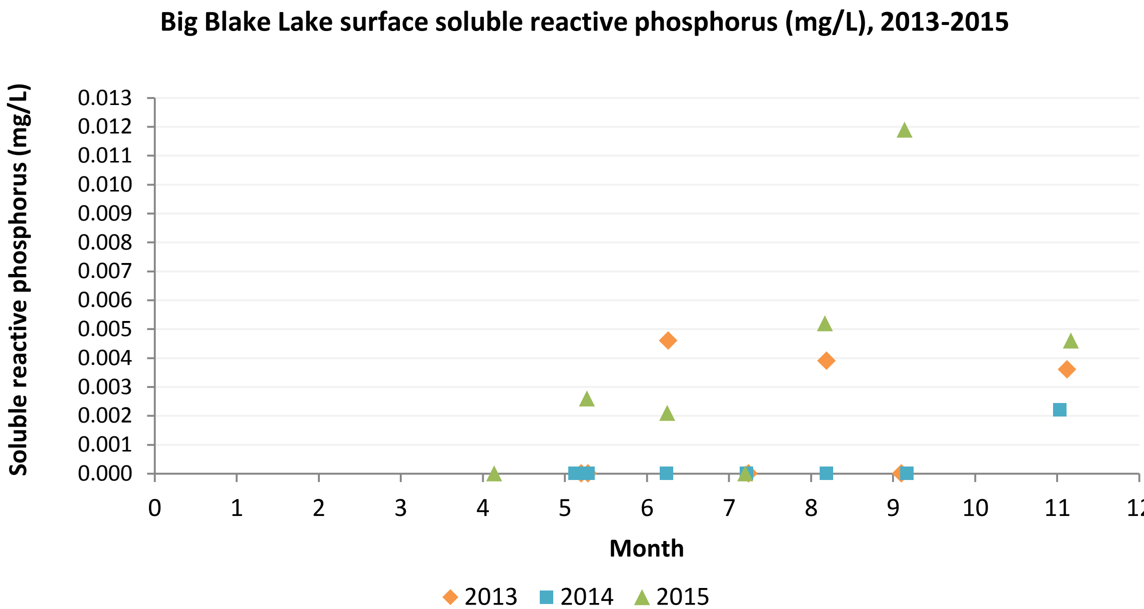


[14] Excludes turnover

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 soluble reactive phosphorus is set at 0.01 mg/L. If a value is above the healthy limit it is more likely that a lake could support nuisance algae blooms.

Surface soluble reactive phosphorus concentrations were below 0.01 mg/L on all sampling dates with the exception of September 14th, 2015. On twelve of the twenty-one dates where samples were taken (57%), soluble reactive phosphorus was below the limit of detection.[15] Soluble reactive phosphorus concentrations were the highest in 2015, with only one of the seven samples being below the limit of detection. Soluble reactive phosphorus concentrations were lowest in 2014, with only one of the seven samples being above the limit of detection.



[16]

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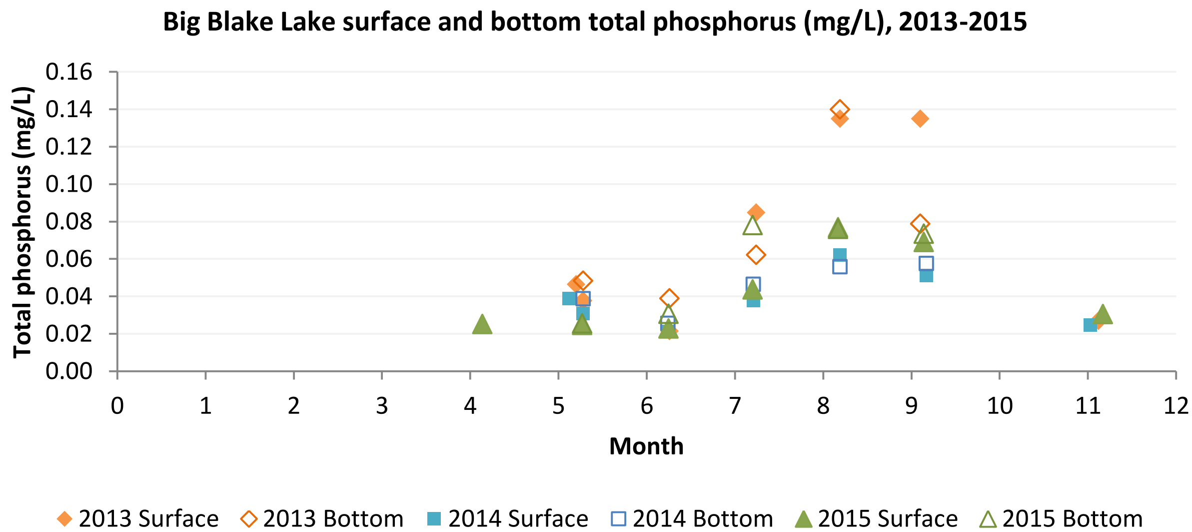
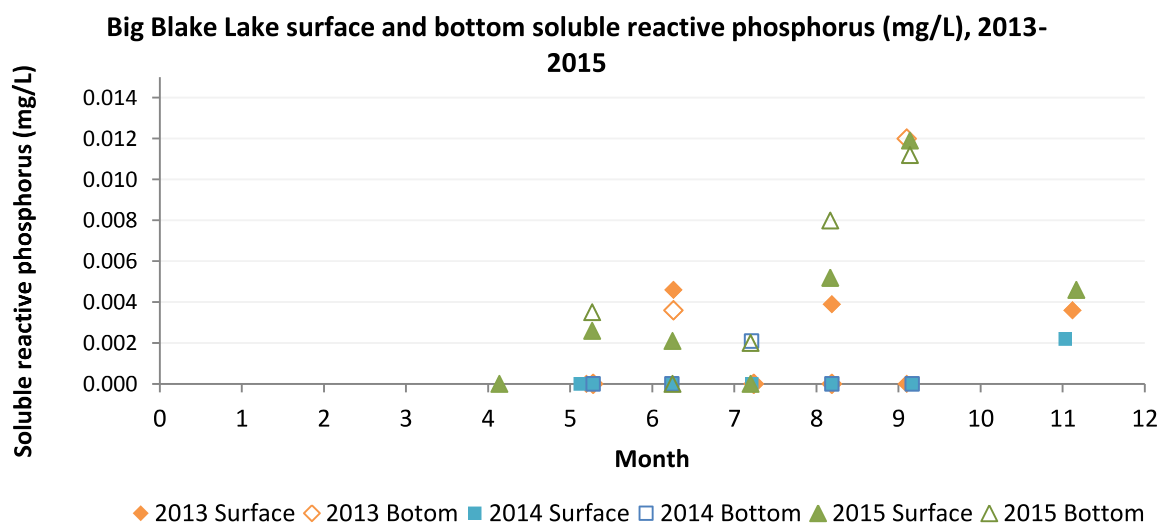
[15] Averages were not calculated for surface soluble reactive phosphorus because over half the samples were below the limit of detection

[16] Values of zero represent sample dates were soluble reactive phosphorus was below the limit of detection

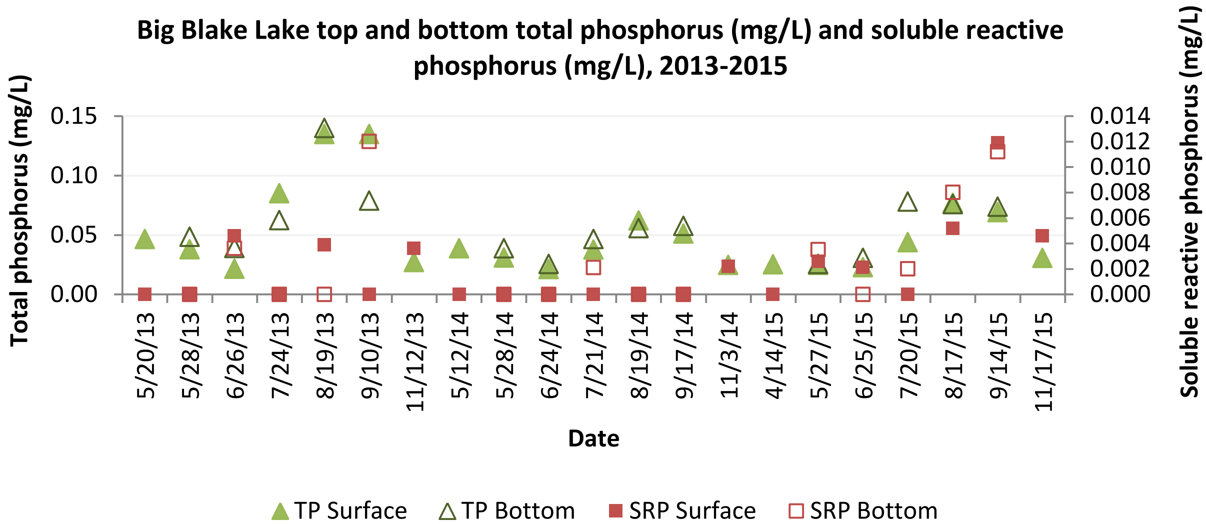
Bottom samples were also collected and analyzed for total phosphorus and soluble reactive phosphorus. Surface and bottom total phosphorus and soluble reactive phosphorus levels were fairly consistent, suggesting that Big Blake Lake is fairly well mixed.

Similar to the top samples, bottom samples for soluble reactive phosphorus were below the limit of detection on eight of the fifteen days where samples were taken (53%). On all but two sampling dates soluble reactive phosphorus concentrations were below 0.01 mg/L (September 10th, 2013 and September 14th, 2015).[17]





[17] Averages were not calculated for bottom soluble reactive phosphorus because over half the samples were below the limit of detection



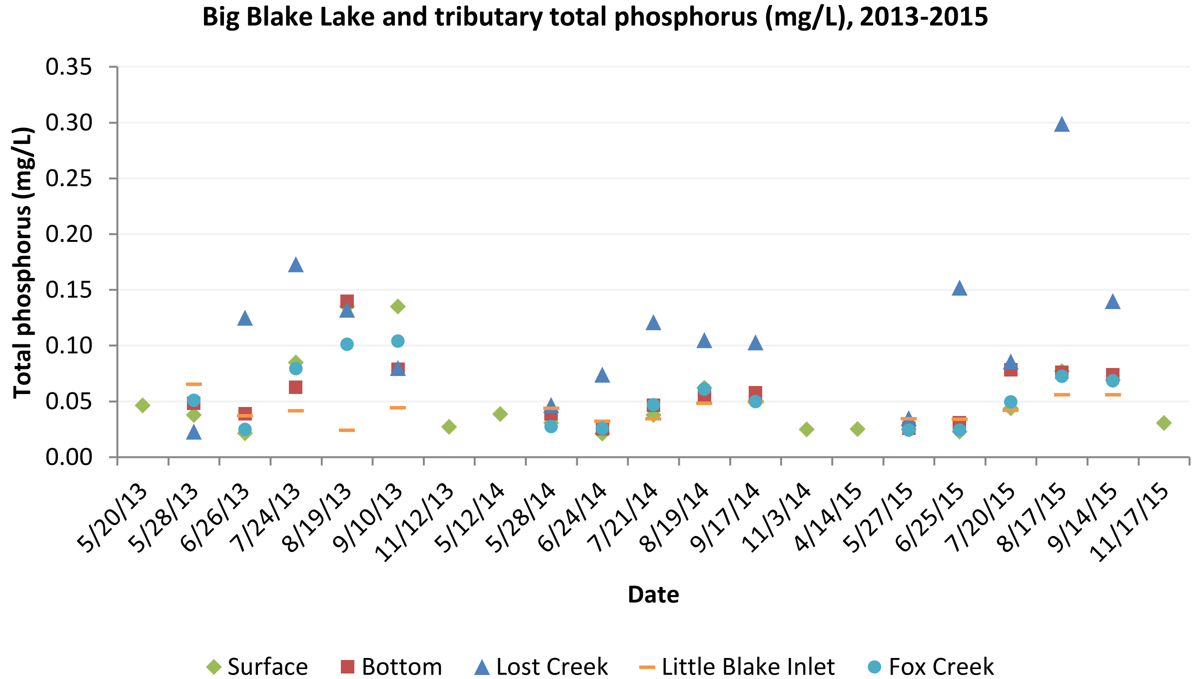
Big Blake Lake top and bottom total phosphorus (mg/L) and soluble reactive phosphorus (mg/L), 2013-2015
Total phosphorus (mg/L)
0.15
0.10
0.05
0.00
Soluble reactive phosphorus (mg/L)
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
5/20/13
5/28/13
6/26/13
7/24/13
8/19/13
9/10/13
11/12/13
5/12/14
5/28/14
6/24/14
7/21/14
8/19/14
9/17/14
11/3/14
4/14/15
5/27/15
6/25/15
7/20/15
8/17/15
9/14/15
11/17/15
Date
TP Surface
TP Bottom
SRP Surface
SRP Bottom

Tributary Phosphorus

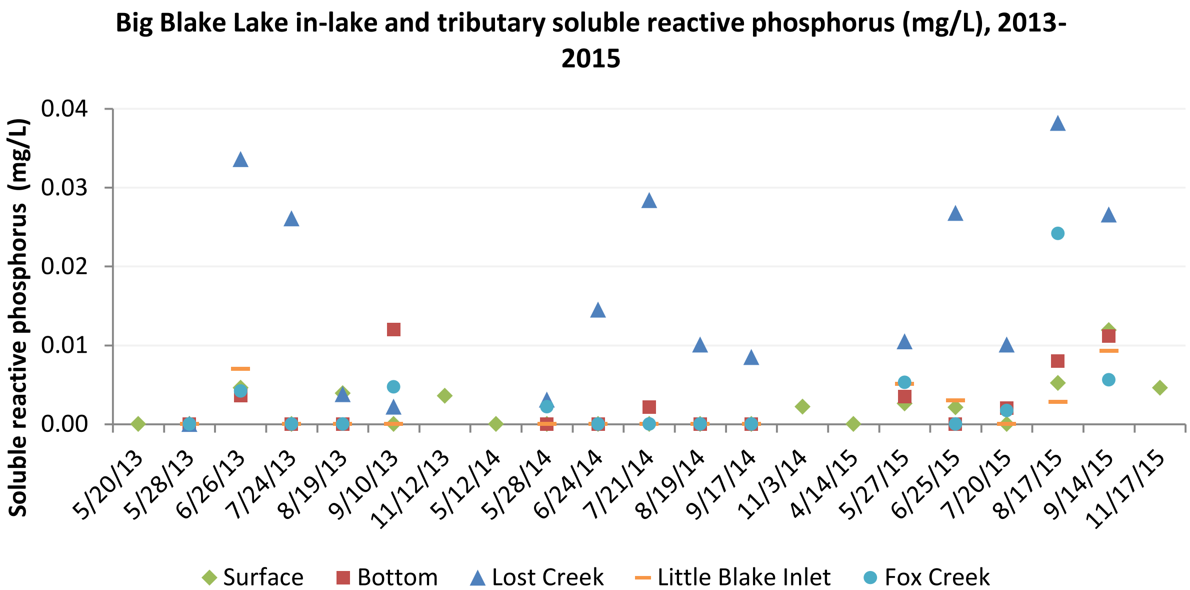
Average total phosphorus concentrations were always greater in Lost Creek as compared to the Little Blake Lake inlet. The average total phosphorus concentration in the water leaving Big Blake Lake through Fox Creek was similar to the average total phosphorus concentration of Big Blake Lake.

Average total phosphorus (mg/L)

	2013	2014	2015
Surface of Big Blake Lake	0.08	0.04	0.05
Bottom of Big Blake Lake	0.07	0.04	0.06
Lost Creek	0.11	0.09	0.14
Little Blake Lake Inlet	0.04	0.04	0.04
Fox Creek	0.07	0.04	0.05



Tributary soluble reactive phosphorus followed the same general trend as in-lake soluble reactive phosphorus, with the majority of 2013 and 2014 sampling dates being below the limit of detection. Lost Creek was the exception, with all but one sampling date being above the limit of detection over the same time period. In 2015 soluble reactive phosphorus was above the limit of detection at all sites on the majority of sampling dates, with concentrations being highest in Lost Creek.



Tributary Phosphorus Budget

Data was collected on the three tributaries of Big Blake Lake: Lost Creek, the inlet from Little Blake Lake, and Fox Creek. Flow data was collected bi-weekly at each tributary with a March McBirney Flo-Mate ™ velocity flowmeter. At each foot interval across each of the tributaries, depth (ft) and velocity (m/s) were measured. Grab samples were collected once monthly on each tributary. Samples were analyzed at the State Lab of Hygiene for total phosphorus, soluble reactive phosphorus, nitrate/nitrite, ammonium, total Kjeldahl nitrogen, and total suspended solids.

The phosphorus data collected is specific to date and location and can be used to theoretically determine how much phosphorus is entering and leaving Big Blake Lake through tributaries. 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 seasonal discharge. Units are then converted and expressed as lb/yr.

The analysis of this data allows for areas of highest phosphorus loading to be identified. Once areas of highest phosphorus loading are identified, the land use and geology of these areas can be investigated for their total phosphorus contribution and best management recommendations can be made.

On average, Little Blake Lake contributes nearly three times the amount of phosphorus to Big Blake Lake as compared to Lost Creek (17,335 pounds/year as compared to 5,955 pounds/year). On an annual basis, an average of 26,545 pounds of phosphorus leaves Big Blake Lake through the outlet at Fox Creek.[18]

Site	TP (mg/L)	Area (m^2)	Discharge (l/s)	Phosphorus (lb/yr)
2013 Fox Creek	0.0720	4.11	4,942	24,755
2014 Fox Creek	0.0422	5.72	10,696	31,402
2015 Fox Creek	0.0477	4.08	7,075	23,479
2013 Lost Creek	0.1065	5.90	360	2,667
2014 Lost Creek	0.0899	7.22	1,227	7,674
2015 Lost Creek	0.1423	8.26	760	7,524
2013 Little Blake Inlet	0.0424	10.37	4,571	13,484
2014 Little Blake Inlet	0.0415	8.17	7,487	21,616
2015 Little Blake Inlet	0.0445	8.21	5,460	16,904

In all three years discharge, or the amount of water flowing through each tributary, was substantially elevated in 2014 as compared to 2013 and 2015. This increase could be partly explained by the dam failure that occurred in May 2014. Discharge was also substantially lower in all three tributaries in 2013 which could be a result of climate. In 2013 only 25-30 inches of rain fell near Big Blake Lake as compared to 35-40 inches in 2014 and 2015.[19]

[18] Values are averages for 2013, 2014, and 2015
[19] National Weather Service precipitation data at http://water.weather.gov/precip/#

Nitrogen

Nitrogen, like phosphorus, is an element necessary for plant growth. Nitrogen sources in a lake can vary widely. Nitrogen does not occur naturally in soil minerals; however, 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.

In 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 circumstances, 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.

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.

Nitrate/nitrite concentrations were below the limit of detection on all sampling dates with the exception of fall turnover (2013-2015) and spring turnover (2015). Ammonium concentrations were below the limit of detection in ten of the twenty-one sampling dates (47%). Inorganic nitrogen was below the healthy limit of 0.3 mg/L on all sampling dates with the exception of November 12th, 2013.[20] In all three sampling years, inorganic nitrogen was below the limit of detection in June and July.

Growing season average[21] surface organic nitrogen was highest in 2013 (1.40mg/L) as compared to 2014 (0.80 mg/L) and 2015 (0.88 mg/L). Summer index period average surface organic nitrogen (July 15-September 15) was also highest in 2013 (1.89 mg/L) as compared to 2014 (1.08 mg/L) and 2015 (1.20 mg/L). In general, organic nitrogen levels in Big Blake Lake increased through August, after which time they began to decrease.

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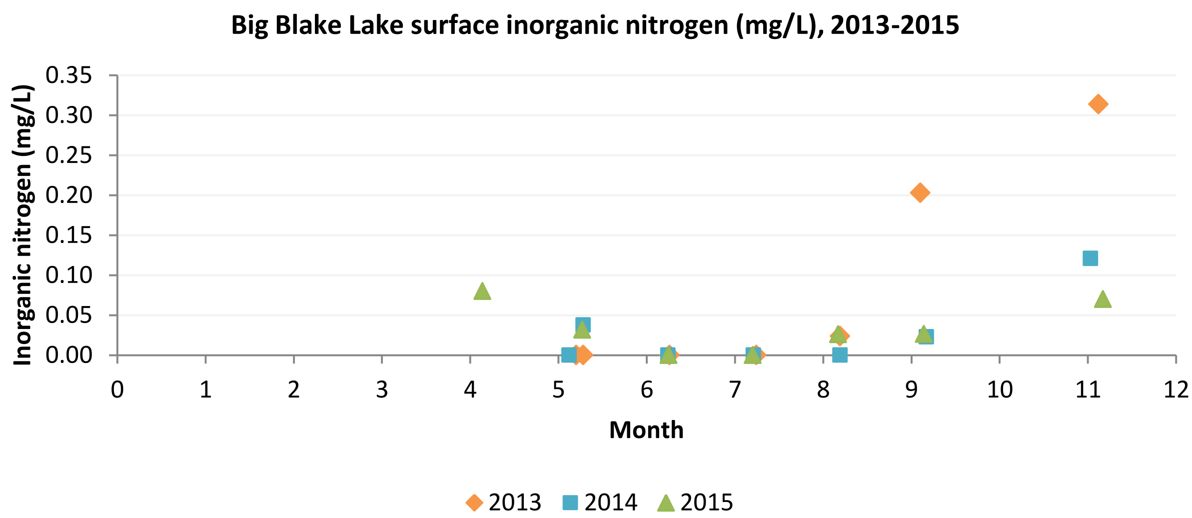
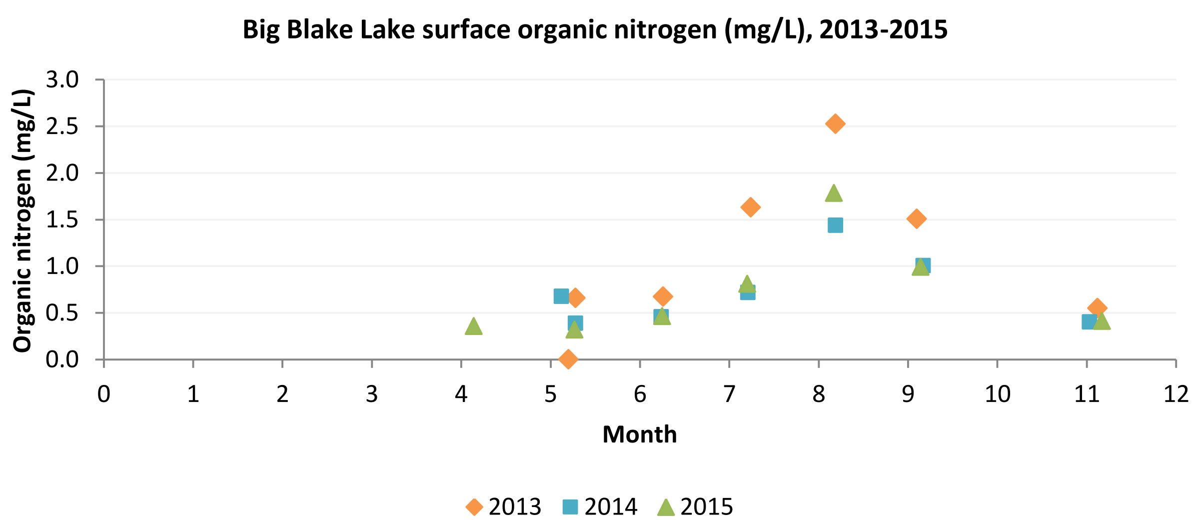
[20] Averages were not calculated for surface inorganic nitrogen because nearly half the samples were below the limit of detection

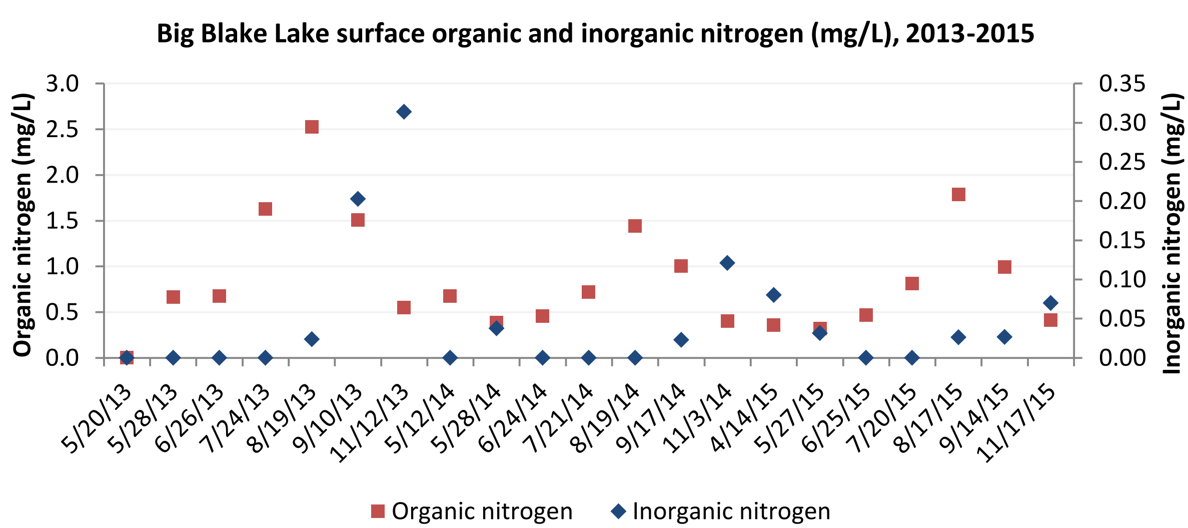
[21] Excludes turnover



Big Blake Lake surface inorganic nitrogen (mg/L), 2013-2015
Inorganic nitrogen (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
2013 2014 2015



Big Blake Lake surface organic nitrogen (mg/L), 2013-2015
Organic nitrogen (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Month
2013 2014 2015



Big Blake Lake surface organic and inorganic nitrogen (mg/L), 2013-2015
Organic nitrogen (mg/L)
Inorganic nitrogen (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5/20/13 5/28/13 6/26/13 7/24/13 8/19/13 9/10/13 11/12/13 5/12/14 5/28/14 6/24/14 7/21/14 8/19/14 9/17/14 11/3/14 4/14/15 5/27/15 6/25/15 7/20/15 8/17/15 9/14/15 11/17/15
Organic nitrogen
Inorganic nitrogen

Tributary Nitrogen

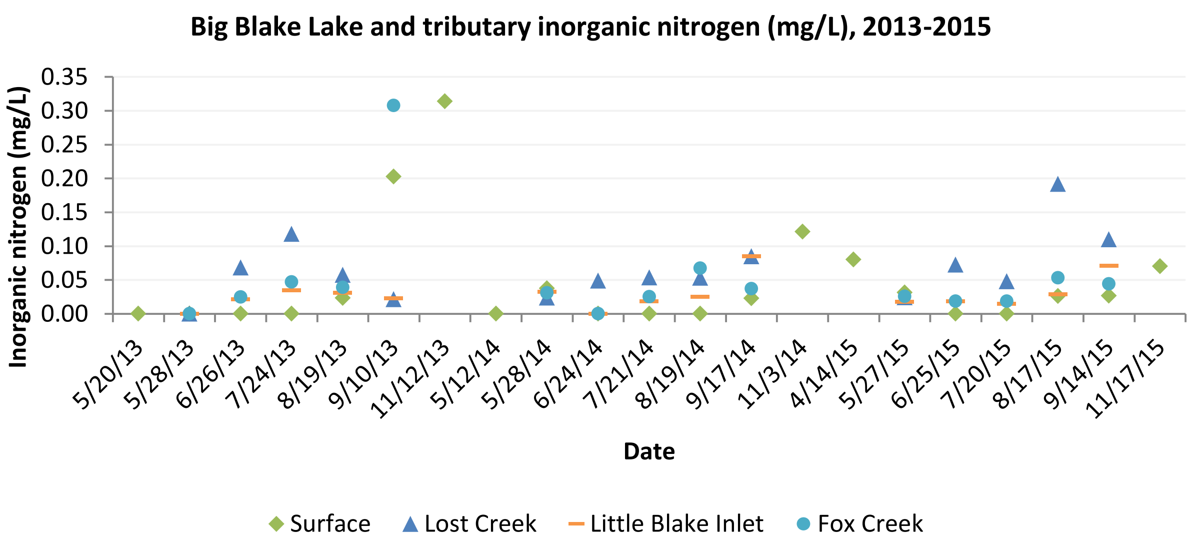
Nitrate/nitrite concentrations were below the limit of detection on all sampling dates in all tributaries with the exception of the Little Blake Lake Inlet on September 17th, 2014.

Growing season average inorganic nitrogen and organic nitrogen were greater in Lost Creek as compared to the Little Blake Lake Inlet in all three sampling years. The concentration of inorganic and organic nitrogen leaving Big Blake Lake via Fox Creek was similar to the in-lake concentration in 2014 and 2015. However, in 2013, the concentration of inorganic and organic nitrogen leaving Big Blake Lake via Fox Creek was less than the in-lake concentration.

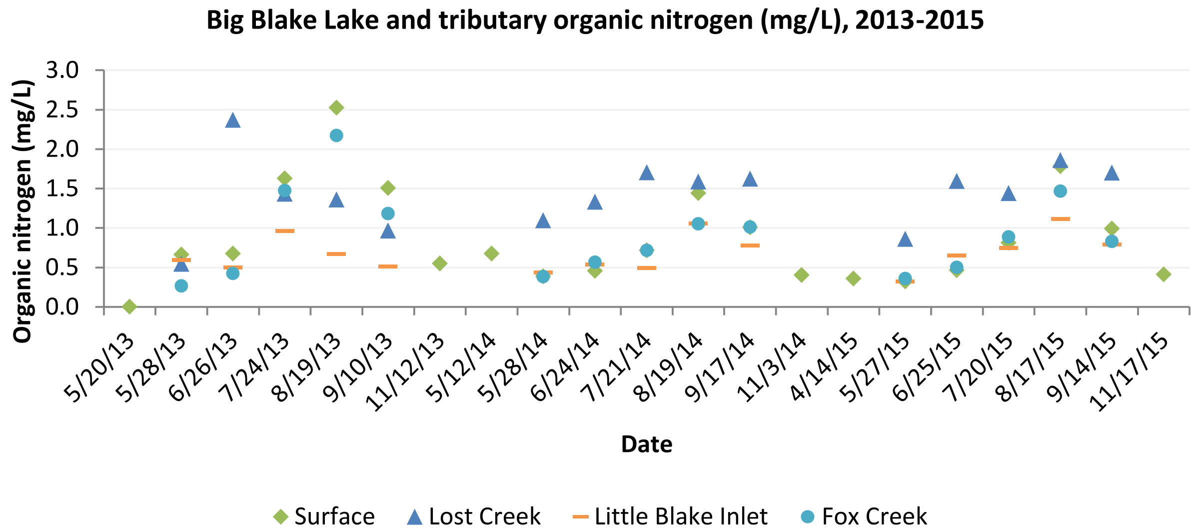
Average inorganic nitrogen (mg/L)			
	2013	**2014**	**2015**
Surface of Big Blake Lake	0.113	0.030	0.028
Lost Creek	0.053	0.053	0.089
Little Blake Lake Inlet	0.022	0.032	0.030
Fox Creek	0.084	0.032	0.032

Average organic nitrogen (mg/L)			
	2013	**2014**	**2015**
Surface of Big Blake Lake	1.40	0.80	0.88
Lost Creek	1.34	1.47	1.49
Little Blake Lake Inlet	0.64	0.66	0.72
Fox Creek	1.10	0.75	0.81

Inorganic nitrogen, or the nitrogen available for plants and algae, was below the healthy limit of 0.3 mg/L on all sampling dates at all sites with the exception of September 10, 2013 in Fox Creek and November 12th, 2013 at the surface of Big Blake Lake. In general inorganic nitrogen concentrations were lowest in the spring and increased towards the end of the growing season.



Growing season average organic nitrogen, or the amount of nitrogen in plants and algae, was highest in Lost Creek followed by Fox Creek and the Little Blake Lake Inlet in all three sampling years. In general, organic nitrogen increased over the course of the growing season through August in all three sampling years.



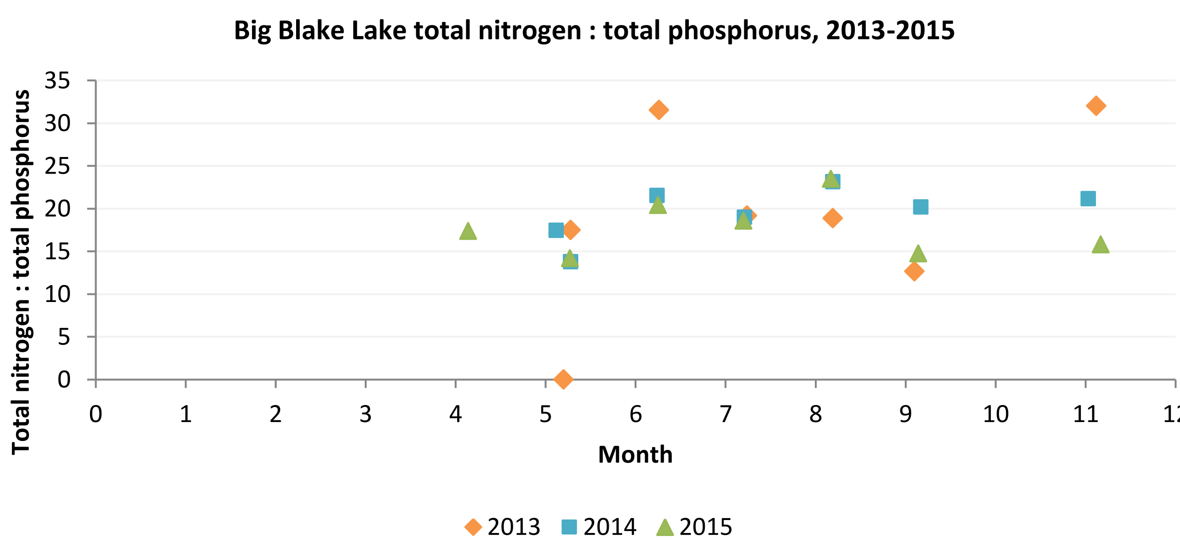
Total Nitrogen to Total Phosphorus Ratio

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, 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.

Total nitrogen is found by adding nitrate/nitrite to total Kjeldahl nitrogen. As previously mentioned, nitrate/nitrite concentrations were below the limit of detection on all sampling dates with the exception of fall turnover (2013-2015) and spring turnover (2015). As a result, total nitrogen is largely reflective of TKN.

With the exception of spring turnover in 2013, data indicate that overall Big Blake Lake is phosphorus limited. In May of 2014 and 2015 and September of 2013 and 2015, data indicate a transitional state. In May of 2013, total nitrogen was below the limit of detection, resulting in a ratio of zero.

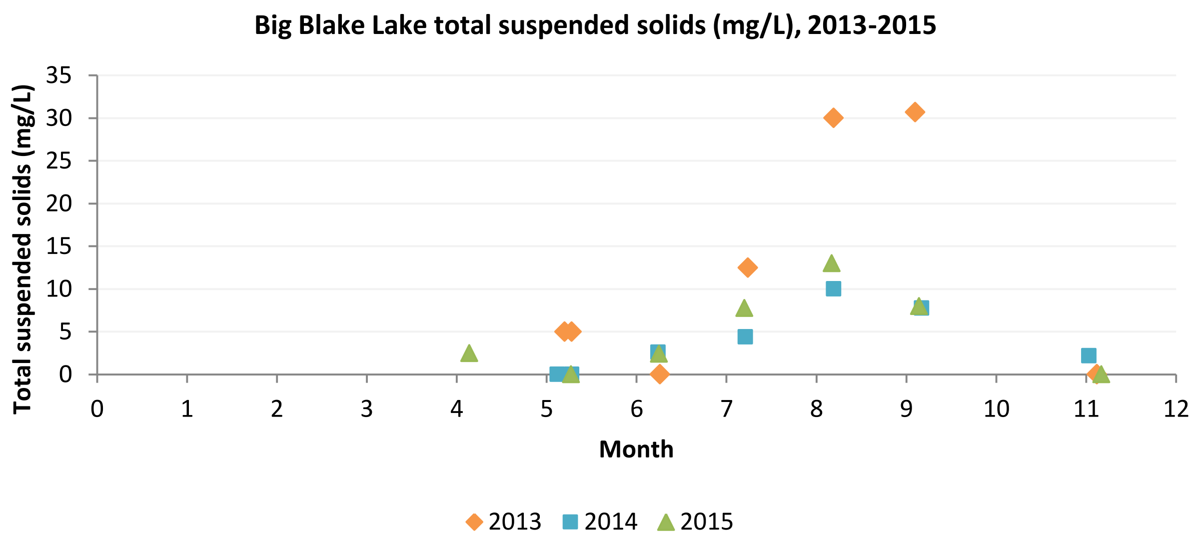


Total Suspended Solids

Total suspended solids (TSS) quantify the amount of inorganic matter that is floating in the water column. Wind, waves, boats, and even some fish species can stir up sediments from the lake bottom re-suspending them in the water column. Fine sediments, especially clay, can remain suspended in the water column for weeks. These particles scatter light and decrease water transparency.

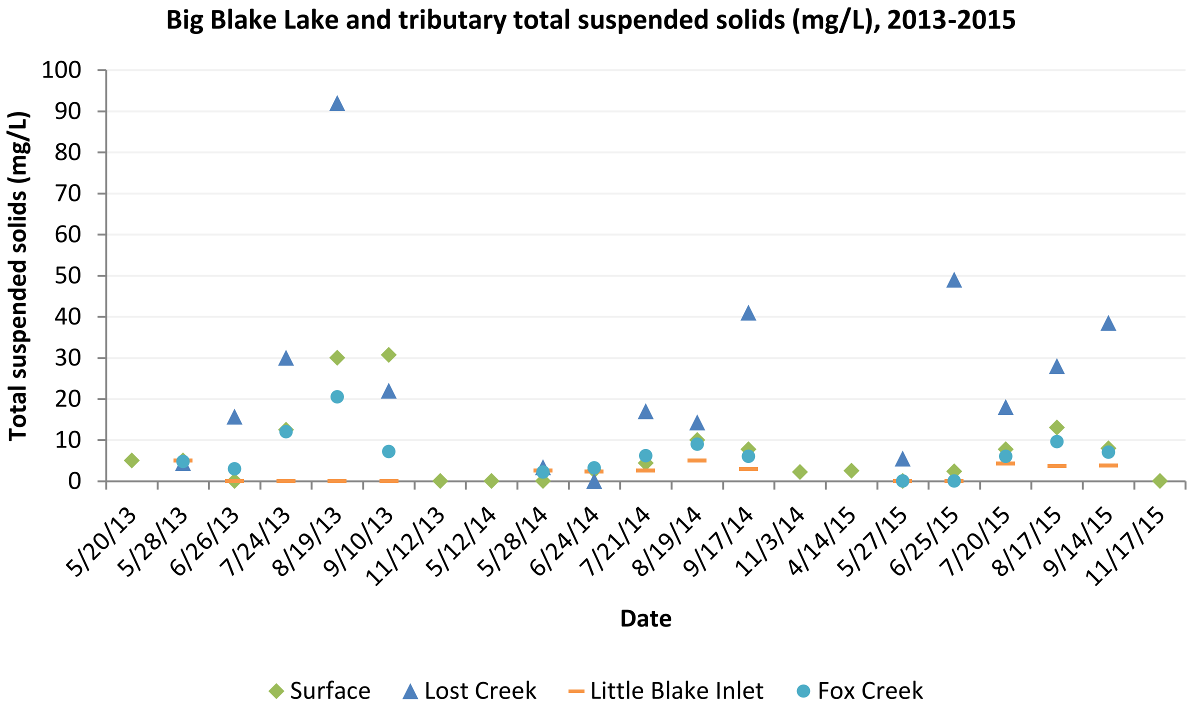
Summer index period average surface total suspended solids (July 15-September 15) were highest in 2013 (24.4 mg/L) as compared to 2014 (7.20 mg/L) and 2015 (9.6 mg/L).

Total suspended solids remained fairly low through June and increased in July and August in all three years data was collected. By November (fall turnover), total suspended solids had returned to what they had been in April/May (spring turnover).



Tributary Total Suspended Solids

In all three sampling years, average total suspended solids were highest in Lost Creek, followed by Fox Creek and the Little Blake Inlet. Total suspended solids increased through the growing season through August and September. In all three sampling years average total suspended solids were highest in 2013, followed by 2015 and 2014 in each tributary.



Chlorophyll

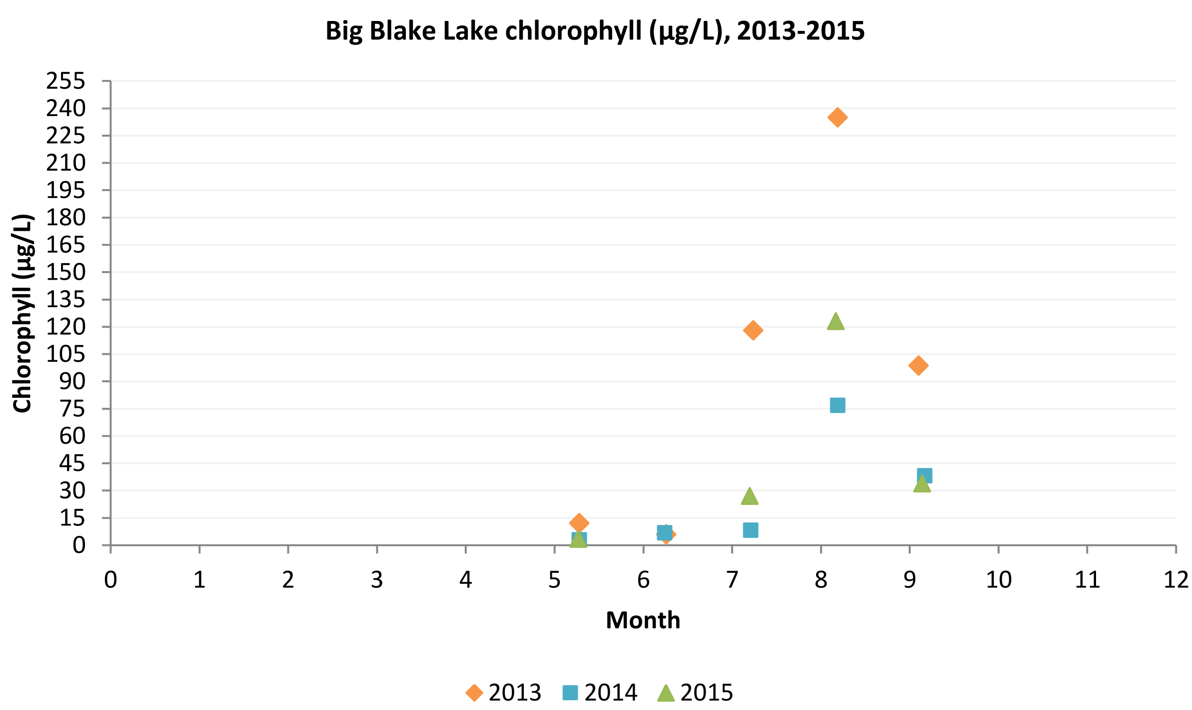
Chlorophyll is a pigment in plants and algae that is necessary for photosynthesis and is an indicator of water quality in a lake. Chlorophyll gives a general indication of the amount of algae growth in a lake, with greater values for chlorophyll indicating greater amounts of algae. However, since chlorophyll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

Chlorophyll seems to have the greatest impact on water clarity when levels exceed 30 µg/L. Lakes which appear clear generally have chlorophyll levels less than 15 µg/L.

Growing season average[22] surface chlorophyll exceeded the healthy limit in 2013 (94 µg/L) and 2015 (47 µg/L). Growing season average surface chlorophyll was just below the threshold in 2014 (27 µg/L).

Summer index period average surface chlorophyll (July 15-September 15) exceeded the healthy limit in 2013 (151 µg/L), 2014 (42 µg/L) and 2015 (61 µg/L).

In 2013 chlorophyll levels remained below 15 µg/L through June and in 2014 they remained below 15 µg/L through July. In 2015 chlorophyll levels remained below 15 µg/L through May and below 30 µg/L through July. [23]



[22] Excludes turnover

[23] The lab did not run the chlorophyll sample for June 25th, 2015 so a data point does not exist for this date

Trophic State Index

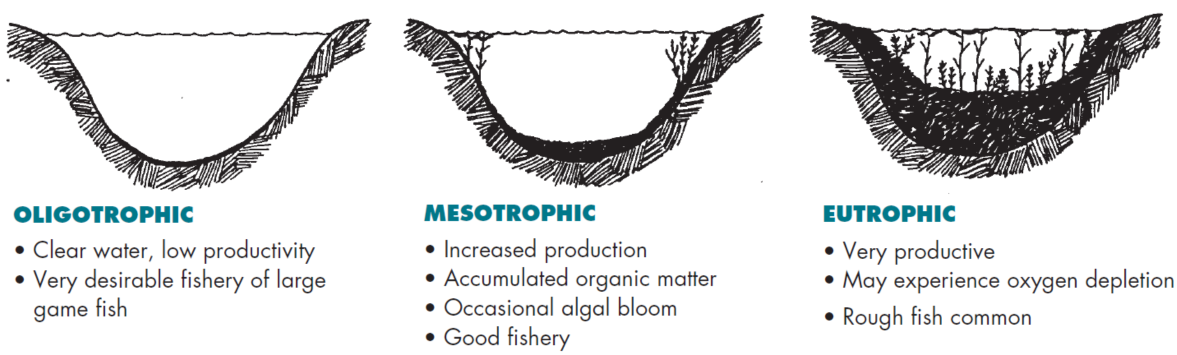
Lakes are divided into three categories based on their trophic states: oligotrophic, eutrophic, and mesotrophic. These categories reflect a lake's nutrient and clarity level and serve as an indicator of water quality. Each category is designed to serve as an overall interpretation of a lake's primary 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 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 plants and animals. 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 that introduce nutrients into a lake (agriculture, lawn fertilizers, and septic systems) can accelerate the process by which lakes age and become eutrophic.



[24]

A common method of determining a lake's trophic state is to compare total phosphorus (important for algae growth), chlorophyll (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 total phosphorus, chlorophyll, 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.

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[24] Figure from Understanding Lake Data (G3582), UW-Extension, Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004

Three equations for summer index period TSI were examined for Big Blake 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 is in µg/L)
TSI (S) = 60-14.41 * Ln [Secchi] (where the secchi depth is in meters)

<u>Big Blake Lake 2013</u>
Average summer index period TSI (total phosphorus) = 73
Average summer index period TSI (chlorophyll) = 80
Average summer index period TSI (secchi depth) = 66
Average summer index period TSI = 73 = hypereutrophic

<u>Big Blake Lake 2014</u>
Average summer index period TSI (total phosphorus) = 61
Average summer index period TSI (chlorophyll) = 67
Average summer index period TSI (secchi depth) = 59
Average summer index period TSI = 62 = eutrophic

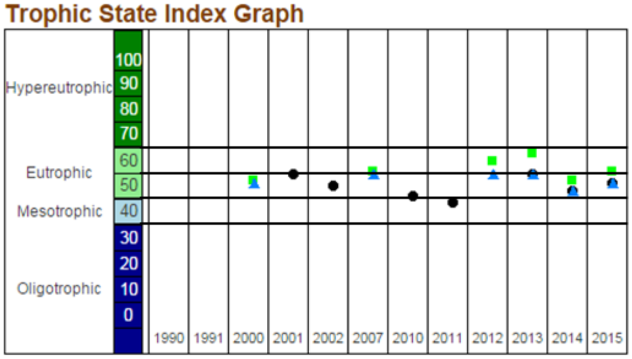
<u>Big Blake Lake 2015</u>
Average summer index period TSI (total phosphorus) = 64
Average summer index period TSI (chlorophyll) = 71
Average summer index period TSI (secchi depth) = 65
Average summer index period TSI = 67 = eutrophic

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

Monitoring the trophic state index of a lake gives stakeholders a method by which to gauge lake productivity over time. TSI data for phosphorus and chlorophyll exist for 2000, 2007, and 2012 and TSI data for secchi exist for 2001, 2002, 2010, and 2011. Complete TSI data exist for 2013-2015.

The majority of the historic TSI data falls between 50 and 70, indicating a eutrophic state. TSI secchi data for 2010 and 2011 indicate a mesotrophic state.

Trophic State Index Graph



Monitoring Station: Big Blake Lake - Deep Hole/Main Basin, Polk County
Past Summer (July-August) Trophic State Index (TSI) averages.

● = Secchi ■ = Chlorophyll ▲ = Total Phosphorus

TSI(Chl) = TSI(TP) = TSI(Sec)	It is likely that algae dominate light attenuation.
TSI(Chl) > TSI(Sec)	Large particulates, such as Aphanizomenon flakes dominate
TSI(TP) = TSI(Sec) > TSI(Chl)	Non-algal particulate or color dominate light attenuation
TSI(Sec) = TSI(Chl) >= TSI(TP)	The algae biomass in your lake is limited by phosphorus
TSI(TP) > TSI(Chl) = TSI(Sec)	Zooplankton grazing, nitrogen, or some factor other than phosphorus is limiting algae biomass

TSI	TSI Description
TSI < 30	Classical oligotrophy: clear water, many algal species, oxygen throughout the year in bottom water, cold water, oxygen-sensitive fish species in deep lakes. Excellent water quality.
TSI 30-40	Deeper lakes still oligotrophic, but bottom water of some shallower lakes will become oxygen-depleted during the summer.
TSI 40-50	Water moderately clear, but increasing chance of low dissolved oxygen in deep water during the summer.
TSI 50-60	Lakes becoming eutrophic: decreased clarity, fewer algal species, oxygen-depleted bottom waters during the summer, plant overgrowth evident, warm-water fisheries (pike, perch, bass, etc.) only.
TSI 60-70	Blue-green algae become dominant and algal scums are possible, extensive plant overgrowth problems possible.
TSI 70-80	Becoming very eutrophic. Heavy algal blooms possible throughout summer, dense plant beds, but extent limited by light penetration (blue-green algae block sunlight).
TSI > 80	Algal scums, summer fishkills, few plants, rough fish dominant. Very poor water quality.

Trophic state index (TSI) is determined using a mathematical formula (Wisconsin has its own version). The TSI is a score from 0 to 110, with lakes that are less fertile having a low TSI. We base the overall TSI on the Chlorophyll TSI when we have Chlorophyll data. If we don't have chemistry data, we use TSI Secchi. We do this rather than averaging, because the TSI is used to predict biomass. This makes chlorophyll the best indicator. Visit Bob Carlson's website, dipin.kent.edu/tsi.htm, for more info.
[25]

[25] https://dnrx.wisconsin.gov/swims/public/reporting.do?type=33&action=post&format=html&stationNo=493144

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. 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.

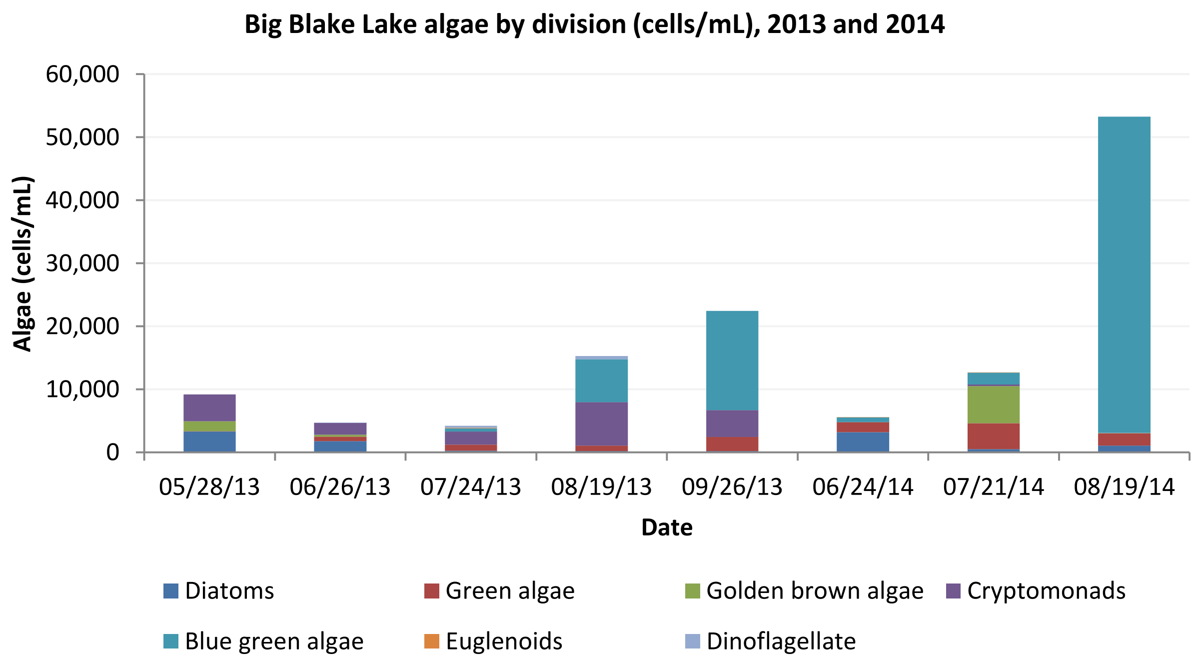
Chlorophyll is a pigment in plants and algae that is necessary for photosynthesis. Chlorophyll gives a general indication of the amount of algae growth in the water column; however, it is not directly correlated with algae biomass. To obtain accurate algae data, composite samples from a two meter water column were collected monthly, preserved with glutaraldehyde, placed on ice, and sent to the State Lab of Hygiene (2013) and UW-Oshkosh (2014 and 2015) for identification and enumeration of algae species.

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.

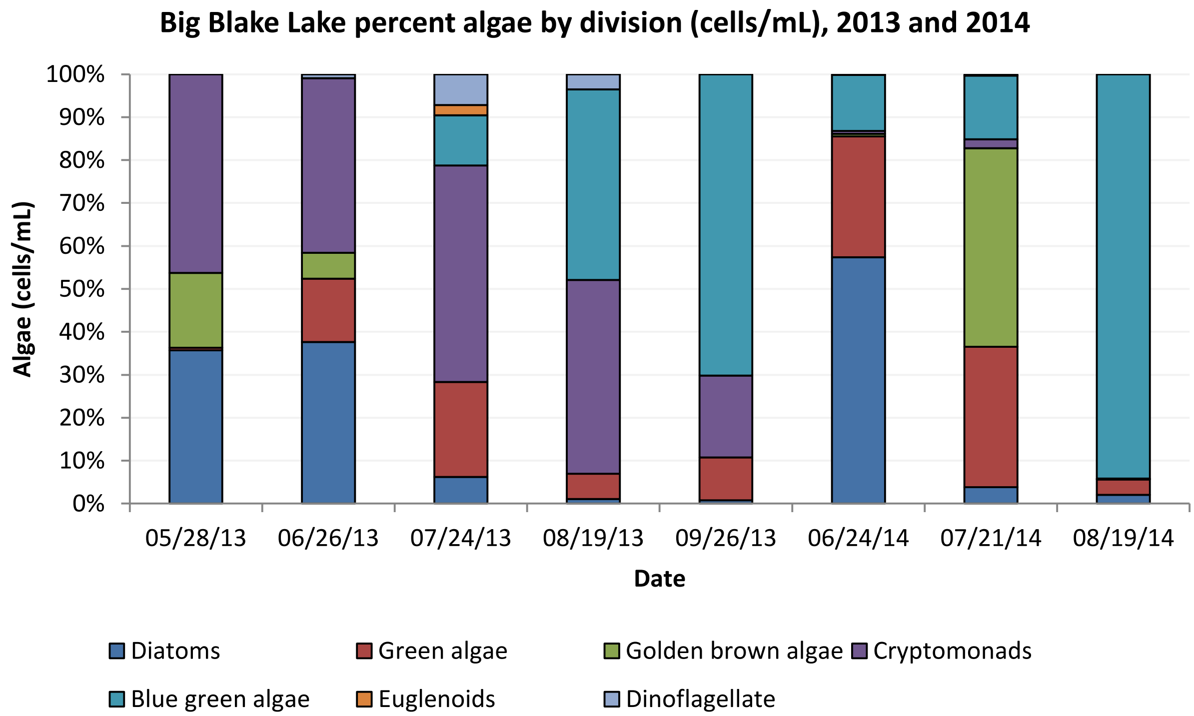
There are 12 divisions of algae found in typical lakes of Wisconsin. Seven divisions were found in Big Blake Lake. UPDATE TABLE

Algal Division	Common Name	Characteristics
Bacillariophyta	Diatoms	Have a siliceous frustule that makes up the external covering. Sensitive to chloride, pH, color, and total phosphorus (TP) in water. As TP increases, see a decrease in diatoms. Generally larger in size. Tend to be highly present in spring and late spring. Can be benthic or planktonic.
Chlorophyta	Green algae	Have a true starch and provide high nutritional value to consumers. Can be filamentous and intermingle with macrophytes.
Chrysophyta	Golden brown algae	Organisms which bear two unequal flagella. 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.
Cryptophyta	Cryptomonads	Have a true starch. Planktonic. 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.
Euglenophyta	Euglenoids	One of the best-know groups of flagellates, commonly found in freshwater that is rich in organic materials. Most are unicellular.
Pyrrhophyta	Dinoflagellate	A large group of protists with brownish pigments. Cells are single and large and can be toxic. Red tides, which occur in marine waters, are explosions of dinoflagellates. In freshwater systems, blooms are more brown than red.

In general, algae populations increased over the course of the sampling season in 2013 and 2014. Algae populations were greatest in August and September of 2013 and August of 2014. On these sampling dates, blue green algae began to dominate the algal community making up approximately 70% of the algal community in September 2013 and over 90% of the algal community in August 2014.



In May and June of 2013 diatoms made up approximately 30% of the algal community and in June of 2014 diatoms made up over 50% of the algal community. In 2013 (with the exception of September) cryptomonads made up nearly 40% of the algal community. However, in 2014 cryptomonads were a minimal component of the algal community. Golden brown algae were fairly absent in the algal community until July of 2014 when they made up over 40% of the algal community. Blue green algae became a dominant component of the algae community beginning in August of 2013 and 2014.



Blue Green Algae

Blue green algae, or cyanobacteria, 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.

Blue green algae are of specific concern because of their ability to 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.

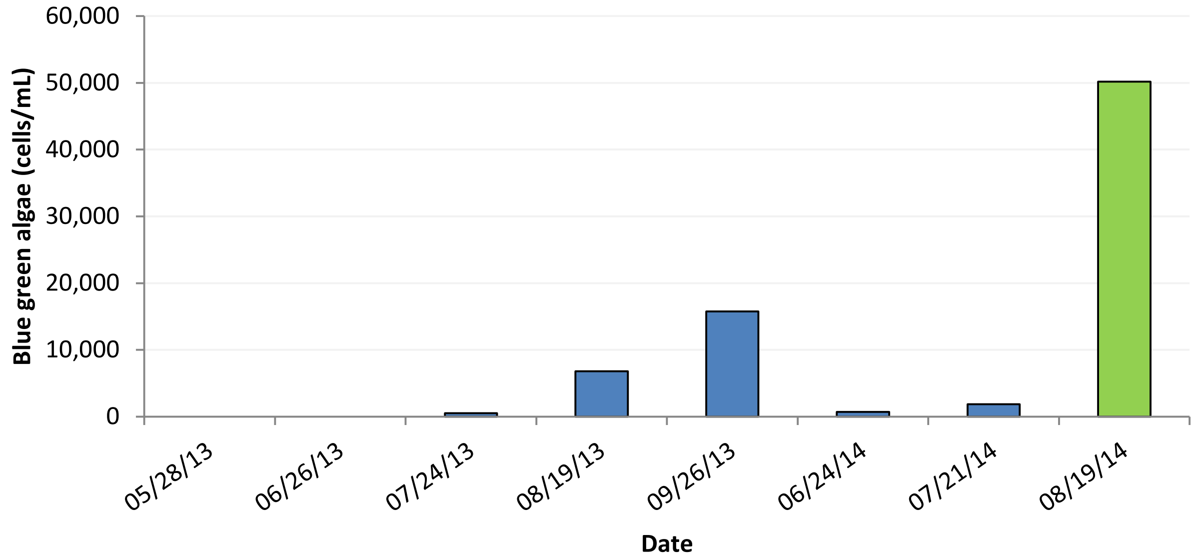
It is not known which environmental conditions cause the production of cyanotoxins, but scientists have found that when blue green algae is present at concentrations over 100,000 cells/mL toxin production is more likely to occur.

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

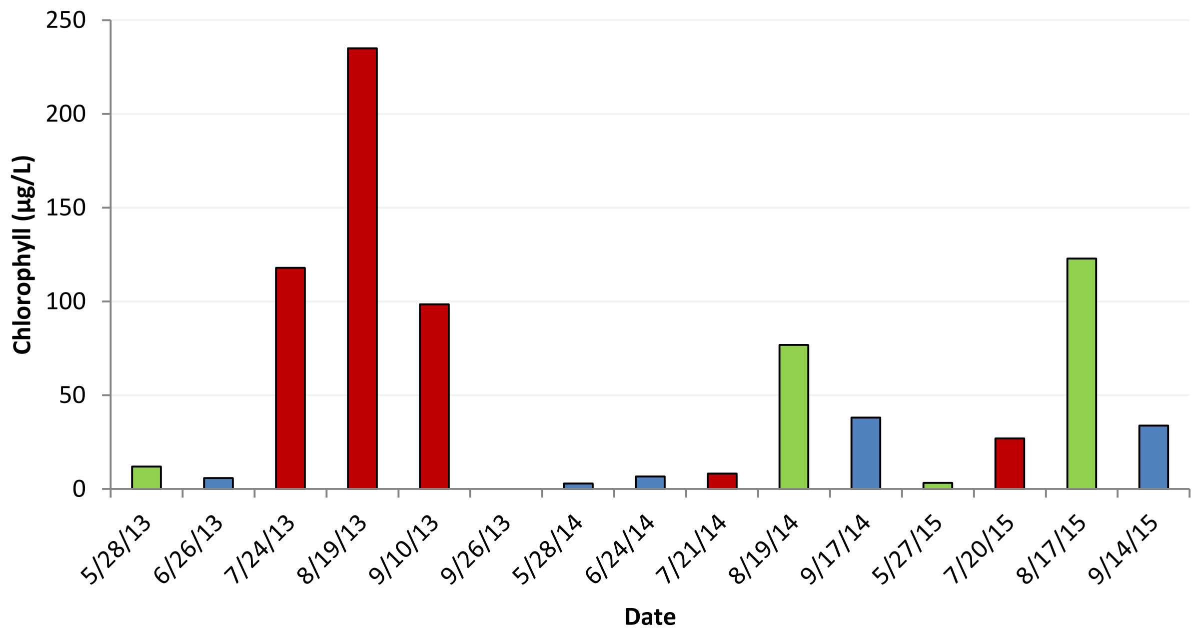
Blue green algae cell density (cells/mL)	Chlorophyll (µg/L)	Risk
Less than 20,000	Less than 10	Low
20,000 to 100,000	10 to 50	Moderate
Greater than 100,000	Greater than 50	High

Based on blue green algae cell density the risks from blue green algae were low on all sampling dates with the exception of August 19th, 2014, when the risk increased to moderate.

Big Blake Lake blue green algae (cells/mL), 2013 and 2014



Big Blake Lake chlorophyll ((µg/L), 2013 and 2014



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 Dr. Toben Lafrancois for identification and enumeration of zooplankton species. This analysis shows the abundance of the major zooplankton groups—cladocera, copepoda, and rotifer—in Big Blake Lake.

GRAPHS

Harvesting and Curly-leaf Pondweed

The Big Blake Lake Protection and Rehabilitation District formed in 1976 in response to concerns about algae blooms and aquatic plants. In the 1980's and 1990's aquatic plants were managed with harvesting (contracted) and chemical treatments by individual property owners.

Efforts to address curly-leaf pondweed, an aquatic invasive species, began in earnest in 1997. Barr Engineering completed a macrophyte survey and Macrophyte Management Plan in 1998 and The Limnological Institute (TLI) completed a macrophyte survey in 2004 that helped the District develop a Lake Management Plan. TLI's plan led to the obtainment of an ACEI Aquatic Invasives Control grant through the WDNR which provided a fifty-percent match for aquatic plant management through harvesting. The District has used harvesting to manage curly-leaf pondweed since 2007.

Curly-leaf pondweed is an exotic plant present in many Wisconsin lakes. Curly-leaf pondweed begins growing in the fall as native plants die off for the year. Curly-leaf pondweed tolerates cold water and low light conditions and continues to grow throughout the winter months under ice cover. It completes its reproductive cycle with the formation of turions, or seeds, in the early summer and dies off in late June through mid-July.

Since curly-leaf pondweed die off occurs when water temperatures are relatively high, biological organisms are very active. As curly-leaf pondweed decays, nutrients released into the water column are available for uptake by algae.

Later in the growing season, coontail reaches nuisance levels in Big Blake Lake. Coontail is a free floating native aquatic plant.

During the course of this study, aquatic plant growth was the most robust in 2015, with 143 total loads of curly-leaf pondweed and 28 loads of coontail being removed from Big Blake Lake. Additionally, due to a warm spring, harvesting for curly-leaf pondweed began about a month earlier in 2015 as compared to 2013 and 2014. In 2012, (prior to this study) 85 loads of curly-leaf pondweed were harvested.

Curly-leaf pondweed harvesting information

	Harvesting start date	Harvesting end date	Loads of curly-leaf pondweed removed
2013	June 16	July 3	8
2014	June 8	July 14	30
2015	May 19	July 1	143

Coontail harvesting information

	Harvesting start date	Harvesting end date	Loads of coontail removed
2013	July 18	September 17	14
2014	August 14	September 18	6
2015	July 22	September 3	28

Curly-leaf Pondweed Biomass and Turion Sampling

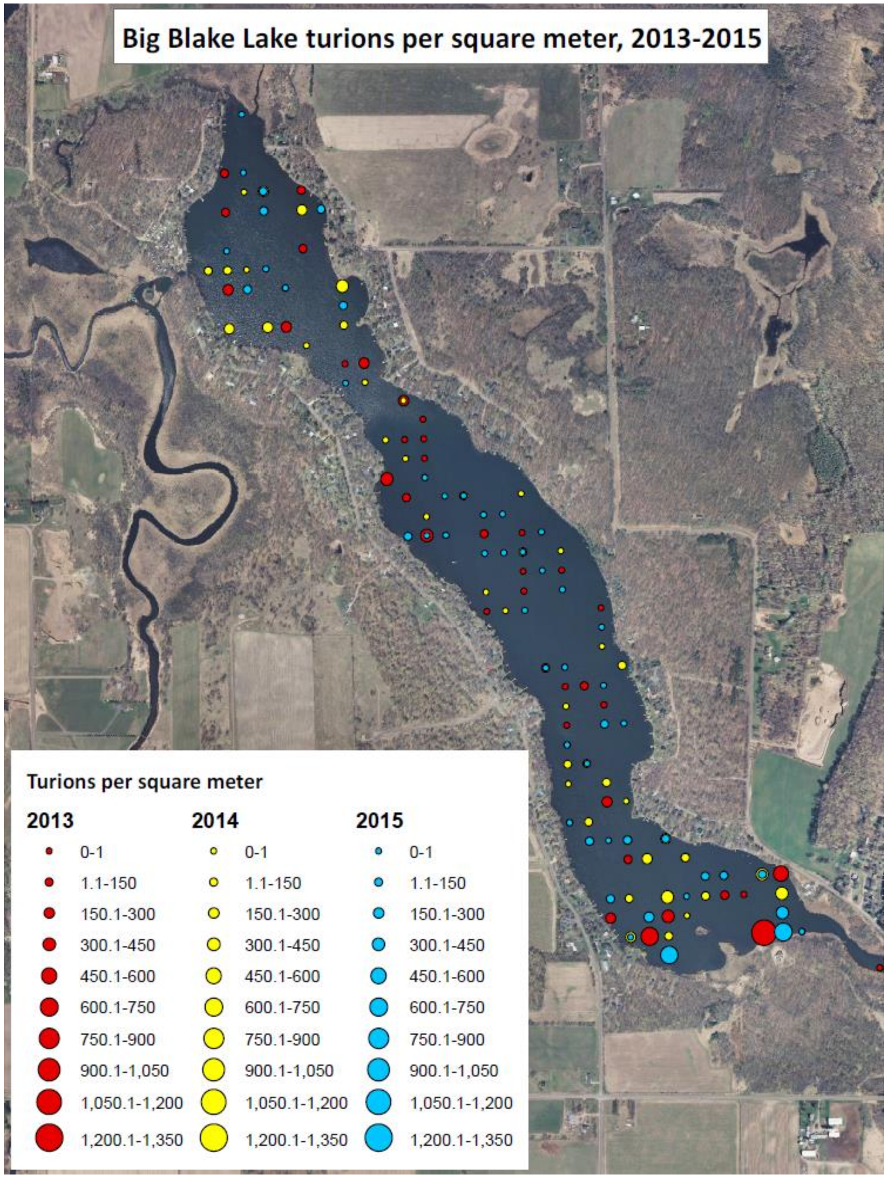
A Petite Ponar Grab Sampler was used to sample the surface sediments at fifty randomly selected points on the point intercept grid. The number of viable turions in the surface sediments were counted at each site. Numbers were extrapolated to determine number of turions per square meter.

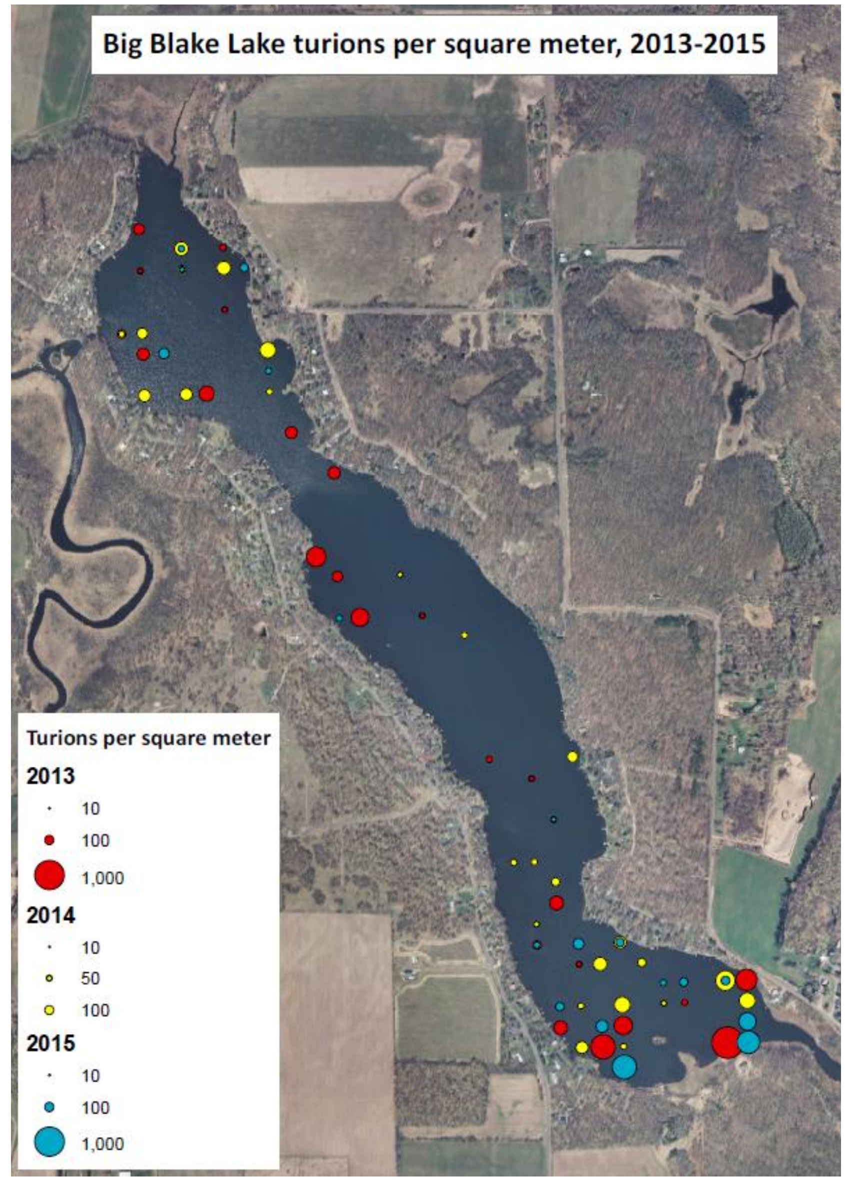
Average number of turions per dredge sample and number of turions per square meter decreased each year of the study. However, at many of the sites on the south end where points were revisited, the number of turions per square meter increased in 2015 as compared to 2013 and 2014.

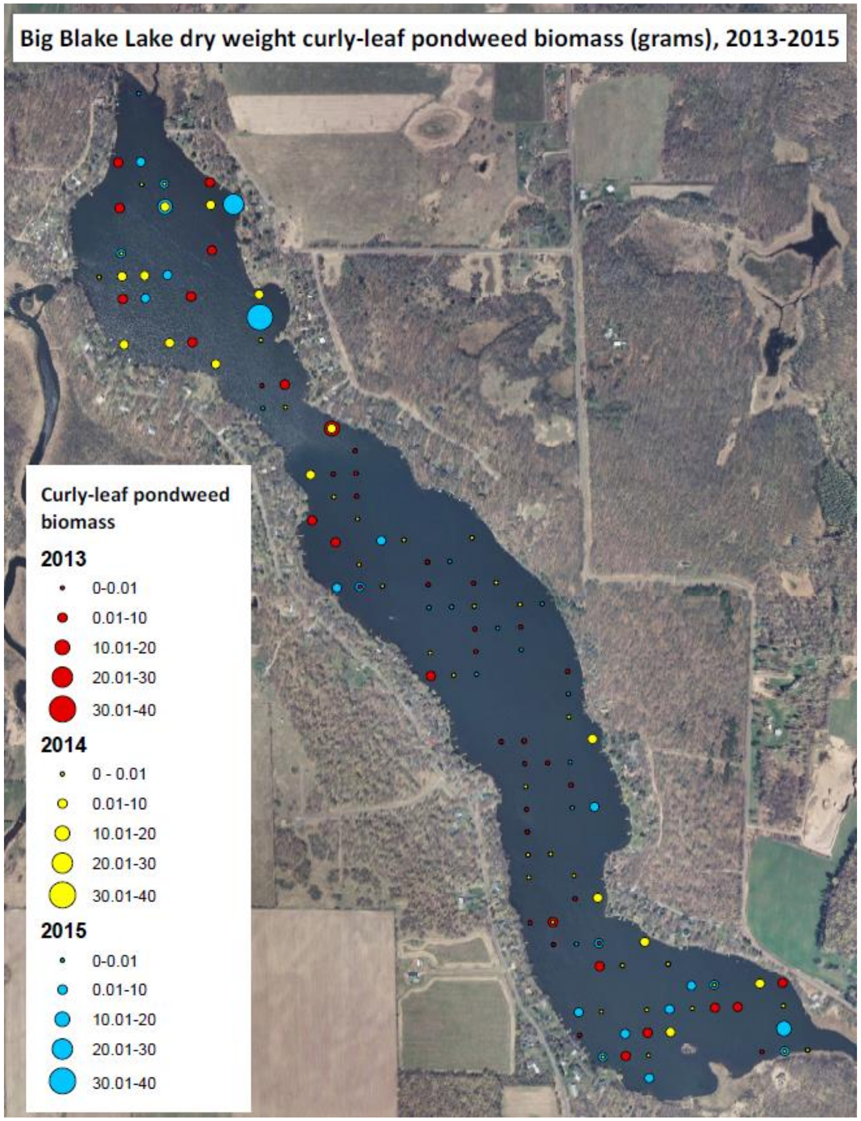
Number of turions per site was greatest on the south end of Big Blake Lake. Turions were not present in the sediments of many of the sites in the middle of Big Blake Lake.

Year	Turions per dredge sample	Turions per square meter	Curly-leaf pondweed biomass (grams)
2013	2.7	117	0.656
2014	1.9	83	0.768
2015	1.3	56	2.272

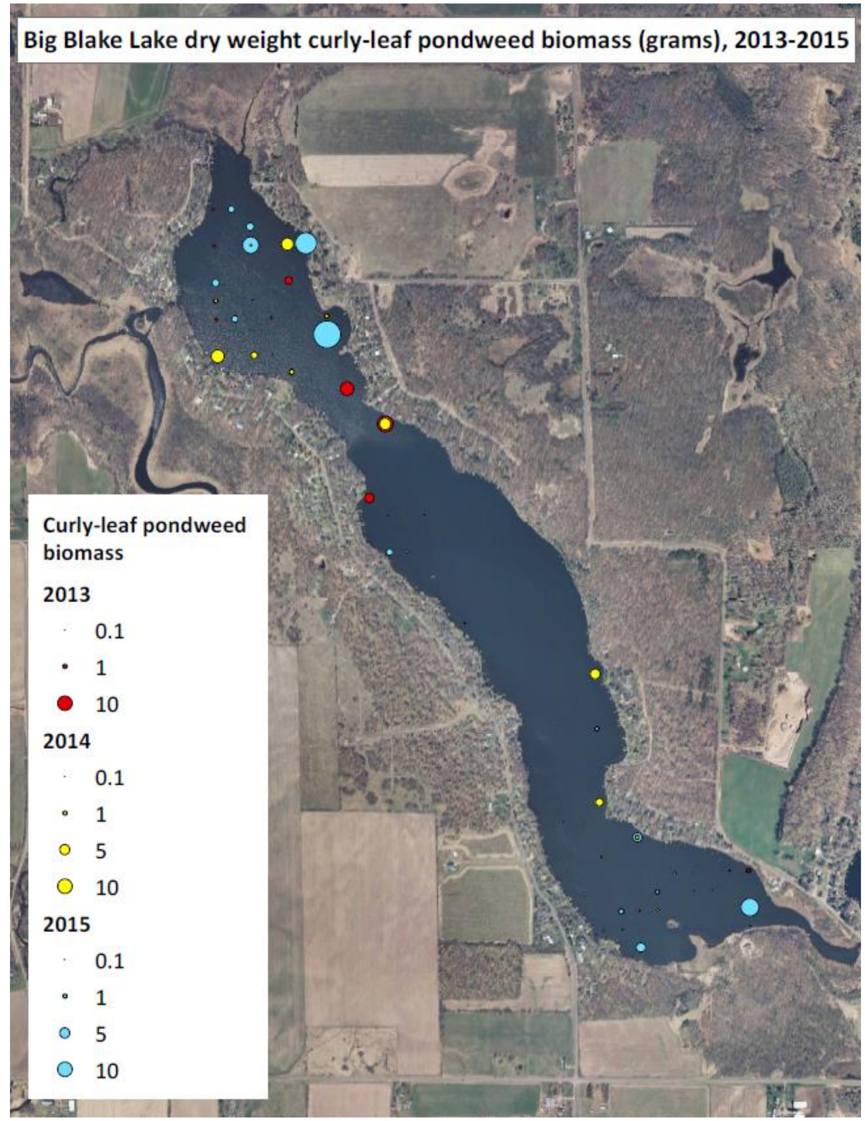
At each of the fifty randomly selected points, a rake was used to sample biomass. Biomass samples were dried and weighed. Average dry weight biomass was greatest in 2015 followed by 2014 and 2013. In general, biomass was greatest in the north and south ends of the lake with much less curly-leaf pondweed being found in the middle of the lake.


Big Blake Lake turions per square meter, 2013-2015
Turions per square meter
2013
0-1
1.1-150
150.1-300
300.1-450
450.1-600
600.1-750
750.1-900
900.1-1,050
1,050.1-1,200
1,200.1-1,350
2014
0-1
1.1-150
150.1-300
300.1-450
450.1-600
600.1-750
750.1-900
900.1-1,050
1,050.1-1,200
1,200.1-1,350
2015
0-1
1.1-150
150.1-300
300.1-450
450.1-600
600.1-750
750.1-900
900.1-1,050
1,050.1-1,200
1,200.1-1,350


Big Blake Lake turions per square meter, 2013-2015
Turions per square meter
2013
10
100
1,000
2014
10
50
100
2015
10
100
1,000



Big Blake Lake dry weight curly-leaf pondweed biomass (grams), 2013-2015
Curly-leaf pondweed biomass
2013
0-0.01
0.01-10
10.01-20
20.01-30
30.01-40
2014
0 - 0.01
0.01-10
10.01-20
20.01-30
30.01-40
2015
0-0.01
0.01-10
10.01-20
20.01-30
30.01-40



Big Blake Lake dry weight curly-leaf pondweed biomass (grams), 2013-2015
Curly-leaf pondweed biomass
2013
0.1
1
10
2014
0.1
1
5
10
2015
0.1
1
5
10

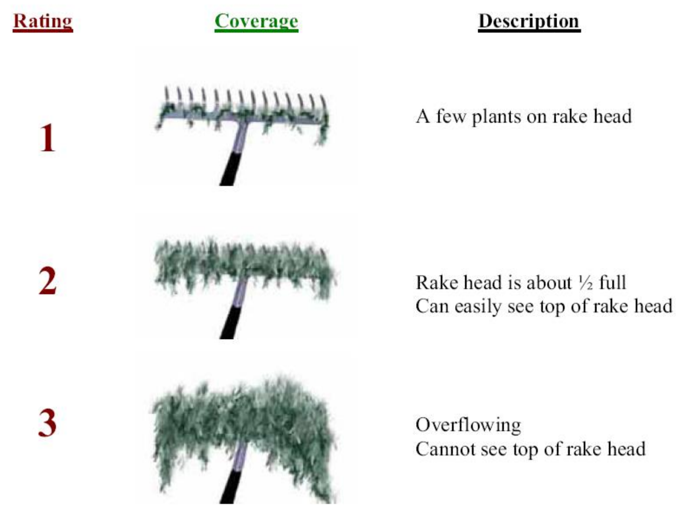
Point Intercept Aquatic Macrophyte Surveys

Spring and fall aquatic macrophyte surveys were conducted on Big Blake Lake in 2013, 2014, and 2015 using the Jessen and Lound Rake Method.

Two hundred seventy six sampling points were established in and around the lake using a standard formula that takes into account the shoreline shape and distance, islands, water clarity, depth, and total lake acres. Points were generated in ArcView and downloading to a GPS unit. These points were then sampled in field.

During the aquatic macrophyte survey, each sampling point was located using a handheld mapping GPS unit. The depth at each sampling point was recorded using a depth finder. At each sampling point a pole rake was used to sample the plant community of an approximately 1 meter section of the benthos.

All plants on the rake, as well as any that were dislodged by the rake, were identified to species and assigned a rake fullness value of 1 to 3 to estimate abundance. Visual sightings of plants within six feet of the sample point were also recorded. The lake bottom type, or substrate, was also assigned at each sampling point where the bottom was visible or it could be reliably determined using the rake. Data was collected at each sampling point, with the exception of those that were too shallow or terrestrial. Shallow communities were characterized visually.



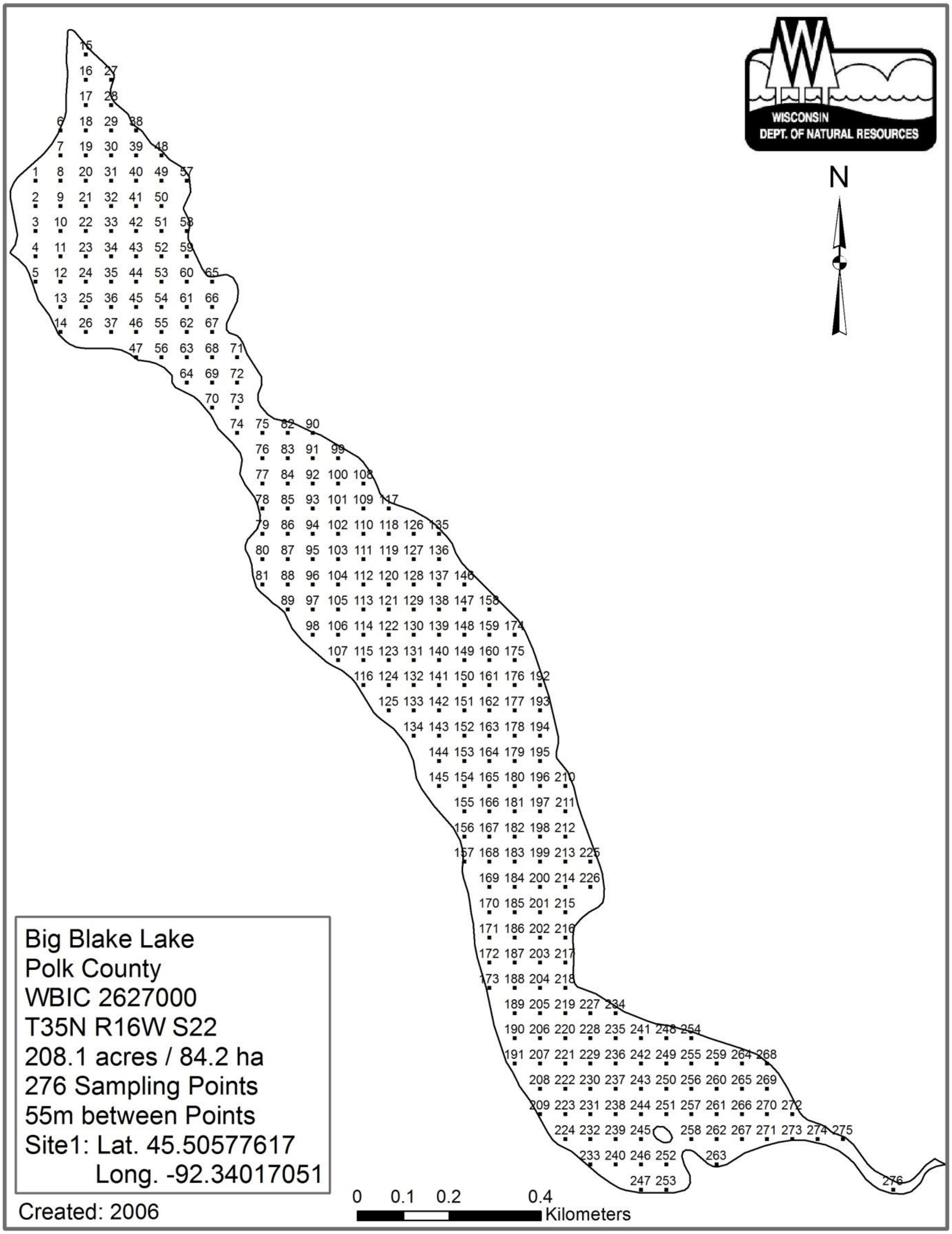
Although two hundred seventy six sampling points were established in Big Blake Lake, it was not possible to reach all sampling points (some were terrestrial).

Twice annual aquatic macrophyte surveys were conducted on Big Blake Lake in 2007 and 2011 and a fall point intercept survey was conducted in 2012. Surveys completed in 2008-2010 represented two intensive management units rather than the full point intercept grid. This summary will include data from 2007 and 2011-2015.

Data collected was entered into a spreadsheet for analysis. The following statistics were generated from the spreadsheet:

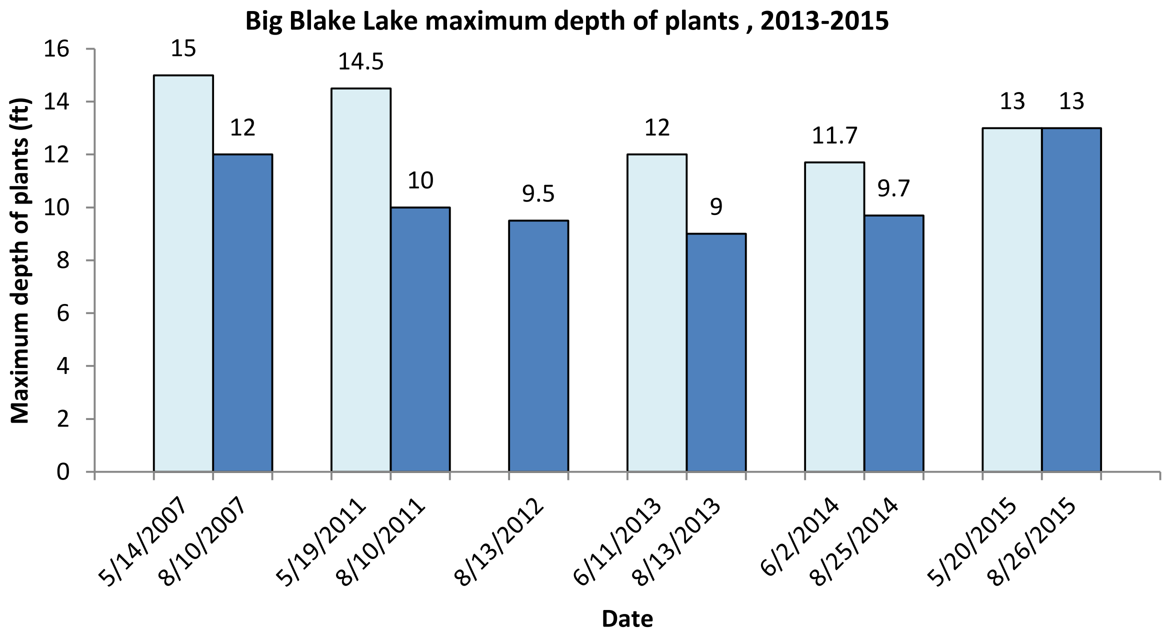
- Maximum depth of plants
- Frequency of occurrence
- Relative frequency
- Sample points with vegetation
- Species richness
- Simpson’s Diversity Index
- Floristic Quality Index

Following are explanations of the various analysis values with data from Big Blake Lake.


WISCONSIN
DEPT. OF NATURAL RESOURCES
N
Big Blake Lake
Polk County
WBIC 2627000
T35N R16W S22
208.1 acres / 84.2 ha
276 Sampling Points
55m between Points
Site1: Lat. 45.50577617
Long. -92.34017051
Created: 2006
0 0.1 0.2 0.4
Kilometers

Maximum Depth of Plants

In lakes, plant growth is limited to certain depths based on availability of light. With greater water clarity, light can penetrate to greater depths and be used by plants for growth. In Big Blake Lake the maximum depth of plants was generally greater in the spring as compared to the fall (12 versus 9 feet in 2013 and 11.7 versus 9.7 feet in 2014, respectively). In 2015, the maximum depth of plants (13 feet) was the same in both spring and fall.



Frequency of Occurrence

Two values are computed for frequency of occurrence: the frequency of occurrence within vegetated areas and the frequency of occurrence at sites shallower than the maximum depth of plants. The maximum depth of plants is the depth of the deepest site sampled at which vegetation was present (maximum depth of plants).

Frequency of occurrence within vegetated areas is defined as the number of times a species was seen in a vegetated area divided by the total number of vegetated sites. This value shows how often the plant would be encountered everywhere vegetation was found in the lake. The greater the value, the more frequently the plant would be encountered in the lake.

In the spring, within vegetated areas, curly-leaf pondweed was the most frequently encountered plant species being found at 100% of sites in 2007, 93% of sites in 2011, 73% of sites in 2013, 59% of sites in 2014, and 93% of sites in 2015. Other frequent species included small pondweed, coontail, forked duckweed, and flat-stem pondweed.

In the fall, within vegetated areas, coontail was the most frequently encountered plant species being found at 86% of sites in 2007, 92% of sites in 2011, 86% of sites in 2012, 82% of sites in 2013, 73% of sites in 2014, and 85% of sites in 2015. Other frequent species included flat-stem pondweed, forked duckweed, and small pondweed.

Spring frequency of occurrence within vegetated areas, 2007, 2011, and 2013-2015					
	5/14/07	5/19/11	6/11/13	6/2/14	5/20/15
Ceratophyllum demersum, coontail	19.52	25.64	34.11	31.6	19.44
Filamentous algae	8.37	5.13	3.88	17.39	4.86
Heteranthera dubia, water star-grass			1.55		0.69
Lemna minor, small duckweed			2.33		
Lemna trisulca, forked duckweed	1.99	12.31	15.5	29.57	5.56
Myriophyllum sibiricum, northern water milfoil		2.05	0.78	2.61	4.17
Nitella sp., nitella					0.69
Nuphar variegata, spatterdock		1.03	0.78	3.48	1.39
Nymphaea odorata, white water lily		0.51	2.33	1.74	0.69
Potamogeton crispus, curly-leaf pondweed	100.00	93.33	72.87	59.13	93.06
Potamogeton praelongis, white-stem pondweed		0.51	3.1	1.74	1.39
Potamogeton pulcher, spotted pondweed		0.51			
Potamogeton pusillus, small pondweed	1.20	13.85	35.66	39.13	18.75
Potamogeton zosteriformis, flat-stem pondweed	2.39	4.10	16.28	13.04	5.56
Ranunculus aquatilis, white water crowfoot			3.1		1.39
Vallisneria americana, wild celery			0.78		
Wolffia columbiana, common watermeal			1.55		
Zizania palustris, northern wild rice			0.78	1.74	1.39

Fall frequency of occurrence within vegetated areas, 2007 and 2011-2015						
	8/10/07	8/10/11	8/13/12	8/13/13	8/25/14	8/26/15
Ceratophyllum demersum, coontail	85.87	91.89	85.71	82.14	73.24	85.29
Chara sp., Muskgrasses						1.47
Elodea canadensis, common waterweed	1.09					4.41
Filamentous algae	8.70		5.36	8.93	9.86	11.76
Heteranthera dubia, water star-grass	1.09	2.70		3.57	7.04	2.94
Lemna minor, small duckweed	3.26	6.76		1.79	5.63	4.41
Lemna trisulca, forked duckweed	14.13	43.24	30.36	28.57	38.03	44.12
Myriophyllum sibiricum, northern water milfoil	3.26	8.11	14.29	8.93	12.68	11.76
Najas flexilis, bushy pondweed	1.09	4.05		1.79	8.45	
Nitella sp., nitella	1.09					
Nuphar variegata, spatterdock		6.76	1.79		4.23	1.47
Nymphaea odorata, white water lily	2.17	4.05	7.14	8.93	5.63	7.35
Potamogeton amplifolius, large-leaf pondweed					1.41	
Potamogeton crispus, curly-leaf pondweed	1.09	1.35	1.79	1.79	1.41	1.47
Potamogeton illinoensis, Illinois pondweed	3.26					
Potamogeton praelongis, white-stem pondweed		2.70		3.57		4.41
Potamogeton pusillus, small pondweed	1.09	8.11		17.86	11.27	2.94
Potamogeton richardsonii, clasping-leaf pondweed	2.17	2.70	1.79	8.93	1.41	4.41
Potamogeton zosteriformis, flat-stem pondweed	15.22	31.08	26.79	48.21	28.17	35.29
Ranunculus aquatilis, white water crowfoot		1.35		1.79	1.41	2.94
Sparganium angustifolium, narrow-leaved bur-reed			8.93			
Spirodela polyrhiza, large duckweed	1.09	6.76		1.79		
Stuckenia pectinata, sago pondweed	1.09					
Vallisneria americana, wild celery		1.35	3.57	5.36		2.94
Wolffia columbiana, common watermeal		1.35		1.79	1.41	4.41
Zizania palustris, northern wild rice		1.35				

Frequency of occurrence at sites shallower than the maximum depth of plants is defined as the number of times a species was seen divided by the total number of sites shallower than the maximum depth of plants. This value shows how often the plant would be encountered within the depths plants can potentially grow (maximum depth of plants). The greater the value, the more frequently the plant would be encountered in the lake.

In the spring, at sites shallower than the maximum depth of plants, curly-leaf pondweed was the most frequently encountered plant species being found at 97% of sites in 2007, 67% of sites in 2011, 53% of sites in 2013, 32% of sites in 2014, and 51% of sites in 2015. Other frequent species included small pondweed, coontail, and forked duckweed.

In the fall, at sites shallower than the maximum depth of plants, coontail was the most frequently encountered plant species being found at 31% of sites in 2007, 52% of sites in 2011, 44% of sites in 2012, 51% of sites in 2013, 42% of sites in 2014, and 22% of sites in 2015. Other frequent species included flat-stem pondweed and forked duckweed.

[26]

[26] Rake of coontail, August 10th, 2007

Spring frequency of occurrence at sites shallower than the maximum depth of plants, 2007, 2011, and 2013-2015					
	5/14/07	5/19/11	6/11/13	6/2/14	5/20/15
Ceratophyllum demersum, coontail	18.85	18.38	25.00	16.74	10.73
Filamentous algae	8.08	3.68	2.84	9.30	2.68
Heteranthera dubia, water star-grass			1.14		0.38
Lemna minor, small duckweed			1.70		
Lemna trisulca, forked duckweed	1.92	8.82	11.36	15.81	3.07
Myriophyllum sibiricum, northern water milfoil		1.47	0.57	1.40	2.30
Nitella sp., nitella					0.38
Nuphar variegata, spatterdock		0.74	0.57	1.86	0.77
Nymphaea odorata, white water lily		0.37	1.70	0.93	0.38
Potamogeton crispus, curly-leaf pondweed	96.54	66.91	53.41	31.63	51.34
Potamogeton praelongis, white-stem pondweed		0.37	2.27	0.93	0.77
Potamogeton pulcher, spotted pondweed		0.37			
Potamogeton pusillus, small pondweed	1.15	9.93	26.14	20.93	10.34
Potamogeton zosteriformis, flat-stem pondweed	2.31	2.94	11.93	6.98	3.07
Ranunculus aquatilis, white water crowfoot			2.27		0.77
Vallisneria americana, wild celery			0.57		
Wolffia columbiana, common watermeal			1.14		
Zizania palustris, northern wild rice			0.57	0.93	0.77

Fall frequency of occurrence at sites shallower than the maximum depth of plants, 2007 and 2011-2015						
	8/10/07	8/10/11	8/13/12	8/13/13	8/25/14	8/26/15
Ceratophyllum demersum, coontail	31.10	52.31	43.64	51.11	41.94	22.22
Chara sp., Muskgrasses						0.38
Elodea canadensis, common waterweed	0.39					1.15
Filamentous algae	3.15		2.73	5.56	5.65	3.07
Heteranthera dubia, water star-grass	0.39	1.54		2.22	4.03	0.77
Lemna minor, small duckweed	1.18	3.85		1.11	3.23	1.15
Lemna trisulca, forked duckweed	5.12	24.62	15.45	17.78	21.77	11.49
Myriophyllum sibiricum, northern water milfoil	1.18	4.62	7.27	5.56	7.26	3.07
Najas flexilis, bushy pondweed	0.39	2.31		1.11	4.84	
Nitella sp., nitella	0.39					
Nuphar variegata, spatterdock		3.85	0.91		2.42	0.38
Nymphaea odorata, white water lily	0.79	2.31	3.64	5.56	3.23	1.92
Potamogeton amplifolius, large-leaf pondweed					0.81	
Potamogeton crispus, curly-leaf pondweed	0.39	0.77	0.91	1.11	0.81	0.38
Potamogeton illinoensis, Illinois pondweed	1.18					
Potamogeton praelongis, white-stem pondweed		1.54		2.22		1.15
Potamogeton pusillus, small pondweed	0.39	4.62		11.11	6.45	0.77
Potamogeton richardsonii, clasping-leaf pondweed	0.79	1.54	0.91	5.56	0.81	1.15
Potamogeton zosteriformis, flat-stem pondweed	5.51	17.69	13.64	30.00	16.13	9.20
Ranunculus aquatilis, white water crowfoot		0.77		1.11	0.81	0.77
Sparganium angustifolium, narrow-leaved bur-reed			4.55			
Spirodela polyrhiza, large duckweed	0.39	3.85		1.11		
Stuckenia pectinata, sago pondweed	0.39					
Vallisneria americana, wild celery		0.77	1.82	3.33		0.77
Wolffia columbiana, common watermeal		0.77		1.11	0.81	1.15
Zizania palustris, northern wild rice		0.77				

Relative Frequency

Relative frequency is the frequency of a particular plant species relative to other plant species. This value is independent of the number of points sampled. Relative frequency can be used to show which plants are the dominant species in a lake. The higher the value a species has for relative frequency, the more common the species is compared to others. The relative frequency of all plants will always add up to 100%. If species A had a relative frequency of 30%, this species occurred 30% of the time compared to all the species sampled or makes up 30% of all species sampled.

Relative frequency example:
Suppose we were sampling 10 points in a very small lake and got the following results:
Plant A present at 3 of 10 sites
Plant B present at 5 of 10 sites
Plant C present at 2 of 10 sites
Plant D present at 6 of 10 sites

Plant D is the most frequently sampled at all points, with 60% (6/10) of the sites having plant D. However, the relative frequency allows us to see what the frequency of Plant D is compared to other plants, without taking into account the number of sites. This value is calculated by dividing the number of times a plant is sampled by the total of all plants sampled. If we add all frequencies (3+5+2+6), we get a sum of 16. We can calculate the relative frequency by dividing by the individual frequency.

Plant A = 3/16 = 0.1875 or 18.75%
Plant B = 5/16 = 0.3125 or 31.25%
Plant C = 2/16 = 0.125 or 12.5%
Plant D = 6/16 = 0.375 or 37.5%

Now we can compare the plants to one another. Plant D is still the most frequent, but the relative frequency tells us that of all plants sampled at those 10 sites, 37.5% of them are Plant D. This is much lower than the frequency of occurrence (60%) because, although we sampled Plant D at 6 of 10 sites, we were sampling many other plants too, thereby giving a lower frequency when compared to those other plants. This then gives a true measure of the dominant plants present.

In the spring, the most dominant plant in Big Blake Lake as indicated by relative frequency was curly-leaf pondweed. Curly-leaf pondweed made up 75% of the plant community in 2007, 61% in 2011, 38% in 2013, 32% in 2014, and 60% in 2015. Other dominant plants, as indicated by relative frequency included small pondweed, coontail, and forked duckweed.

In the fall, the most dominant plant in Big Blake Lake as indicated by relative frequency was coontail. Coontail made up 59% of the plant community in 2007, 41% in 2011, 46% in 2012, 36% in 2013, 36% in 2014, and 38% in 2015. Other dominant plants, as indicated by relative frequency included flat-stem pondweed and forked duckweed.

Spring relative frequency, 2007, 2011, and 2013-2015					
	5/14/07	5/19/11	6/11/13	6/2/14	5/20/15
Ceratophyllum demersum, coontail	14.6	16.7	17.8	17.1	12.6
Filamentous algae	6.3				
Heteranthera dubia, water star-grass			0.8		0.5
Lemna minor, small duckweed			1.2		
Lemna trisulca, forked duckweed	1.5	8.0	8.1	16.1	3.6
Myriophyllum sibiricum, northern water milfoil		1.3	0.4	1.4	2.7
Nitella sp., nitella					0.5
Nuphar variegata, spatterdock		0.7	0.4	1.9	0.9
Nymphaea odorata, white water lily		0.3	1.2	0.9	0.5
Potamogeton crispus, curly-leaf pondweed	74.9	60.7	38.1	32.2	60.4
Potamogeton praelongis, white-stem pondweed		0.3	1.6	0.9	0.9
Potamogeton pulcher, spotted pondweed		0.3			
Potamogeton pusillus, small pondweed	0.9	9.0	18.6	21.3	12.2
Potamogeton zosteriformis, flat-stem pondweed	1.8	2.7	8.5	7.1	3.6
Ranunculus aquatilis, white water crowfoot			1.6		0.9
Vallisneria americana, wild celery			0.4		
Wolffia columbiana, common watermeal			0.8		
Zizania palustris, northern wild rice			0.4	0.9	0.9

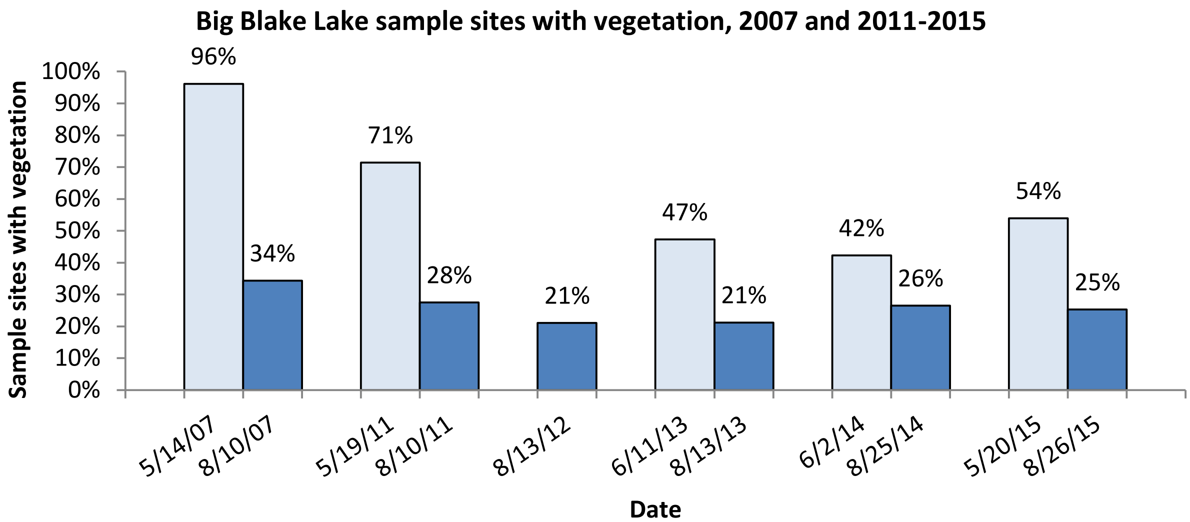
Fall relative frequency, 2007, 2011, and 2013-2015						
	8/10/07	8/10/11	8/13/12	8/13/13	8/25/14	8/26/15
Ceratophyllum demersum, coontail	58.5	40.7	45.7	36.2	36.4	38.4
Chara sp., Muskgrasses						0.7
Elodea canadensis, common waterweed	0.7					2.0
Filamentous algae	5.9		2.9			
Heteranthera dubia, water star-grass	0.7	1.2		1.6	3.5	1.3
Lemna minor, small duckweed	2.2	3.0		0.8	2.8	2.0
Lemna trisulca, forked duckweed	9.6	19.2	16.2	12.6	18.9	19.9
Myriophyllum sibiricum, northern water milfoil	2.2	3.6	7.6	3.9	6.3	5.3
Najas flexilis, bushy pondweed	0.7	1.8		0.8	4.2	
Nitella sp., nitella	0.7					
Nuphar variegata, spatterdock		3.0	1.0		2.1	0.7
Nymphaea odorata, white water lily	1.5	1.8	3.8	3.9	2.8	3.3
Potamogeton amplifolius, large-leaf pondweed					0.7	
Potamogeton crispus, curly-leaf pondweed	0.7	0.6	1.0	0.8	0.7	0.7
Potamogeton illinoensis, Illinois pondweed	2.2					
Potamogeton praelongis, white-stem pondweed		1.2		1.6		2.0
Potamogeton pusillus, small pondweed	0.7	3.6		7.9	5.6	1.3
Potamogeton richardsonii, clasping-leaf pondweed	1.5	1.2	1.0	3.9	0.7	2.0
Potamogeton zosteriformis, flat-stem pondweed	10.4	13.8	14.3	21.3	14.0	15.9
Ranunculus aquatilis, white water crowfoot		0.6		0.8	0.7	1.3
Sparganium angustifolium, narrow-leaved burreed			4.8			
Spirodela polyrhiza, large duckweed	0.7	3.0		0.8		
Stuckenia pectinata, sago pondweed	0.7					
Vallisneria americana, wild celery		0.6	1.9	2.4		1.3
Wolffia columbiana, common watermeal		0.6		0.8	0.7	2.0
Zizania palustris, northern wild rice		0.6				

Sample Points with Vegetation

This value shows the number of sites where plants were actually collected and gives an approximation of the plant coverage of a lake. If 10% of all sample points had vegetation, then it is implied that approximately 10% of the lake is covered with plants.

In all sample years the percent of Big Blake Lake that is covered with plants was greater in spring as compared to fall. Overall, plant coverage has decreased when comparing the earliest sampling years (2007 and 2011) to the later sampling years. The decrease is much more pronounced in the spring sampling period.

In the years with the most dense curly-leaf pondweed growth (2007, 2011, and 2015), the percent of the lake covered with plants in the spring was also the greatest. This arises because the majority of the plants sampled in these years were curly-leaf pondweed.

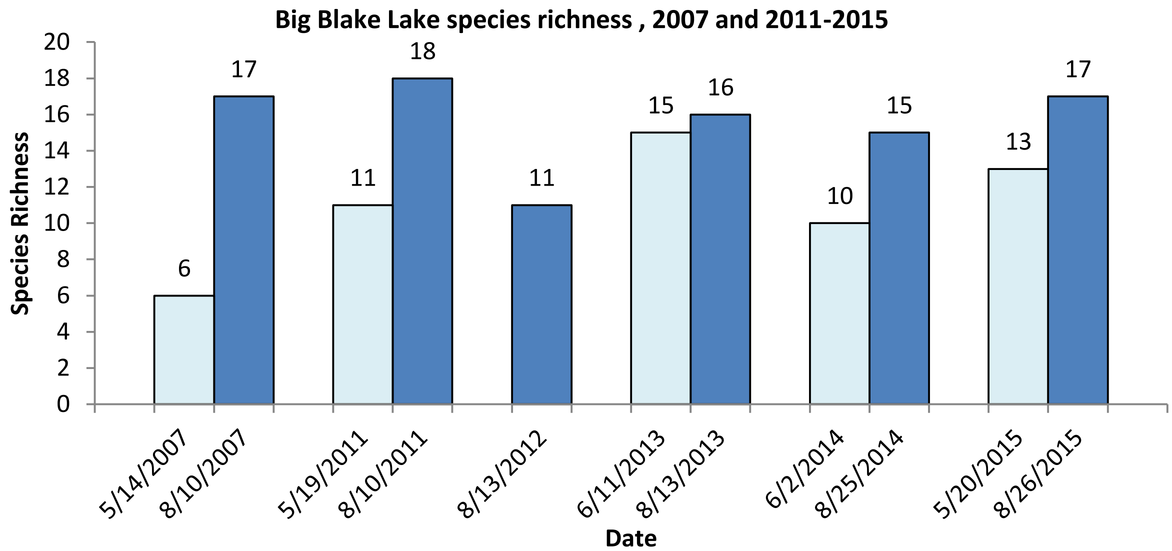


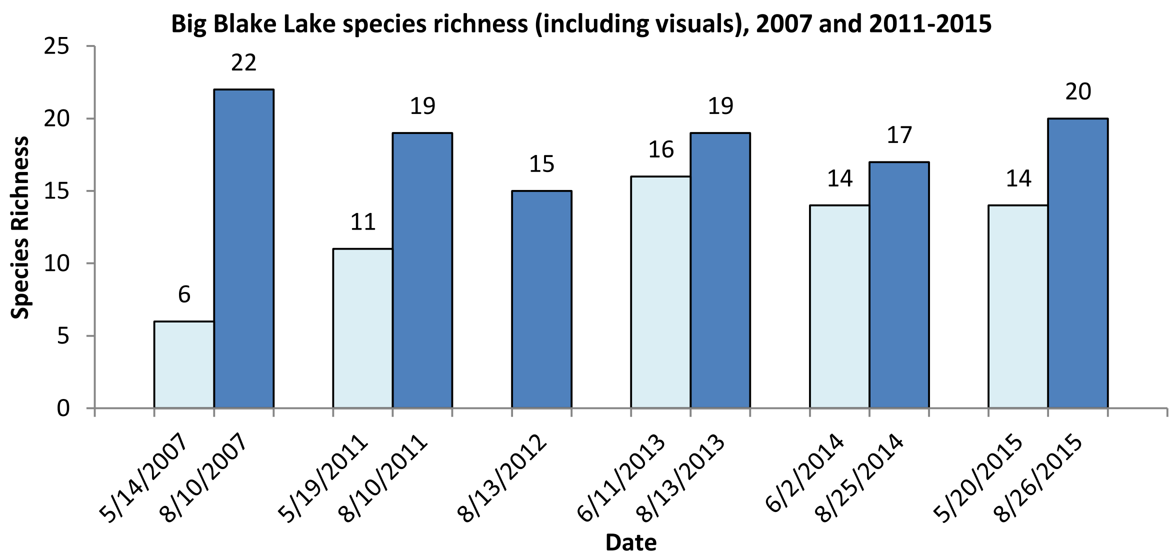
Species Richness

Species richness is a measure of the number of different individual species found in a lake. Species richness can be computed based on plants sampled or based on plants sampled/visually seen during the survey.

In all sampling years, species richness was greater in the fall as compared to the spring.

Species richness was notably lower in spring 2007 as compared with all other sampling years. This was the year curly-leaf pondweed growth was the most prolific. However, across all other years species richness has remained fairly constant, with the exception of fall 2012.





Simpson's Diversity Index

Simpson's Diversity Index (D) is used to determine how diverse the plant community in a lake is by measuring the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). This value ranges from zero to one, with greater values representing more diverse plant communities. In theory, the value for Simpson's Diversity Index is the chance that two species that are sampled will be different. An Index of one means that the two plants sampled will *always* be different (very diverse) and an Index of zero means that the two plants sampled will *never* be different. Simpson's Diversity Index can be calculated by using the equation

$$D = \frac{\sum n(n-1)}{N(N-1)};$$

Where: D = Simpson's Diversity Index;
n= the total number of organisms of a particular species; and
N=the total number of organisms of all species.

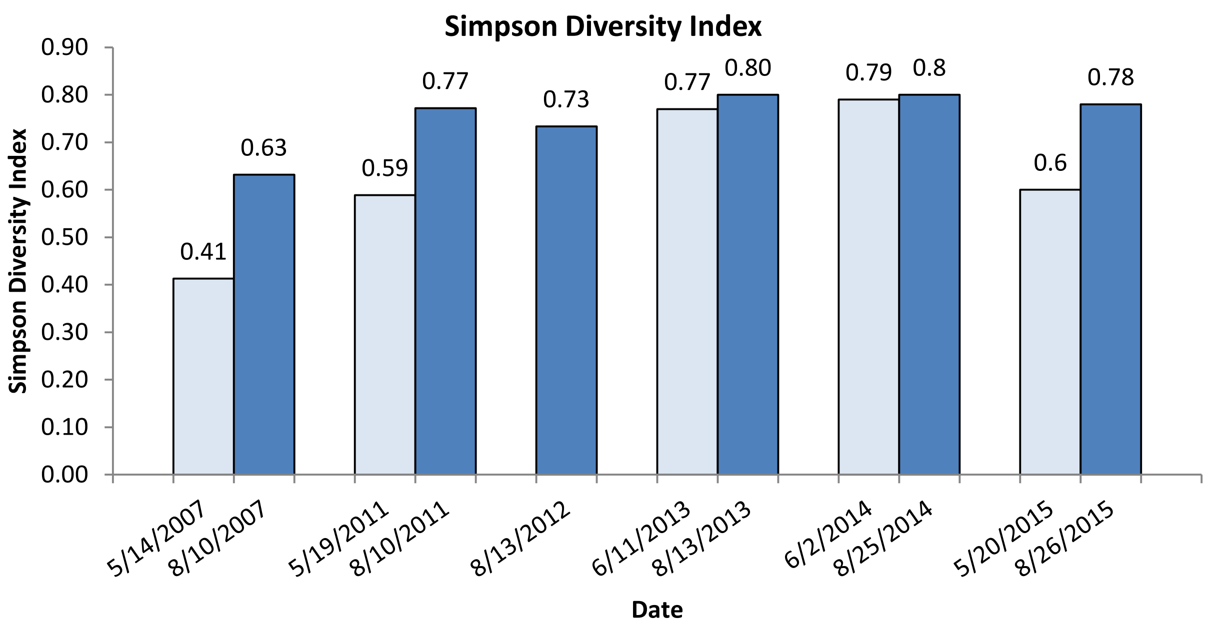
Simpson's Diversity Index example:

If one went into a lake and found just one plant, the Simpson's Diversity Index would be "0." This is because if two plants were sampled randomly, there would be a 0% chance of them being different, since there is only one plant.

If every plant sampled were different, then the Simpson's Diversity Index would be "1." This is because if two plants were sampled randomly, there would be a 100% chance they would be different since every plant is different.

These are extreme and theoretical scenarios, but they do make the point. The greater the Simpson's Diversity Index is for a lake, the greater the diversity since it represents a greater chance of two randomly sampled plants being different.

Diversity in Big Blake Lake has remained relatively constant since 2012. In 2007 spring and fall diversity values were notably lower as compared to all other sampling years. Additionally, low spring diversity values occurred in the years curly-leaf pondweed growth was the most prolific.



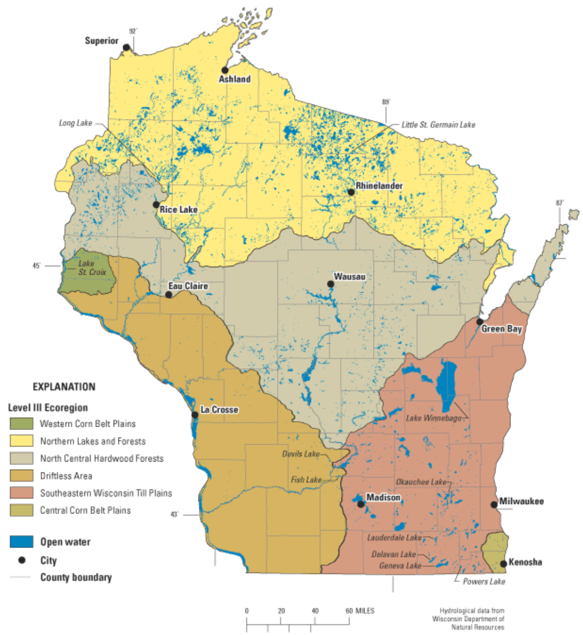
Floristic Quality Index
The Floristic Quality Index (FQI) is designed to evaluate the closeness of the flora in an area to that of an undisturbed condition. It can be used to identify natural areas, compare the quality of different sites or locations within a single lake, monitor long-term floristic trends, and monitor habitat restoration efforts. This is an important assessment in Wisconsin because of the demand by the Department of Natural

Resources (DNR), local governments, and riparian landowners to consider the integrity of lake plant communities for planning, zoning, sensitive area designation, and aquatic plant management decisions.

The FQI takes into account the species of aquatic plants found and their tolerance for changing water quality and habitat modification using the equation $I = \overline{C}\sqrt{N}$

Where I is the Floristic Quality Index;
$\overline{C}$ is the average coefficient of conservation (http://www.botany.wisc.edu/wisflora/FloristicR.asp);
and $\sqrt{N}$ is the square root of the number of species.

The Index uses a conservatism value assigned to various plants ranging from 1 to 10. A high conservatism value indicates that a plant is intolerant of change while a lower value indicates a plant is tolerant of change. Those plants with higher values are more apt to respond adversely to water quality and habitat changes. The FQI is calculated using the number of species and the average conservatism value of all species used in the Index. Therefore, a higher FQI indicates a healthier lake plant community. It should be noted that invasive species have a conservatism value of 0.



Summary of North Central Hardwood Forest values for Floristic Quality Index

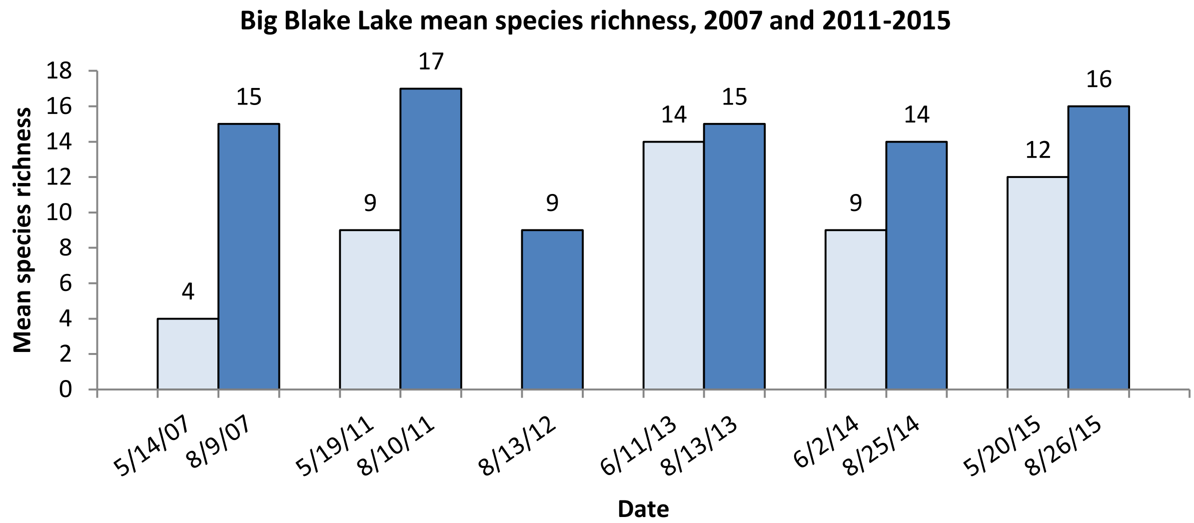
Mean species richness = 14
Mean average conservatism = 5.6
Mean Floristic Quality = 20.9*

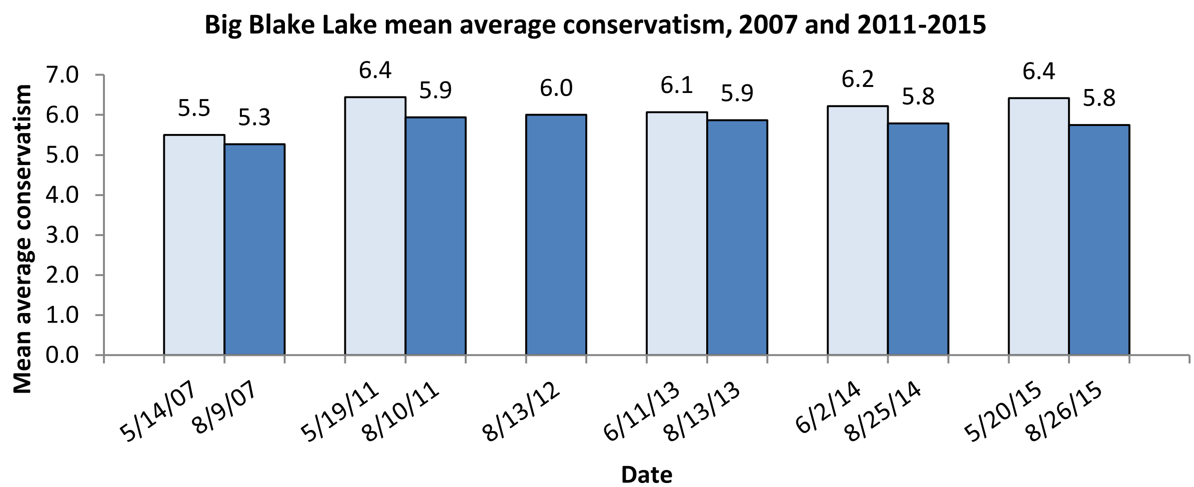
**Floristic Quality has a significant correlation with area of lake (+), alkalinity (-), conductivity (-), pH (-) and secchi depth (+). With a positive correlation, as that value rises so will FQI. With a negative correlation, as a value rises, the FQI will decrease.*

Using data from 2007 and 2011-2015, the mean species richness for Big Blake Lake is 12, which is below the mean value for the North Central Hardwood Forest. The mean average conservatism value for Big Blake Lake is 5.9, which is above the mean value for the North Central Hardwood Forest. The mean Floristic Quality value for Big Blake Lake is 20.4 which is just below the mean value for the North Central Hardwood Forest.

Using data from only the past three years during which the study took place (2013-2015), the mean species richness for Big Blake Lake is 13, which remains below the mean value for the North Central Hardwood Forest. However, the mean average conservatism value (6.0) and the mean Floristic Quality (21.8) are both above the value for the North Central Hardwood Forest.

Mean species richness, mean average conservatism, and mean floristic quality for spring of 2007 were substantially lower as compared with spring 2011-2015.


Big Blake Lake mean species richness, 2007 and 2011-2015
Mean species richness
0
2
4
6
8
10
12
14
16
18
4
15
9
17
9
14
15
9
14
12
16
5/14/07
8/9/07
5/19/11
8/10/11
8/13/12
6/11/13
8/13/13
6/2/14
8/25/14
5/20/15
8/26/15
Date


Big Blake Lake mean average conservatism, 2007 and 2011-2015
Mean average conservatism
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
5.5
5.3
6.4
5.9
6.0
6.1
5.9
6.2
5.8
6.4
5.8
5/14/07
8/9/07
5/19/11
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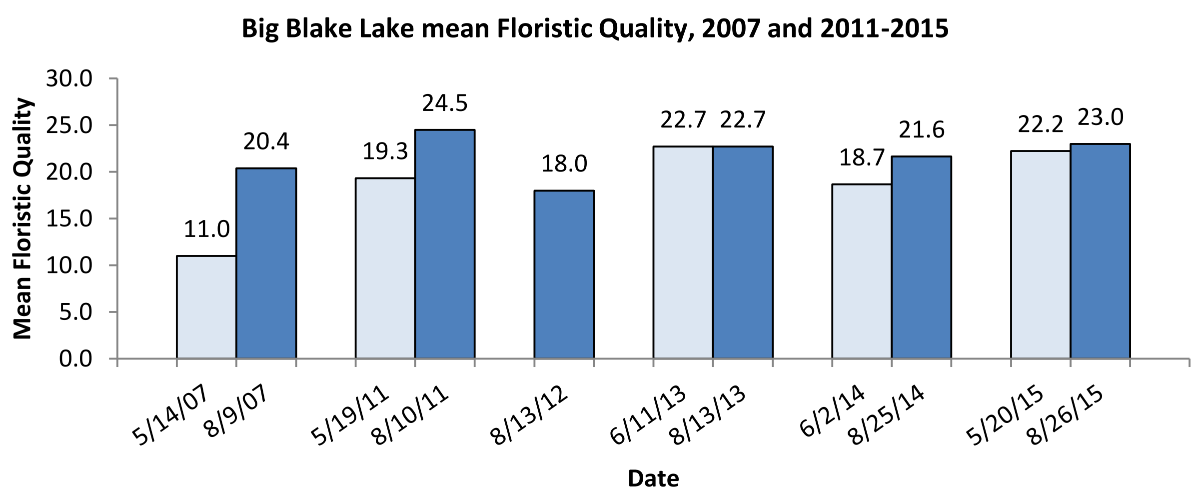
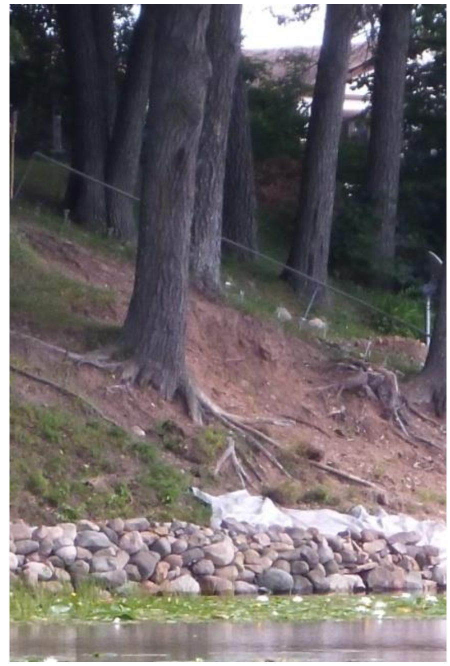
5/20/15
8/26/15
Date


Big Blake Lake mean Floristic Quality, 2007 and 2011-2015
Mean Floristic Quality
0.0
5.0
10.0
15.0
20.0
25.0
30.0
11.0
20.4
19.3
24.5
18.0
22.7
22.7
18.7
21.6
22.2
23.0
5/14/07
8/9/07
5/19/11
8/10/11
8/13/12
6/11/13
8/13/13
6/2/14
8/25/14
5/20/15
8/26/15
Date

Land Use and Water Quality



The health of 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 hard, man-made surfaces such as rooftops, paved driveways, and concreate patios that make it impossible for rain to infiltrate into the ground.

By making it impossible for rainwater to infiltrate into the soil, impervious surfaces increase the volume of rainwater that washes over the soil surface and runs off directly into lakes and streams. 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.

In extreme precipitation events erosion and gullies can result. The signs of erosion are unattractive and can cause decreases in property values. Sediment can also have negative impacts on aquatic life: fish eggs will die when covered with sediment and sediment influxes to a lake can decrease water clarity making it difficult for predator fish species to locate food.

Increases in impervious surfaces and lawns 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. 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, cause decreases in fisheries habitat.

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, soil capacity is reduced and the impacts of erosion can be intensified.

Avoiding establishing lawns 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 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.

Historical Land Use in the Big Blake Lake Watershed

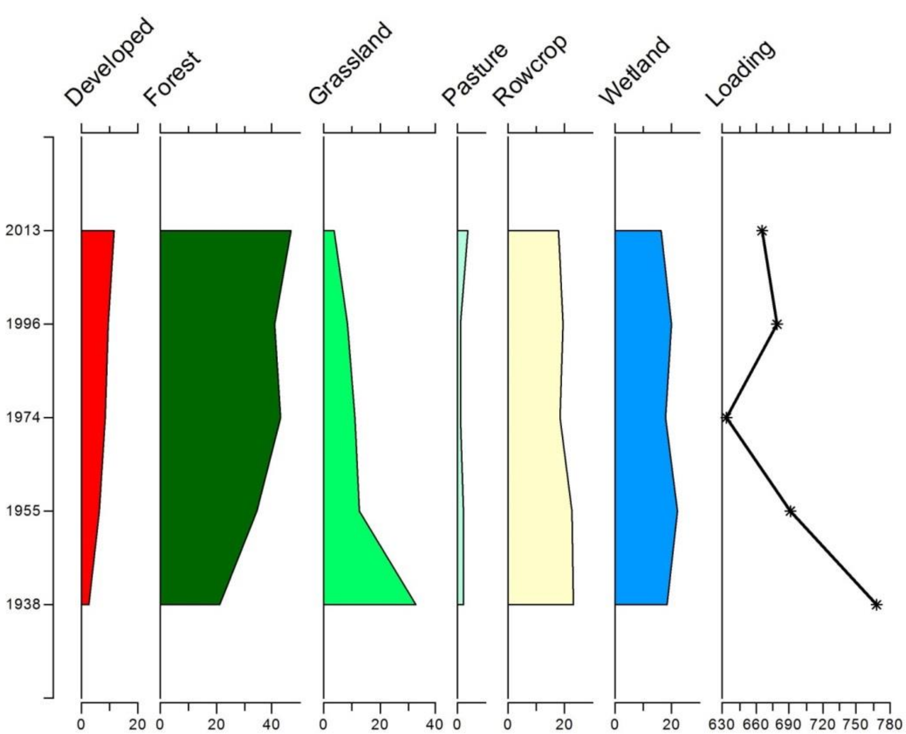
The area of land that drains to a lake is called a watershed. A student from the University of Wisconsin-River Falls delineated the land use in the Big Blake Lake watershed for the years 1938, 1955, 1974, 1996, and 2013. Land use was categorized as developed, forest, grassland, pasture, row crop, and wetland.

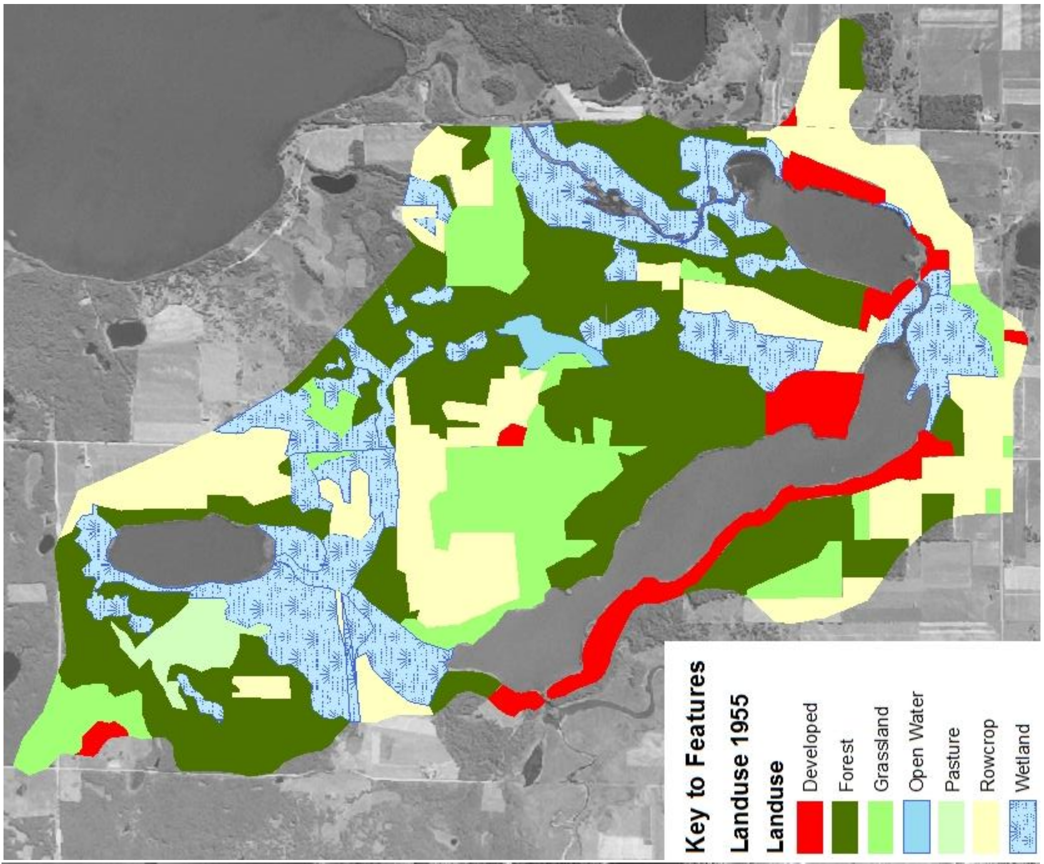
Over this timeframe, the amount of pasture, row crop, and wetland has remained fairly consistent; the amount of grassland has decreased (33% to 4%); and the amount of forest and developed land has increased (21% to 47% and 3% to 12%, respectively).

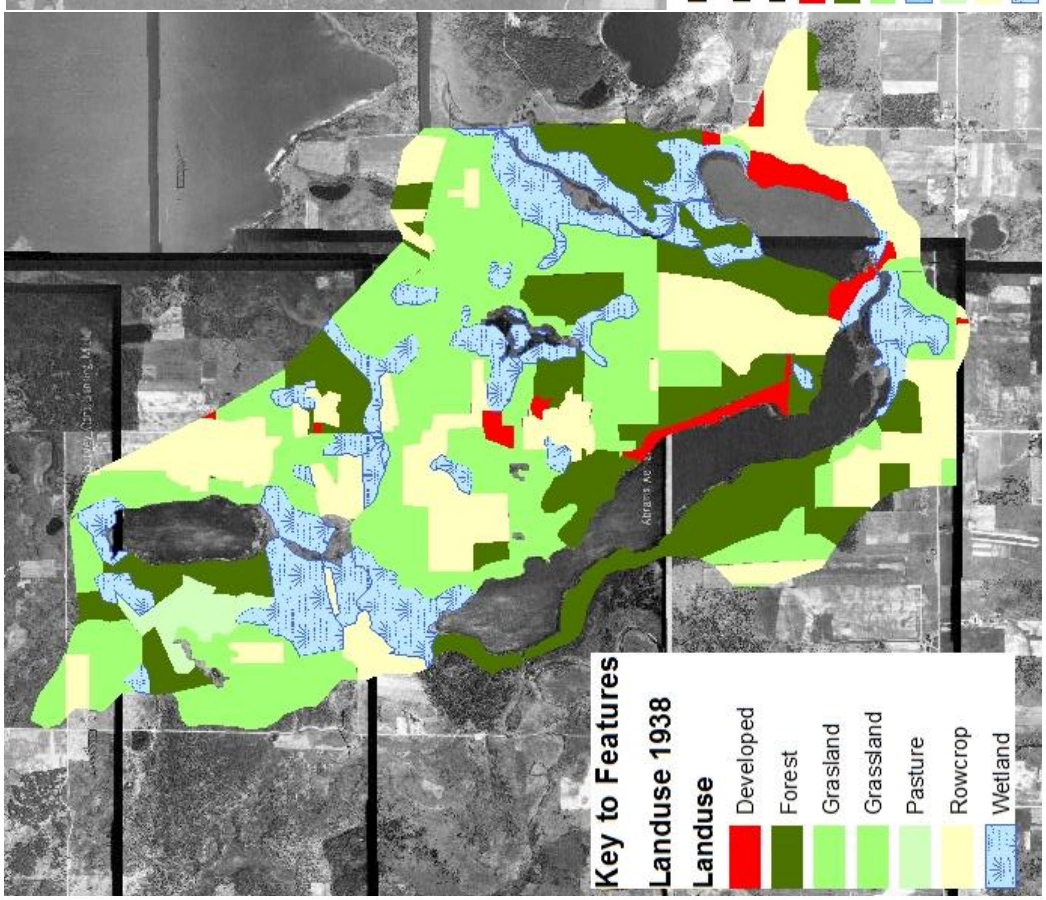
The Wisconsin Lakes Modeling Suite (WiLMS) was used to model conditions for Big Blake Lake each year and estimate land use nutrient loading for the watershed. Phosphorus is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algae growth in most waterbodies.

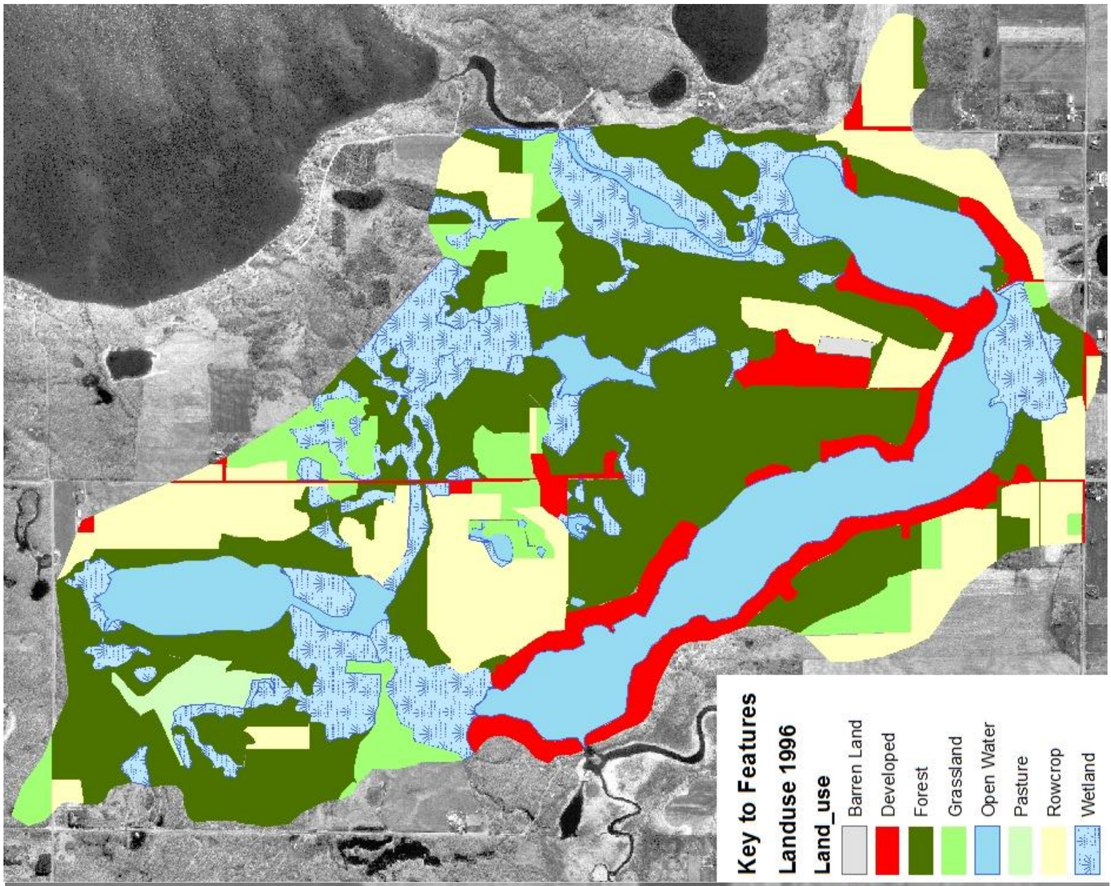
This data indicated that based on land use, phosphorus loading was greatest in 1938 (769 lbs/yr), followed by 1955 (691 lbs/yr), 1996 (679 lbs/yr), 2013 (666 lbs/yr), and 1974 (634 lbs/yr).

Date	Developed (acres)	Forest (acres)	Grassland (acres)	Pasture (acres)	Row crop (acres)	Wetland (acres)	Phosphorus loading (lbs/yr)
1938	57, (3%)	451, (21%)	705, (33%)	40, (2%)	490, (23%)	391, (18%)	769
1955	132, (6%)	753, (35%)	279, (13%)	40, (2%)	489, (23%)	474, (22%)	691
1974	179, (8%)	922, (43%)	244, (11%)	26, (1%)	392, (18%)	379, (18%)	634
1996	204, (10%)	873, (41%)	177, (8%)	28, (1%)	417, (20%)	421, (20%)	679
2013	250, (12%)	1004, (47%)	80, (4%)	80, (4%)	390, (18%)	348, (16%)	666

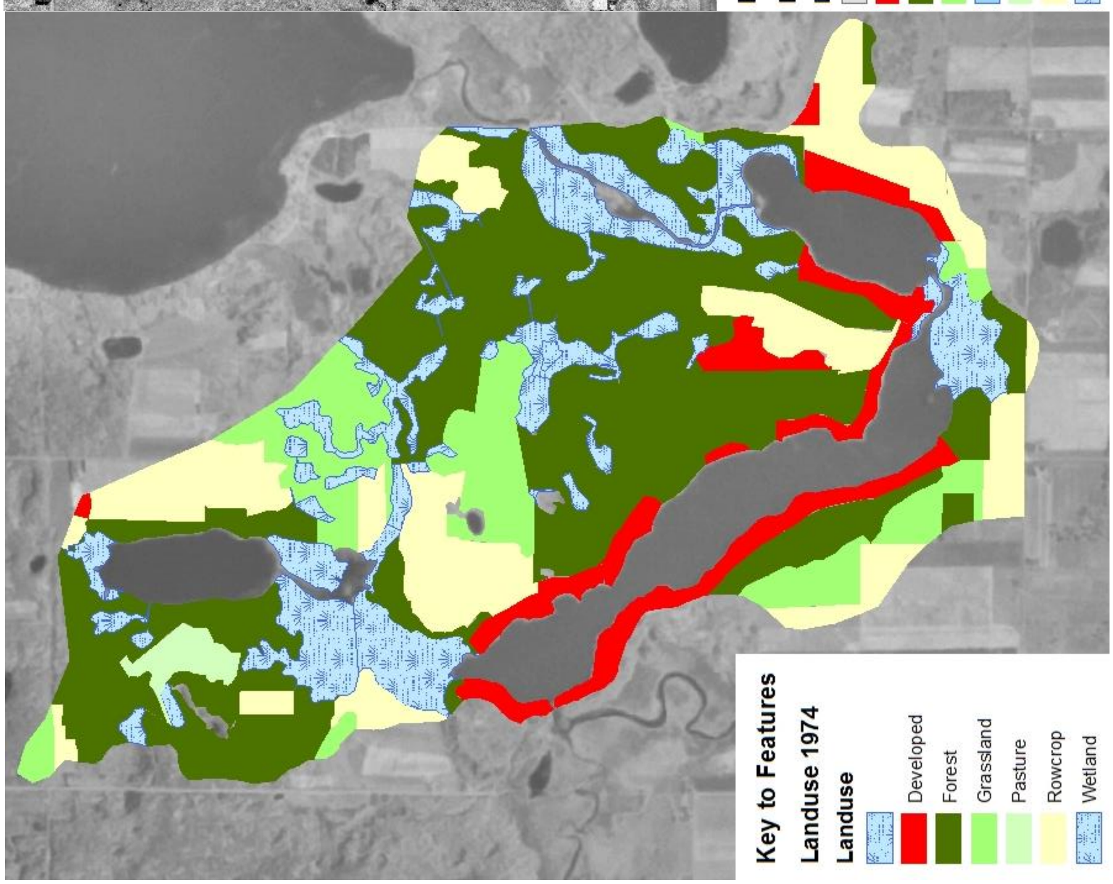



Key to Features
Landuse 1955
Landuse
Developed
Forest
Grassland
Open Water
Pasture
Rowcrop
Wetland

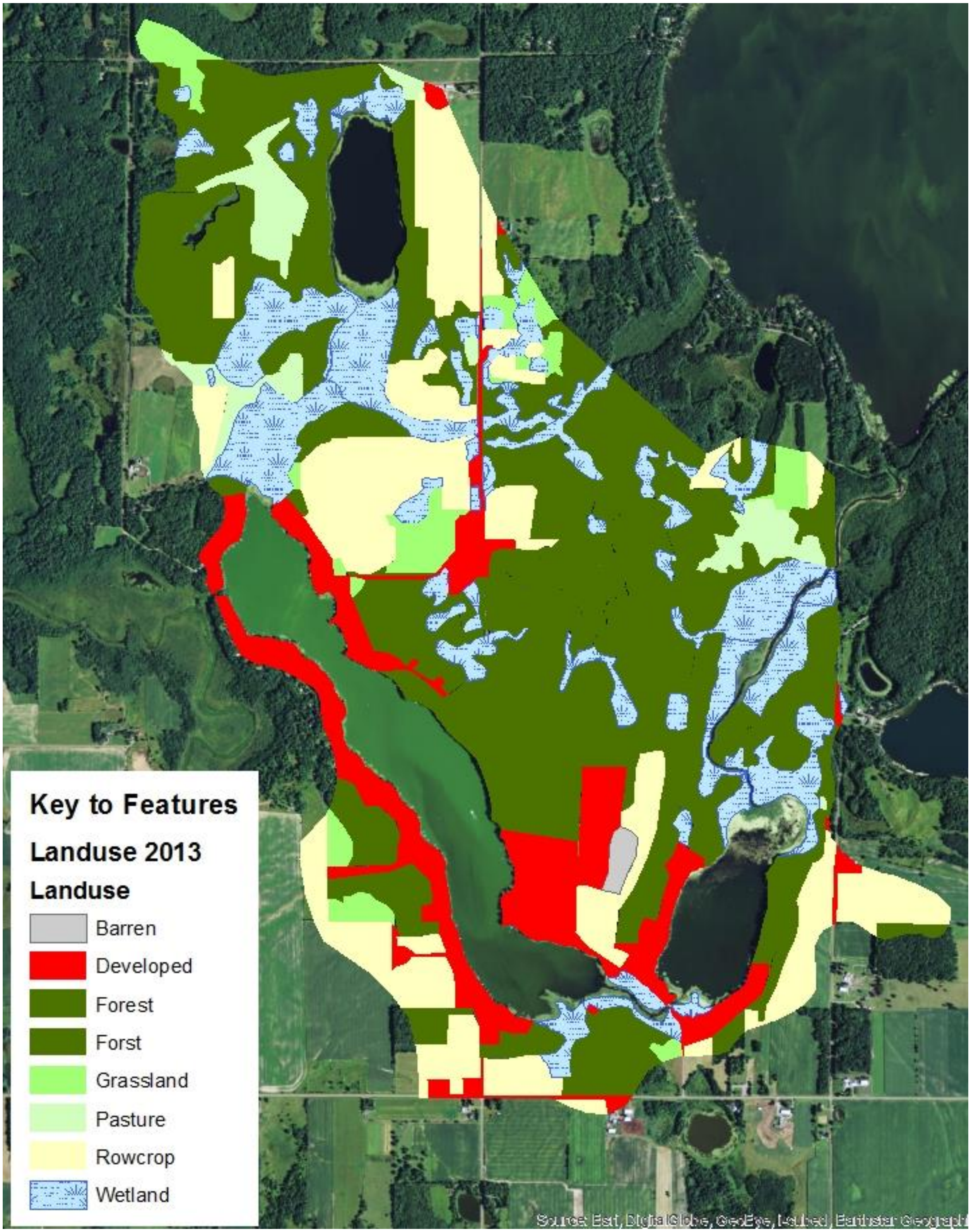

Key to Features
Landuse 1938
Landuse
Developed
Forest
Grasland
Grassland
Pasture
Rowcrop
Wetland



Key to Features
Landuse 1996
Land_use
Barren Land
Developed
Forest
Grassland
Open Water
Pasture
Rowcrop
Wetland



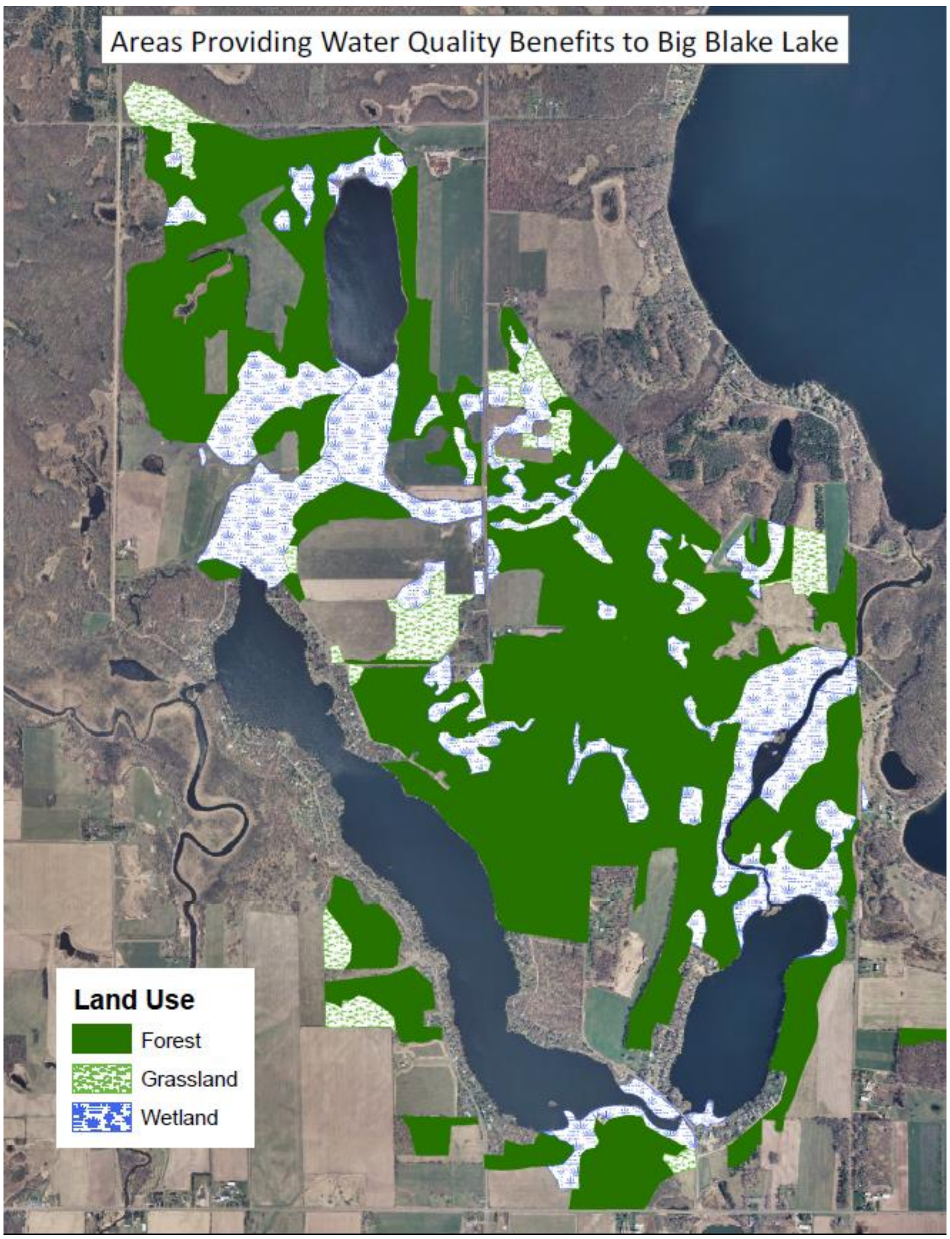
Key to Features
Landuse 1974
Landuse
Developed
Forest
Grassland
Pasture
Rowcrop
Wetland


Key to Features
Landuse 2013
Landuse
Barren
Developed
Forest
Forst
Grassland
Pasture
Rowcrop
Wetland
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographi

Areas Providing Water Quality Benefits to Big Blake Lake

Natural areas such as forests, grasslands, 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.

Forests make up the largest land use in the Big Blake Lake watershed (47%) and wetlands make up the third largest land use (16%). Grasslands make up only 4% of the land use in the Big Blake Lake watershed. These areas should be considered sensitive areas and preserved for the benefits they provide to the lake.



Information and Education[27]

The Big Blake Lake Protection and Rehabilitation District is actively providing information and education opportunities to their membership. The District communicates with their membership during their spring and fall meetings, through their newsletter and mailings, and through direct contact with their volunteers. Additionally, Polk County Land and Water Resources Department staff attended the District Spring and Fall meetings in 2013, 2014, and 2015 and communicated grant updates to attendees.

2013 Information and Education Summary

A total of 42 volunteers signed up to assist with the Big Blake Lake Clean Boats, Clean Waters program in 2013. New supplies were ordered for volunteers and current literature, forms, shirts, and supplies were refreshed and distributed. Weekly contact was made with each volunteer through email or phone in June and July. Volunteers spent 379 hours at the north access and inspected 45 boats and contacted 93 people. Volunteers spent 38 hours at the west access and inspected 11 boats and contacted 17 people.

A volunteer cookout was organized to coordinate with the July 4th Landing Blitz. Sixteen volunteers attended. Photo opportunities for a press release were organized in June to promote the Landing Blitz. A press release for the Landing Blitz was distributed to 5 media outlets. The press release and photo were published in the Polk County Leader and a county-wide release which mentioned Big Blake Lake was published in the Amery Free Press.

All 212 members of the District received two direct mailings which included AIS information. The Blake Lake Bugle Newsletter contained one page of information on Clean Boats, Clean Waters and AIS. Another mailing included: the Wisconsin Boating Regulations pamphlet and the Clean Boats, Clean Waters flyer. Additionally, AIS flyers and brochures were distributed at area bait shops and places where bait is sold.

[27] Information and photos provided by Peggy Lauritsen, Clean Boats, Clean Waters Volunteer Coordinator

2014 Information and Education Summary

A total of 52 volunteers signed up to assist with the Big Blake Lake Clean Boats, Clean Waters program in 2014, which was a 20% increase from the previous year. New supplies were ordered for volunteers and current literature, forms, shirts, and supplies were refreshed and distributed. Contact was made with each volunteer through email or phone in June and July. Volunteers spent 202 hours at the north access and inspected 38 boats and contacted 75 people over the course of the boating season. Volunteers spent 205 hours at the west access and inspected 42 boats and contacted 70 people over the course of the boating season.

At the May 17th Spring District Meeting, a Clean Boats, Clean Waters display was set up and a flyer was circulated to all attendees. The Drain Campaign was also announced to attendees. Approximately 150 people attended the meeting.

For the first time, the District participated in the statewide Drain Campaign which took place on June 14th and 15th. On June 14th, Katelin Holm with the Polk County Land and Water Resources Department provided a special AIS training session for members of the Big Blake Lake District. Ten people attended this supplementary training.

The District participated in the 2014 statewide Landing Blitz over the 4th of July weekend. A press release for the Landing Blitz was distributed to 3 media outlets and was published in The Leader. A county-wide press release which mentioned Big Blake Lake was also published in area newspapers.

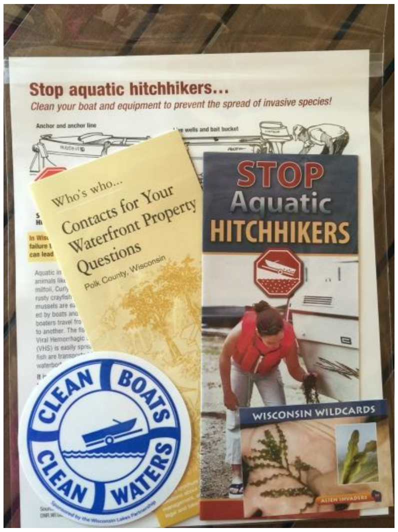
Similar to 2013, the Big Blake Lake Bugle Newsletter contained one page of information on Clean Boats, Clean Waters and AIS.

Three volunteers of the Big Blake Lake Protection and Rehabilitation District attended a county-wide Aquatic Invasive Species Citizen Lake Monitoring Network Training on June 11th, 2014. The training included a hands-on session to view specimens of AIS with a focus on native as well and invasive plants.

Additionally, AIS flyers and brochures were distributed at area bait shops and places where bait is sold.

2015 Information and Education Summary

A total of 40 volunteers signed up to assist with the Big Blake Lake Clean Boats, Clean Waters program in 2015. New supplies were ordered for volunteers and current literature, forms, shirts, and supplies were refreshed and distributed. Weekly contact was made with each volunteer through email or phone in June and July. Clean Boats, Clean Waters volunteers spent 276 hours at the north access and inspected 24 boats and contacted 35 people over the course of the boating season. Volunteers spent 132 hours at the west access and inspected 8 boats and contacted 13 people over the course of the boating season.



At the Spring and Fall District Meetings, a Clean Boats, Clean Waters display was set up and a packet of AIS information, including the Big Blake Lake waterproof AIS flyer was circulated to all attendees. The latest information from state and county sources was also provided.

A total of seventeen volunteers attended trainings on Saturday, June 6th and Saturday, June 13th as part of the WDNR Drain Campaign. Polk County Land and Water Resources Department staff attended the June 13th training and provided supplemental AIS information. As in years past, the District also participated in the statewide Landing Blitz and authored a press release which was published in the Inter-County Leader.

Additionally, AIS flyers and brochures were distributed at area bait shops and places where bait is sold.

On Thursday, July 2nd a pontoon classroom was held by the Polk County Land and Water Resources Department for members of the Big Blake Lake Protection and Rehabilitation District. The classroom was attended by eight members of the District. During the pontoon classroom participants had the opportunity to collect physical and chemical data, zooplankton samples, algae samples, sediment samples, and plant samples. Data were explained and participants saw zooplankton and examined aquatic plants (native and invasive). Preserved specimens of common aquatic invasive species were also shown to attendees. A brief overview of all the projects included in the grant was also provided. Topics of conversation included aquatic plants, wild rice, and lake sediments.

Summary of Rules and Legislation

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 <Departments < Land Information < Comprehensive Plan

Town, City and Village Comprehensive Plans are available at:
http://www.co.polk.wi.us < Departments < Land Information < Comprehensive Plan < City, Village, and Town Comprehensive Plans

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

Polk County's oldest portions of the current zoning code are over 40 years old. Over the years, there have been numerous revisions to the original code. However, the current zoning code is in need of a comprehensive rewrite in order to address current and future issues in Polk County and to implement the vision set forth in the County's adopted comprehensive plan. Recognizing this, the County began a rewrite process in March 2010. A Zoning Citizen Advisory Committee (CAC) met to review the existing ordinances and make suggestions on how to appropriately rewrite them for the past 3+ years.

After reviewing the input of the advisory committees, public hearings and other changes, the Conservation, Development, Recreation and Education (CDRE) Committee, at their September 2, 2015 meeting, recommended that the ordinance be moved on to the County Board's agenda for consideration of passage at the September 15, 2015 meeting. At the September 15th, 2015 Polk County Board of Supervisors Meeting, the ordinance below was adopted.

Now that the ordinance has been passed, each Town within Polk County will have one calendar year to decide if they want to adopt county zoning or not. Each town participating in county zoning will be responsible for developing the zoning map for their town. Staff from the Land Information Department will be assisting the towns in this process over the next year.

The current Comprehensive Zoning Ordinance is available at:
http://www.co.polk.wi.us < Departments < Land Information < Ordinances (Zoning)

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 < Departments < Land Information < Ordinances (Zoning)

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 < Departments < Land & Water Resources < Ordinances.

Storm Water and Erosion Control

This 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.

The ordinance is available online at:
http://www.co.polk.wi.us < Departments < Land & Water Resources < Ordinances.

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

Amended Illegal Transport of Aquatic Plants and Invasive Animals

The purpose of this ordinance, passed in June 2011, is to prevent the spread of aquatic invasive species in Polk County and surrounding water bodies by prohibiting the transport of boats, trailer, personal watercraft, and equipment if aquatic invasive plants or invasive animals are attached.

The ordinance is available online at:
http://www.co.polk.wi.us < Departments < Land & Water Resources < Ordinances.

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