CalMan Lakes

Calumet and Manitowoc Counties, Wisconsin

Watershed Management Planning Project

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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

CalMan Lakes Planning Committee

The Planning Committee was responsible for much of the volunteer coordination and oversight that occurred with this project.

Calumet County Staff	Manitowoc County Staff	Volunteers
Danielle Santry	Jerry Halverson	Bob Sengbush
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Organization

Brillion Conservation Club
Long Lake Advancement Association

Wisconsin Dept. of Natural Resources

Mary Gansberg	Steve Hogler	Adam Nickel

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EXECUTIVE SUMMARY

The four lakes addressed in this study are known collectively as the CalMan lakes and include Long Lake in Manitowoc County and Round, Boot, and Becker lakes in Calumet County. These four lakes are in the same drainage system with Round and Boot lakes being headwater lakes which drain to Long Lake, and Long Lake drains into downstream Becker Lake. Becker Lake is drained via Spring Creek which ultimately flows into the Manitowoc River.

The water quality data collected as part of this project and earlier studies indicate that all of the lakes are eutrophic to hypereutrophic (overly productive) with excessive nutrient and algal levels and low water clarity. Average phosphorus, chlorophyll-*a*, and Secchi disk transparencies in these lakes are three to ten times worse than median values for lakes within the ecoregion and state. Poor water quality conditions have resulted in all four lakes being placed on the Wisconsin Impaired Waters listing to the U.S. Environmental Protection Agency. In all four lakes, the levels of phosphorus and chlorophyll-*a* exceeded impairment thresholds for recreational use and fish and aquatic life use.

Aquatic plant surveys completed as part of this project showed that the lakes are sparsely vegetated and their aquatic plant communities are highly degraded. The low-light conditions in combination with highly flocculent sediments (and carp in Long Lake) serve to suppress aquatic plant growth. The native aquatic plant species that are present, such as sago pondweed and coontail, are more tolerant of the low-light conditions found in these lakes. In addition, the disturbance-tolerant, non-native aquatic plant species of Eurasian watermilfoil and curly-leaf pondweed dominate the plant communities of Long and Becker lakes, another indication of their impaired condition. The aquatic plant communities of the CalMan lakes are of significantly lower quality when compared to other lakes in the ecoregion and the state.

The paleoecological study completed as a part of this project found that prior to the arrival of Euroamerican settlers in the nineteenth century, Round Lake was a bog lake with a low pH and low phosphorus concentrations. Boot Lake was also likely a bog lake prior to Euroamerican settlement. Historically, Long and Becker lakes were alkaline, mesotrophic lakes but their water quality became degraded soon after the arrival of Euroamerican settlers. Agricultural activities in the late 1800s transformed all of the lakes into highly productive lakes with elevated levels of phosphorus and algae, poor water clarity, and sparse aquatic plant growth.

In order to estimate where the primary sources of phosphorus originate in these lakes, some of the inflowing streams were monitored, watershed modeling was completed, and internal phosphorus loads were measured. Continuous flow monitoring instrumentation was deployed just upstream of where the major water courses enter Round, Long, and Becker lakes. Samples for phosphorus and suspended solids were periodically collected and analyzed at these same sites. Stream flow in all of these streams was intermittent with flows being highest during spring runoff and following major precipitation events. Flows were reduced or often stagnant during the summer and part of the fall months. The flow monitoring in Round Lake proved to be problematic as during high flows water overflowed the road and bypassed the culvert. At other times the lake level was high enough that water back-flowed from the lake into the upstream wetland.

To supplement the flow monitoring, watershed modeling was completed to estimate the amount of phosphorus that enters these lakes from land use in the watersheds, including runoff from shoreland homes and septic systems. The modeling effort found that the greatest external source of phosphorus from the watersheds is the result of agricultural activity. There are a number of shoreland homes around Long Lake and these properties contributed additional phosphorus from lawn runoff and septic systems.

Phosphorus and chlorophyll-*a* concentrations in these lakes are highest in the spring, soon after ice off, and again immediately following fall turnover. Although many lakes experience elevated phosphorus levels during the spring following higher runoff from snowmelt, the highest chlorophyll-*a* concentrations are typically measured in late summer. The high chlorophyll-*a* concentrations measured in spring and fall in the CalMan lakes are due to a large pulse of phosphorus which originates from deep-water sediments during summer stratification (internal phosphorus loading). During summer stratification, phosphorus is released from bottom sediments into the overlying water. In fall, mixing mobilizes this sediment-released phosphorus to the surface where it fuels late-season algal blooms. In calcareous lakes like the CalMan lakes, the sediment-released phosphorus mobilized to the surface in the fall largely remains suspended within the water over the winter and contributes to algal blooms in the spring. Upon dying, algae sink to the bottom, contributing to the buildup of phosphorus in bottom waters during the summer.

As mentioned, a combination of tributary monitoring, watershed modeling, and in-lake studies was used to estimate the total annual phosphorus load (external and internal) that enters each lake. These analyses indicate that Round and Boot lakes each receive approximately 200 pounds of phosphorus per year while Long and Becker lakes receive over 1,000 pounds per year each. Even though Boot and Round lakes receive similar amounts of phosphorus, because of Boot Lake's smaller water volume, phosphorus and chlorophyll-*a* concentrations are higher. Similarly, while Becker and Long lakes receive similar phosphorus loads, Long Lake's larger water volume is better able to dilute incoming phosphorus, resulting in lower in-lake concentrations.

These analyses also indicate that a significant portion of the CalMan lakes' annual phosphorus budget originates from the internal loading of phosphorus. The annual proportion of phosphorus that originates from internal phosphorus loading ranges from approximately 20% (~50 pounds) in Boot Lake to greater than 60% (~140 pounds) in Round Lake. Model results showed that even if 90% of internally loaded phosphorus could be eliminated in these lakes, for example through an alum treatment, the phosphorus levels would still place the lakes on the Wisconsin Impaired Waters list. Even in Round Lake where internal phosphorus loading is the largest source of phosphorus, there would also need to be a reduction in external phosphorus loading from the watershed by about 44%.

The other three lakes would need a greater reduction in external loading from the watershed to reach the phosphorus and chlorophyll-*a* concentrations necessary for the lakes to be delisted. The threshold phosphorus concentration for these lakes, is 30 μg/L. Achieving this phosphorus goal would require reducing internal phosphorus loading by 90% and external phosphorus loading by 75- 95%.

Reduction of phosphorus and algal blooms is likely most feasible in Round Lake given its relatively small surface area and watershed. This could be achieved by implementing best management practices within the watershed to reduce the external loading of phosphorus in combination with the application of alum to reduce the internal loading of phosphorus. The application of alum to reduce internal loading has been done on lakes throughout the world since 1970 and it is well understood how to implement a successful treatment. Eighteen lakes have been treated in Wisconsin. It is possible that the external load could be sufficiently reduced by either restoring the upstream wetland or replacing it with a properly sized sedimentation basin. Changing the land use from row crops to a cover crop would reduce phosphorus input even more.

The completion of an alum treatment on Long, Becker, or Boot lakes to reduce the internal loading of phosphorus would likely result in detectable improvements to water quality. Importantly, if there are no reductions in the external loading of phosphorus, the positive effects of the alum treatments would be short-lived and would likely not last more than five years. Continued external loading of phosphorus and sediments would bury the layer of alum and make it ineffective at retaining phosphorus. If the external loading of phosphorus can be reduced significantly, the effects of an alum treatment can be expected to last at least 20 years.

1.0 INTRODUCTION

The CalMan Lakes consist of four lakes located along the Calumet-Manitowoc County border in northeastern Wisconsin (Map 1). The project sponsor, the Calumet County Resource Management Department (CCRMD), began developing an action plan to document ecological health issues on the lakes with two small-scale lake management planning grants through the Wisconsin Department of Natural Resources (WDNR) in 2011. The resulting CalMan Lakes Organizational Project report (2012) included watershed land use inventories, private on-site wastewater treatment system (POWTS) inventories, lake monitoring group data to document water quality impairments, and an action plan to organize future efforts towards improving the lakes. Most notably, this report listed application for, and development of, a CalMan Lakes Plan through the WDNR Lake Management Planning Grant Program.

Field Survey Notes

All lakes surrounded by beautiful rolling farmlands. Inlet/outlet streams observed flowing in spring months, but had mostly dried during summer. Numerous AIS observed on lakes during 2013 surveys. Deceased fish observed on Boot Lake during spring 2013 field visit.

Photograph 1.0-1. Calumet County and Onterra staff, Long Lake, 2013

Lakes at a Glance - The CalMan Lakes

		Round Lake	Boot Lake	Long Lake	Becker Lake
Morphometry	Surface Area (acres)	12	11	129	37
	Maximum Depth (ft)	55	15	38	51
	Mean Depth (ft)	21	8	12	16
	Volume (acre-ft)	246	88	1,509	572
	Watershed Size (acres)	44	116	747	1,258
	Watershed to Lake Area	3:1	9:1	5:1	32:1
Vegetation	Comprehensive Survey Date*	2013	2014	2012	2013
	Number of Native Species	8	6	14	7
	Number of Non-Native Species	2	1	4	4
Water Quality	Trophic State	Eutrophic to Hypereutrophic			
	Limiting Nutrient	Phosphorus			
	pH	Range 7.2 - 8.4			
	Avg. Summer Secchi Disk Depth (ft)	4.0	0.9	2.8	2.1

**Point-intercept surveys completed by Wisconsin Department of Natural Resources*

In addition to the actions documented within the CalMan Lakes Organizational Project report, local volunteers have collaborated with WDNR, Manitowoc and Calumet Counties, and other organizations to partake in activities aimed at monitoring the condition of these lakes. In 2009, 2012, 2013, 2014, and 2016 volunteers monitored watercraft at the public access points at Becker and Round Lakes as part of the state's Clean Boats Clean Waters (CBCW) Program, which is intended to reduce the transport of aquatic invasive species between waterbodies. A greater presence of CBCW volunteers can be seen at the Long Lake public access, where in 2013 volunteers spent 75 hours inspecting 208 watercraft and educating 506 people on aquatic invasive species related issues.

Wisconsin Department of Natural Resources staff and citizen volunteers have collected water quality data on several of the CalMan Lakes. Long Lake is included within the WDNR's Long-term Trends water quality monitoring program. Becker Lake has a volunteer collecting water quality data through the Citizen Lake Monitoring Network (CLMN). The lakes are impaired largely by nutrients, which have resulted in late-summer algal blooms as well as dissolved oxygen depletion. Several accounts of winter fish kill have been documented on Becker and Round lakes. The poor water quality has impacted Becker and Round lakes to such an extent that in a 2012 correspondence, regional fisheries biologist Steve Hogler wrote:

The success or failure of restocking efforts in both Becker and Round lakes will depend on improving the water quality of each lake. If additional low oxygen events occur during succeeding winters, fish stocking will not restore a desirable mix of self-reproducing fish back into the lakes. To achieve long-term stability of a desirable mix of fish species, long-term improvements in water quality will be necessary. To improve water quality in these lakes, changes in the watershed that reduce sediment and phosphorus runoff into the lake will be required. Additional management actions may be required even with decreases of external phosphorus levels to ensure long-term stability of the lake and its fish community.

Along with preventing the spread of aquatic invasive species, it is the long-term objective of the CCRMD to create a comprehensive management plan for these four lakes and their watersheds. This management planning project was completed in a series of phases, with initial studies beginning in 2013-2014 and more specific studies following. Developing a management plan for these lakes over the course of several phases allowed for financial savings to be realized in project costs while creating a manageable project that allowed for sufficient attention to be applied to each lake's needs. The staff at the CCRMD played a critical role in the management planning process between collecting data in the field, co-facilitating public forums, contacting local landowners, and reviewing reports as they were produced. The collaboration between the WDNR, county staff, local stakeholders, and private consultants were crucial to the project's success.

CalMan Lakes Description and Designated Use

Section 101(a)(2) of the Clean Water Act specifies that waterbodies be assigned one or several "uses". Designated uses are essentially definitions of the water quality standards for any given lake, river, stream segment, etc. They may be thought of as water quality goals, management objectives, or functions that are supported by a level of water quality. They are of course necessary for water quality goal establishment, but also in communicating these goals to the public. Examples of common designated uses include protection of aquatic life, recreation, domestic water supply, livestock irrigation and navigation. Designated uses for Wisconsin waterbodies are determined by the WDNR, and include categories of Fish and Aquatic Life, Recreation, Public Health and Welfare, and Wildlife. The designated use for each CalMan Lake, along with a brief description of the waterbody, is included subsequently. Historical accounts for Calumet County lakes were obtained from Fassbender, 1971. Long Lake historical text was obtained from the Surface Water Inventory of Wisconsin, 1968.

Round Lake Designated Use: Fish and Aquatic Life

Round Lake is a deep headwater drainage lake. It's maximum depth of 55 feet makes it the deepest lake in Calumet County. In 1959, the lake was chemically treated to remove rough warm-water species of fish and subsequent stocking of bluegill, largemouth bass and rainbow trout followed. The lake is known to host a variety of waterfowl during migration seasons. The lake has suffered in recent decades from agricultural runoff and subsequent algal blooms. Public access is available through a boat launch and roadside parking. Fassbender (1971) noted that, "Round Lake is the most valuable water from a recreational and ecological viewpoint in Calumet County and as such should be subjected to every effort to protect and enhance its natural attributes."

Boot Lake Designated Use: Fish and Aquatic Life

Boot Lake is a deep headwater lake that is the shallowest of the four CalMan Lakes with a maximum depth of 15 feet. During high water periods, Boot Lake drains to Long Lake. As with Round Lake, Boot Lake was treated in 1965 to remove undesirable fish species. Northern pike, largemouth bass, bluegill, and brook trout were introduced. It is likely that brook trout are no longer present in the lake with perch and bullhead being reintroduced. In 1971, the lake was described as having frequent heavy algal blooms, with winterkill also occurring often. The Brillion Conservation Club owns property on the north-northeast shoreland, but the lake is otherwise surrounded by private land.

Long Lake Designated Use: Fish and Aquatic Life

Long Lake is classified as a deep headwater drainage lake due to its maximum depth of 38 feet and the intermittent inlet from a northern wetland complex and intermittent outlet to Becker Lake. The lake has a walleye, northern pike, and panfish fishery. Major use problems include frequent algal blooms, stunted panfish, and a reported substantial carp population. Public access is ample with a county-owned launching ramp, large parking lot and picnic area.

Becker Lake Designated Use: Fish and Aquatic Life

The furthest downstream of the four CalMan Lakes, Becker Lake, has an intermittent inlet from Long Lake and an intermittent outlet draining to Grass Lake. It is classified as a deep headwater drainage lake. Becker Lake has a maximum depth of 51 feet and a mean depth of 15 feet. The lake is documented to experience frequent algal blooms in the summer months, with a fish community structure that is evident of numerous winterkill events. Carp are abundant within the lake. Public access is available from a county-owned launching ramp.

Within this report, water quality standards and goals for the CalMan Lakes will be referenced to those set forth for the Fish and Aquatic Life category. If the water quality in the lakes do not allow it to meet their designated use, then it does not meet Wisconsin's water quality standards and the waterbody is considered impaired. The waterbody is then placed on the 303(d) list, commonly known as the impaired waters list. In 2010, Long Lake was included on the 303(d) list for impairment due to excessive total phosphorus, which resulted in impairments, including eutrophication, a degraded biological community, and excessive algal growth.

Watershed Planning Process

The CalMan Watershed Planning Project began as a multi-phased, science-based collaborative approach that is consistent the outline suggested in the United States Environmental Protection Agency's (USEPA's) *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA, 2008). Specifically, the handbook outlines nine key elements that are critical for achieving improvements in water quality (Figure 1.0-1).

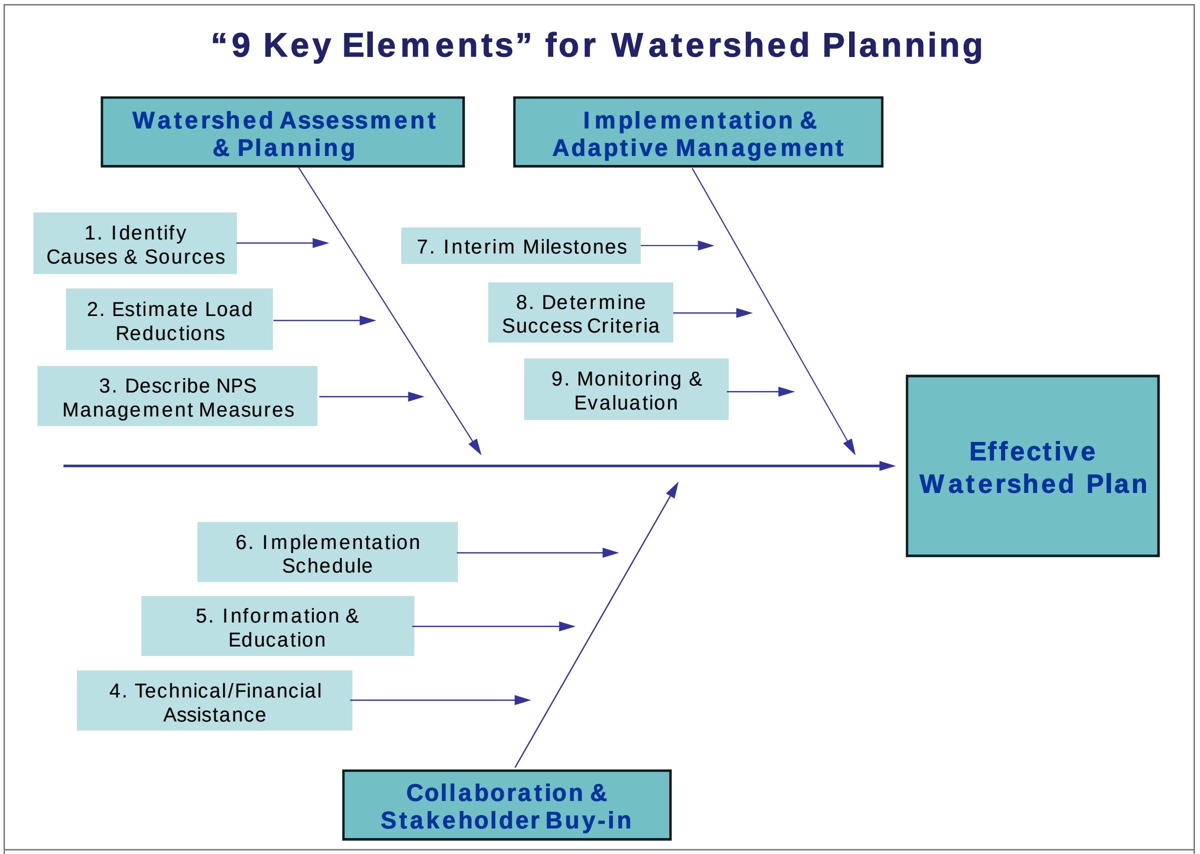


Figure 1.0-1. USEPA nine key elements for watershed planning. Adapted from USEPA 2008.

Phase I of the CalMan Lakes Watershed Planning Project began with an assessment of the pollutants, namely nutrients, which were believed to be impacting the lakes. Phase II continued these studies with strategic monitoring of tributary streams that drain small, subwatersheds of the CalMan Lakes. During this same time, efforts will be made to pinpoint critical areas in each subwatershed and estimate potential pollutant reductions through nonpoint source management efforts.

Note: Calumet County is working with their agency partners to develop this plan.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa.

The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve numerous watershed stakeholders, volunteer activities in the watershed and various other educational initiatives. The highlights of this component are discussed in the next section. Materials used during the planning process can be found in Appendix A.

Project Planning Process

Kick-off Meeting

On August 22, 2013, Onterra ecologists Dan Cibulka and Tim Hoyman met with Calumet County staff, Brillion Conservation Club, and other watershed stakeholders to introduce the project and its components. The meeting was announced through a mailing and personal contact by Calumet County staff and Brillion Conservation Club members. The attendees observed a presentation given by Mr. Cibulka, which started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved and the various scientific components. The presentation was followed by a question and answer session.

Watershed Planning Meetings

Note: We can add in additional information from Dani here, if it is available.

The first watershed planning meeting was held on May 19, 2014. The meeting was attended by Calumet County and Manitowoc County conservation staff, as well as WDNR lakes coordinator Mary Gansberg and Onterra ecologists Dan Cibulka and Tim Hoyman. During this meeting, a presentation was delivered by Mr. Cibulka which included results of the in-lake studies and watershed assessments that had taken place in 2013. Following the presentation, the group discussed approach that would be taken in the following phase of the project.

Project Update Meetings by the Calumet County

Calumet County staff provided updates to local stakeholder groups throughout the project. On August 24, 2014, Dani Santry presented an update to the Brillion Conservation Club, highlighting the 2014 lake data and shoreland inventory results. Approximately 25 people were in attendance. Draft shoreland maps were presented at the meeting along with draft analysis on data to date, followed by discussion. Positive reports from attendants including improved cropland practices in critical areas as well as solid panfish reports from Becker Lake anglers.

On June 27, 2015, Dani Santry presented the shoreland inventory data and maps to the Long Lake Advancement Association (LLAA) at their annual meeting. The meeting was open to the public and promoted by LLAA. Approximately 50 people were in attendance. Most discussion revolved around shoreland property practices and program assistance for restoration projects. Ms. Santry also provided an update on progress of the entire project, including the upcoming tributary monitoring, flow stations and equipment deployment, and the upcoming survey scheduled for Winter 2016. Both updates were followed by question and answer sessions.

Additional information was made available to stakeholders through the Calumet County Website, posting updates every six months. Ms. Santry also attended the LLAA Board meeting on December 2015 to present the data collected in 2015 and upcoming stakeholder survey in Winter of 2016. Ms. Santry provided written updates to LLAA for the 2016 Annual Meeting, as well as annual updates in the Calumet LWCD newsletter.

Public Information Meeting

On April 13, 2017, Tim Hoyman and Paul Garrison presented the results of the project thus far, including in-lake water quality monitoring, tributary sampling, estimates of external and internal nutrient loadings, and the conclusions of the paleoecological studies completed on the CalMan Lakes. At the end of the meeting, Mr. Hoyman and Mr. Garrison presented the next steps and additional studies that would be completed during the 2017 field season. Finally, they, along with Dani Santry, answered questions and took comments from the audience.

Stakeholder Survey

In May 2016, a six-page, 26-question survey was mailed to 250 stakeholders within the CalMan Lakes watershed. Nineteen percent of the surveys were returned with stakeholders answering an online survey on the website SurveyMonkey.com. If hard copies were requested, the Calumet County Land and Water Conservation Department entered the results of that survey into SurveyMonkey. The data were then summarized and analyzed by Onterra for use at meetings and within the watershed management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed further in this section.

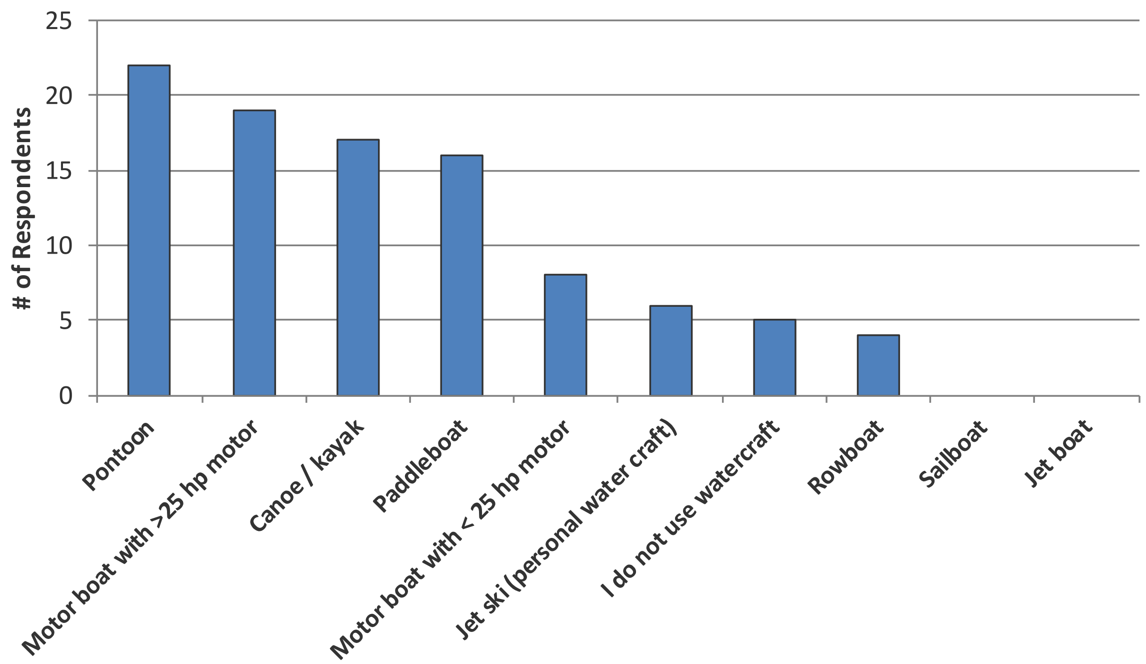
Prior to the stakeholder being sent out, Dani Santry and other staff from the Calumet County Land and Water Conservation Department started conducting interviews with agricultural producers within the CalMan Lakes watershed. In all, eight surveys were completed over the course of two years. The overall consensus from these interviews is that the area within the CalMan Lakes watershed is hilly with clay soils. No till farming is used throughout the watershed but is difficult in locations due to steep topography. The agricultural producers within the watershed do their best to keep cover crops, like alfalfa, year-round, but if they do not use cover crops, they make sure to have a strong crop rotation to minimize soil erosion. Most agricultural producers interviewed believe they are doing the best they can to avoid soil erosion and believe most others in the area are as well. The full survey and results can be found in Appendix B.

After completing the interviews, the agricultural producers were given a three-page, 10-question survey, similar to the stakeholder survey, and asked to complete it. All eight of the surveys were returned. The Calumet County Land and Water Conservation Department then entered those surveys into SurveyMonkey.com to be analyzed by Onterra. The full survey results can be found in Appendix B with a general summary discussed below.

For ease of discussion, the answers from both SurveyMonkey surveys have been combined, but remain separated in Appendix B. Due to the low percentage of responses, the survey answers cannot be used to statistically predict the response of the whole watershed, but the answers can be used to get an idea of what stakeholders within the CalMan Lakes watershed think about the watershed and its lakes. The majority of stakeholders who responded to the surveys live on or associate with Long Lake the most (81%), followed by Round Lake (8%), Becker Lake (6%) and Boot Lake (5%). Of these respondents, 33% are year -round residents, 26% are seasonal residents (summer months), 21% visit on the weekends, 13% have undeveloped land, and 8% rent their land from someone else. Sixty-nine percent of respondents indicated they have owned or rented their property on the CalMan Lakes for 15 years or less with another 18% having owned or rented for more than 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within the surveys. Twenty-two of the survey respondents indicated they use a pontoon boat on the CalMan Lakes while another 19 responded they use a motor boat with a motor of 25 hp or greater, followed by another 17 who indicated they use a canoe or kayak on the lakes. Two of the three activities that are important to watershed stakeholders include boating, fishing and motorboating, while relaxing and entertaining was the other important reason for owning or renting their property on the CalMan Lakes. Water quality degradation, algal blooms, and excessive aquatic plant growth were the top three choices as factors potentially impacting the CalMan Lakes negatively. While water quality degradation and algal blooms were the top two concerns, shoreline development was ranked third. However, shoreland developed was ranked 6th for factors currently impacting the CalMan Lakes.

Question 12: What types of watercraft do you currently use on the CalMan Lakes?



Question 13: Please rank up to three activities that are important reasons for owning your property on or near the CalMan Lakes.

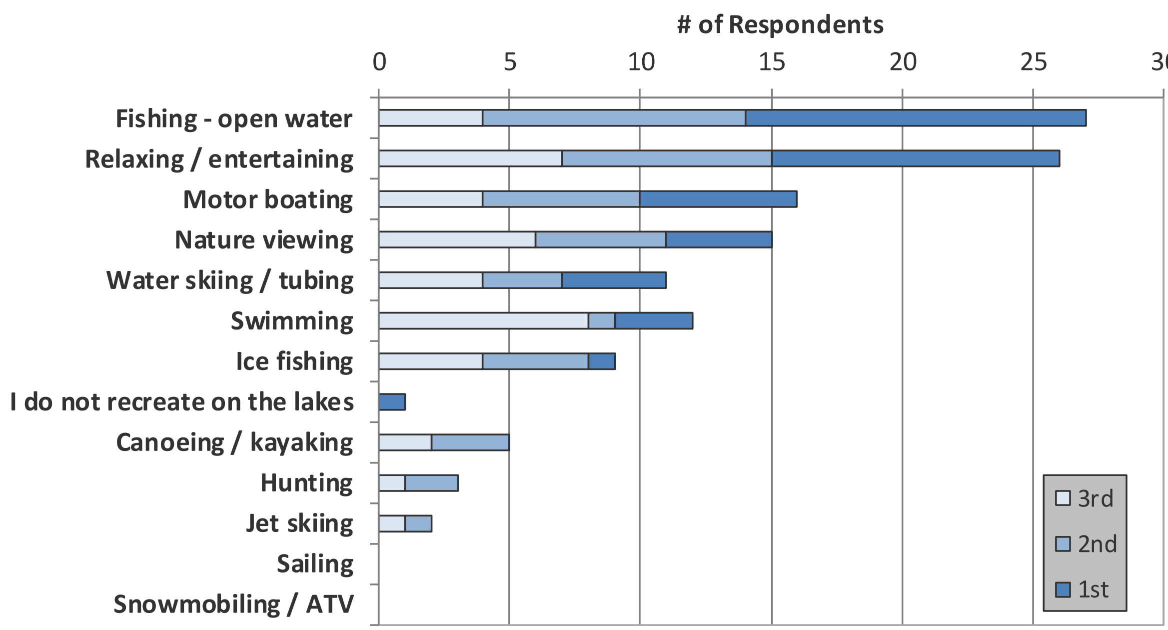
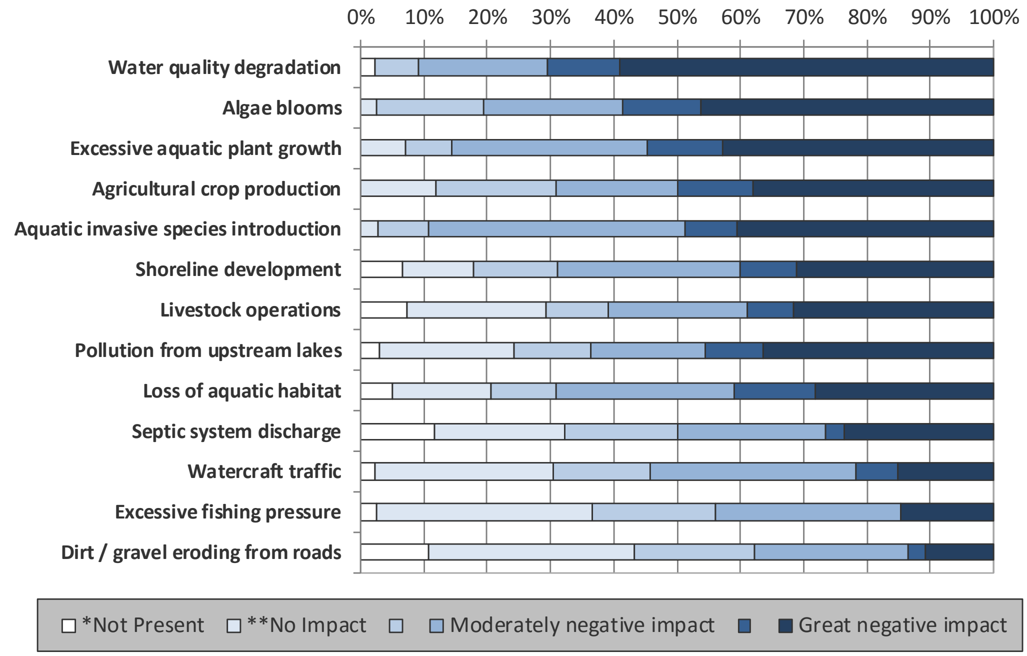


Figure 2.0-1. Select survey responses from the CalMan Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

To what level do you believe these factors may be negatively impacting the CalMan Lakes?



Please rank your top three concerns regarding the CalMan Lakes.

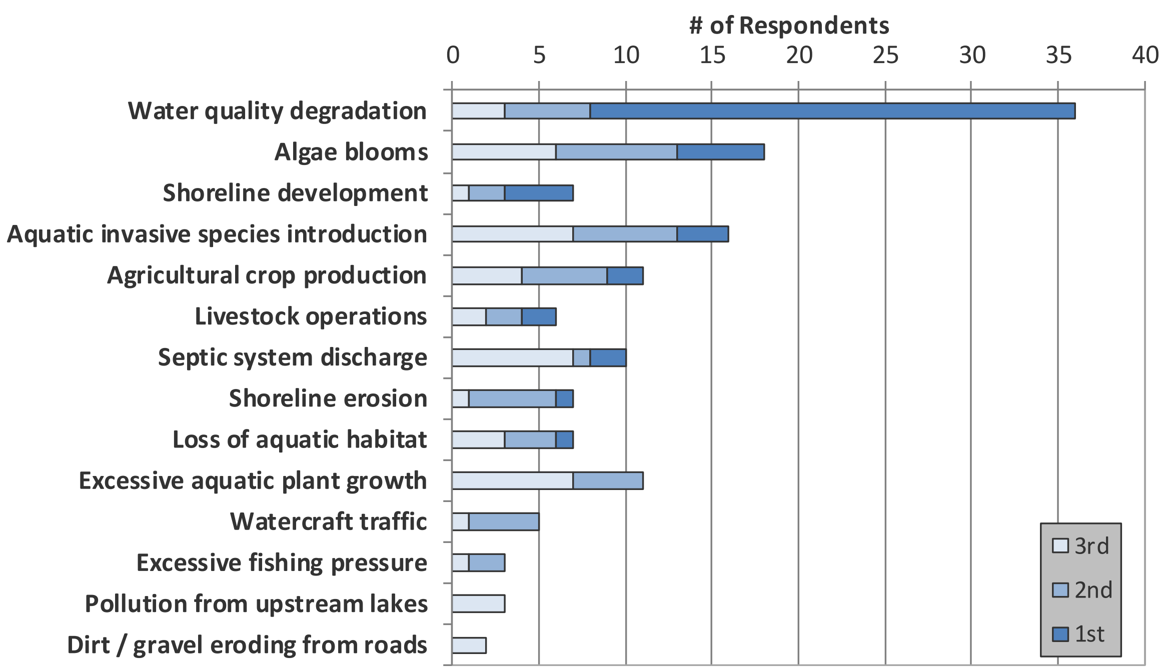


Figure 2.0-2. Select survey responses from the CalMan Lakes Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on the CalMan Lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix B). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the CalMan Lakes' water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter et al. 1994, Dinius 2007, and Smith et al. 1991).

Trophic State

Trophic states describe the lake's ability to produce plant matter (production) and include three continuous classifications: Oligotrophic lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. Eutrophic lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. Mesotrophic lakes fall between these two categories.

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the trophic state of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: oligotrophic, mesotrophic, and finally eutrophic. Every lake will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in many Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a more clear understanding of the lake's trophic state while facilitating clearer long-term tracking. Carlson (1977) presented a trophic state index that gained great acceptance among lake managers.

Limiting Nutrient

The limiting nutrient is the nutrient which is in shortest supply and controls the growth rate of algae and some macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

In most Wisconsin lakes, phosphorus is the limiting nutrient controlling the production of plant biomass. As a result, phosphorus is often the target for management actions aimed at controlling plants, especially algae. The limiting nutrient is determined by calculating the nitrogen to phosphorus ratio within the lake. Normally, total nitrogen and total phosphorus values from the surface samples taken during the summer months are used to determine the ratio. Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is less than 10:1, it is considered nitrogen limited. Values between these ratios indicate a transitional limitation between nitrogen and phosphorus.

Temperature and Dissolved Oxygen Profiles

Temperature and dissolved oxygen profiles are created simply by taking readings at different water depths within a lake. Although it is a simple procedure, the completion of several profiles over the course of a year or more provides a great deal of information about the lake. Much of this information relates to whether the lake thermally stratifies or not, which is determined primarily through the temperature profiles. Lakes that show strong stratification during the summer and winter months need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epilimnion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fishkills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading

In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days at a time).

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations consistently exceeding 200 μg/L.
- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

Specific to the final bullet-point, during the watershed modeling assessment, the results of the modeled phosphorus loads are used to estimate in-lake phosphorus concentrations. If these estimates are much lower than those actually found in the lake, another source of phosphorus must be responsible for elevating the in-lake concentrations. Normally, several possibilities exist; 1) shoreland septic systems, 2) internal phosphorus cycling, 3) shoreland runoff, sediment resuspension, or 4) high nutrient groundwater input. If the lake is considered a candidate for internal loading, the buildup of phosphorus in the hypolimnion is used to estimate that load.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2016 Consolidated Assessment and Listing Methodology (WisCALM) for CWA Section 303(d) and 305(b) Integrated Reporting* (WDNR 2015) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of the CalMan Lakes will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, hydrology. An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

The WDNR lists Round and Boot Lakes as seepage lakes; however, both lakes possess an outlet and drain to Long Lake. For this reason, following the review of Round and Boot Lake's watershed and aerial photography, it was determined that Round and Boot Lakes are instead deep headwater drainage lakes (category 3 on Figure 3.1-1). Long and Becker Lakes are also classified as deep headwater drainage lakes. In the following section, all four CalMan Lakes will be compared with deep headwater drainage lakes in Wisconsin.

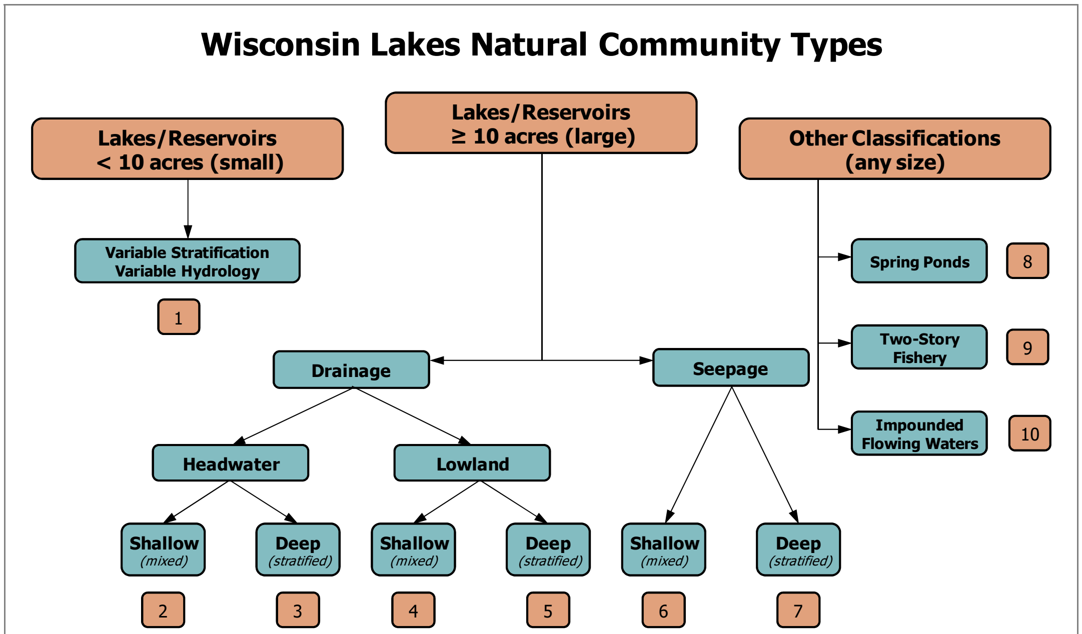


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

Garrison et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. The CalMan Lakes are within the Southeastern Wisconsin Till Plains ecoregion (Figure 3.1-2).

The Wisconsin 2016 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

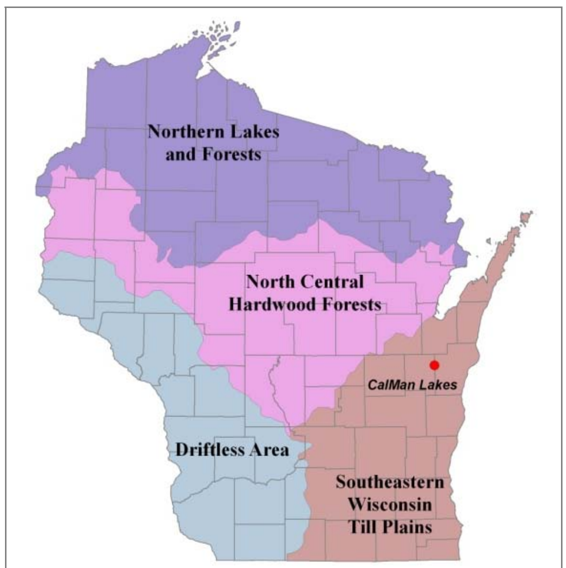


Figure 3.1-2. Location of the CalMan Lakes within the ecoregions of Wisconsin. After Nichols 1999.

CalMan Lakes Water Quality Analysis

CalMan Lakes Nutrient Content and Clarity

The amount of historical water quality data existing on the CalMan Lakes varies by lake. Volunteers have been monitoring Long Lake and Becker Lake through the WDNR's Citizens Lake Monitoring Network (CLMN), collecting nutrient samples or Secchi disk clarity data several times each summer. Long Lake is also a part of the WDNR's Long Term Trend Monitoring Program, which has included water quality and aquatic plant sampling over the course of several decades. Round and Boot Lakes do not have active CLMN volunteers and because of this, there are few historical data to compare against the data that were collected as a part of this project. The importance of consistent, reliable data cannot be stressed enough; just as a person continuously monitors their health parameters, the water quality of a lake should be continually monitored in order to understand the system better and make sounder management decisions.

Calumet County and Onterra staff collected water quality samples and monitored Secchi disk clarity on each CalMan lake during the course of this project. Monitoring occurred during the spring, summer, fall of 2013 and the following winter in 2014 through 2016. Additionally, historical data was researched and is presented within this section as appropriate. Unless otherwise indicated, parameters represent samples collected from the sub-surface (~3.0 feet) of each lake.

Phosphorus

WisCALM procedures for 303(d) listings of waterbodies include two years of data collection. Additionally, these samples must be taken between June 1 and September 15 to represent the time of the year in which nutrient impacts would be shown the most. Therefore, some of the phosphorus data in this section will be presented in a fashion compatible with WisCALM guidelines, while comparisons consistent with Garrison et. al (2008) are made elsewhere.

Total phosphorus concentrations were collected from the sub-surface and near bottom areas of each CalMan Lake for the years 2013 - 2016. Figure 3.1-3 displays the summer sub-surface total phosphorus averages. During the period 2013-2016, the median phosphorus concentrations in all lakes were higher than 30 μg/L, which is the threshold for impairment in deep headwater drainage lakes with a Fish and Aquatic Life Use designation. The impairment was particularly notable in Boot Lake, where all summer values but one exceeded 100 μg/L.

Phosphorus data for Round Lake have been collected in 1996 and 2012-16. Growing season and summer values are generally exceed 100 μg/L with the exception of 2012 (Figure 3.1-4). During this year precipitation was below normal and the reduced concentrations reflect the lower input of phosphorus from the watershed. Even though mean values were usually less than 150 μg/L, maximum values in some years exceeded 350 μg/L. The weighted mean summer concentrations are significantly higher than other deep headwater drainage lakes in Wisconsin and other lakes in the Southeastern Wisconsin Till Plains (SWTP) ecoregion. The phosphorus concentrations in Round Lake place it in the poor category.

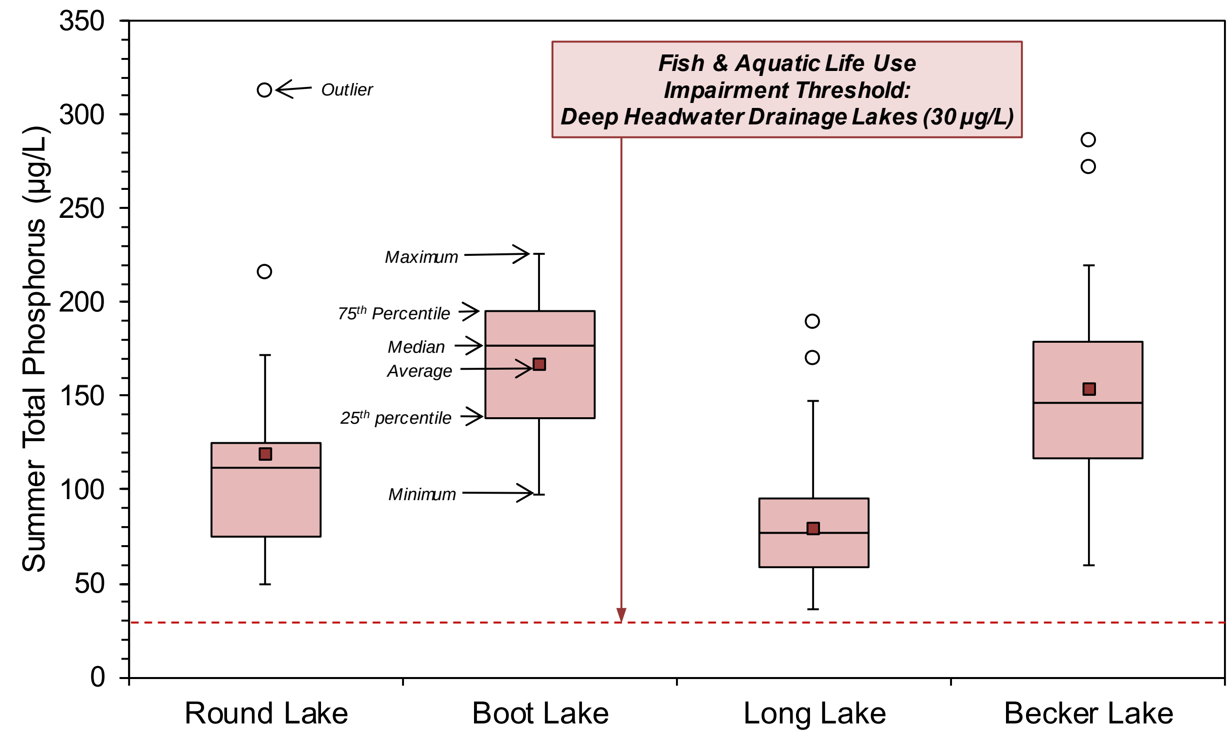


Figure 3.1-3. CalMan Lakes surface phosphorus concentrations. Values calculated with summer months' surface sample data and methodology from WDNR 2015.

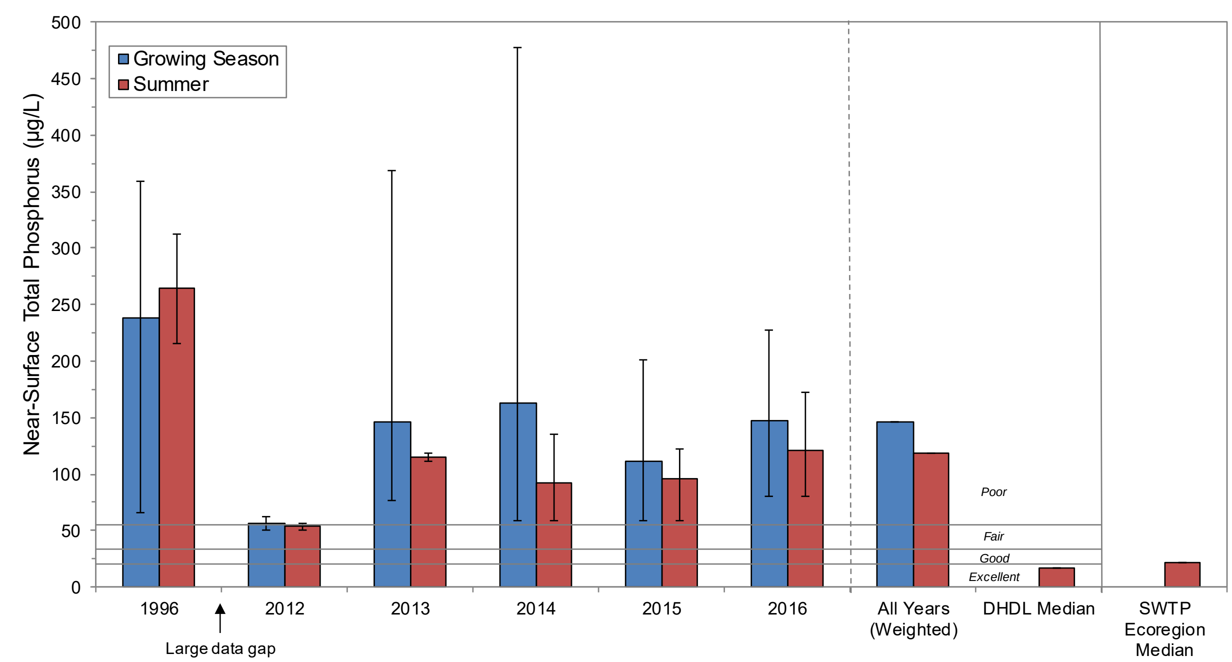


Figure 3.1-4. Round Lake, deep headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Growing season and summer phosphorus concentrations in Boot Lake were higher than in Round Lake. Boot Lake is a headwater drainage lake like Round Lake but the watershed of Boot Lake is much larger and the lake is much shallower. Boot Lake, with its smaller water volume relative to watershed size, is less able to dilute incoming phosphorus when compared to Round Lake. Although mean growing season and summer levels are similar most years, the lake experiences a large range of concentrations during the year (Figure 3.1-5). As with Round Lake, the summer mean concentrations are much higher than other deep headwater drainage lakes throughout the state and lakes in the SWTP ecoregion. Boot Lake's phosphorus concentrations place it well into the poor category.

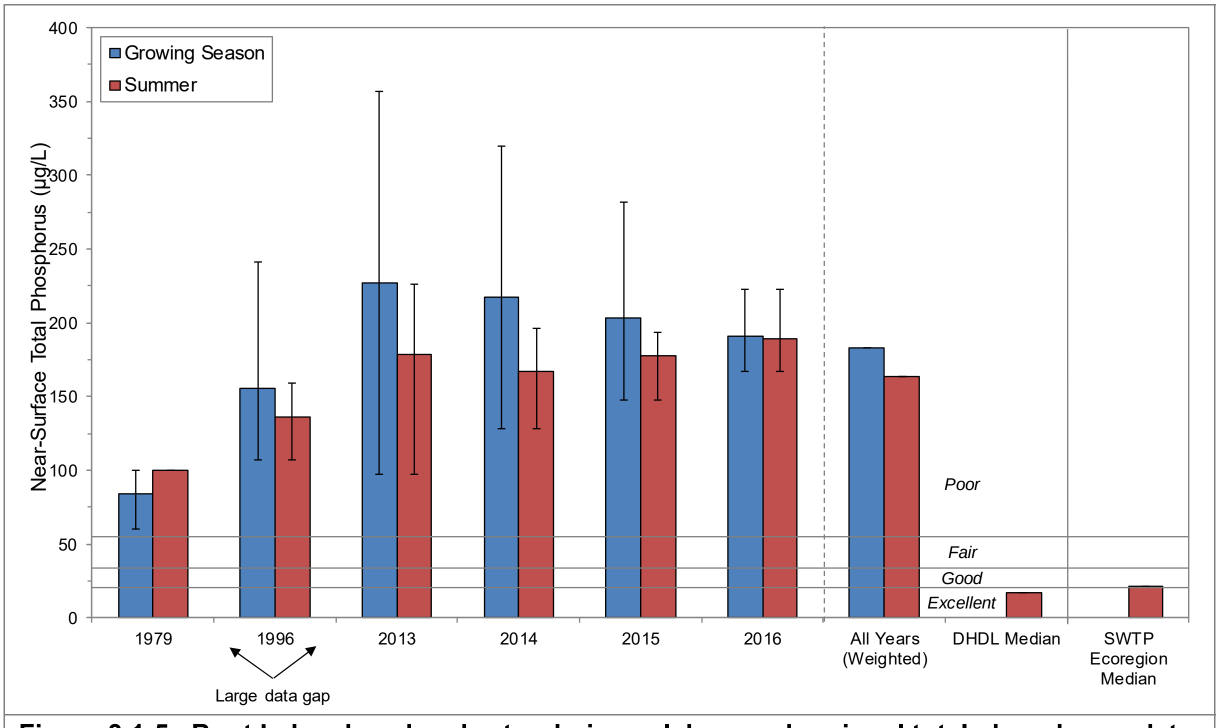


Figure 3.1-5. Boot Lake, deep headwater drainage lakes, and regional total phosphorus data. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Long Lake has the most historical phosphorus data of any of the four lakes in this study. This is due in part because it is one of the lakes in WDNR long-term trends lakes program. From the period 1988 through 1999 data were collected multiple times each year. In more recent years a continuous record has been collected since 2008 (Figure 3.1-6). From 2008-2016, phosphorus concentrations have tended to be higher than they were during the 1980-90s. However, the earlier period of record at times experienced elevated concentrations, especially during years with above average precipitation (e.g. 1993). The long-term mean phosphorus concentration places Long Lake in the poor category for phosphorus concentrations, although there have been years when concentrations were in the fair category (e.g. 2006). As with the previous two lakes, phosphorus concentrations in Long Lake are much higher than other headwater drainage lakes and also higher than other lakes in the SWTP ecoregion.

In Becker Lake, growing season and summer mean total phosphorus concentrations are in the poor category (Figure 3.1-7). Although mean concentrations usually were less than 200 µg/L, values exceeding 300 µg/L occurred most years. Phosphorus levels in Becker Lake were significantly higher than other deep headwater lakes throughout the state and other lakes in the SWTP ecoregion.

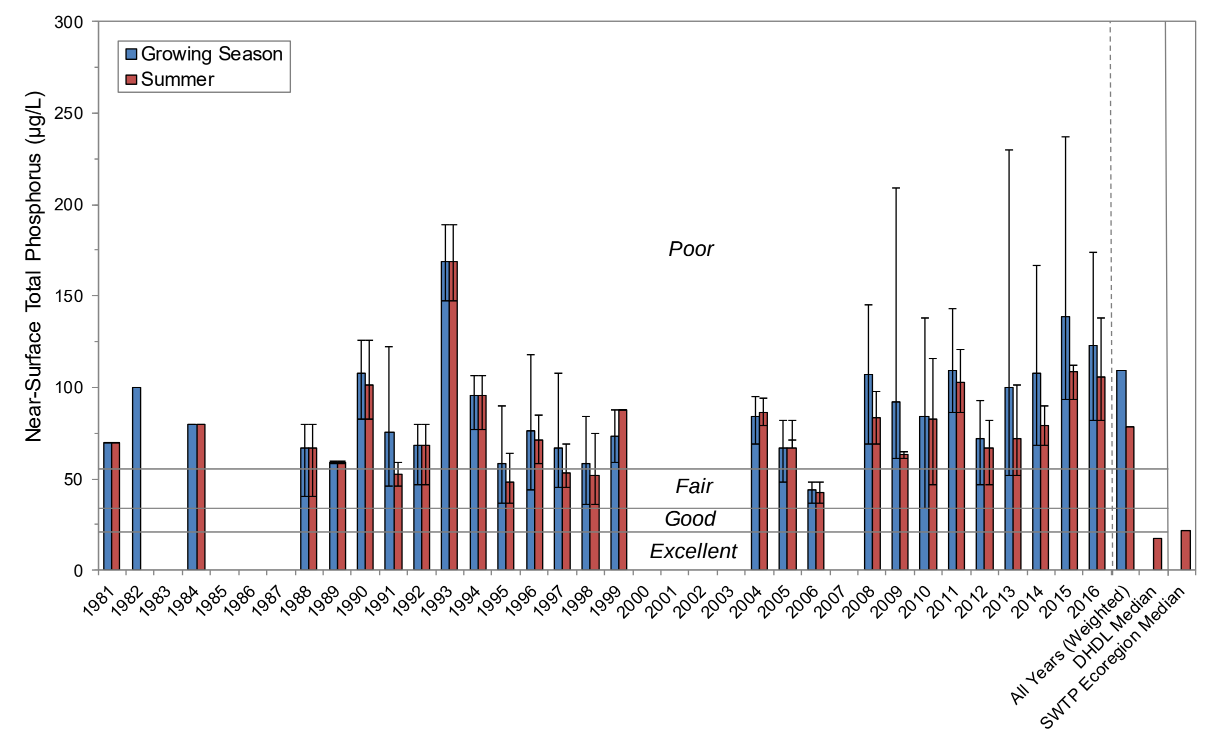


Figure 3.1-6. Long Lake, deep headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

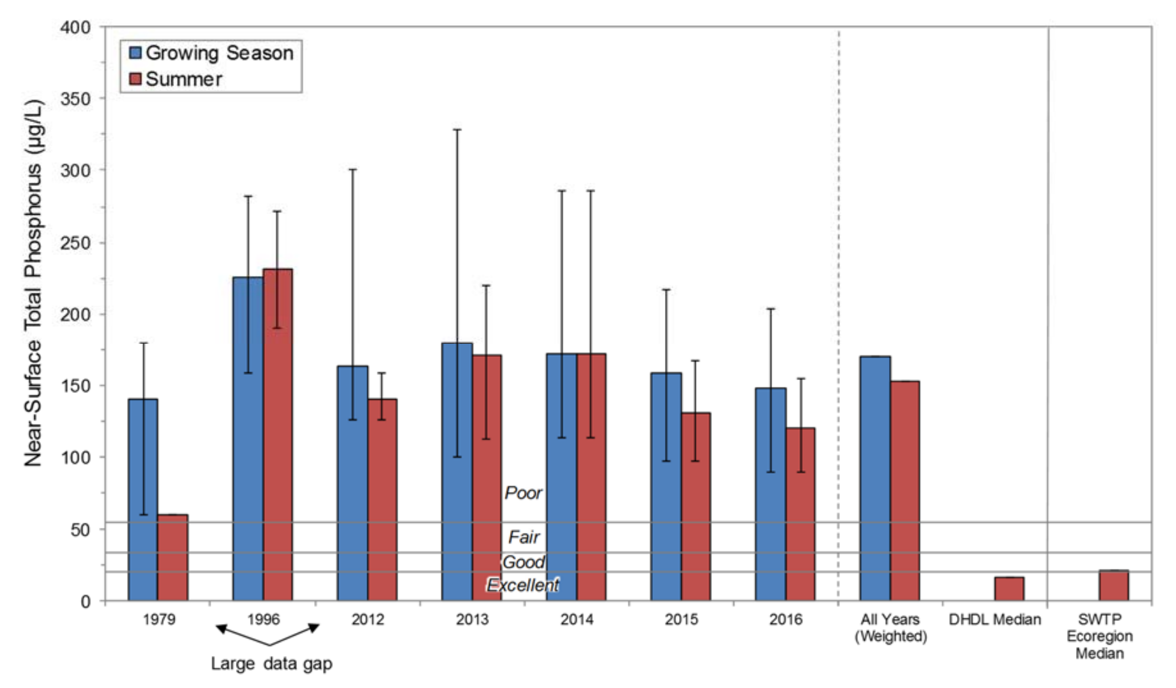


Figure 3.1-7. Becker Lake, deep headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a*

Given phosphorus concentrations are generally positively correlated with chlorophyll-*a* concentrations, it is not surprising to see high chlorophyll-*a* concentrations in the CalMan Lakes. Like total phosphorus concentrations, chlorophyll-*a* concentrations can be quite variable in the CalMan Lakes (Figure 3.1-8). Round and Long lakes which have the lowest phosphorus concentrations of the four study lakes also had the lowest chlorophyll-*a* concentrations (Figure 3.1-3). Boot Lake had the highest concentrations with many values exceeding 100 µg/L. The chlorophyll values are high enough that summer algal blooms are a common occurrence in all of these lakes. The median value for all of the lakes exceeded the impairment threshold for fish and aquatic life use.

Chlorophyll-*a* samples have been collected from Round Lake annually from 2012-2016. The concentrations for growing season and summer mean means usually place the lake in the poor category (Figure 3.1-9). The exception was in 2012 when summer means were within the fair category. As mentioned above, precipitation was below normal which resulted in less phosphorus being delivered to the lake from the watershed. Since phosphorus is the nutrient limiting algal growth, chlorophyll-*a* levels were reduced that year. Chlorophyll-*a* concentrations for Round Lake are significanlty higher than the median value for other deep headwater drainage lakes in Wisconsin and the median value for other lakes in the SWTP ecoregion.

Chlorophyll-*a* concentrations in Boot Lake were very high, with growing season means usually exceeding 100 µg/L, primarily because of high algal levels during the spring. In hypereutrophic lakes, the highest algal levels usually occur during the summer during blue-green algal blooms. It is likely the high spring values are the result of internal loading which occurred the previous year. It is also likely that during the spring runoff, the algae that have grown in the riparian wetland are transported into the lake and help fuel algal blooms. Figure 3.1-10 does not show the chlorophyll-*a* data from 1996. During this year, the concentrations were very high with the growing season mean exceeding 450 µg/L and summer mean exceeding 800 µg/L. Chlorophyll-*a* levels place the lake in the poor category. Algal levels in Boot Lake are significantly higher than the median value for other deep headwater drainage lakes in Wisconsin and the median value for other lakes in the SWTP ecoregion.

In Long Lake, as with phosphorus, there is a long record of chlorophyll-*a* values. Growing season and summer means are variable between years but most years place the lake in the poor category (Figure 3.1-11). The years with the lowest concentrations were 1996-98 and 2006. The years with the highest concentrations were 1989, 2010, and 2012. While chlorophyll-*a* levels were very high in 1996 in Boot Lake, this was not the case in Long Lake. Chlorophyll-α levels in Long Lake are much higher than most deep headwater drainage lakes in Wisconsin and higher than most lakes in the SWTP ecoregion.

In Becker Lake, chlorophyll-*a* concentrations are only available for the last five years. During that time, the growing season mean often exceeded 50 µg/L (Figure 3.1-12). As with the other three lakes, chlorophyll-*a* levels place the lake in the poor category. Concentrations are much higher than most other deep drainage lakes and other lakes in the SWTP ecoregion.

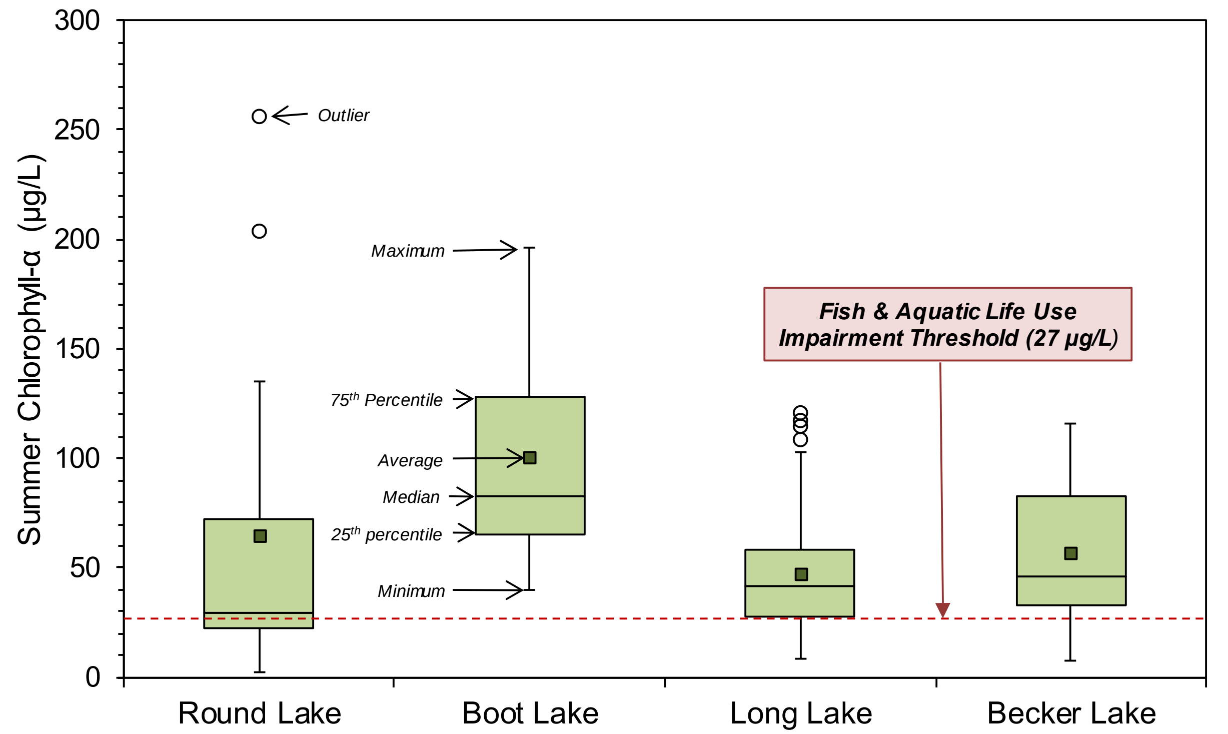


Figure 3.1-8. CalMan Lakes surface chlorophyll-a concentrations. Values calculated with summer month surface sample data and methodology from WDNR 2015.

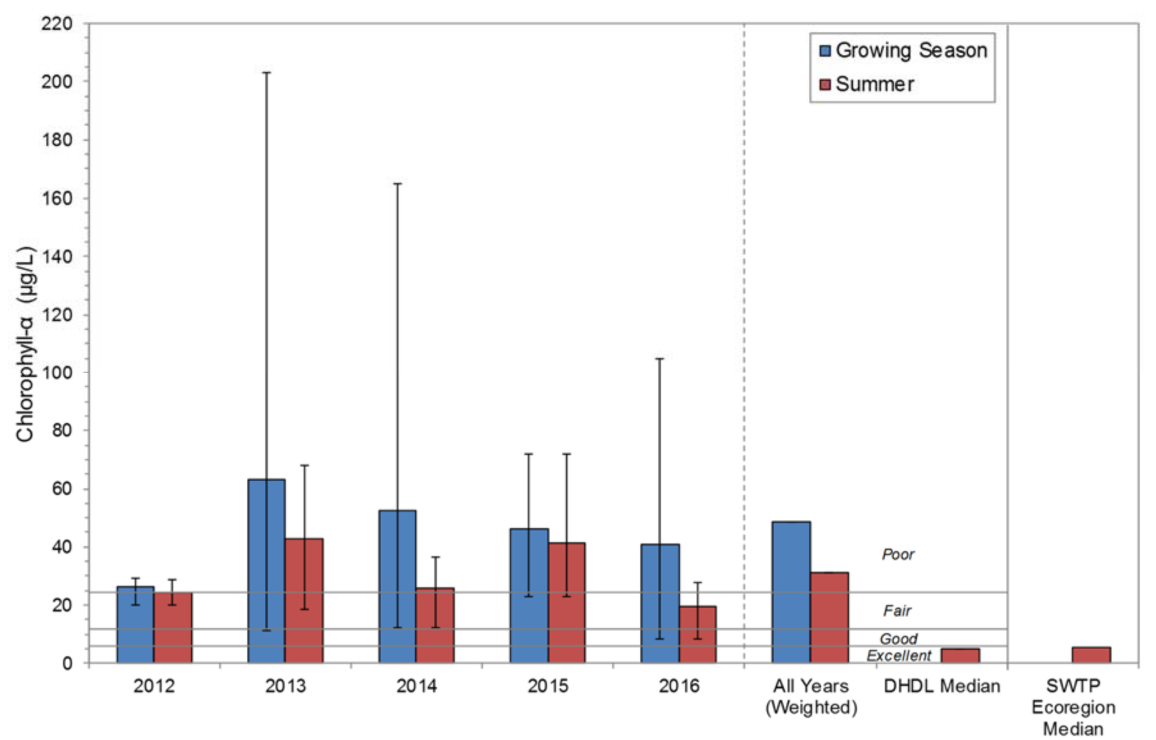


Figure 3.1-9. Round Lake, deep headwater drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

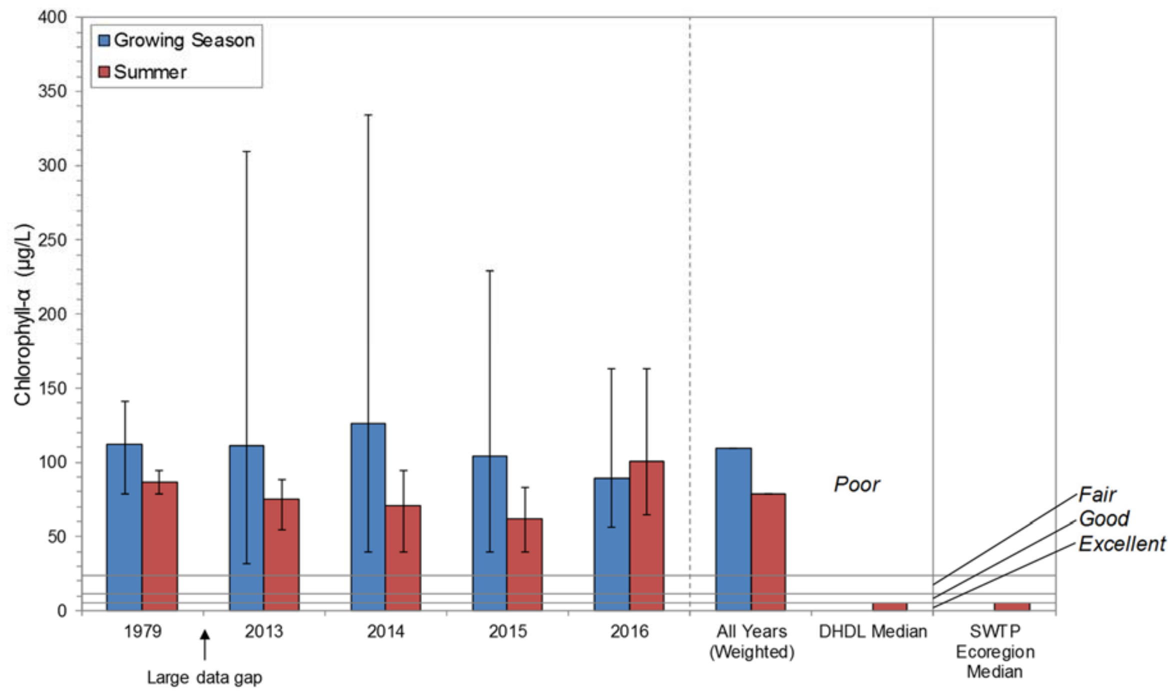


Figure 3.1-10. Boot Lake, deep headwater drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913. Concentrations for 1996 are not shown as they were much higher (> 450 µg/L) than other years and including 1996 would make it difficult to compare with other years.

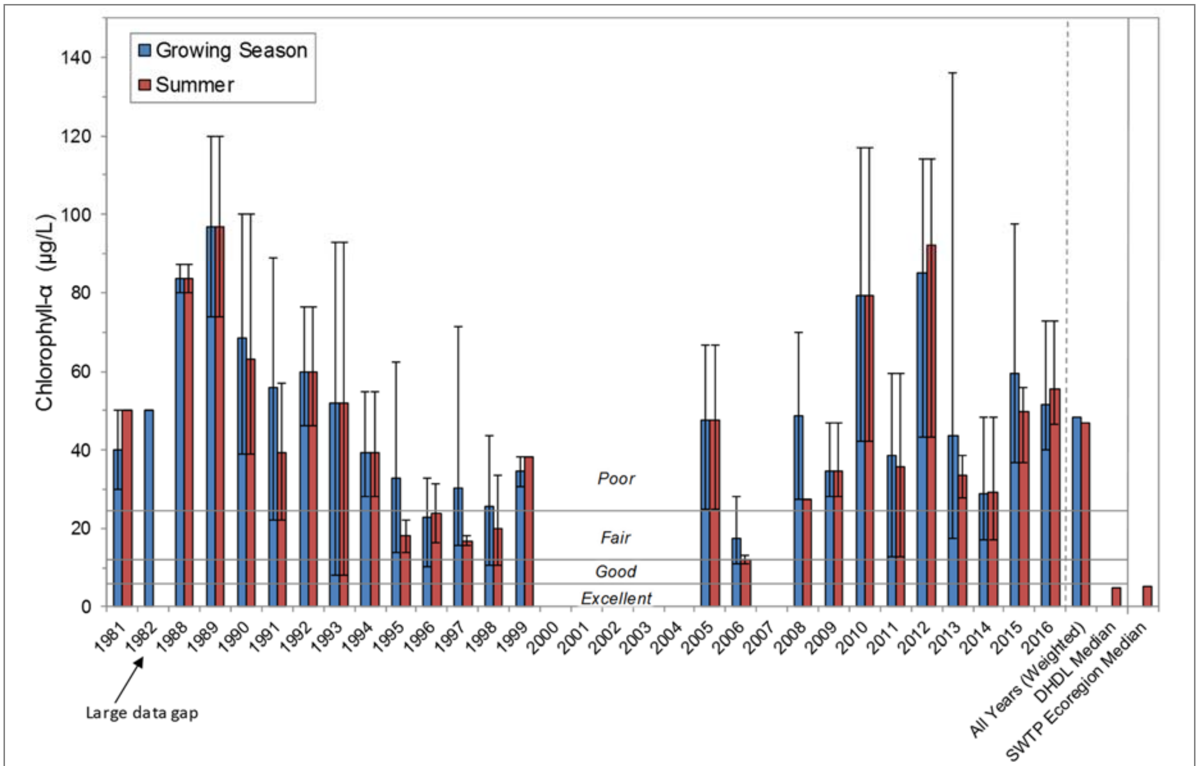


Figure 3.1-11. Long Lake, deep headwater drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

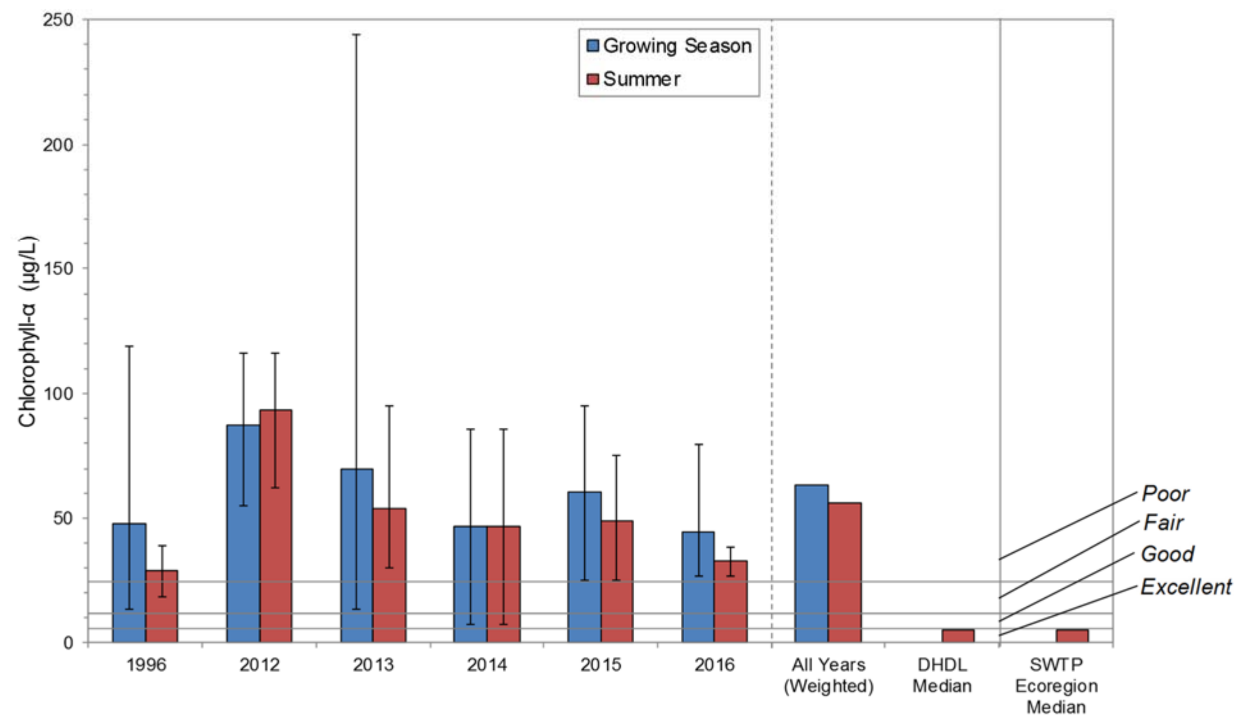


Figure 3.1-12. Becker Lake, deep headwater drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water Clarity

The water clarity of a lake can be influenced by a number of factors. These factors include both dissolved compounds (i.e. humic substances) and particulates (e.g. algae and suspended sediments). Dissolved compounds change the color of the water and absorb light, reducing water clarity. For instance, dissolved humic substances give the lake a brown or tea-like color and reduce water clarity. Particulate substances also reduce clarity by absorbing and scattering light.

In Round Lake, the Secchi disk transparency placed the lake in the fair category. This is a better category than phosphorus and chlorophyll-*a* placed the lake. Apparently in Round Lake water clarity is better than expected given the chlorophyll-*a* and phosphorus levels. However, it is not known why water clarity is higher than expected. The mean summer Secchi disk transparency was 4 to 5 feet with the mean for all the years being 4 feet (Figure 3.1-13). The water clarity is lower than most deep headwater drainage lakes in the state and lower when compared to other lakes in the SWTP ecoregion.

In Boot Lake, the Secchi disk transparency was much worse than Round Lake which would be expected given the higher chlorophyll-*a* concentrations in Boot Lake. Both growing season and summer mean values place the lake in the poor category (Figure 3.1-14). The mean water clarity for the last 4 years is about 1.0 feet. This value is much worse than most other deep headwater drainage lakes in the state and other lakes in the SWTP ecoregion.

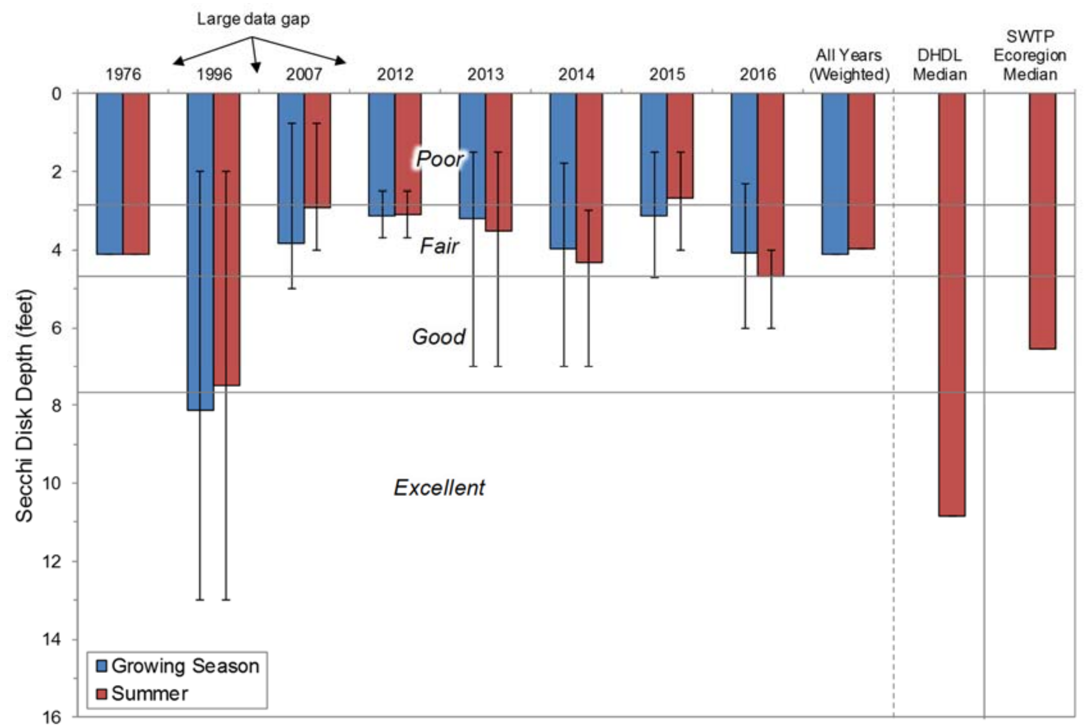


Figure 3.1-13. Round Lake, deep headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

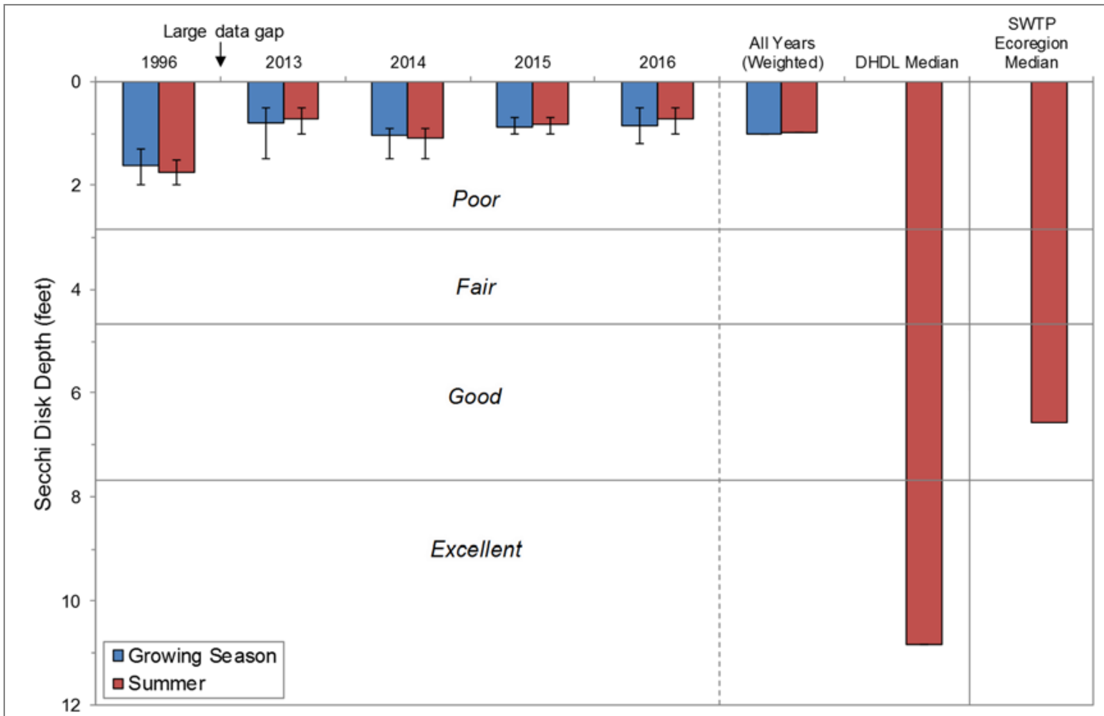


Figure 3.1-14. Boot Lake, deep headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As with phosphorus and chlorophyll-*a*, Long Lake has the longest record of Secchi disk transparency among the project lakes. Water clarity values were collected all years since 1989 except for the period 1998-2001 (Figure 3.1-15). Summer mean Secchi disk transparencies for the period 1989-2009 average 2.9 feet but during the last seven years the summer value has been about half that at 1.5 feet. Water clarity in the earlier period would place the lake in the fair category but for the last seven years it is in the poor category. Even in the years when Secchi disk transparency was best, the water clarity was much worse than most other deep drainage lakes and other lakes in the SWTP ecoregion.

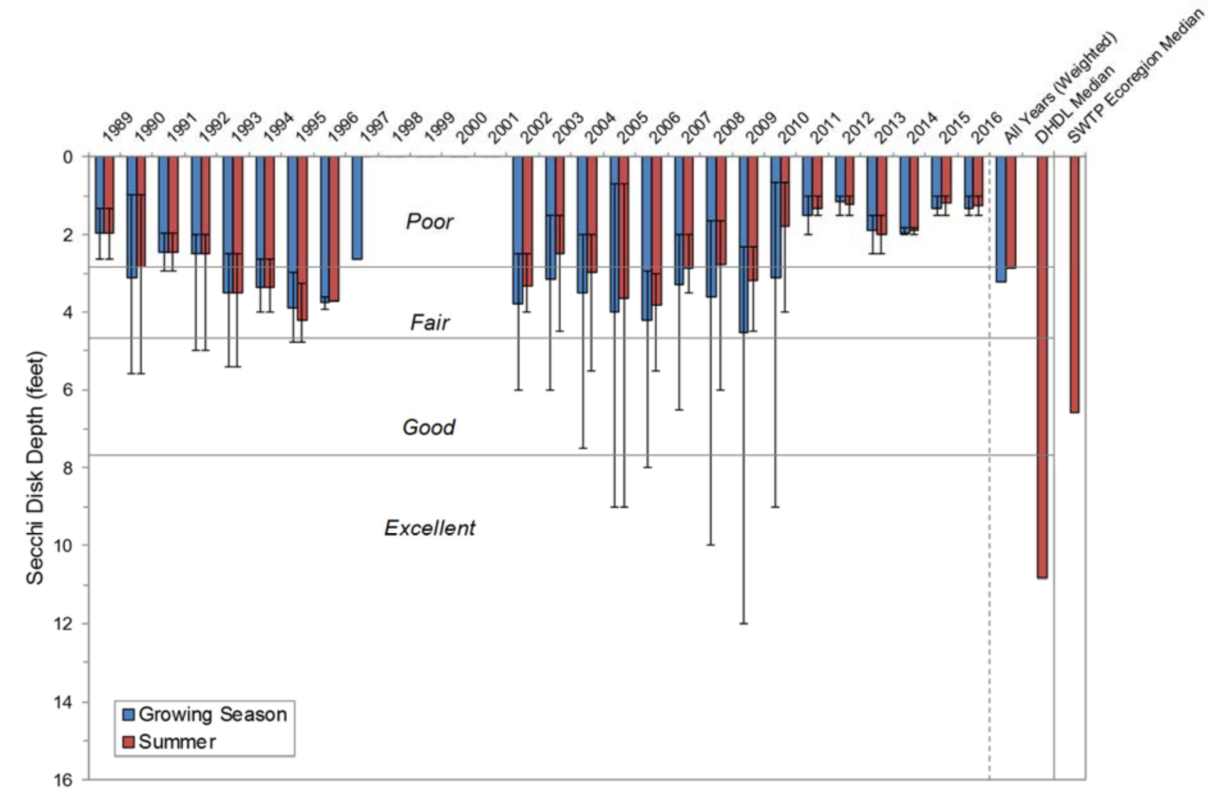


Figure 3.1-15. Long Lake, deep headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

In Becker Lake, the mean Secchi disk transparency was 2 feet, which places the lake in the poor category (Figure 3.1-16). Water clarity was best in 1996 when the mean exceeded 4 feet. Since 2011, no values greater than 3 feet have been recorded. The worst years of record were 2012, 2013, and 2016 and recently the best years were 2011 and 2015 when summer mean values were 2.5 feet. As with the other three lakes, water clarity in Becker Lake is much worse than most other lakes in the state of similar classification and other lakes in the SWTP ecoregion.

True color measures the dissolved materials in water. Water samples collected in April of 2012 were measured for this parameter, and were found to range between 30 and 60 Platinum-cobalt units (Pt-co units, or PCU) in the CalMan Lakes. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having low color, 40-100 PCU as medium color, and >100 PCU as high color. In other words, the higher a PCU value is, the more a lake's water clarity may be impacted.

Total suspended solids (TSS) are a measure of inorganic and organic particles suspended in the water, and include everything from algae to clay particles. High TSS creates low water clarity, and prevents light from penetrating into the water to support aquatic plant growth. Total suspended solids were measured in the CalMan Lakes near the surface and near the bottom in spring, fall, and winter. Average total suspended solids values ranged between 8 mg/L in Round Lake and 23 mg/L in Boot Lake in 2013.

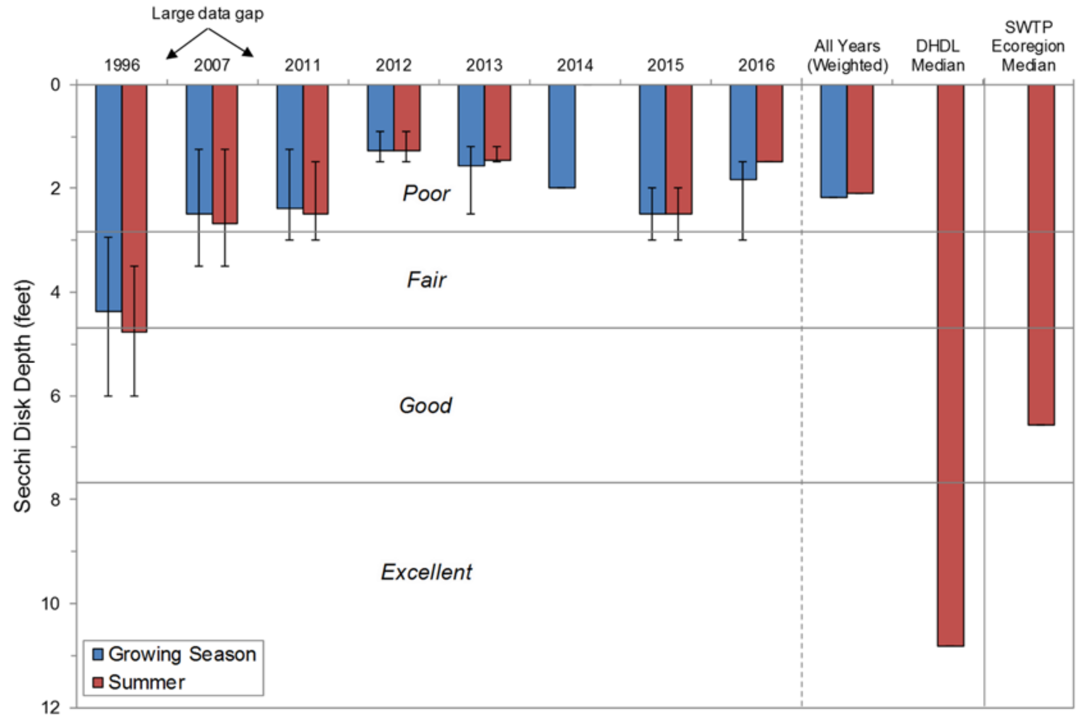


Figure 3.1-16. Becker Lake, deep headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of the CalMan Lakes

Using average nitrogen and phosphorus concentrations from all lakes included in the CalMan Lakes study, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.1-1). In Boot and Long Lakes, the ratio weighed heavily in favor of nitrogen, meaning that phosphorus is clearly the limiting nutrient. Round Lake and Becker Lakes had ratios still in favor of nitrogen, but were closer to the ratio managers consider to be transitional between phosphorus and nitrogen limitation (10-15:1). This finding indicates that CalMan Lakes are indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs will limit algae and plant growth within the lakes.

Table 3.1-1. CalMan Lakes nitrogen:phosphorus ratios. Ratios calculated from sub-surface samples taken in summer from each lake.

Lake Name	N:P Ratio
Round Lake	24:1
Boot Lake	29:1
Long Lake	34:1
Becker Lake	19:1

Nitrogen

Nitrogen is a nutrient that occurs in lakes in several forms, all of which may be quantified separately and are linked through multiple chemical and physical properties. Nitrate (NO^{3}-), ammonia (NH^{4}+), and nitrite (NO^{2}-) are all nitrogen-based compounds that may be converted from one form to the other under a number of processes. Typically, in lake systems, nitrogen is reported as total nitrogen, which is the sum of all nitrogen forms. Currently, Wisconsin has adopted water quality standards for some nitrogen compounds in groundwater and drinking water sources, but a standard for surface recreational waters has yet to be determined.

Chapter NR 140 of Wisconsin's Administrative Code states an enforcement standard of 10 mg/L for nitrate (expressed as N) for groundwater. This is the same threshold for drinking water, as defined by NR 809. For nitrite, 1 mg/L is the maximum contaminant level for drinking water. These standards have been developed based upon the risk of methernoglobenernia (blue-baby syndrome) in infants. US Fish and Wildlife Service guidance suggests that nitrate levels not exceed 3,000 mg/L for lakes with trout or warm water fish species (Piper et. al, 1982). Livestock risk to excessive nitrates does not typically occur until this compound reaches 20+ mg/L. Aquatic life is not impacted by nitrate except for at extremely high concentrations (Chern et. al, 1999).

Figure 3.1-17 displays the mean mid-summer 2013 and 2014 surface water total nitrogen values in the CalMan Lakes. For reference, the units in Figure 3.1-14 are in units of µg/L, or parts per billion (ppb). 1,000 µg/L is equal to 1.0 mg/L.

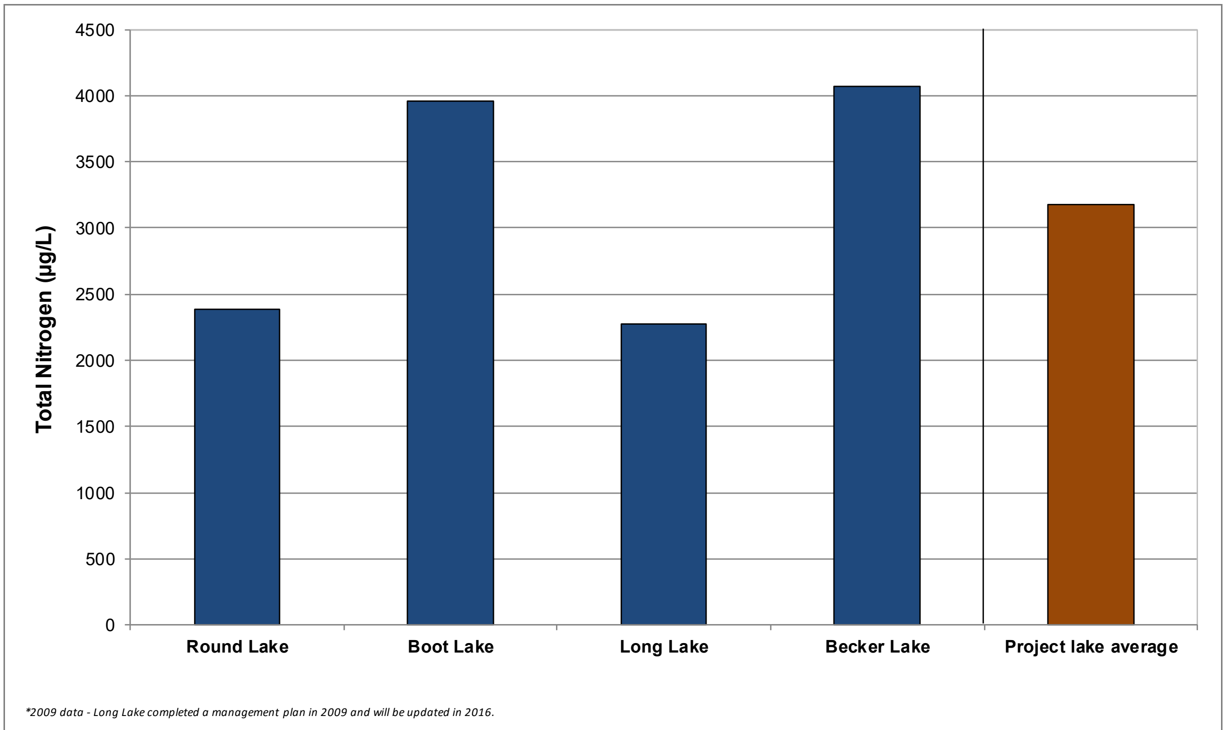


Figure 3.1-17. Mid-summer nitrogen values from the CalMan Lakes. Values are the mean of 2013 and 2014 mid-summer surface sample data.

CalMan Lakes Trophic State

Figure 3.1-18 contains the Trophic State Index (TSI) values for the CalMan Lakes. In general, the best values to use in judging a lake's trophic state are the biological parameters. The CalMan Lakes may be classified as upper eutrophic, with Boot and Becker Lakes extending in a higher, hypereutrophic category. As previously mentioned, eutrophic lakes are characterized by having abundant nutrients, algae and aquatic plants, low visibility, and often soft sediments. Eutrophic lakes at the upper end of the classification often experience excessive algae or aquatic plant growth and may see winter fish kills. Hypereutrophic lakes are characterized by being dominated by algae, few rooted aquatic plants, and low dissolved oxygen.

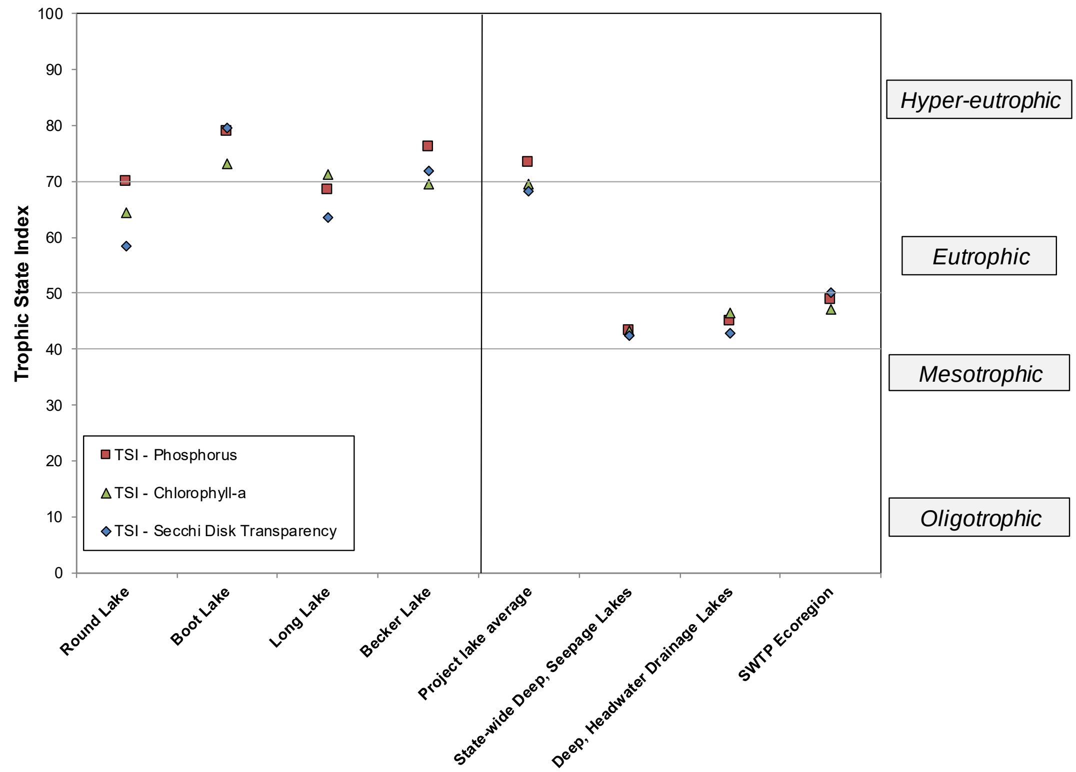


Figure 3.1-18. CalMan Lakes, deep headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data from 2012-2016 using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature were measured during water quality sampling visits to the CalMan Lakes by Calumet County and Onterra staff. During the spring (typically April-May), the water column within deep headwater drainage lakes may be thoroughly or partially mixed, with similar temperatures and dissolved oxygen being present from the surface to the bottom of the lake. This same relationship is often seen in the fall as winds increase and air/surface water temperatures cool.

During the summer months, deep headwater drainage lakes typically undergo thermal stratification. While the hypolimnetic waters remain cool/cold, the epilimnetic waters warm as the sun's rays hit them and air temperatures increase. A gradient of oxygen often occurs during this time as well. Oxygen is typically higher in the epilimnion, where oxygen exchange occurs with the atmosphere and contribution of oxygen from aquatic plants also occurs. Near the bottom of the lake, these sources of oxygen are not present. Additionally, bacteria feed upon organic material and in the process, use any available oxygen and convert it to carbon dioxide. Sometimes, strong summer winds may mix the water column, replenishing oxygen and warmer water to the hypolimnion. However, this only occurs when the force of the wind is able to overcome the depth and density differences of the lake.

During the winter months, lakes become inversely stratified when temperatures near the ice at the surface are the coldest and the denser, warmer water sinks to the bottom. Oxygen may become depleted during this time as well. Heavy snow over ice reduces light penetration, leading to a reduction in oxygen production through photosynthesis by plants and algae. In productive lakes, the decomposition of organic matter rapidly depletes available oxygen. With the ice preventing atmospheric diffusion of oxygen into the water, anoxic conditions can develop and lead to fish stress or mortality. Some fisheries biologists believe that sport fish can usually handle low dissolved oxygen levels under the ice, even for weeks at a time. Fish may sustain levels as low as 1.0 mg/L for 2-3 weeks.

The February dissolved oxygen levels in the upper waters of the CalMan lakes were lower in 2014 compared with 2015 (Figure 3.1-19). The higher concentrations in 2015 were likely because snow cover was less in 2015. With the reduced snow cover, more light penetrates into the upper waters allowing sufficient photosynthesis to maintain higher oxygen levels. Only Boot Lake had dissolved oxygen levels low enough that a fish kill may have occurred during the winter of 2013-14. In the winter 2014-15, Boot Lake contained enough oxygen that a winter fish kill was unlikely. Long Lake had the highest oxygen levels during the winter 2013-14 so this lake is the one least likely to experience a winter fish kill.

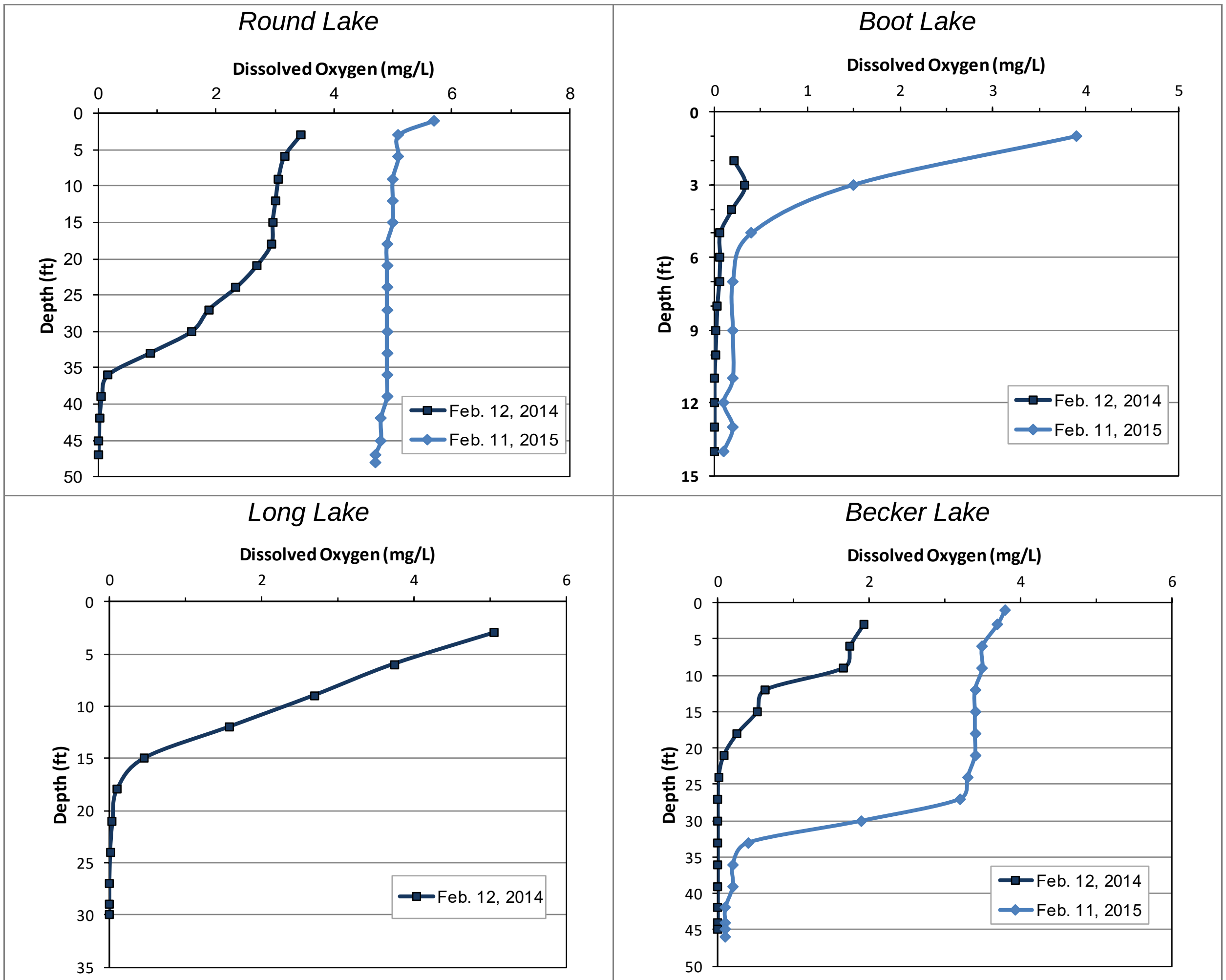


Figure 3.1-19. CalMan Lakes winter dissolved oxygen profiles, 2013 and 2014. A profile was not collected from Long Lake during the winter of 2015.

All of the lakes stratify with respect to temperature and oxygen during the summer (Figures 3.1-20 and 3.1-21). The bottom waters of all of the lakes become anoxic early in the stratification period although Round Lake maintains oxygen longer than the other lakes. This is an indication that the lake is less productive than the other lakes although it is still a eutrophic lake. Round, Long, and Becker lakes remain stratified into mid to late /October. Boot Lake which is shallower, undergoes fall mixing in late September to early October.

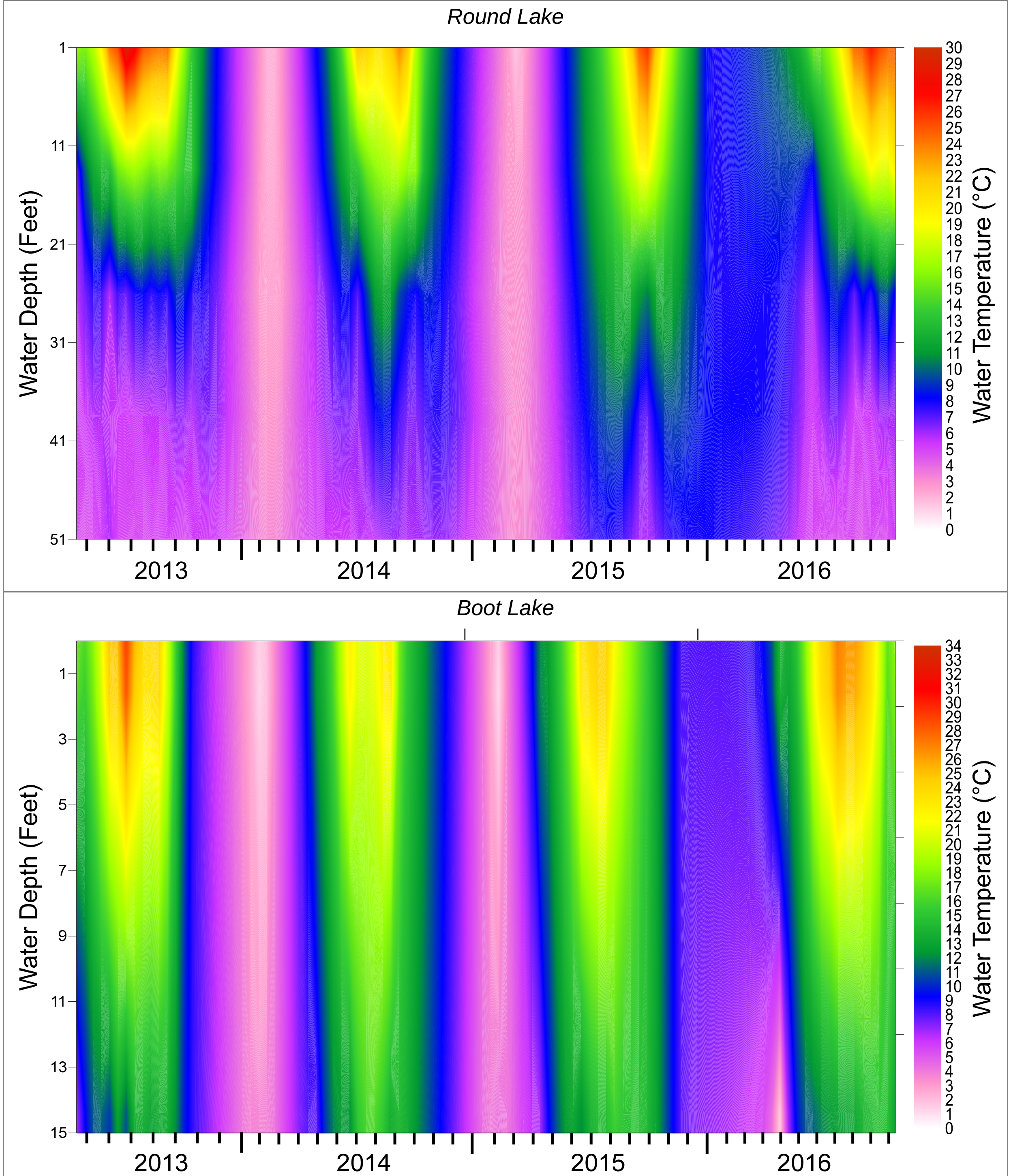


Figure 3.1-20. CalMan Lakes temperature isotherms. Data was incomplete in Long Lake in 2014 and 2015. All of the lakes become stratified during the spring and remain so until fall overturn. Only spring turnover data was collected from Becker Lake in 2014.

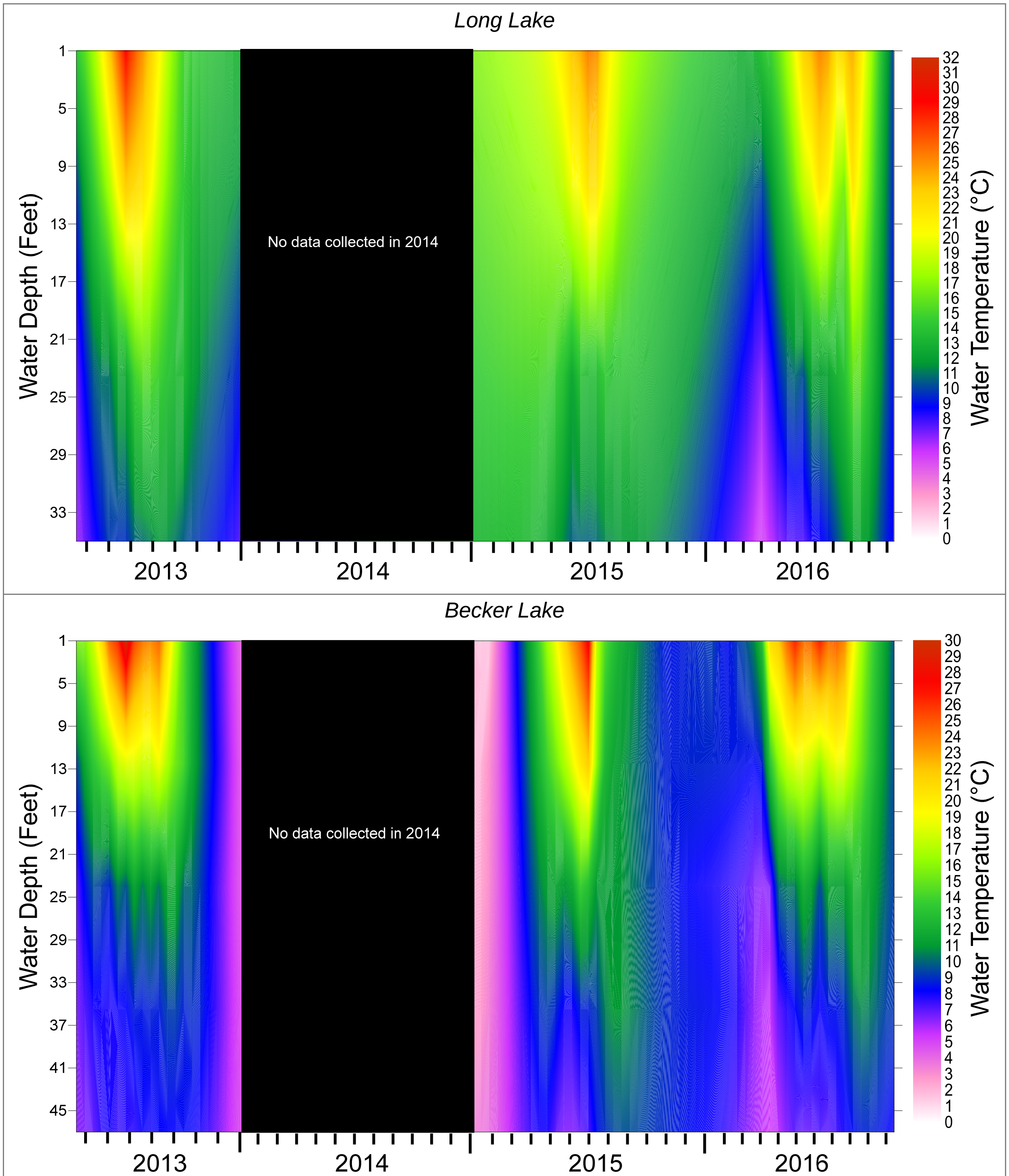


Figure 3.1-20 continued. CalMan Lakes temperature isotherms. Data was incomplete in Long Lake in 2014 and 2015. All of the lakes become stratified during the spring and remain so until fall overturn. Only spring turnover data was collected from Becker Lake in 2014.

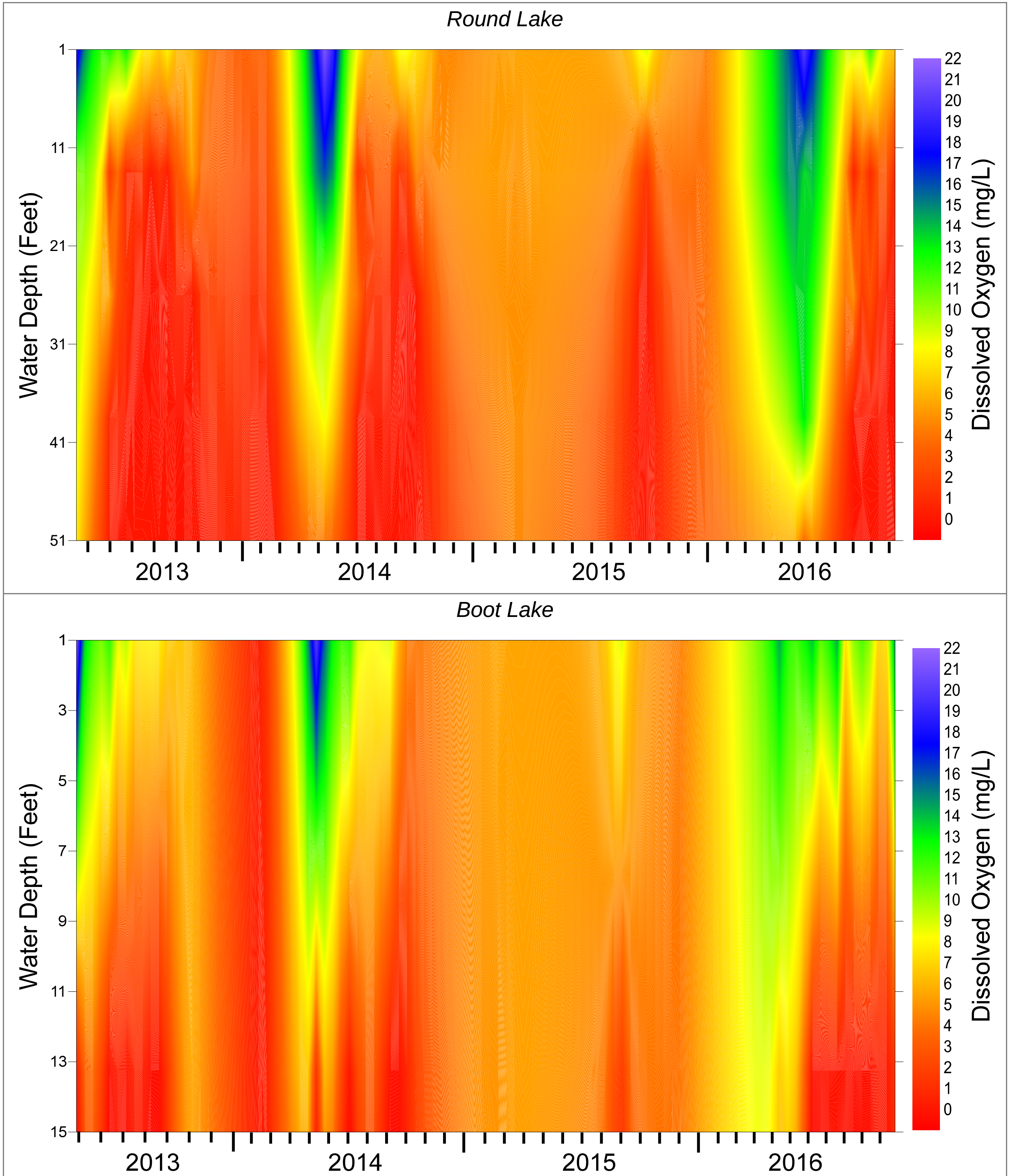


Figure 3.1-21. CalMan Lakes dissolved oxygen isopleths. Data was incomplete in Long Lake in 2014 and 2015 and only spring turnover data was collected from Becker Lake in 2014.

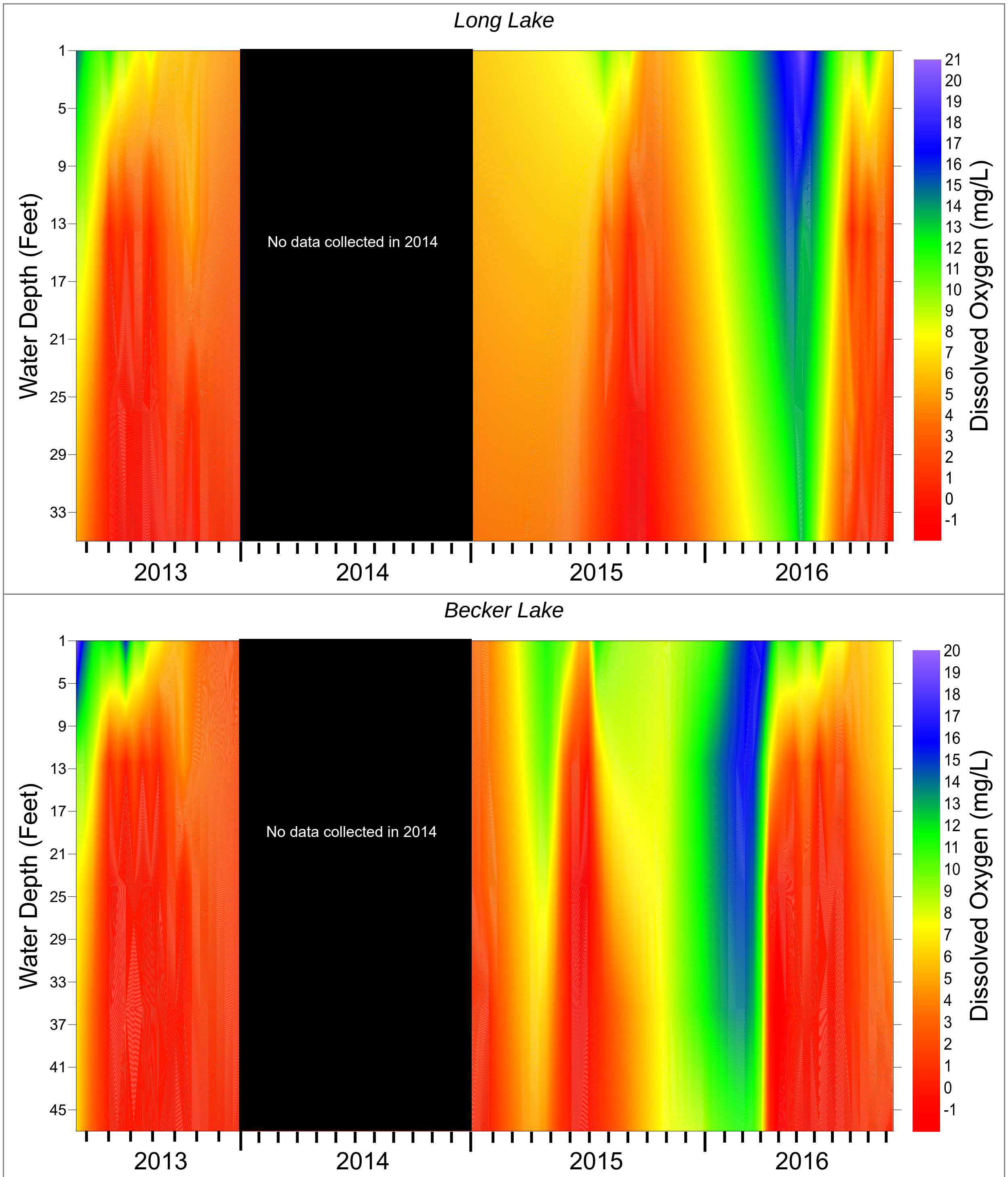


Figure 3.1-21 continued. CalMan Lakes dissolved oxygen isopleths. Data was incomplete in Long Lake in 2014 and 2015 and only spring turnover data was collected from Becker Lake in 2014.

pH and Alkalinity

The water quality information discussed above is centered on lake eutrophication; however, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of the CalMan Lake's water quality and are recommended as a part of the WDNR Long-Term Lake Trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14.0 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7.0 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7.0 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7.0 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985).

The variability in pH between lakes is most likely attributable to a number of environmental factors, with the chief determiner being geology near the lake and within its surface and underground watersheds. On a smaller scale within a lake or between similar lakes, photosynthesis by plants can impact pH because the process uses dissolved carbon dioxide, which acts as a carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. Round, Long and Becker lakes have similar pH values of around 9.0. This value is higher than is often found in hard water lakes like the CalMan lakes but this is the result of the high algal levels in these lakes. Boot Lake's pH was found to be closer to neutral at 7.1 (Figure 3.1-22).

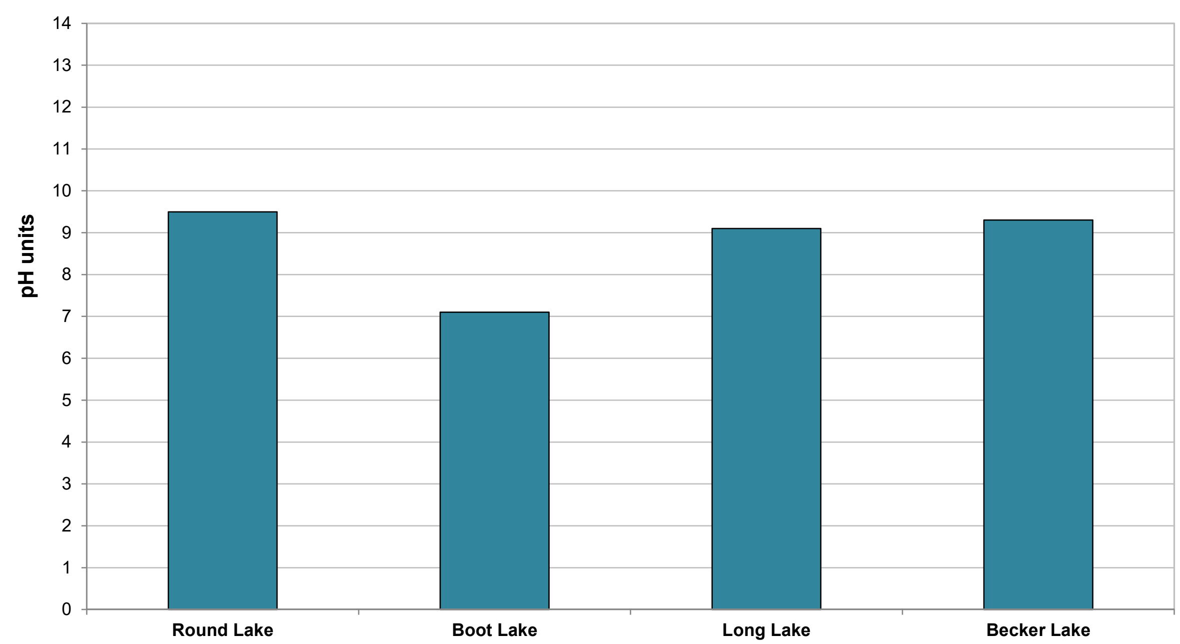


Figure 3.1-22. CalMan Lakes pH values. Data collected from summer month surface samples.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering acidic inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity it contains. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. Alkalinity values are quite similar between the CalMan Lakes and are at values expected for lakes in this region, which are located above rock groupings that are relatively high in calcium carbonate. (Figure 3.1-23). Alkalinity determines the sensitivity of a lake to acid rain. Values between 2.0 and 10.0 mg/L as $CaCO_3$ are considered to be moderately sensitive to acid rain, while lakes with values of 10.0 to 25.0 mg/L as $CaCO_3$ are generally considered to have low sensitivity, and lakes above 25.0 mg/L as $CaCO_3$ are non-sensitive.

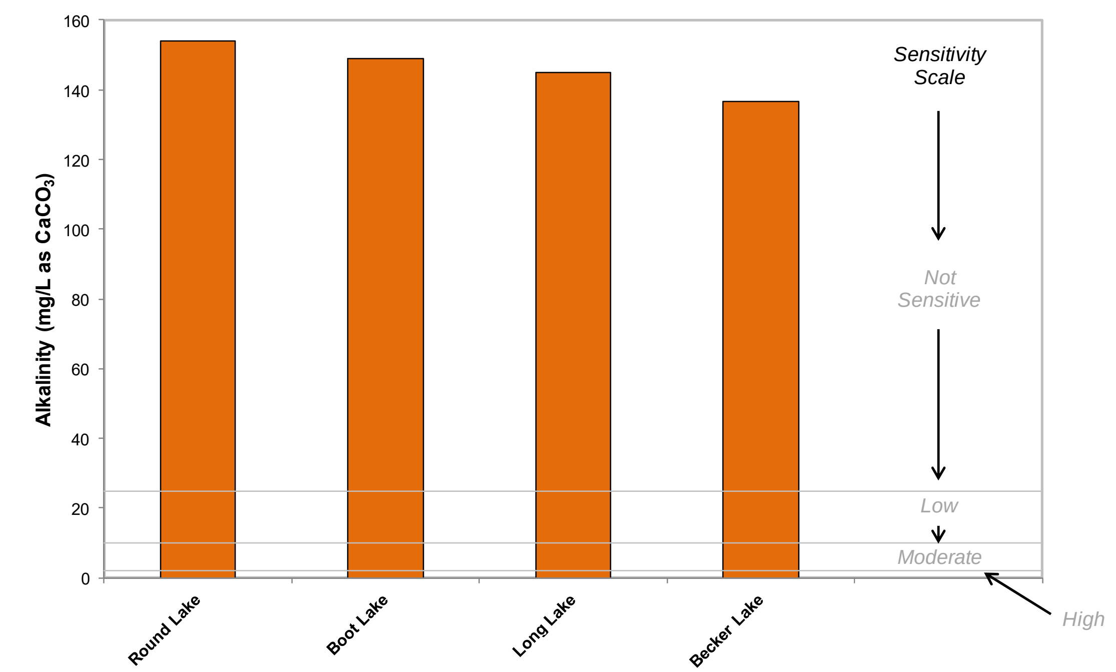


Figure 3.1-23. CalMan Lakes alkalinity values and acid rain sensitivity ranges. Data collected from summer month surface samples.

Stakeholder Survey Response Regarding Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figure 3.1-24 displays the responses of the CalMan Lakes stakeholders to questions regarding the current water quality of the CalMan Lakes and how it has changed since they first visited their lake. When asked how they would describe the current water quality of the CalMan Lakes, 78% of respondents indicated that the water quality is poor to very poor, 8% indicated good, 6% indicated fair, 6% indicated unsure, and 2% indicated that the water quality is excellent. The agreement by stakeholders that the water quality of the CalMan Lakes is of poor to very poor is reflected in the data collected over the last five years.

When asked how water quality in the CalMan Lakes has changed since they first visited their lake, 73% of respondents indicated that the water quality has somewhat to severely degraded, 18% indicated that the water quality has remained the same, 6% indicated it has somewhat improved, and 3% indicated they were unsure (Figure 3.1-24). While there is some historical data for the CalMan Lakes, there is not extensive data, which makes determining water quality patterns difficult. The overall water quality seems to be degrading but further study is required to establish trends.

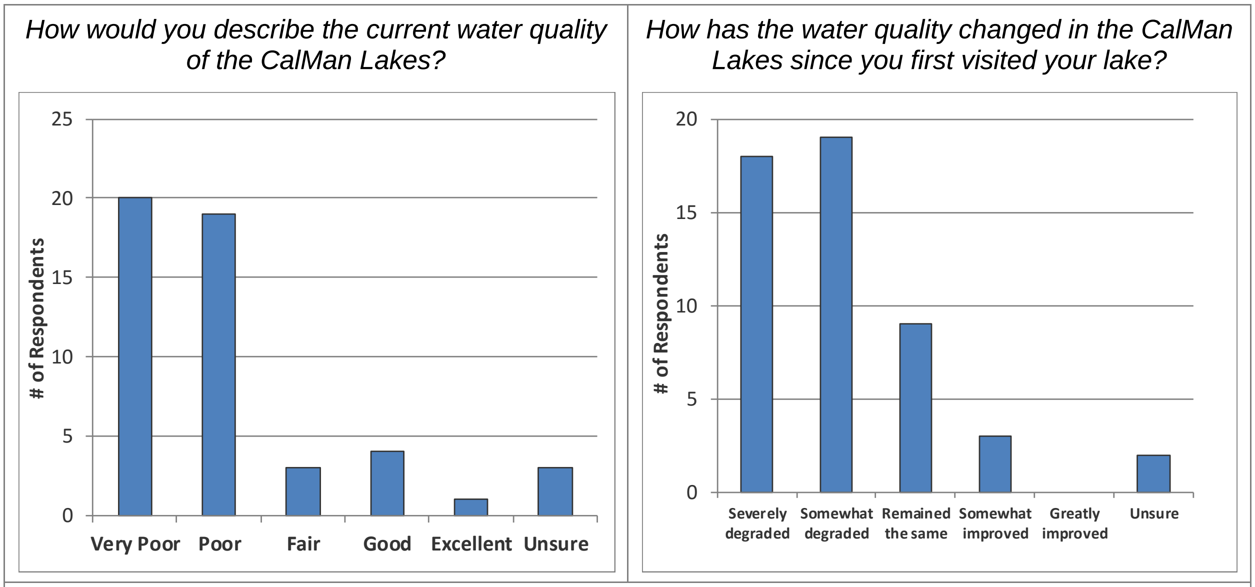


Figure 3.1-24. CalMan Lake stakeholder survey response to questions regarding water quality. N = 51 respondents.

3.2 Watershed Assessment

Watershed Characteristics

As illustrated through this section, a lake's watershed has great influence over the water chemistry, hydrologic properties, and overall ecology of the waterbody. Various characteristics of the watershed may determine the quantity of nutrients, sediments, inorganic pollutants and water that reach a lake. Additionally, aspects of the watershed determine how fast (e.g. flow rate) these components reach a lake's waters. Aspects of a watershed that are important for any study include soil type, slope of the land, land cover type.

Private Onsite Wastewater Treatment Systems

Improperly maintained or faulty septic systems may impact both the health of individuals using the lake and also the water quality of a lake. A properly operating system will remove most disease-causing pathogens, but may not remove or treat nutrients such as phosphorus or nitrogen entirely. Besides the obvious health concerns, leaky septic systems may contribute nutrients to a lake, which can promote algae and aquatic plant growth.

The Wisconsin Department of Commerce oversees private onsite wastewater treatment systems (POWTS) through Chapter SPS 383 (formerly Chapter Comm 83). Although there are an estimated 772,000 private septic systems located in the state of Wisconsin, the exact number and location of these systems was largely unknown for some time. Recent legislation has prompted counties to develop a comprehensive inventory of their septic systems. As of January 2013, it is currently believed that 83% of the estimated number of systems have been inventoried.

In Manitowoc and Calumet counties, all pre-1980 POWTS within the county must be inspected by a licensed professional and reported back to the county on a POWTS Inventory Inspection Report form. This report form is reviewed by staff and sorted into different categories depending upon the status of each system. Report forms that identify a properly functioning POWTS are scanned and attached to a parcel in a tax/parcel database and are entered into a three year POWTS maintenance tracking software program. The POWTS Inventory Inspection Report form documents the type of system (mound, conventional, holding tank, privy, etc.), the condition of that system (failing or functioning), and a location of each system component if known.

If a system is deemed functioning, it is added to the county's maintenance program and the owner is required to have the system inspected by a licensed professional every three years and the septic tank pumped. If the system is a holding tank, the system is placed on a pumping schedule that reflects the size of the holding tank and the number of rooms in the dwelling unit. If the system is failing, it is ordered to be replaced. The county does assist low income individuals in seeking financial assistance from the state to offset the costs of installing a replacement system. Due to income limitations and the type of existing system, not all property owners or systems qualify for grant money.

Creating an inventory of POWTS throughout the state of Wisconsin is important, but maintaining these systems so that they operate correctly is critical. The enacted legislation has developed rules that establish a maintenance program for private sewage systems, and even encourages failing system replacement and rehabilitation through a funding program called the Wisconsin Fund. A condition for a county to participate in this program is that the county must adopt and implement a maintenance program, and must do so by the state-wide deadline of October 1, 2015. Because each program is governed on a county basis, the local health or zoning and planning department will be able to provide information on maintenance program and funding opportunities available.

It is generally recommended that POWTS are pumped or inspected every three years for proper functioning. Between inspections, there are several ways to determine if your septic system may require maintenance:

- Sewage has backed up in your drains, toilets or basement
- Drains begin to run slower than normal
- Wet areas or bright green grass appear over the drain field
- A dense colony of aquatic plants or algae appears near your shoreland
- Bacteria or nitrates are found in your well water
- Biodegradable dye flushed through the system appears in the lake or stream

Additionally, there are many ways to keep your septic system in top shape, and reduce the chances of system failure:

- Have your system inspected on a regular basis (every three years is recommended)
- Avoid driving or parking vehicles on the drain field
- Do not dispose of materials in drains that enter the septic tank. These items (fats, grease, paper towels, disposable diapers, sanitary napkins, etc.) may clog the septic tank and other items (cleaning fluids, oils, paints, etc.) may not be treated and end up in groundwater.

Soils and Geology

Geology and soils play an important role in controlling how water moves over and through a watershed. By studying the properties, position in the landscape and watershed hydrology associated with geology and soils, a better understanding can be achieved about how the watershed functions. In addition to their impact on water flow and quality, soils and geology play a pivotal role in a number of human activities, such as agricultural production, home site development, road construction, landscaping, etc. Thus, a general knowledge of soils is essential for implementation of successful watershed management activities.

Calumet and Manitowoc counties are underlain primarily by Silurian-age (443-416 million years ago) dolostone. Dolostone is a carbonate-based rock; in other words, it is a rock that is rich the mineral dolomite ($CaMg(CO_3)_2$). Most carbonate rocks begin as deposition of calcium carbonate ($CaCO_3$) derived from a variety of biochemical or chemical sources on the bottom of an ocean. After burial, the grains of calcium carbonate along with other materials become lithified (turned to rock under pressure). Thus, the Silurian dolostone we see today is rich in dolomite (calcium carbonate) and may include indications of sea life from 416 million years past.

Soils may be classified in many ways, relating to their infiltration capacity, chemical composition, material and texture, etc. For example, soils are classified into several hydrologic groups (A, B, C and D) which describe general infiltration of the areas and water movement ability. All of these soil types may be found within the CalMan Lakes watershed.

Hydrologic soil group A is made up of soils that have high infiltration rates when thoroughly wetted. They consist chiefly of deep, well- to excessively-drained sands and/or gravels. Hydrologic soil group B is characterized by soils with moderate infiltration when thoroughly wetted. These soils include those that are primarily moderately to very deep, moderately to well-drained and have moderately fine to moderately coarse textures. The soils in hydrologic group C have a slower rate of water infiltration when thoroughly wetted. This group includes soils with either a moderately impervious layer or soils with a moderately fine to fine texture. Lastly, hydrologic soil group D is characterized by soils with a very slow rate of water transmission and very slow infiltration rate when thoroughly wetted. This grouping includes clay soils with high swelling potential, soils with high permanent water table, soils with clay pan or clay layer at/near the surface, and shallow soils over nearly impervious materials. Generally speaking, hydrologic soil groups C and D are more likely to generate stream or overland flow, while groups A and B are more likely to have thorough infiltration.

Round Lake Watershed Soil Groups

The Round Lake watershed contains four soil types. The most common is the Kewaunee loam 6-12% slope (KnC2) at 45% of the watershed. The KnC2 soil type is characterized as being well-drained. It has a Hydrologic Soil Group category of C, which indicates the soil has a slow infiltration rate when thoroughly wet. This is due to the soil having a layer that impedes downward movement of water. The KnC2 grouping is susceptible to high levels of surface runoff and has a slope generally between 6-12%.

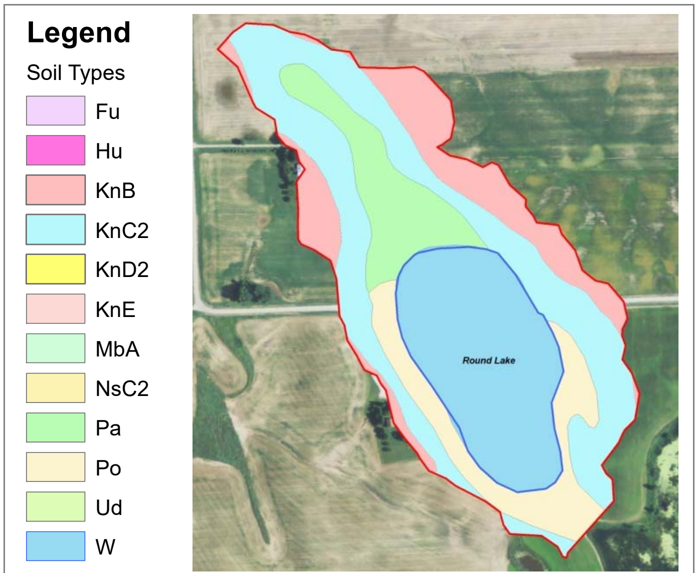


Figure 3.2-1. Round Lake watershed soil types. Data provided by Natural Resource Conservation Service Soil Survey.

The soils immediately north-northwest of Round Lake are classified as Palms Muck (Pa). At 16% of the watershed, this area holds a wetland complex that a good portion of the watershed drains to before entering Round Lake. Indeed, Palms muck is described as being subject to long and frequently ponding during the winter and spring and brief or long occasional ponding in late spring and fall. It is a soil that incorporates nearly 87% organic matter.

Boot Lake Watershed Soil Groups

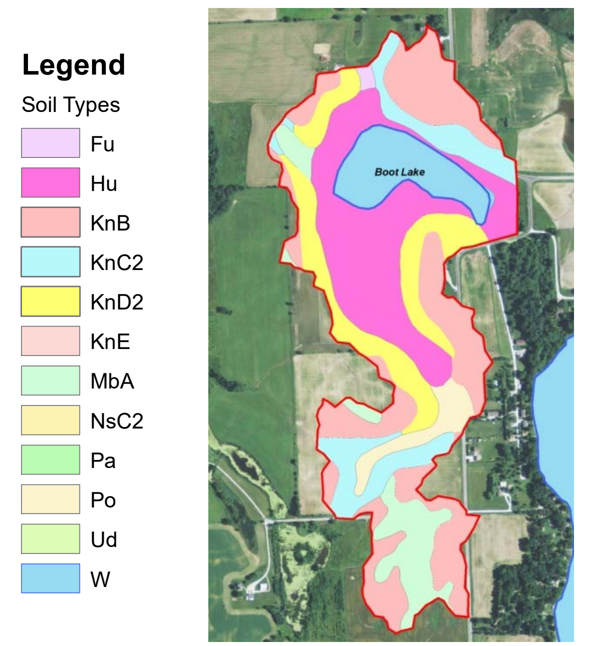


Figure 3.2-2. Boot Lake watershed soil types. Data provided by Natural Resource Conservation Service Soil Survey.

The Boot Lake watershed consists of seven soil types, of which the Kewaunee loam 2-6% slope (KnB) is the most common at 32% of the watershed. Similar to the Kewaunee loam (KnC2), it is a well-drained soil that is classified as hydrologic soil grouping C, which indicates a slow infiltration rate. At 2-6% slope, the soil has a high surface runoff potential. The second most common soil in the watershed, which also surrounds the immediate area of Boot Lake, is the Houghton much (Hu) grouping. This is a poorly-drained soil (unless artificially drained) and has characteristics of slow infiltration rates and high runoff potential, as well as high organic matter percentage at nearly 85%. Because of slow infiltration rates, Palm mucks are known to pond frequently.

Long Lake Watershed Soil Groups

Similar to the Boot Lake watershed, the Long Lake watershed is dominated by Kewaunee loam 2-6% slope (KnB) at 29% of the watershed, and secondly by Houghton muck (Hu) at 22% of the watershed. Additional soil groups of interest in this watershed include Kewaunee loam 12-20% slope (KnD2) and Kewaunee loam 6-12% slope (KnC2). The KnD2 grouping consists of well-drained soils with a very high surface runoff rating due to their great slope. All of the Kewaunee loam units are characterized as having high sand (~44%) and silt (~40%) with a lesser amount of clay material (~16%), which contributes to this soil type's good draining capability.

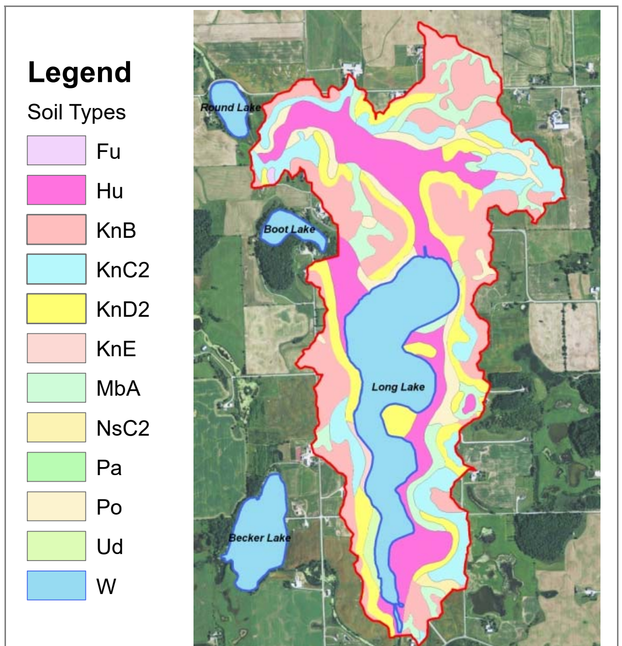


Figure 3.2-3. Long Lake watershed soil types. Data provided by Natural Resource Conservation Service Soil Survey.

Becker Lake Watershed Soil Groups

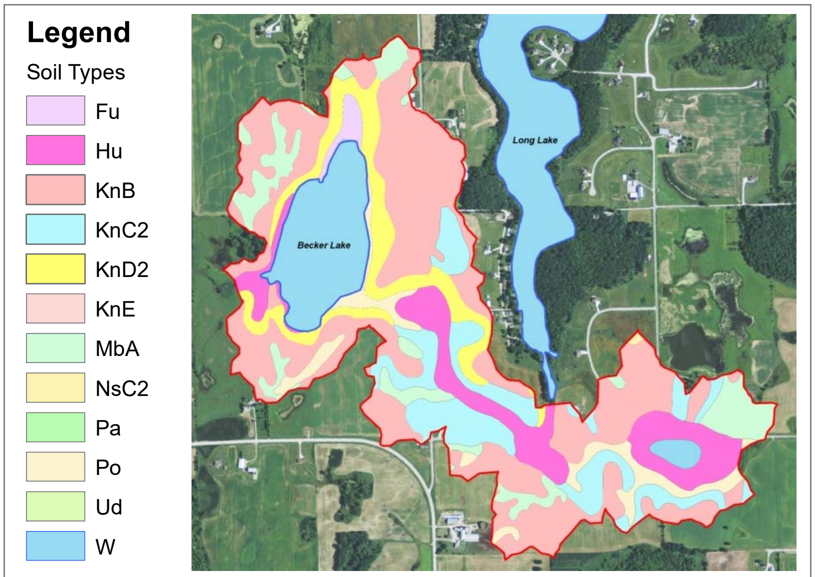


Figure 3.2-4. Becker Lake watershed soil types. Data provided by Natural Resource Conservation Service Soil Survey.

The Becker Lake watershed, like the Boot and Long Lake watersheds, is dominated by the Kewaunee loam 2-6% slope (KnB) soil group at 46% of the total watershed. Kewaunee loam 6-12% (KnC2) and Houghton muck (Hu) make up smaller portions of the watershed as well at 14% and 13% respectively.

Land Slope and Nutrient Management

The slope of a land in a watershed determines its boundaries. Areas of high slope percentage generally have higher runoff rates and sediment yields. Additionally, these areas have higher susceptibility to further erosion, including gully formation. In small watersheds, overland flow is seen more so than channel flow, which occurs often in larger watersheds with a more complex and defined drainage network. In small watersheds, sheet and rill erosion is thus a primary concern. Sheet and rill erosion occur when water follows many paths over the land to reach a waterbody. In areas of higher slope, sheet and rill erosion are more prolific as the pull of gravity advances this form of water runoff. Thus, these areas are important to consider in watershed management planning as they often can be the location of high erosion.

Particularly in developed watersheds, slope can have a magnifying effect on sensitive areas. Wisconsin Nutrient Management Code 590 states that in high slope zones (greater than 12%), winter manure applications are prohibited. Winter manure applications are restricted within zones of greater than 9% slope – there may be an option for fields of up to 12% slope that exercise contoured or contour strip farming.

Within Figure 3.2-5, high slope zones are depicted in the CalMan Lakes watershed. Roughly 174 acres of land with 9-12% slope are located within the watershed, while 153 acres have greater than a 12% slope. Together, these areas make up 26% of the watershed. Figure 2.3-5 also displays Surface Water Quality Management Areas (SWQMAs). These include areas within 1,000 feet of lakes and ponds or within 300 feet of perennial rivers and streams. While there are four lakes within the CalMan Lakes watershed, the streams that connect them are considered intermittent.

Winter mechanical nutrient applications are prohibited in SWQMAs. Nutrient applications on unfrozen ground in SWQMA's are restricted and must be accompanied by at least one of the following four management actions:

1. Establish permanent vegetative buffers
2. Incorporate nutrient within three days
3. Maintain greater than 30% residue or vegetative cover
4. Establish cover crops after application

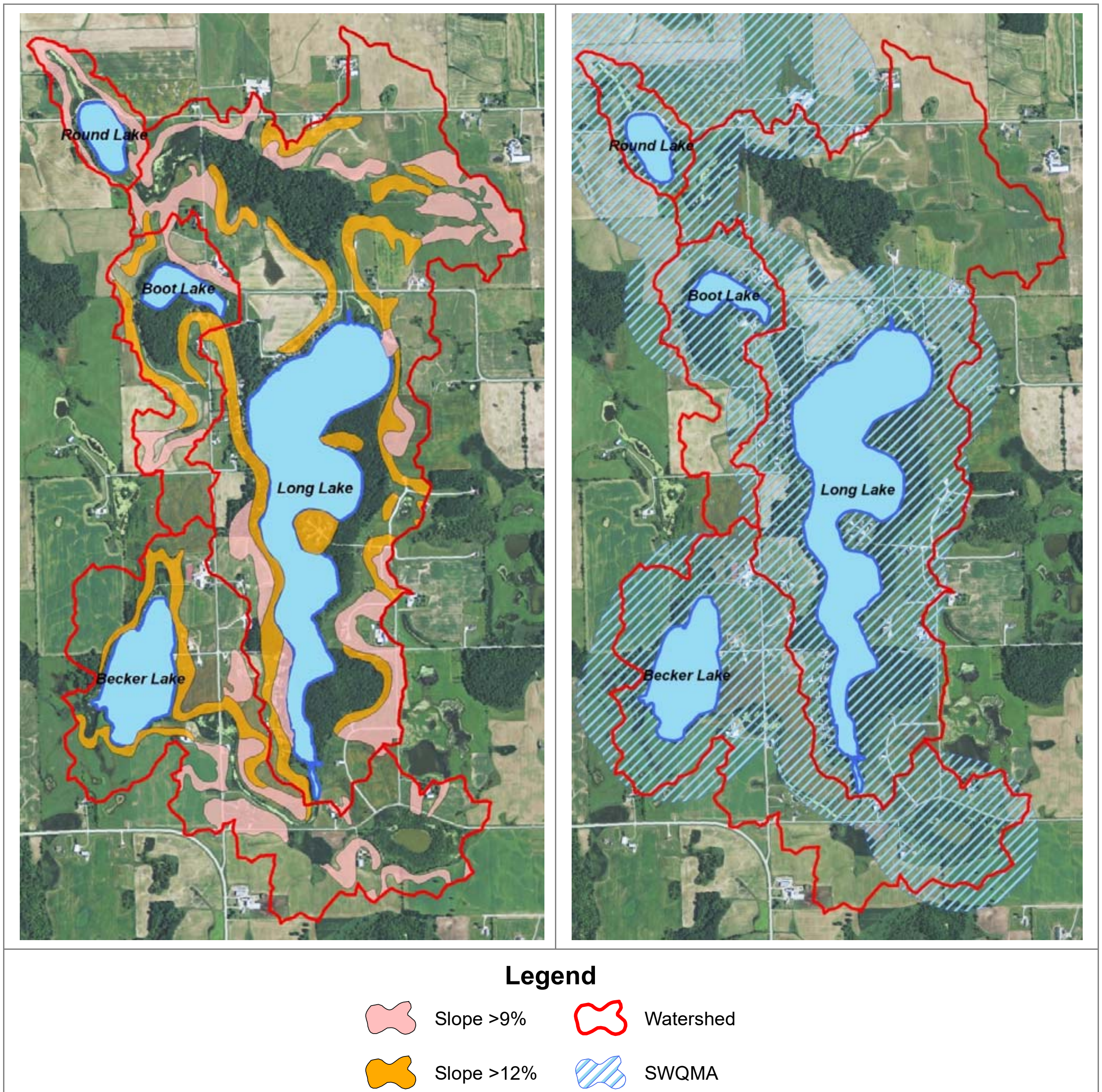


Figure 3.2-5. High slope zones and Surface Water Quality Management Areas. Data extracted from Wisconsin Manure Management Advisory System Interactive Map (http://www.manureadvisorysystem.wi.gov/).

Land Cover and Watershed Size

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake: 1) the size of the watershed and 2) the land cover (land use) within the watershed. The impact of the watershed size is dependent on how large it is relative to the size of the lake. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drains to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load.

The type of land cover that exists in the watershed, along with the factors discussed the previous section, determines the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas, minimize infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased phosphorus and pollutant loading; which, in turn, can lead to nuisance algal blooms, excessive sedimentation, and/or overabundant macrophyte populations.

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems, the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. Additionally, there are a number of Best Management Practices (BMP's) that can be implemented on developed land to reduce the impact on water quality. These include nutrient management actions (alternative nutrient application, winter cover crops), vegetative buffer strips, manure containment systems, etc. In the end, if the phosphorus load is reduced greatly changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

In systems with high WS:LA ratios, like those 10-15:1 or higher, the impact of land cover may be tempered by the amount of land draining to the lake. Situations actually occur where lakes with forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads enough to see a change in plant production. Both of these situations occur frequently in impoundments.

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS – Panuska, 2003). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. And, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

CalMan Lakes Watershed Assessment

As mentioned above, the size of a watershed in relation to the lake to which it drains may have a profound impact on the lake's water quality and ecology. Round Lake, at the upper reaches of the CalMan Lakes watershed, has a watershed that is only three times larger than the size of the lake. Boot Lake, also at the upper reaches of the CalMan Lakes watershed, has roughly ten times the lake acreage draining to the lake. The larger Long Lake has a relatively small ratio, as its size encompasses a larger area in respect to its watershed. Finally, Becker Lake, at the downstream end of the CalMan Lakes watershed, has a large watershed to lake area ratio which is the result of a large watershed and a moderately small lake.

The watershed to lake area ratio impacts the quality and quantity of water a lake receives. Watershed to lake area ratios and lake flushing rate data area presented in Table 3.2-1. A lake's flushing rate is simply a determination of the time required for the lake's water volume to be completely exchanged. Residence time describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

Table 3.2-1. CalMan Lakes watershed and hydrologic characteristics. Hydrology statistics computed through WiLMS (Panuska, 2003).

Lake Name	Direct Watershed to Lake Area Ratio	Lake Flushing Rate (1/yr.)	Water Residence Time (years)
Round Lake	3:1	0.10	10.03
Boot Lake	10:1	0.53	1.90
Long Lake	6:1	0.37	2.70
Becker Lake	8:1	1.46	0.69

The land use in the CalMan Lakes watershed is predominately agricultural-based. Approximately 38% (469 acres) of the land use in the entire watershed consisted of row crops in 2006, according to satellite imagery from that year. Pasture and grassland constitute the second most abundant land use, at 32% of the entire watershed (394 acres). The surface area of each of the four lakes makes up roughly 16% of the watershed, while wetlands (9%), rural residential land (3%) and forest (2%) round out the remaining land use in the watershed. Individually, each direct sub-watershed in the greater CalMan Lakes watershed holds high percentages of row crops (between 30% and 51%) as well as pasture/grass (between 19% and 51%). Figure 3.2-6 displays the individual sub-watershed characteristics for the CalMan Lakes, while land within the watershed is displayed in Map 2.

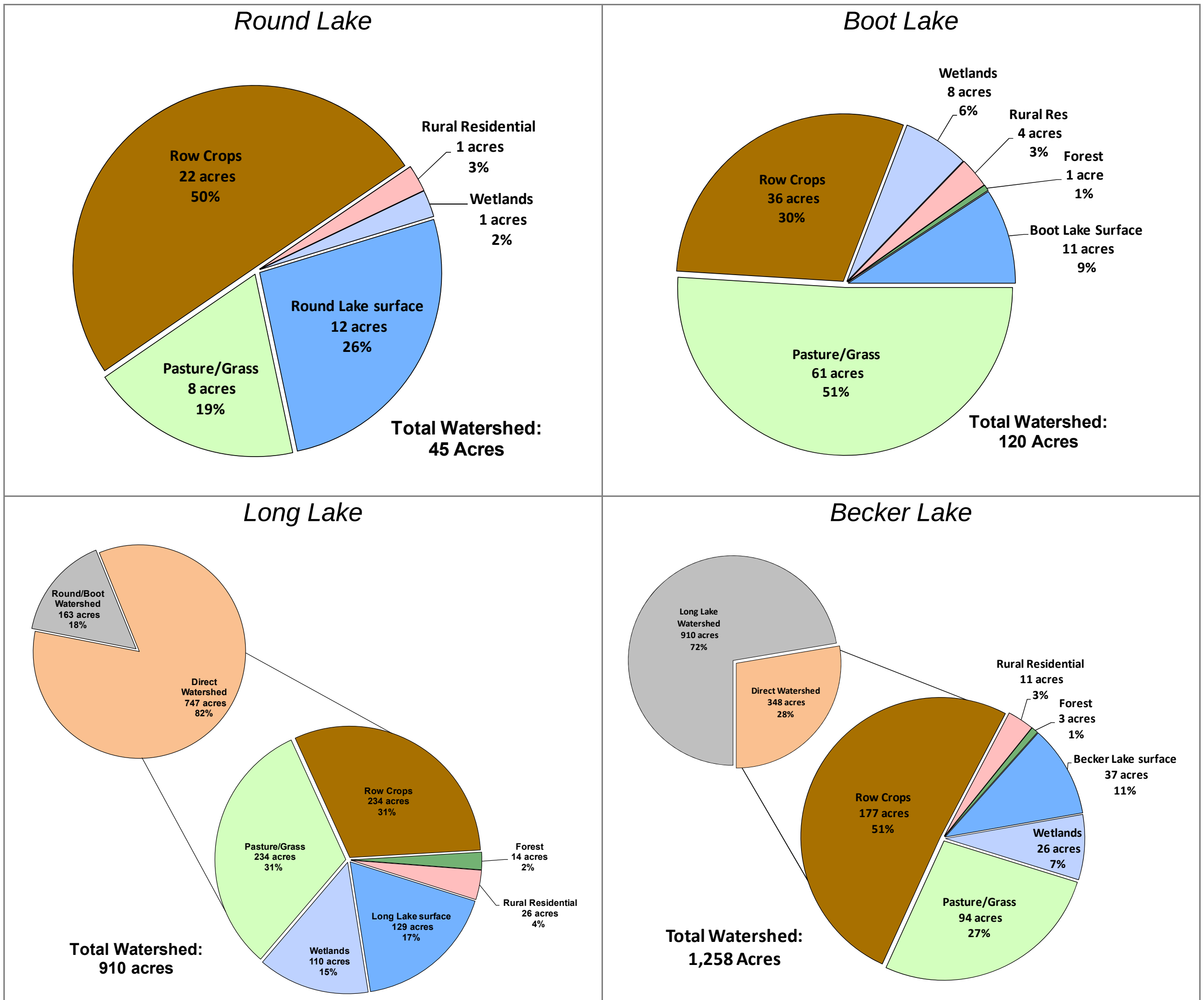


Figure 3.2-6. Land use within the CalMan Lakes sub-watersheds. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

External Phosphorus Sources

Tributary Stream Monitoring

The CalMan Lakes drainage basin is relatively small in size and the drainage patterns in the basin are reflective of this, with "flashy" streams that may run for only several hours following a rain event. Three of the lakes have intermittently running tributary streams – Round, Long and Becker lakes. All four of the lakes receive surface water runoff during spring snow melt and may receive input during large rain events. Figure 3.2-7 shows the three sites where stream monitoring occurred as well as the culvert sites.

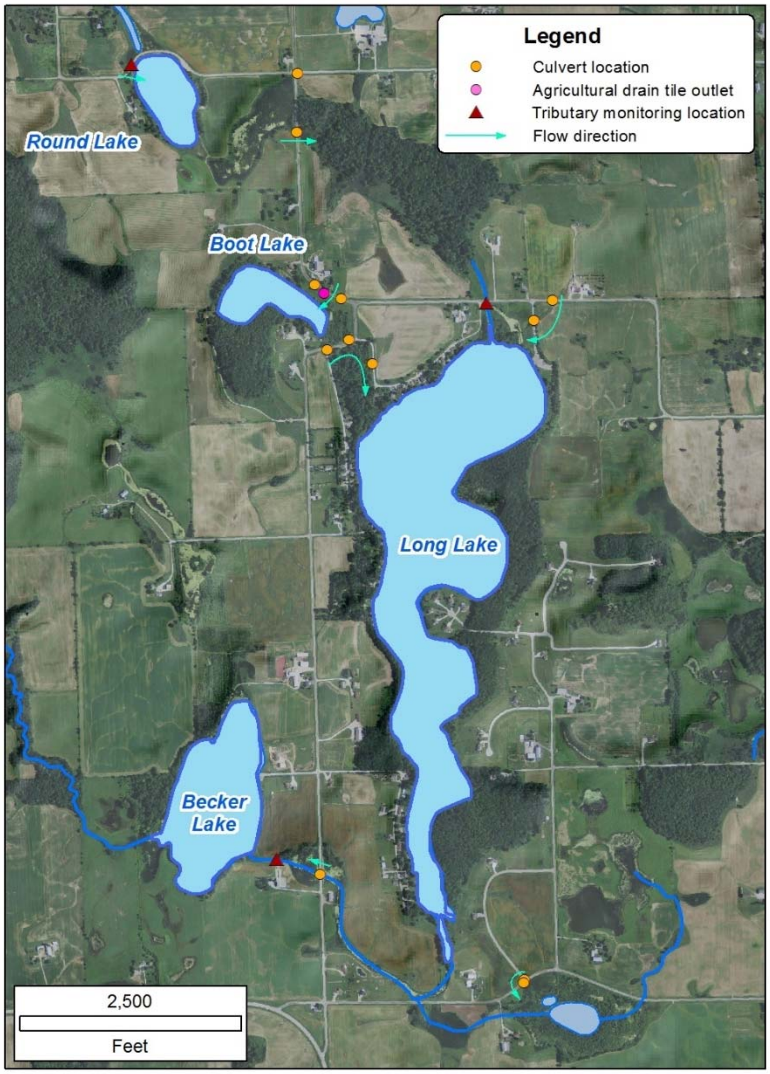


Figure 3.2-7. Aerial photo showing study lakes and stream monitoring sites. The three triangles are the sites of the continuous recorders. The culvert sites were sampled when flow occurred.

The CalMan Lakes are headwater lakes with the drainage pattern being Round and Boot lakes draining into Long Lake and Long Lake draining into Becker Lake. The stream leaving Becker Lake flows into Grass Lake and becomes Black Creek. Efforts have been undertaken to understand the flow regimes at three sites within the watershed. Numerous culverts that drain towards the CalMan Lakes were also sampled on an infrequent basis. The continuous monitoring sites are: 1) the inlet to Round Lake, 2) where the stream draining Round Lake enters Long Lake, and 3) where the stream enters Becker Lake. During 2015 and 2016, the three streams and numerous culverts were assessed for flow during storm events by CCLWCD and Onterra staff. Flow monitors were deployed on the Round, Long and Becker Lake tributaries to collect flow on a 10-minute interval. Water flow volumes and nutrient loads were collected in 2015 and 2016 using flow monitoring units from Blue Siren® (www.blue-siren.com). Data collected from the culverts in 2014 did not prove useful as flow was often minimal and difficult to quantify.

Round Lake Tributary (Site ID ROT1):

A single culvert runs underneath Round Lake Rd., connecting the western part of Round Lake's 32-acre watershed to the lake itself. On the northwestern side of the road, a small wetland complex exists and on the southeastern side is Round Lake. The culvert connects the lake and the wetland complex. In 2014, CCLWCD used survey-grade GPS to measure the length and slope of the culvert. These data indicate that the culvert is slightly negatively pitched, in other words, sloping from the lake towards the wetland. Very often the surface water elevation is the same on the wetland- and lake-side of Round Lake Rd. While the culvert's intention is to drain water from the wetland into Round Lake, it is actually more or less acting as a level conduit between the two basins on either side of the road. Meaning that the wetland is not actually uphill from the lake with its water flowing into the lake, it is actually at the same elevation as the lake and the culvert allows water to flow both ways between the two. Additionally, often during early season rain events, flow overtops the road making nutrient loading impossible to quantify.

In 2015, monitoring of ROT1 began on March 11 and continued through November 18. In 2016, monitoring began March 11 and continued through November 3. CCLWCD and Onterra staff collected samples during runoff events as well as during lower flow periods. In 2015, ten total phosphorus (TP) samples were collected while total suspended solids and dissolved phosphorus samples were also collected. In 2016, 23 total phosphorus samples were collected. In 2016, most of the samples were collected in March as this was when most of the flow was expected because of spring runoff. Samples were collected only when visible flow was occurring (stagnant conditions not sampled).

Even following rain events, flow was not always observed in the culvert. It is believed that the hydrology of this area is such that water backs up in the lake, and thus the wetland across the road, for a period of time until sufficient draining can occur at the lake's outlet. Despite these challenges, several rain events were recorded and sampled during 2015. Figure 3.2-8 displays TP samples collected over the flow monitored timeframe in 2015 and 2016. Measured flows in 2015 were suspect because the culvert enters directly into Round Lake and is always partially filled. Also, low battery level during June 2015 adversely affected the accuracy of flows. It is doubtful that flow was continuously occurring in 2015 during the period of collection. In 2016, the recorded flow regime appears more reasonable but again, because of the placement of the culvert the accuracy of the flow is in question. Overall, based upon visual observations by Onterra staff and comparing flow regimes with the inlets at Long and Becker lakes, it is doubtful that flow monitoring at this site is accurate.

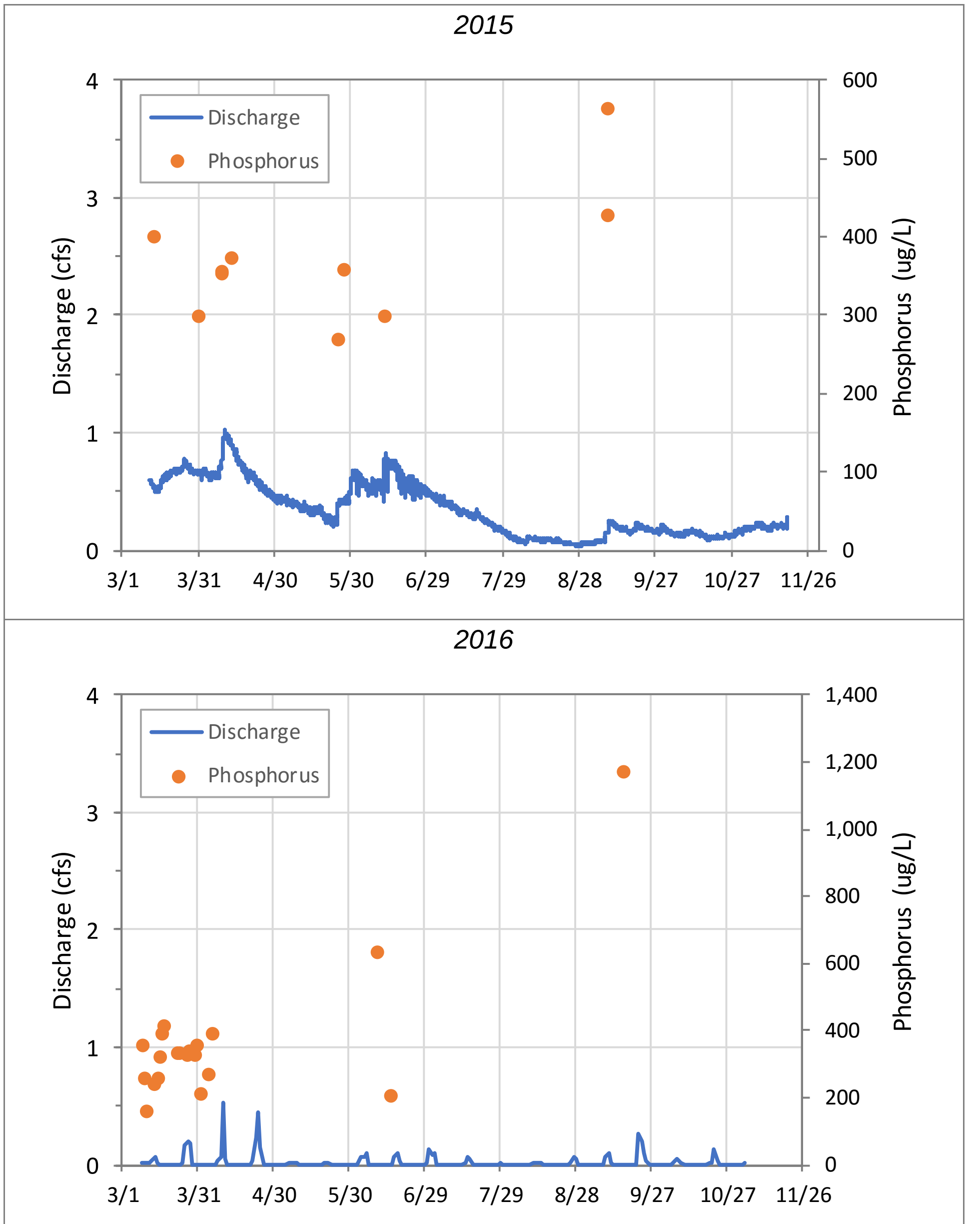


Figure 3.2-8. Round Lake discharge (cfs) and total phosphorus (µg/L) during ice free season in 2015 (top) and 2016 (bottom). Because of the placement of the culvert, it is likely that accurate flow measurements were not obtained. See the text for more detail.

Long Lake Tributary (Site ID LOT1):

Once water leaves Round Lake, it collects with other runoff from Long Lake's watershed in a forested wetland just north of Long Lake. It then flows south, under Boot Lake Rd. bridge into Long Lake. As with ROT1, this inlet's water elevation is like the lake's water level and has a low slope. As such, water velocity is often minimal and largely derived by spring runoff and rain events. During multiple field visits during smaller rain events, an increase in the water depth was noticed but visible flow was not always observed. This would indicate the stream and lake level could be rising at a consistent rate, the stream fed by northern upstream sources and the lake fed by inputs from the west and eastern shoreline.

In 2015, monitoring began March 9 and continued through November 19. In 2016 monitoring began March 8 but data were not captured after August 1 because of a low battery. Based upon visual observations and monitoring in 2015, there likely was not significant flow after this time.

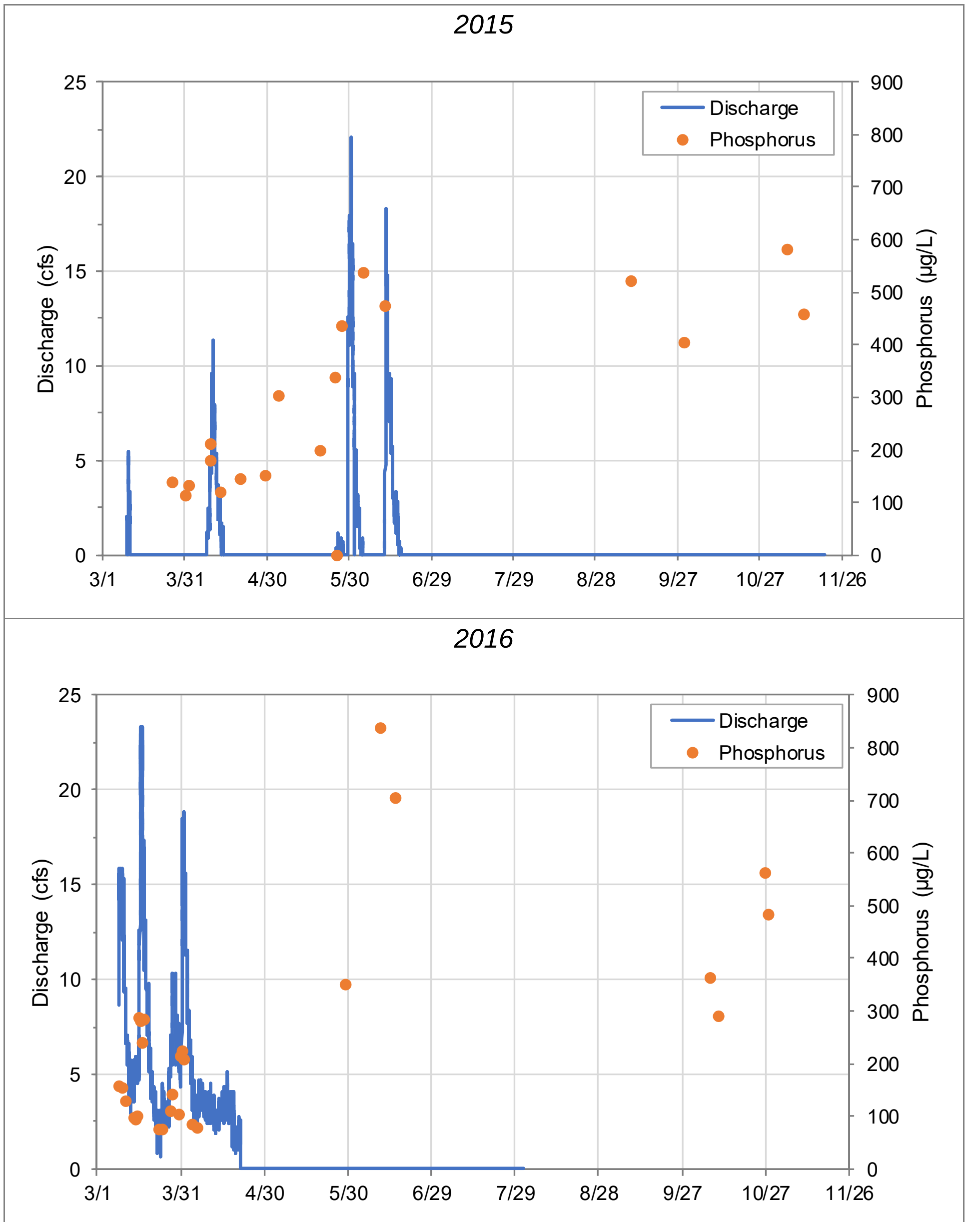


Figure 3.2-9. Long Lake discharge (cfs) and total phosphorus (µg/L) during ice free season in 2015 (top) and 2016 (bottom). Equipment failure in 2016 occurred after August 1 but it is likely no significant flow was missed.

In 2015, three significant rain events were captured at LOT1, including during mid-April and early and mid-June (Figure 3.2-9). Moderate rain events occurring in the fall were not captured. It is likely that after a long period of dry weather, these moderate rain events may have percolated into the soil or been absorbed by the riparian wetland and not triggered a substantial flow. There was greater snowfall during the winter of 2015-17 compared to the previous winter resulting in greater spring runoff in 2016. In 2016, measured flows were much higher and continuous in March and the first part of April compared with 2015. During 2016, some rain events did occur during the summer but they were not great enough to produce a runoff event. It is likely that during the growing season, growing crops absorb much of the precipitation and further absorption occurs in the riparian wetland, significantly reducing runoff. In both years, elevated phosphorus concentrations were observed when no flow was observed. These high levels were the result of the stagnating water accumulating phosphorus from the stream sediments. Even though this high phosphorus water would get pushed into the lake with a runoff event, it would contribute less than 0.5% of the annual load from the watershed.

Becker Lake Tributary (Site ID BET1):

The primary tributary to Becker Lake is outflow from Long Lake and meanders to the west, under Long Lake Rd, and into the southeastern corner of Becker Lake. The Becker Lake tributary monitoring site is located on private property; permission was graciously given for this project by the property owner. At this location, water runs through a cattail wetland and through 5-ft diameter culvert that lies under a farm equipment passageway (two-track trail). The culvert would be an ideal location for flow monitoring except that a mound of cement, put in place to hold the culvert and surrounding structure in place during high water periods, partially covers the opening of the culvert and creates an uneven and oddly shaped weir. The velocity sensors could not be placed at the top of this weir, so they were placed inside the culvert and the weir accounted for by creating a spill depth in which to gauge water depth and flow. Essentially, at this location water pools inside the culvert until it reaches the spill depth, at which time it tips over the weir. During low flow periods, water may sit in the culvert and a depth measurement may be registered, however the water is not flowing downstream.

In 2015, monitoring was conducted from March 12 through November 19. In 2016, monitoring occurred from March 17 through November 5. Numerous samples were collected for total phosphorus, primarily during spring and early summer and also in the fall (Figure 3.2-10). Flow was much higher in 2015 compared with 2016 unlike Long Lake inlet where measured flows were similar each year. Unlike the Long Lake inlet some flow occurs at times throughout the ice-free season although flow was reduced during the summer. One possible reason for the higher flow at the Becker Lake inlet is the small amount of riparian wetlands in the Becker Lake watershed compared to the relatively large amount of wetland between Boot and Long lakes and between Round and Long lakes. The elevated phosphorus values in August and September of both years are likely the result of the water becoming stagnant behind the sill and not an indication of high phosphorus material from the watershed.

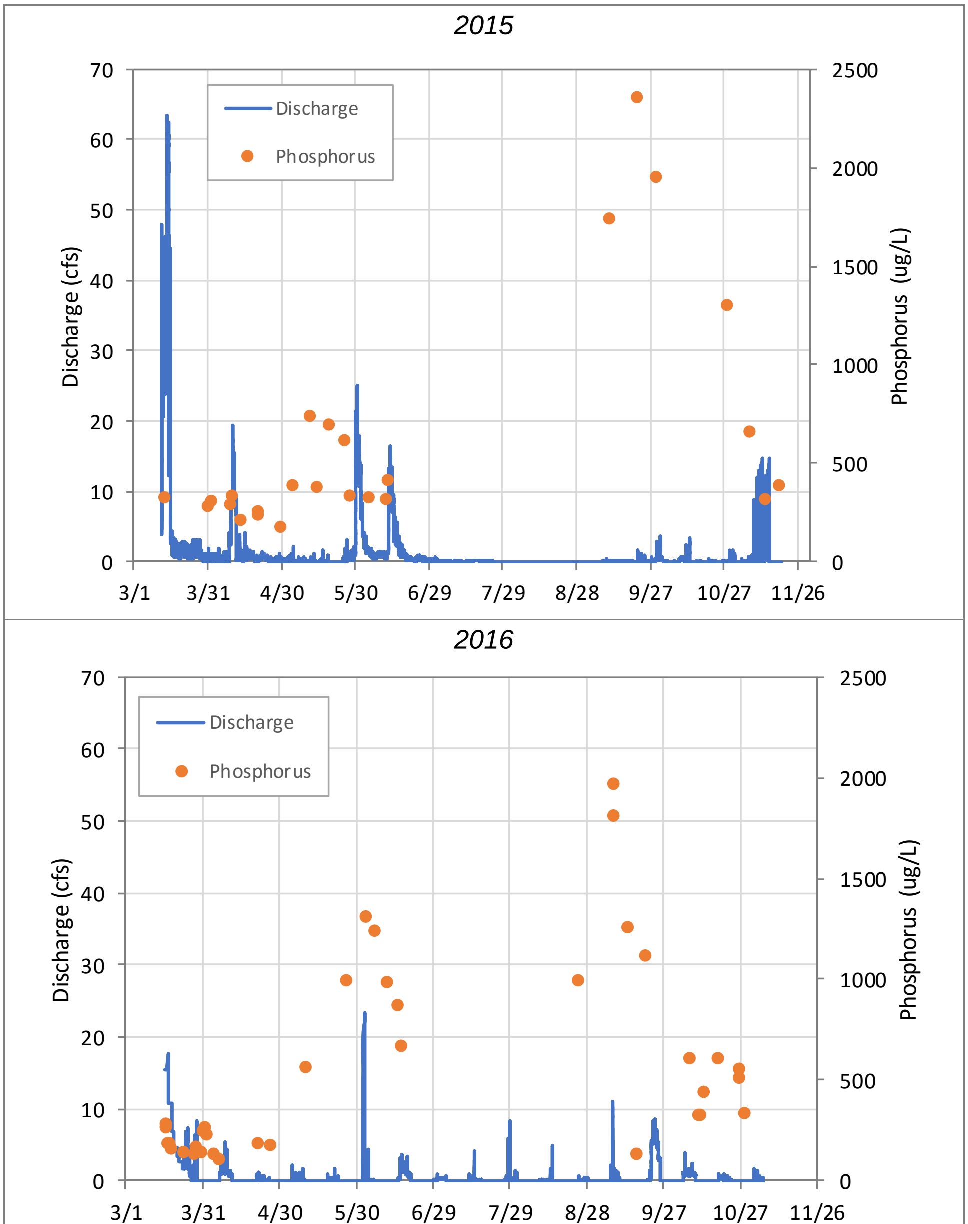


Figure 3.2-10. Becker Lake discharge (cfs) and total phosphorus (µg/L) during ice free season in 2015 (top) and 2016 (bottom).

Internal Phosphorus Sources

During October 2015, Onterra staff visited the CalMan Lakes to collect detailed water column data to estimate the importance of internal phosphorus loading from the sediments when the bottom waters are devoid of oxygen. When oxygen is absent in the deep waters, phosphorus that is bound with iron in the sediments is released into the overlying waters. In these lakes, this release occurs nearly the entire period of stratification which typically lasts from spring through mid-October. By measuring the phosphorus mass at the end of stratification, managers can estimate the amount of internal phosphorus loading.

Dissolved oxygen and total phosphorus samples were collected at numerous intervals throughout the water column. By multiplying the concentration of phosphorus at each interval across the volume of water for that given interval, the total phosphorus mass was calculated for each lake. Typically, these data are compared to spring turnover concentrations. During the spring, the entire water column is oxygenated and sediment nutrient release is minimal. In essence, this is the starting point for internal nutrient release for the season. As noted above, phosphorus levels in these lakes are high at spring turnover because of spring runoff and high algal growth. Spring oxygen and phosphorus revealed that the high phosphorus concentrations were generally throughout the water column. It is likely that much of this phosphorus, which is attached to particles such as algae, settle out of the water column to the sediments as the external inputs cease; therefore, phosphorus concentrations measured at spring turnover do not accurately represent the true starting point to estimate internal loading. To provide a more accurate estimate of the internal load in the lakes, the June surface concentration was used as the starting point. In 2017, phosphorus profiles were collected monthly from June through September to more accurately measure the internal load.

As Figure 3.2-11 illustrates, Round, Long, and Becker lakes accumulated large amounts of phosphorus in their hypolimnions by the end of summer stratification. This is the result of sediment phosphorus migrating from the lake bottom into the overlying water under anoxic conditions. Long and Becker lakes achieve higher phosphorus concentrations than Round Lake indicating internal loading is greater in the first two lakes. The bottom waters of Becker Lake contain more phosphorus mass than Long Lake only because of its greater depth. The phosphorus release rate is similar in the two lakes.

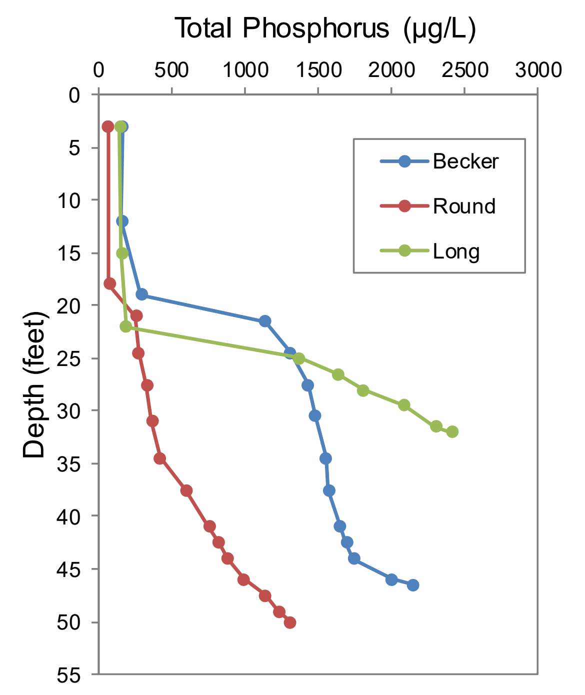


Figure 3.2-11. Fall phosphorus profiles from Round, Long, and Becker Lakes collected in October 2015. All the lakes exhibit significant phosphorus sediment release resulting in high internal loading to the lakes.

The monthly profiles that were done in Round, Long, and Becker lakes was not done in Boot Lake because it was thought Boot Lake periodically mixes during the summer as a result of its shallow depth. The bottom waters do become anoxic and sediment phosphorus release does occur. A different technique was used to initially estimate internal load. Sediment cores were collected at two sites in the lake and these cores were incubated in the laboratory of Dr. William James of UW-Stout to estimate the sediment phosphorus release rate. In most lakes the phosphorus release rate is higher under anoxic conditions compared with aerobic conditions. The fact that the rates were similar at Site 1 probably reflects the high amount of sediment phosphorus available for internal loading.

During 2016, more frequent profiles of dissolved oxygen and temperature were collected by a volunteer at Boot Lake and it was apparent that the lake does remain stratified throughout the summer despite its shallow depth. Even though the bottom waters could quickly become anoxic after mixing and a subsequent calm period, the fact that water temperature in the bottom waters

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remain constant from June through September indicate that the lake was stratified all summer (Figure 3.2-12). Therefore, internal loading for Boot Lake was calculated by two methods: lab results (Table 3.2-2) and field measurements.

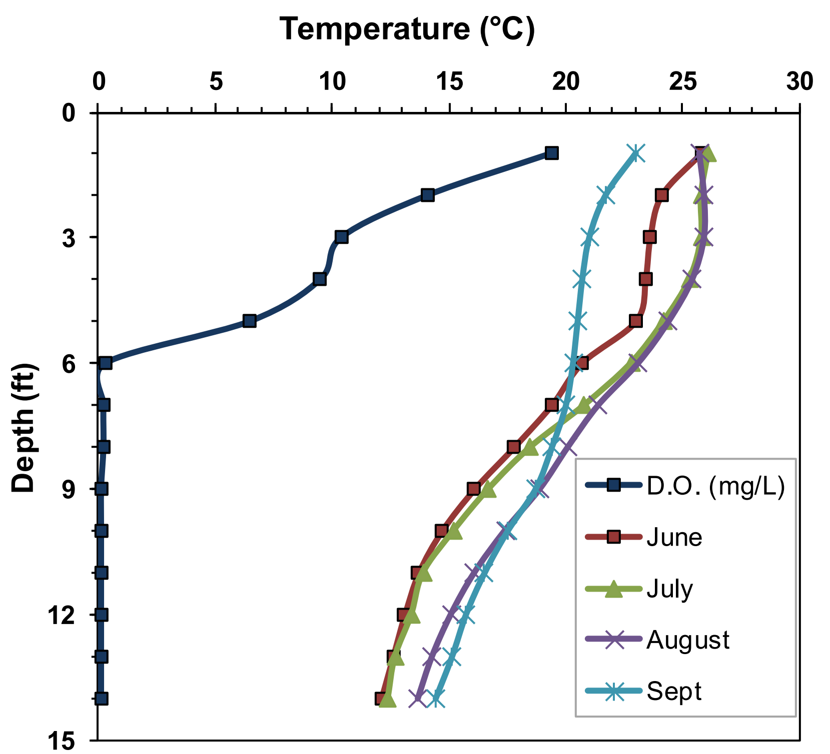


Figure 3.2-12. Selected profiles of temperature in Boot Lake during 2016. A representative profile of dissolved oxygen (June) is also

Table 3.2-2. Rates of phosphorus release in the presence and absence of oxygen in Boot Lake (mg/m2/day).

Station	Diffusive P Flux	
	Aerobic	Anaerobic
Site 1	4.25	4.12
Site 2	4.31	2.41

The latest in the season when phosphorus top and bottom samples were collected in Boot Lake was late August to early September. Onterra staff estimated internal loading by using the dissolved oxygen and temperature profiles to determine the depth of stratification and the bottom phosphorus concentration as late in the stratification period as was available. In 2016, when more detailed temperature and oxygen profiles were taken, summer stratification did not end until about October 1, but the last phosphorus samples were collected on August 18, 2016. It is likely the estimated internal loading is higher than measured because additional phosphorus was released from the sediments during the last six weeks of stratification. Even with this underestimation, internal loading in 2016 was higher than during the previous three years. The average amount of internal loading in Boot Lake for the period 2013-2016 was 66 pounds, with the range being 27 to 126 pounds.

In Boot Lake, the amount of internal loading estimated from the field measurements was higher than the rate measured in the lab. This has been observed in other shallow lakes that stratify. It is thought that the lab analysis underestimates the internal loading because as the sediment released phosphorus migrates upward it comes in contact with the bottom part of the mixed upper waters. During wind events this sediment released phosphorus mixes with the surface waters. This removal of phosphorus in the upper part of the hypolimnion accelerates the release of sediment phosphorus.

Hoffman et al. (2013) found that in calcareous lakes like the CalMan lakes, a significant portion of the phosphorus build up in the hypolimnion during the summer stratification is the result of regeneration of epilimnetic phosphorus that is present in the spring. Another source of the summer phosphorus build up is the release of phosphorus from the deep water sediments. This high level of hypolimnetic phosphorus remains in the lake over the winter and fuels the large algal growth the following spring and summer. This means that the internal loading of phosphorus remains in the lake for more than one year resulting in very high levels of phosphorus in the surface waters which results in large algal blooms.

In all of the CalMan lakes there was a large increase in phosphorus concentrations in the hypolimnion throughout the summer (Figure 3.2-13). In all of the lakes, the mass of phosphorus significantly increases from spring turnover to late summer. In Round and Long lakes there is a doubling of the phosphorus mass while in Becker and Boot lakes, the phosphorus mass triples during the open water period. Therefore, to reduce phosphorus concentrations in these lakes it will be necessary to significantly reduce the release of phosphorus from the deep-water sediments.

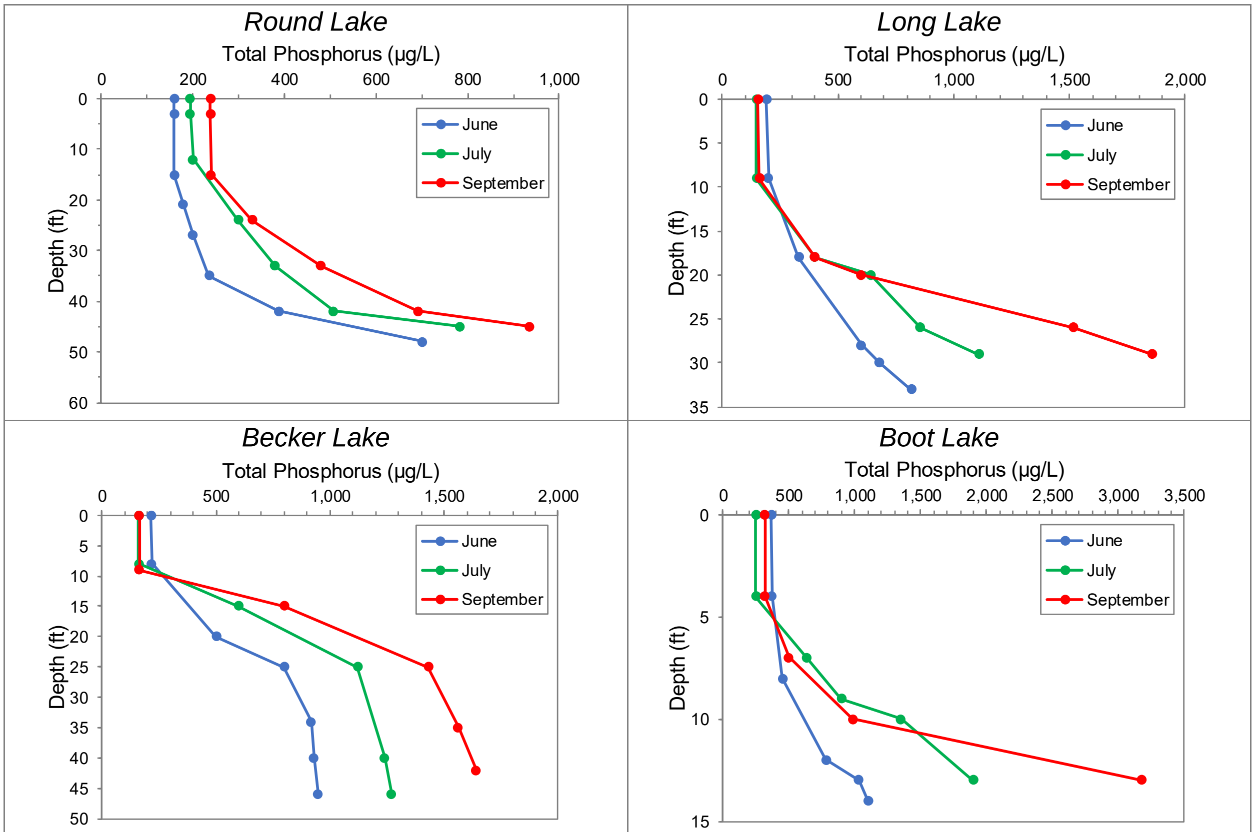


Figure 3.2-13. Phosphorus profiles from Round, Long, Becker and Boot lakes collected in during the summer 2017. All the lakes exhibit significant increase in hypolimnetic phosphorus concentrations during the summer.

Comparing the estimation of internal loads done in 2015 and that done in 2017 indicates that the amount of internal load was underestimated in Round Lake while it was similar in the other lakes (Table 3.2-3). The phosphorus release rate was also calculated for each of the lakes since the total mass released from the sediments is partially dependent upon the volume of the hypolimnion. The highest release rate was in Round Lake followed by Becker Lake (Table 3.2-3). Long and Boot lakes had similar rates at 6 and 7 $mg/m^2/day$, respectively. These rates are similar or higher than some other Wisconsin lakes. The rate in Cedar Lake, Polk County was 12 $mg/m^2/day$ (James et al. 2015) while it is 20 $mg/m^2/day$ in Little Green Lake, Green Lake County and ranges from 9 to 13 in Kentuck Lake, Vilas County.

Table 3.2-3. Internal loading from sediment release during summer anoxia measured in 2015. Loading in Boot Lake was estimated from the phosphorus increase in the bottom waters as well as the release rate measured in the lab. The result from field measurements is the average for 2013-16.

Lake Name	Phosphorus Internal Load (lbs) 2015	2017	Release Rate ($mg/m^2/day$)
Round	92	114	27
Long	381	365	6
Becker	334	332	16
Boot	46[1] 66[2]	46	7

[1]measured in the lab
[2]field measurements

Phosphorus Load Inputs

In the CalMan lakes the external phosphorus loads were determined using a combination of field measurements and WiLMS modeling. The tributary monitoring data at the Long and Becker inlets for 2015 and 2016 were used to estimate watershed loading for this part of their watersheds. Since the monitors were only used part of the year, it was assumed that only 75% of the load was captured. The phosphorus loading from the parts of the four lakes' watershed that were not monitored was estimated with WiLMS modelling. The internal loading was determined in Round, Long, and Becker lakes from 2015 data and the average loading in Boot Lake for the years 2013-2016.

Round and Boot lakes had the lowest phosphorus load (Figure 3.2-14) at around 200 pounds per year, but because the volume of the Boot Lake is much less than Round Lake, the inlake phosphorus concentration is much greater in Boot Lake. As mentioned previously, lake size and volume also have to be taken into consideration when discussing phosphorus loading. Using the estimated annual phosphorus loads and the volume of each lake, the annual phosphorus load per acre-foot of lake was calculated (Figure 3.2-14, right frame). This analysis shows, for example, that while Round and Boot receive similar amounts of phosphorus per year, the phosphorus loading relative to lake volume is much lower in Round Lake, 0.95 lbs/ac-ft, than in Boot Lake, 2.35 lbs/ac-ft, and the phosphorus concentration within Round Lake would be expected to be lower than in Boot Lake. Long and Becker lakes receive a much greater phosphorus load than the other two lakes. Similar to Boot Lake, Becker Lake has a higher phosphorus concentration compared with Long Lake because of its smaller water volume. This means that Boot and Becker lakes would need to have the phosphorus load reduced more than the other two lakes to achieve similar phosphorus concentrations.

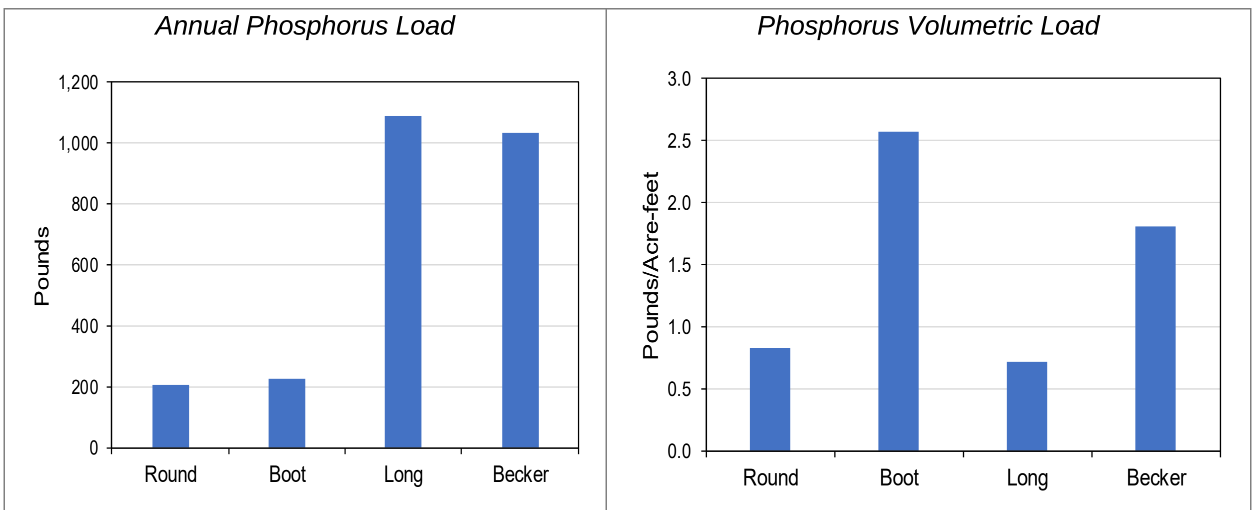


Figure 3.2-14. CalMan lakes annual phosphorus load (left) and volumetric load (right). The smaller lake volumes in Boot and Becker lakes mean that the phosphorus load is diluted less than the other two lakes.

Figure 3.2-15 shows the external and internal phosphorus loads for each of the lakes. In Round Lake, the internal load is the largest source while in Long and Becker lakes internal load is about one third of the total load. In Boot Lake surface runoff from its watershed provides three quarters of the phosphorus. The contrasting amounts of external and internal loads in these lakes likely means different management scenarios need to be implemented for each lake or a group of lakes.

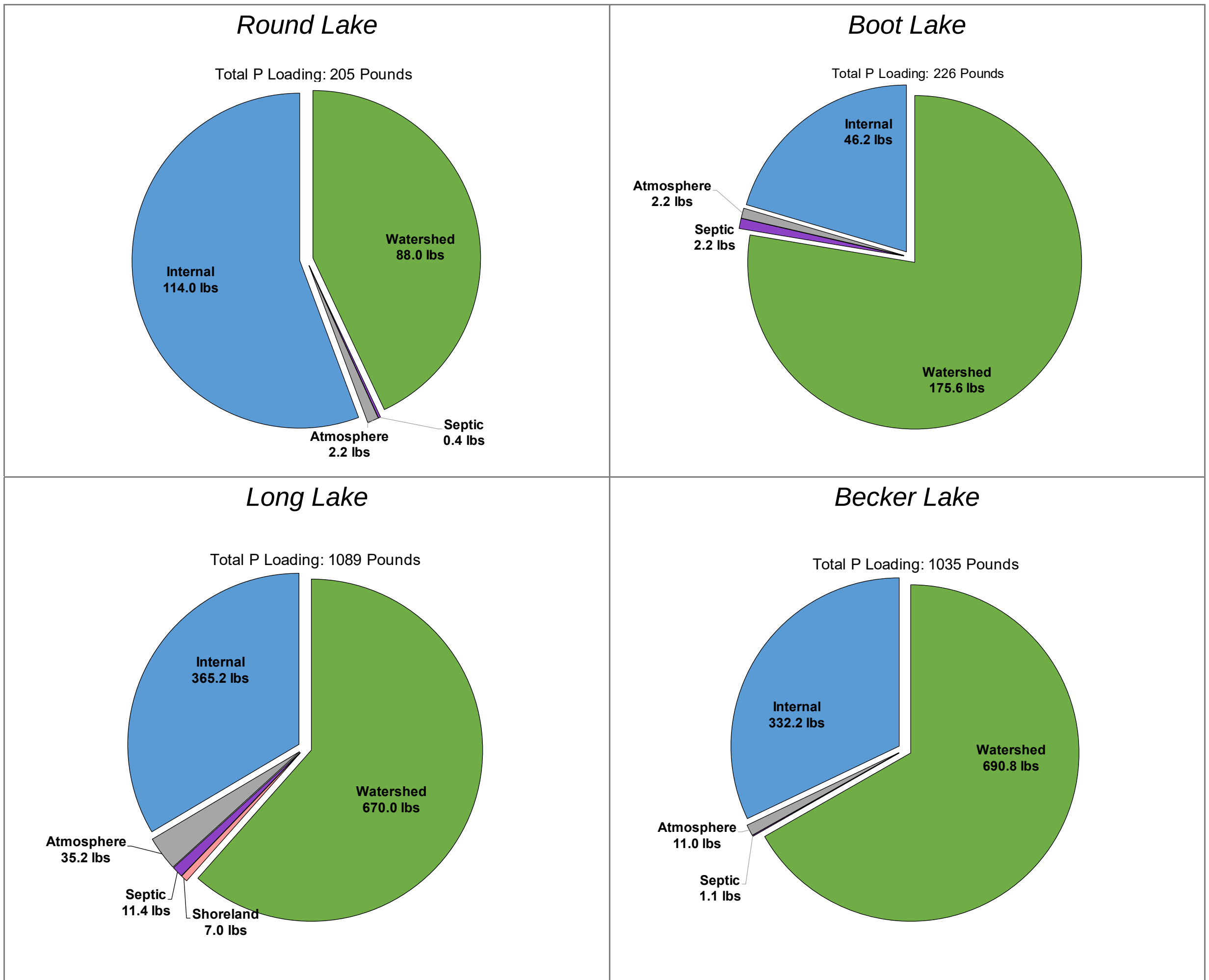


Figure 3.2-15. Phosphorus loading for the CalMan Lakes. Budgets were constructed from field observations and modelling. Units are pounds. See text for more detail.

Modeling Scenarios

The mean summer phosphorus concentration in all of the lakes exceeds the impairment threshold for fish and aquatic life use that has been set by the Wisconsin DNR (Figure 3.1-3). Modeling has been completed to estimate how much the annual phosphorus load would need to be reduced for the lakes not to be considered impaired. Additional scenarios were modeled to determine how the lake's phosphorus levels would be improved if most of the internal load was eliminated and various reductions in the loads from the watershed were reduced. Reducing the internal load is generally easier to accomplish than reducing the external load, especially where agriculture is a significant part of the land use in the watershed. The application of alum (aluminum sulfate) has been used successfully in many lakes, including a number of Wisconsin lakes, e.g. East Alaska Lake, Kewaunee County, Bullhead and Silver lakes, Manitowoc County, to reduce internal load from deep water sediments by about 90%.

In all of the lakes, reducing the internal load by 90% results in phosphorus concentrations remaining above the impairment threshold (Figure 3.2-16, left column). The phosphorus impairment concentration is 30 µg/L for all of the lakes. Even Round Lake, where internal load is estimated to be about 60% of the total phosphorus budget, does not achieve a sufficient reduction in the phosphorus concentration. This illustrates the importance of reducing the phosphorus load from the watershed in order to significantly improve the water quality of these lakes. The percentage of reduction by reducing internal loading is the least in Boot Lake where internal load is about 25 percent of the total phosphorus input. In Long Lake if the internal load were reduced 90% the phosphorus coming from the watershed would still need to be reduced by 85% for the lake not to be considered impaired. To achieve a phosphorus concentration of 30 µg/L, the total phosphorus loads in all of the lakes would need to be reduced by 86 to 94 percent. In Round and Long lakes reducing the internal load by 90% lowers the trophic status from hypereutrophic to eutrophic. In Boot Lake the watershed loading would need to be reduced by about 67% as well as a 90% reduction in internal loading to change the trophic status from hypereutrophic to eutrophic. The phosphorus concentration in Boot Lake would be about 96 µg/L which would result is algal blooms but there would be smaller in size than at the current phosphorus concentration. The watershed loading in Becker Lake would need to be reduced by about 41% as well as a reduction in internal loading of 90% for the trophic status to be improved to eutrophic.

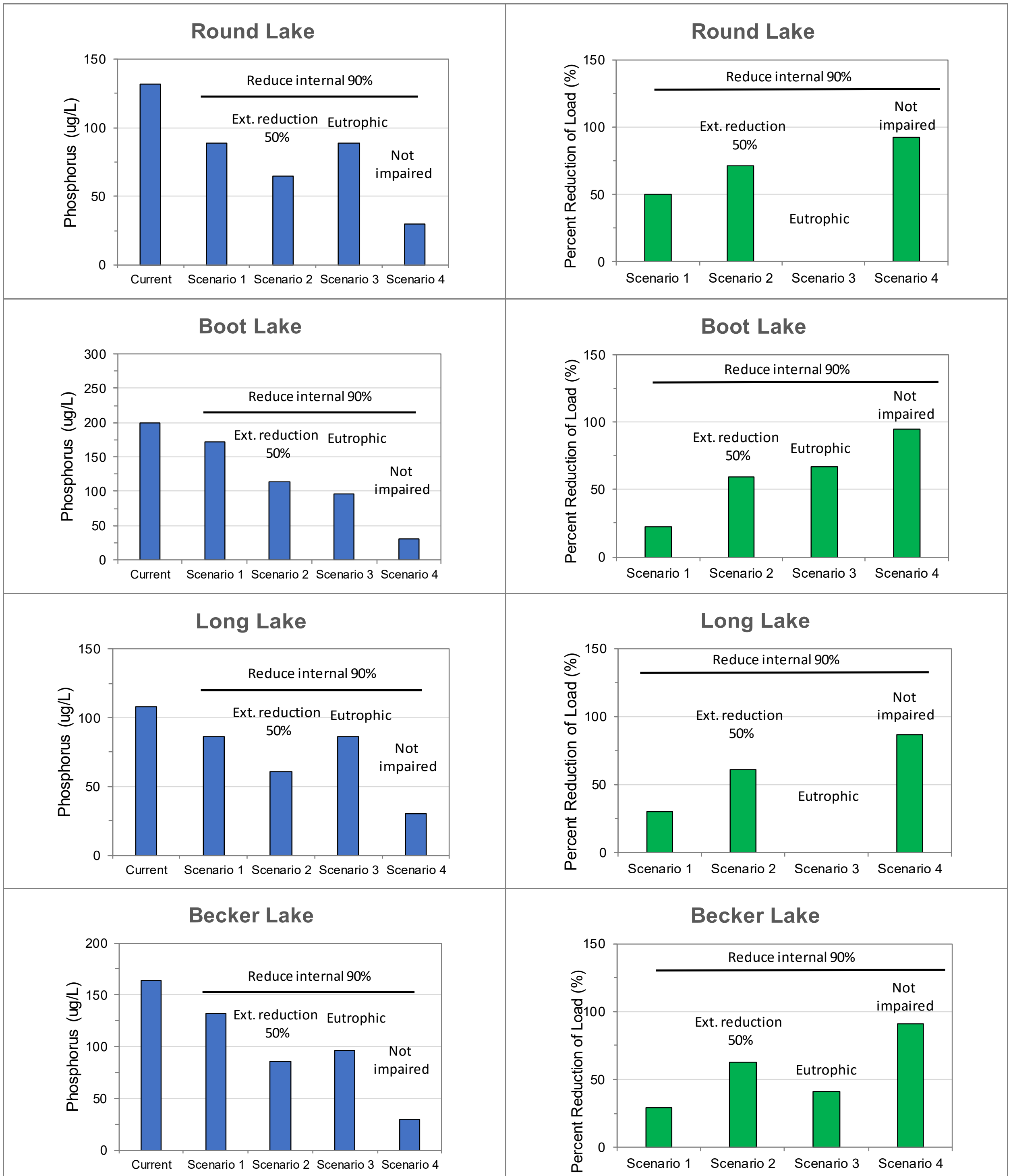


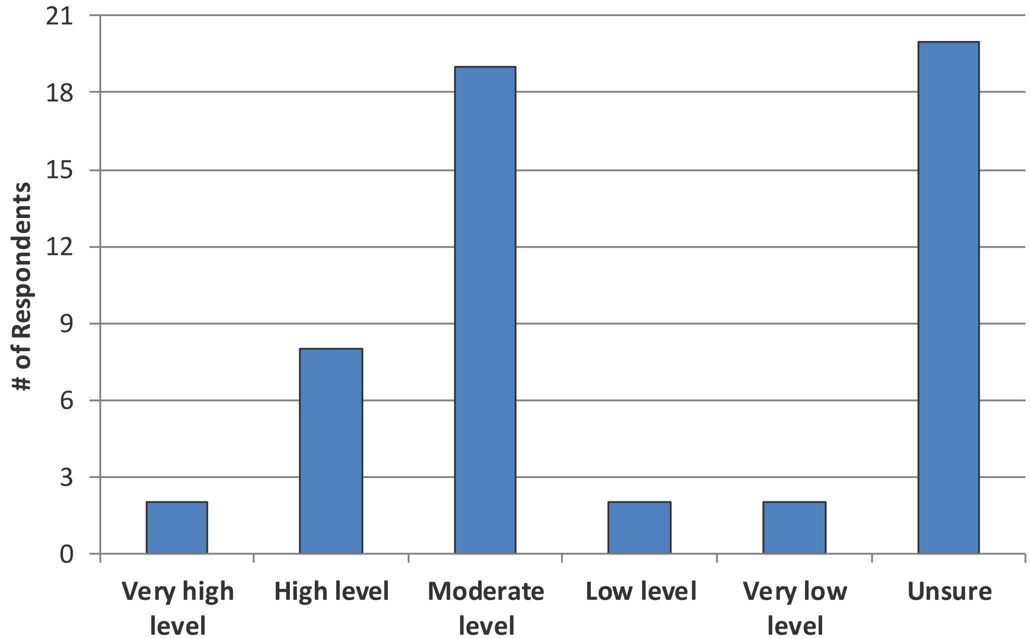
Figure 3.2-16. Modelling results with different scenarios for the reduction of the annual phosphorus load. The panels on the left would be the growing season mean phosphorus concentration after the reduction in the phosphorus load. **Current** is the concentration at the present time. The panels on the right are the percentage of reduction needed to match the criteria in each scenario. **Scenario 1**: reduce internal load by 90%; **Scenario 2**: reduce internal load by 90% and external load by 50%; **Scenario 3**: reduce internal load by 90% and necessary reduction in watershed loading to move the lake from hypereutrophic to eutrophic; **Scenario 4**: necessary reduction of phosphorus load so lake is not phosphorus impaired, 30 µg/L.

Stakeholder Survey Response Regarding the CalMan Watershed

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to the watershed and its management. Figure 3.2-17 displays the responses of CalMan stakeholders regarding the watershed and their opinions on the conservation practices used within the watershed. When asked how they would describe the current level of development within the CalMan Lakes watershed, 38% indicated they were unsure about the level of development, 36% indicated there is a moderate level of development, 15% indicated a high level of development, and 3.7% indicated either a very high level, a low level or a very low level of development. The high level of respondents answering that they were unsure about the development of the watershed indicates that the development of the watershed is not something that impacts the average stakeholder within the CalMan watershed. The data modeled by Onterra show that most of the watershed is covered in row crops which is considered a moderate level of development.

CalMan stakeholders were also asked if they were familiar with conservation practices and if they believed those practices were being used within the watershed. Forty-three percent of stakeholders are very familiar with the conservation practice and have worked with these methods while another 32% are familiar with the practices but have no experience with them, 15% are familiar with the goal of conservation practices, and 11% have little to now familiarity with conservation practices. Figure 3.2-17 displays the responses of stakeholders to what level they believe conservation practices are used within the CalMan watershed. Eighteen respondents indicated they believe conservation practices are either minimally (38%) or moderately (38%) being used within the watershed, 11% indicated that conservation practices are being used to a large extent throughout the watershed, 9% are unsure, and 4% believe there are no conservation practices being used within the watershed. For further explanation of what agricultural producers do within the watershed, see Appendix B.

How would you describe the current level of development in the CalMan Lakes' watershed?



To what level do you believe conservation practices are being used in the CalMan Lakes' watershed?

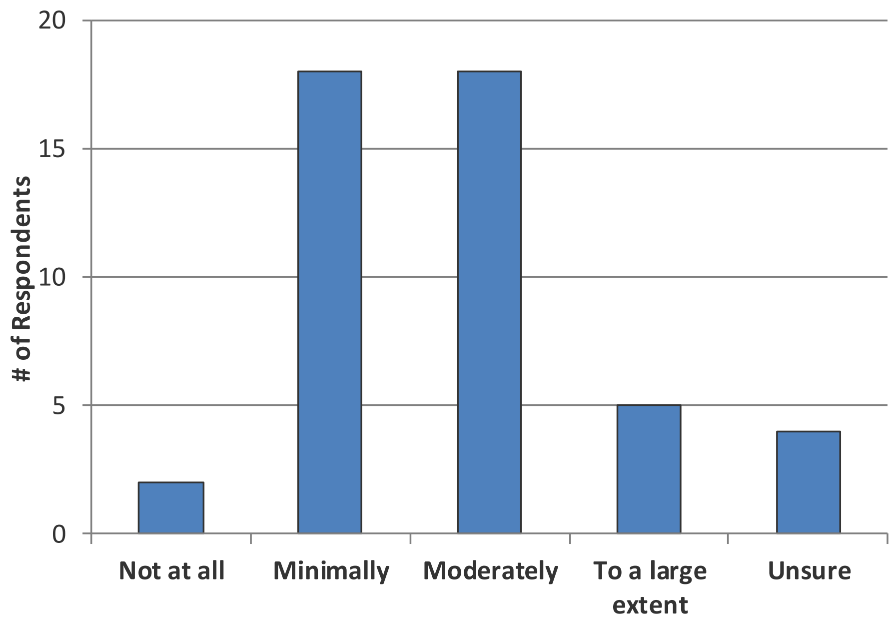


Figure 3.2-17. CalMan Lake stakeholder survey response to questions regarding the watershed. N = 53 respondents.

3.3 Paleoecology

Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants.

The diatom community are especially useful in reconstructing a lake's ecological history as they are highly resistant to degradation and are ecologically diverse. Diatom species have unique features as shown in Figure 3.3.1, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as aquatic plants or the lake bottom. The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

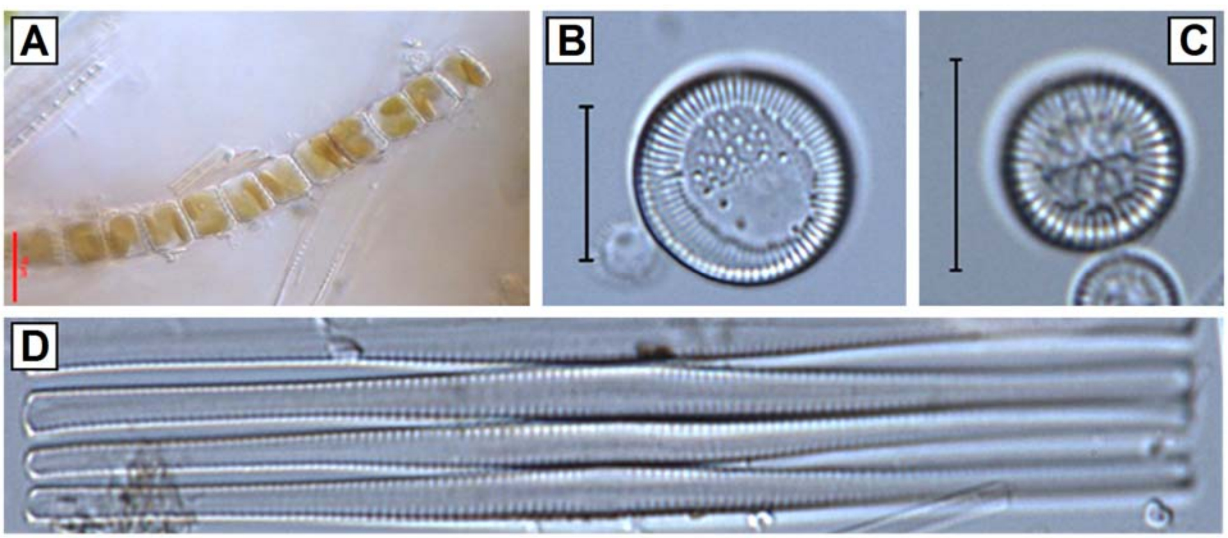


Figure 3.3-1. Photomicrographs of the diatoms commonly found in the sediment cores from these lakes. The top diatom (A) is *Aulacoseira ambigua* which was found in most of the lakes. The next diatom, *Fragilaria crotonensis* is more common with moderate phosphorus levels but indicates higher nitrogen concentrations. *Fragilaria capucina var. gracilis* (C) was found in Round and Boot lakes. *Stephanodiscus minutulus* (D) indicates elevated phosphorus levels and was the most common diatom in the lakes.

One often used paleoecological technique is collecting and analyzing top/bottom cores. The top/bottom core only analyzes the top (usually 1 cm) and bottom sections. The top section represents present day conditions and the bottom section is hoped to represent pre-settlement conditions by having been deposited at least 100 years ago. While it is not possible to determine the actual date of deposition of bottom samples, a determination of the radionuclide lead-210 estimates if the sample was deposited at least 100 years ago. The primary analysis conducted on this type of core is the diatom community leading to an understanding of past nutrients, pH, and general macrophyte coverage.

CalMan Lakes Paleoecological Results

Top/bottom cores were collected from all four lakes. The core from Round Lake was collected February 11, 2016. The total length of the core was about 40 cm. Cores were collected from the other three lakes on June 15, 2016. It was felt that the cores from Long and Becker lakes were not long enough to reach pre-Euroamerican time, so additional cores were collected November 15, 2016. A radiochemical analysis was performed on the bottom samples of the cores from Long and Becker lakes. This analysis indicated that the bottom samples may have been deposited since the arrival of Euroamerican settlers. Therefore another core was taken on September 18, 2017 from these lakes that was longer in length. In both cases the depth of the bottom sample was about 76 cm. Based upon the earlier radiochemical analysis, these latest bottom samples represent a time period prior to the arrival of European settlers. Although the length of core from Boot Lake did not reach pre-Euroamerican times, it was felt the historical conditions in this lake were likely similar to Round Lake. The cores from all the lakes were collected with a gravity corer.

Multivariate Statistical Analysis

Various statistical methods were used to compare environmental conditions at the top and bottom of the cores. An exploratory detrended correspondence analysis showed that the gradients of species responses were relatively long and so a unimodal, detrended model was used for constrained (detrended correspondence analysis; DCA) ordinations (CANOCO 5 software, ter Braak and Smilauer, 2012). The analysis has been done on many WI lakes including the CalMan lakes. This analysis was used for a comparison of environmental conditions in the top and bottom samples of each lake. To determine the main directions of variation in the limnological variables, a canonical correspondence analysis (CCA), using inter-sample distances on a correlation matrix of log-transformed values. Species data was square root transformed with downweighting of rare species.

The DCA analysis was performed to examine the similarities of the diatom communities between all of the lakes but most importantly between the top and bottom samples of the same lake. These lakes are those that are relatively deep and stratify during the summer. The results revealed two clear axes of variation in the diatom data, with 39% and 26% of the variance explained by axis 1 and axis 2, respectively (Figure 3.3-2). Sites with similar sample scores occur in close proximity reflecting similar diatom composition. The arrows symbolize the trend from the bottom to the top samples.

The lake with the greatest change between the bottom and the top was Round Lake. If a suitable bottom sample had been obtained from Boot Lake it is very likely the diatom community would also have changed as much as Round Lake. The large amount of change experienced in Round and likely Boot lakes has only been documented in one other lake in WI. This is Desair Lake in Barron County. As will be detailed in the next section Desair Lake like the two CalMan lakes historically was bog lake which changed into a hypereutrophic lake as a result of agricultural activity in the watershed.

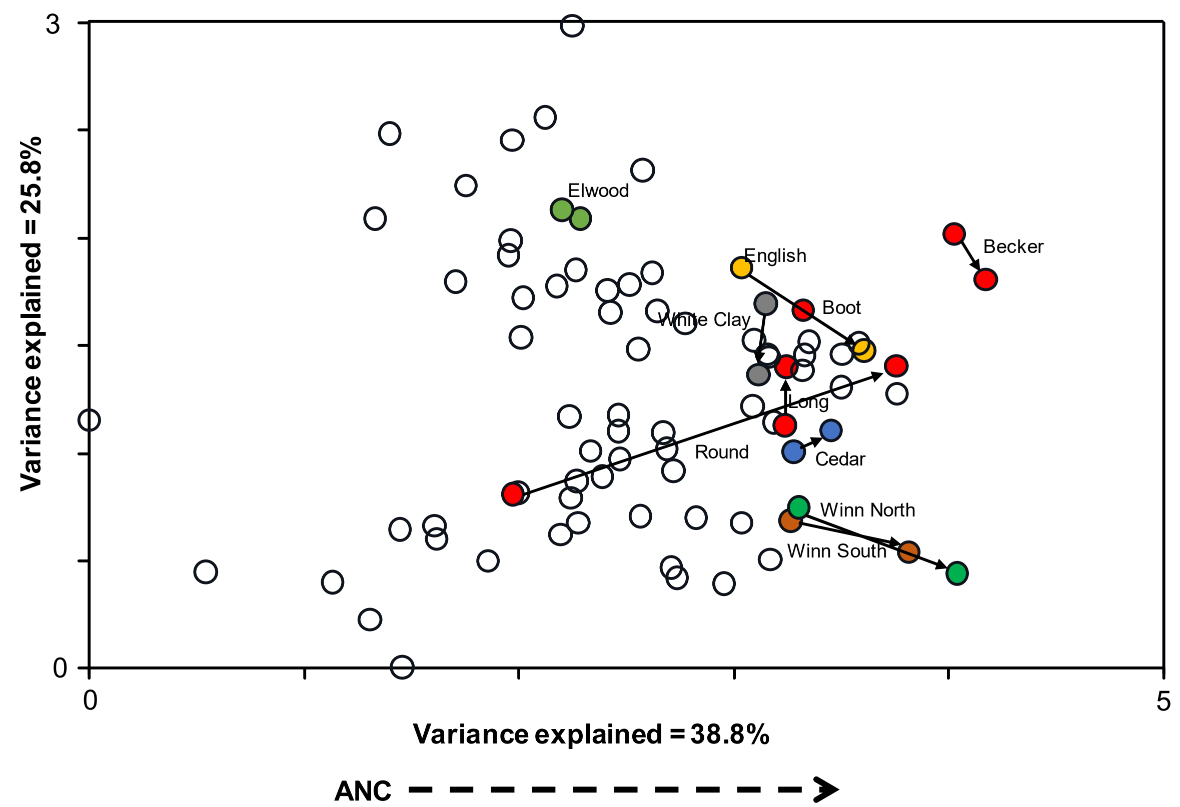


Figure 3.3-2. DCA plot of CalMan Lakes as well as other lakes where top bottom samples have been analyzed. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. A suitable bottom sample was not obtained from Boot Lake but it is likely the bottom sample would be similar to Round Lake. The CalMan Lakes are colored red. White Clay, Cedar and English lakes are also in watersheds where most of the land use is agriculture.

Both Long and Becker lakes experienced a much smaller change in the diatom community from the bottom to the top samples. Long Lake moved in a similar trajectory as Round Lake. Becker Lake moved a lesser amount than Long Lake but in a trajectory perpendicular to the other lakes. While it is not possible to determine which were the most important environmental variables ordering the diatom communities, one trend is apparent. Axis 1 probably represents the acid neutralizing capacity (ANC = alkalinity) of the lakes. Other studies on Wisconsin and Vermont lakes indicate that the most important variable ordering the diatom communities is ANC or conductivity. Lakes on the right side of the DCA graph tend to have the highest ANC values while the lowest are on the left side.

Round Lake

In the bottom sample, the dominant diatom was the filamentous diatom *Aulacoseira tenella* and long narrow diatoms such as *Fragilaria capucina* var. *gracilis* (Figure 3.3-3) and *Synedra subrhombica*. *A. tenella* and *S. subrhombica* are typically found in lakes with low pH and stained water. The bottom sample also contained a large amount of Chrysophyte cysts and scales which also are indicative of low alkalinity waters.

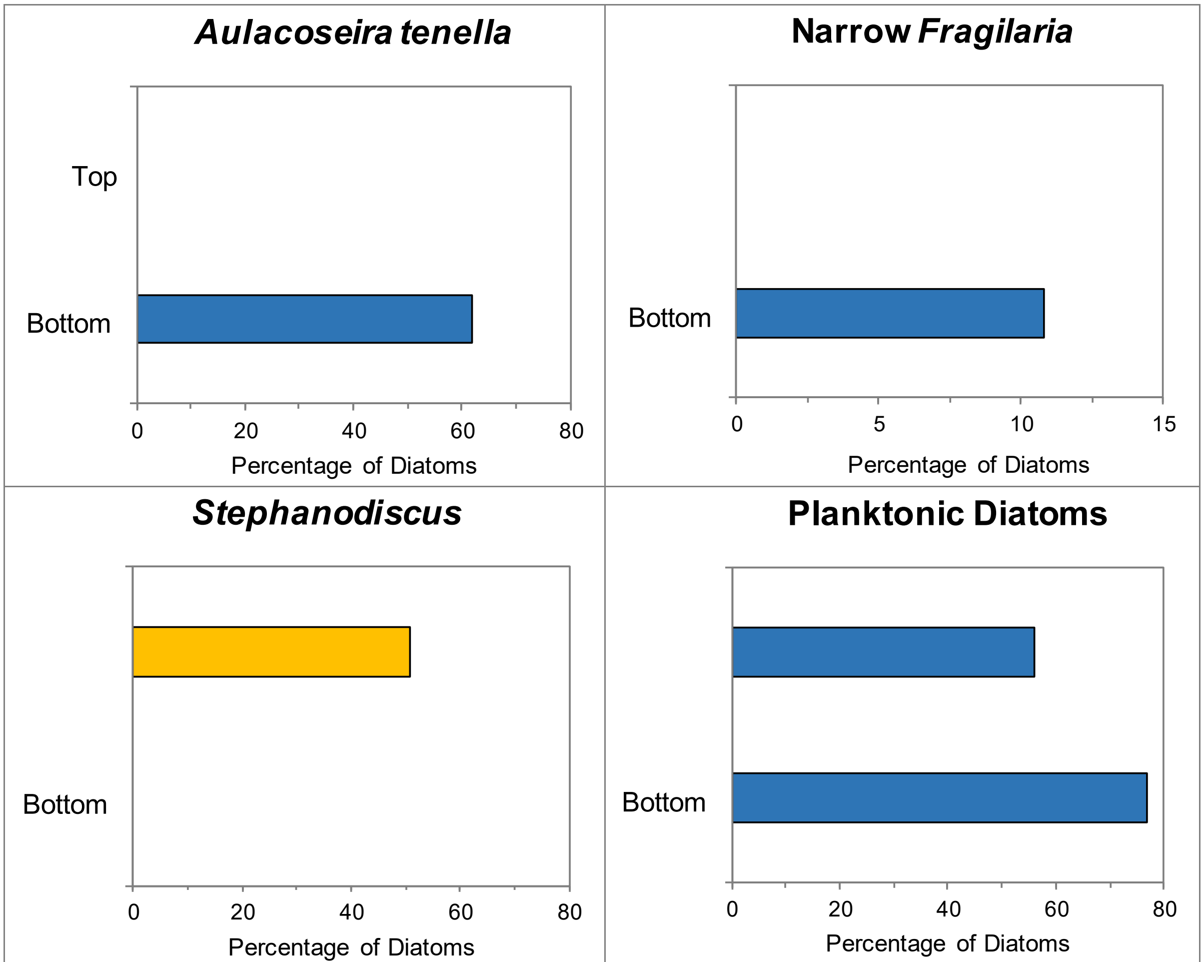


Figure 3.3-3. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Round Lake. The bottom sample is indicative of a low pH bog lake while the top sample is characteristic of a eutrophic alkaline lake.

The diatom community in the top sample is dramatically different from the bottom sample. The dominant taxa in the bottom sample, *A. tenella* is replaced by *Stephanodiscus minutulus* and *S. hantzschii* which are found in eutrophic alkaline lakes. It is clear this lake has undergone a significant shift in its lake ecology as a result of the large input of nutrients since European settlement. This nutrient input has significantly changed the lake character from a bog lake similar to lakes like Spruce and Cedar lakes in the Kettle Moraine State Forest to a eutrophic, alkaline lake like nearby Bullhead Lake.

Boot Lake

It was not possible to collect a suitable bottom sample from Boot Lake. It is not clear whether this was because of the lake's shallow depth which results in it mixing frequently and thus disturbing the lake sediments or whether the sedimentation rate was so high that a long enough core was not collected. The diatom community in the top sample was similar to that in Round Lake with the dominant taxa being *S. minutulus* and S. *hantzschii* (Figure 3.3-4). Again, these are indicative of eutrophic, alkaline lakes. It is very likely that if a suitable bottom sample had been collected from the lake the diatom community would be very similar to that found in the bottom sample of Round Lake. That is a community suggesting a low pH, bog lake. It is very likely that Boot Lake has undergone a profound change in the lake's ecology that is similar to Round Lake.

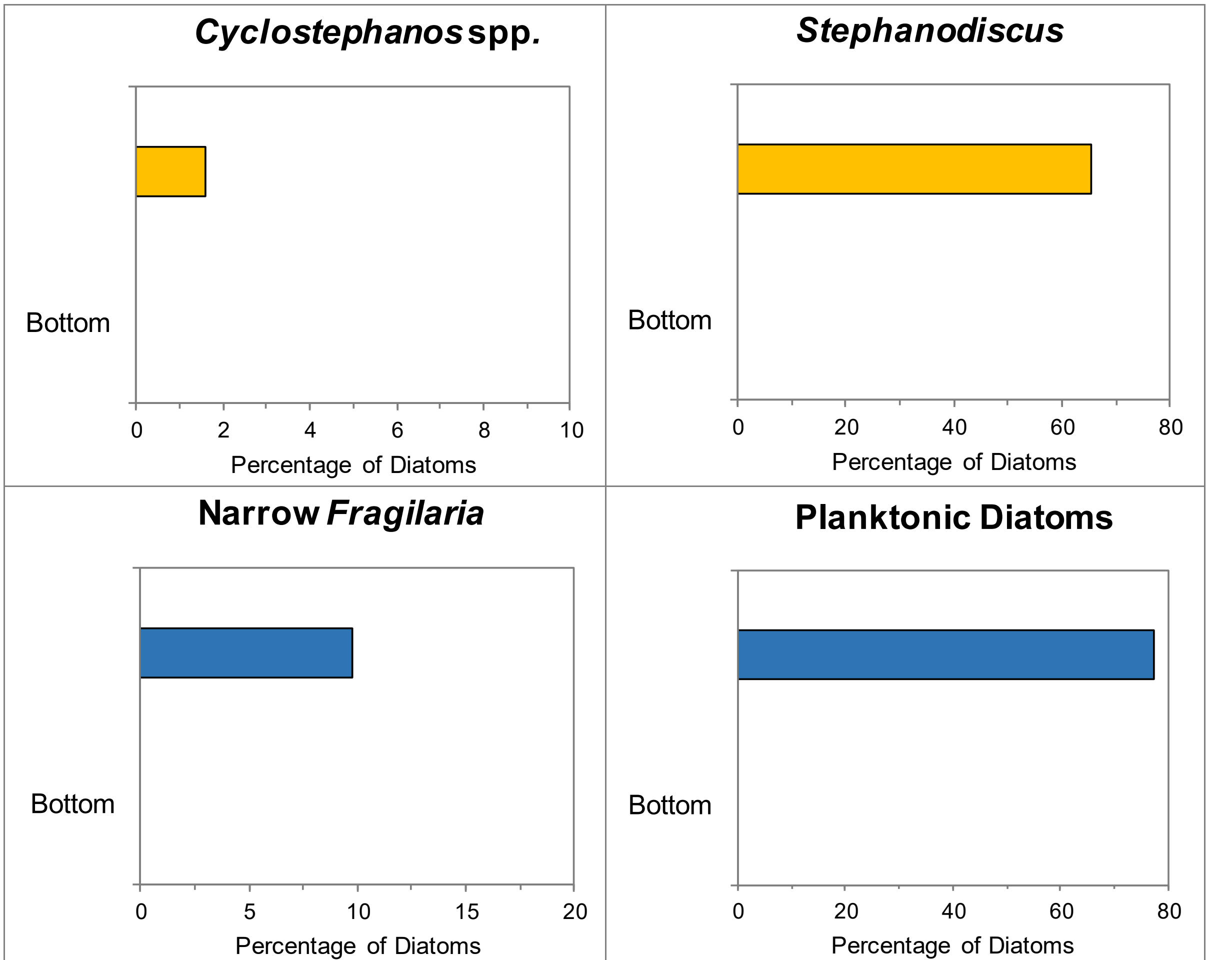


Figure 3.3-4. Important diatoms found in the top of the sediment core from Boot Lake. A suitable bottom sample was not collected from this lake but it is very likely the diatom community in the bottom sample would be similar to Round Lake. That is, a community indicative of a low pH bog lake.

Long Lake

Unlike Round and Boot lakes, the diatom community in the bottom samples are not significantly different from the top sample. The graphs are a composite of the two cores taken from the lake. The depth of 52 cm represents the first "bottom" sample and the 76 cm sample represents the bottom sample from the longer core. The diatoms are dominated by planktonic taxa which are those that grow in the open water of the lake. This is not surprising as this is a relatively deep lake. The most common diatoms in the bottom sample are the eutrophic taxa *Aulacoseira ambigua, A. granulata, S. minutulus,* and *S. hantzschii* (Figure 3.3-5). The top sample contained lesser amounts of *Aulacoseira*. This likely signals an increase in phosphorus. Also, the decrease in the abundance of planktonic diatoms likely indicates there are more macrophytes at the present time compared with pre-Euroamerican times. Unlike Round Lake, the pH in Long Lake does not appear to have changed much.

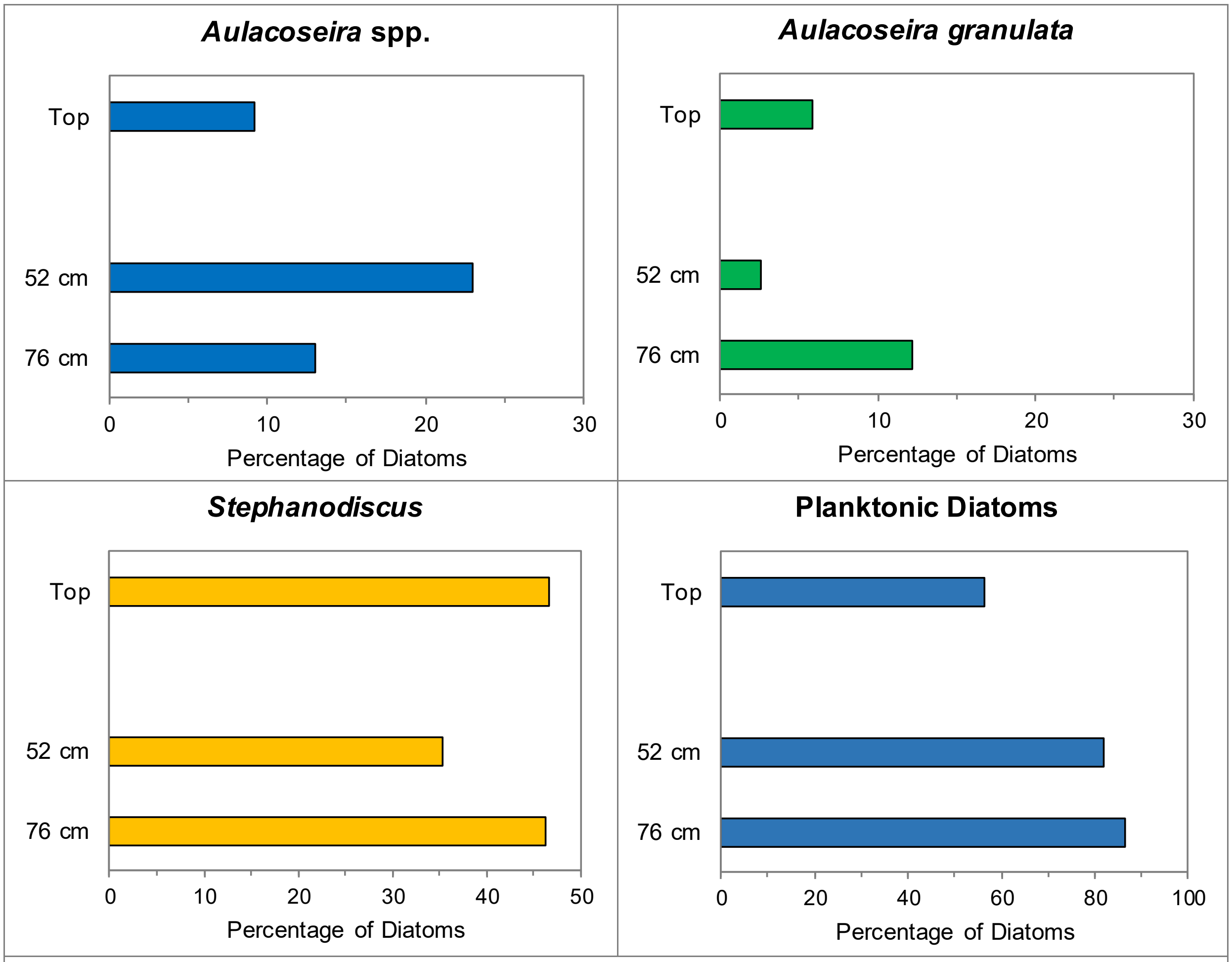


Figure 3.3-5. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Long Lake. Unlike Round Lake, the diatom communities are somewhat similar between the bottom and top samples. The diatoms in the top sample indicate that lake presently has slightly higher phosphorus levels and more macrophytes.

Becker Lake

The graphs are a composite of the two cores taken from the lake. The depth of 58 cm represents the first "bottom" sample and the 76 cm sample represent the bottom sample from the longer core. The diatom communities in the top and bottom samples of Becker Lake are more similar to Long Lake than Round Lake indicating that historically these lakes were not low pH bog lakes. The dominants in the bottom sample are *S. minutulus* and *S. hantzschii* (Figure 3.3-6). The diatom community in the bottom samples is indicative of a eutrophic, alkaline lake. In the top sample, there is a decline in *Stephanodiscus* and an increase in *A. granulata*. *Fragilaria capucina* also is more abundant in the top sample. This taxon is a filamentous diatom often associated with floating algal mats. The abundance of planktonic diatoms in the bottom and top sample are similar indicating little change in the abundance of macrophytes in this lake.

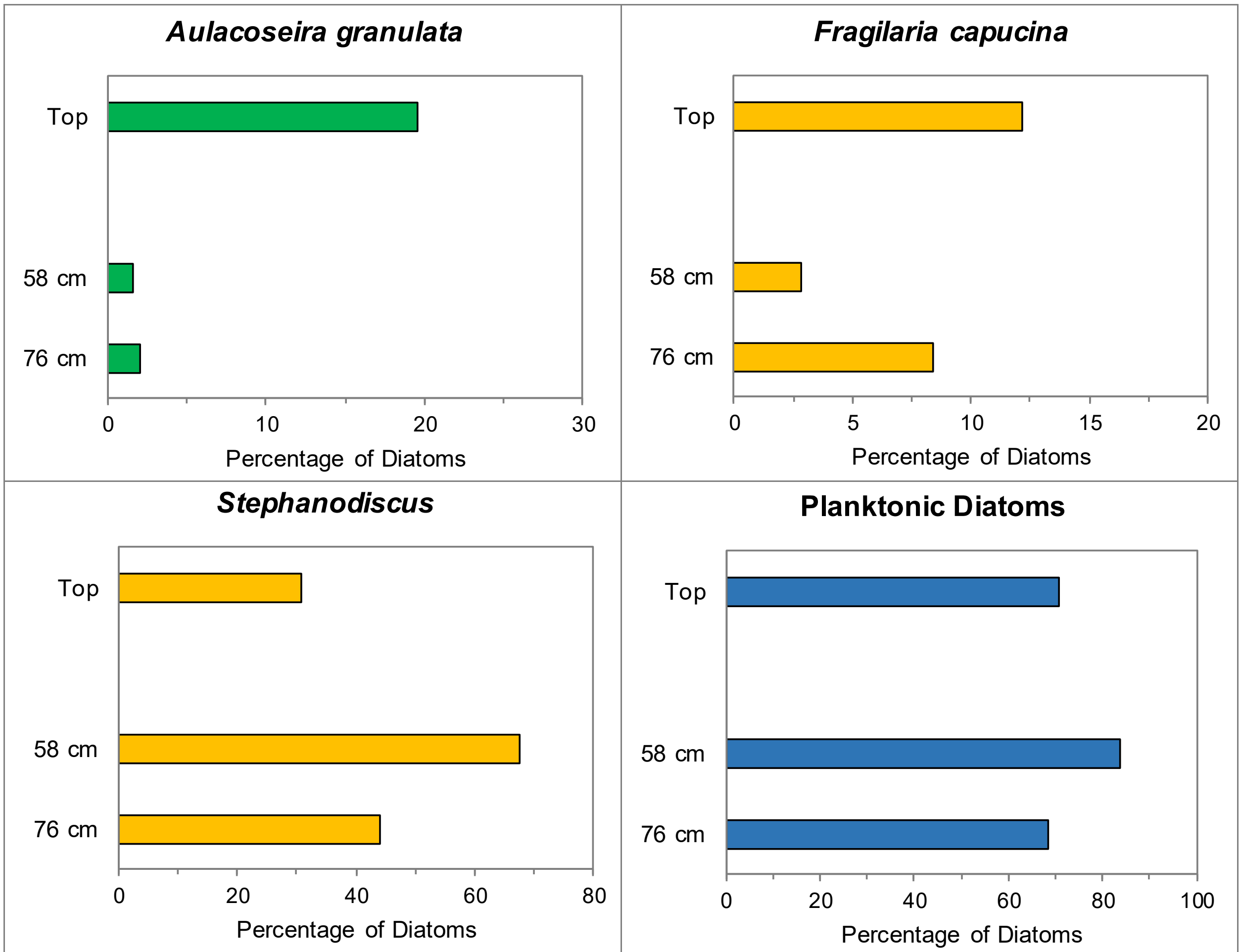


Figure 3.3-6. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Becker Lake. Unlike Round Lake the diatom communities are somewhat similar between the bottom and top samples. The increase in *F. capucina* in the top sample likely indicates floating algal mats are more abundant at the present time.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson et al. 2013). The LDCI uses diatoms to assess the ecological condition of lakes. The LDCI ranges from 0 to 100 with a higher score representing better ecological integrity. The index is weighted towards nutrients, but also incorporates ecological integrity by examining species diversity where higher diversity indicates better ecological condition. The index also incorporates taxa that are commonly found in undisturbed and disturbed conditions. The breakpoints (poor, fair, good) were determined by the 25th and 5th percentiles for reference lakes in the Upper Midwest. The LDCI was used in the 2007 National Lakes Assessment to determine the biological integrity of the nation's lakes.

The LDCI classifies all of the CalMan lakes at the present time in poor condition (Figure 3.3-7). The bottom most samples of the lakes indicates that Round Lake was in good condition, while Long Lake was near the fair/poor condition and Becker Lake was in better condition in the fair category. The decline in the LDCI between the "bottom" sample of the second and first cores (76 vs 52 cm; 76 vs 58 cm) in Long and Becker lakes indicates that the first cores were not long enough to reach the time period represented by pre-Euroamerican settlement. Early settlement appears to have rapidly degraded the water quality of these lakes. Even though the phosphorus levels in Long and Becker lakes were high prior to the arrival of European settlers, the ecological integrity of the lakes was in much better than it was soon after settlement and better than it is at the present time.

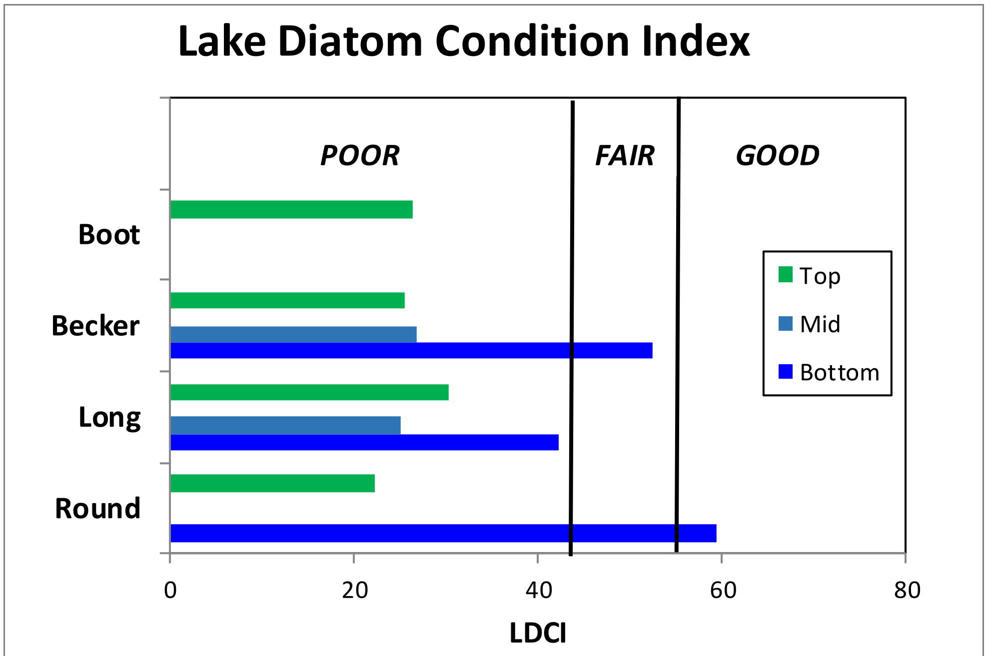


Figure 3.3-7. The Lake Diatom Condition Index (LDCI) for the project lakes. A suitable bottom sample was not obtained from Boot Lake but this lake likely was very similar to Round Lake prior to the arrival of European settlers. A mid sample was collected from Becker and Long lakes. It is believed these samples were deposited soon after settlers began farming the watersheds of these lakes.

Inference models

Diatom assemblages have been used as indicators of trophic changes in a qualitative way (Bradbury 1975, Carney 1982, Anderson et al. 1990) but quantitative analytical methods exist. Ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration (Birks et al. 1990). Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

Weighted averaging calibration and reconstruction (Birks et al., 1990) were used to infer historical water column summer average phosphorus in the sediment cores. A training set was developed from 107 stratified Wisconsin lakes. Training set species and environmental data were analyzed using weighted average regression software (C2; Juggins 2014).

The diatom communities in the top/bottom samples indicate that Round (and likely Boot Lake) were bog lakes with low pH and phosphorus values prior to the arrival of European settlers (Table 3.3-1). At the present time, these lakes are eutrophic alkaline lakes. It is very likely that the bottom sample collected from Boot Lake was not deep enough to represent pre-settlement conditions. If the core had been long enough it is very likely the bottom sample in Boot Lake would be very similar to the bottom sample in Round Lake. Historically, Long and Becker lakes were alkaline, eutrophic lakes with elevated phosphorus concentrations. Long Lake appears to have more macrophytes now compared with historical times while Becker Lake does not have more macrophytes but likely has more extensive floating algal mats. The modelling underestimates the present phosphorus concentrations in all of the lakes. This is likely because blue-green algae are found in such high numbers and they limit the growth of diatoms. Diatoms are likely only growing in the lakes during early spring or late fall.

Table 3.3-1. Estimated values for phosphorus and pH in the top and bottom samples. Phosphorus units are µg/L.

Lakes	Phosphorus	pH
Round Top	73	8.9
Round Bottom	15	5.6
Boot Top	66	8.9
Long Top	66	8.7
Long Bottom	78	8.6
Becker Top	86	8.7
Becker Bottom	74	9.1

3.4 Shoreland Condition

Lake Shoreland Zone and its Importance

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

The intrinsic value of natural shorelands is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. The roots of shoreland plants stabilize the soil, thereby preventing shoreland erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Thus, both the removal of vegetation and the inclusion of development reduces many forms of habitat for wildlife.

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however, the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmers' itch. Development such as rip rap or masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails; this is not desirable for lakes that experience problems with swimmers' itch, as the flatworms that cause this skin reaction utilize snails as a secondary host after waterfowl.

In the end, natural shorelines provide many ecological and other benefits. Between the abundant wildlife, the lush vegetation, and the presence of native flowers, shorelands also provide natural scenic beauty and a sense of tranquility for humans.

Shoreland Zone Regulations

Wisconsin has numerous regulations in place at the state level which aim to enhance and protect shorelands. Additionally, counties, townships and other municipalities have developed their own (often more comprehensive or stronger) policies. At the state level, the following shoreland regulations exist:

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: Language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods.

Wisconsin Act 31

While not directly aimed at regulating shoreland practices, the State of Wisconsin passed Wisconsin Act 31 in 2009 in an effort to minimize watercraft impacts upon shorelines. This act prohibits a person from operating a watercraft (other than personal watercraft) at a speed in excess of slow-no-wake speed within 100 feet of a pier, raft, buoyed area or the shoreline of a lake. Additionally, personal watercraft must abide by slow-no-wake speeds while within 200 feet of these same areas. Act 31 was put into place to reduce wave action upon the sensitive shoreland zone of a lake. The legislation does state that pickup and drop off areas marked with regulatory markers and that are open to personal watercraft operators and motorboats engaged in waterskiing/a similar activity may be exempt from this distance restriction. Additionally, a city, village, town, public inland lake protection and rehabilitation district or town sanitary district may provide an exemption from the 100-foot requirement or may substitute a lesser number of feet.

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. Groundwater inputs to the lake were found to be significant in terms of water flow and nutrient input. Nitrate plus nitrite nitrogen and total phosphorus yields to the ground-water system from a lawn catchment were three or sometimes four times greater than those from wooded catchments.

A separate USGS study was conducted on the Lauderdale Lakes in southern Wisconsin, looking at nutrient runoff from different types of developed shorelands – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites (Garn 2002). One of the important findings stemming from this study was that the amount of dissolved phosphorus coming off of regular fertilizer application lawns was twice that of lawns with non-phosphorus or no fertilizer. Dissolved phosphorus is a form in which the phosphorus molecule is not bound to a particle of any kind; in this respect, it is readily available to algae. Therefore, these studies show us that it is a developed shoreland that is continuously maintained in an unnatural manner (receiving phosphorus rich fertilizer) that impacts lakes the greatest. This understanding led former Governor Jim Doyle into passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale, and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1 2010, use of this type of fertilizer is prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay et al. 2002). And studies on shoreland development and fish nests show that undeveloped shorelands are preferred as well. In a study conducted on three Minnesota lakes, researchers found that only 74 of 852 black crappie nests were found near shorelines that had any type of dwelling on it (Reed, 2001). The remaining nests were all located along undeveloped shoreland.

Photograph 3.4-1. Example of coarse woody habitat in a lake.

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. Coarse woody habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin et al 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

With development of a lake's shoreland zone, much of the coarse woody habitat that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions due to logging practices. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities (boating, swimming, and, ironically, fishing).

National Lakes Assessment

Unfortunately, along with Wisconsin's lakes, waterbodies within the entire United States have shown to have increasing amounts of developed shorelands. The National Lakes Assessment (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers from all 50 U.S. states in an effort to assess waterbodies, both natural and man-made, from each state. Through this collaborative effort, over 1,000 lakes were sampled in 2007, pooling together the first statistical analysis of the nation's lakes and reservoirs.

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with* *poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.4-2. Example of a biolog restoration site.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

Advantages	Disadvantages
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreland erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Once native plants are established, they require less water, maintenance, no fertilizer; provide wildlife food and habitat, and natural aesthetics compared to ornamental (non-native) varieties. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait three to four years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

CalMan Lakes Shoreland Zone Condition

Shoreland Development

County staff and volunteers performed shoreland assessments on each of the four CalMan lakes. The goal of the assessment was to better understand near-shore habitats and conditions. The entire shoreline was assessed linearly for changes in land use and documented vegetation, erosion issues, and anthropogenic disturbances. In addition, a shoreland health scoring system was developed and a score was calculated for each parcel. A scoring system can be used to communicate quality of shoreland conditions riparian property owners and to the general public.

Previous shoreline assessments were conducted on Wisconsin lakes by several entities (UW-Steven Point CLUE, Northland College, National Lakes Assessment). No standard protocols had been established prior to the CalMan Lakes Assessment. Staff used methods developed by UW-Stevens Point CLUE and Winnebago County in an effort to collect similar data throughout the County and Winnebago System (LPL-1538-14, LPL-1539-14).

Parcel data from Manitowoc and Calumet Counties was downloaded onto a Trimble GeoXH. Aerial photos with parcel information were also used in the field verify locations and assess properties with treed shorelines. Data sheets were modified from Winnebago County to record additional information for the parcel score survey.

Riparian Buffer Survey

Riparian buffers provide several ecological benefits to a shoreline area. They provide habitat for riparian wildlife, buffer nutrient loading from non-point sources, and stabilize shorelines, preventing erosion. Riparian buffers were assessed by collecting linear data along the entire shoreline of each lake. Line segments were created by establishing waypoints at observed changes in habitat or buffer width. Observations were performed by the same staff person (observer/data recorder) to maintain consistency in the data. For each line segment, the maximum buffer distance inland (width of buffer) was estimated from a distance of 40 feet from shoreline. Presence and absence was recorded for each of the following vegetation types: forbs (< 3 feet tall), shrub (4-20 feet canopy), mowed vegetation, barren (included disturbed or susceptible to erosion), new shoreline restoration, organic leaf matter (healthy, undisturbed), wetland species, invasive species, trees (> 20 feet canopy), in-lake woody vegetation. The dominant vegetative type was recorded.

Data was entered into GIS and vegetative buffer maps were created for each lake. The maps can be viewed at http://www.co.calumet.wi.us/index.aspx?NID=318.

Development Point Survey

The development point survey documented anthropogenic disturbances along the shoreland area. Disturbances were categories as structures (boathouses, docks, decks, other), impervious surfaces (personal landings, paved areas), seawalls, rip-rap and other areas susceptible to erosion. Observations were made from a distance of 40 feet from shoreline. For smaller parcels (less than 65 feet wide, subdivision plats), one waypoint may represent multiple development points due to accuracy of collecting points 40 feet away from shoreline. For parcels greater than 65 feet, multiple waypoints were taken documenting spatial location of multiple structures or disturbances.

Maps were created displaying the various development points using ArcMap. Several maps were created for Long Lake, which have the most developed shoreline in the study, in order to development points with higher resolution. The maps can be viewed at http://www.co.calumet.wi.us/index.aspx?NID=318.

Shoreline Health Parcel Score Survey

A survey was conducted to assess varying land use practices within 75 feet of the ordinary high water mark (OHW) on every riparian property. This assessment was an opportunity to document more than just buffering capabilities of properties, incorporating encouraged practices (such as establishing tall canopy), implementation of encouraged erosion control practices, and greater detailed buffer zones (0-10ft, 10-30ft, >30ft). Data collected were used to set up a "scoring" system as a means communicate with landowners (Figure 3.4-1). The parcel score was designed to give credit for small practices implemented, and communicate opportunities for improvement.

An observation station was established for each parcel* along the shoreline. Stations were assessed using the layout described in Figure 3.4-1. Observations were conducted at varying distances from OHW; 0-10 feet, 10-30 feet, and greater than 30 feet. Observations were limited to the corridor between the OHW and 75 feet, which is the minimum setback requirements for the shoreland zoning in the state of Wisconsin (NR 115). Each observation determined presence, absence and dominance of three vegetation types (trees, shrubs, forbs/grasses), poor vegetative practices (mowed vegetation, barren), and other practices (impervious surfaces, invasive species control).

As with many lakes that were significantly developed prior to shoreland zoning regulations, several parcels contain non-conforming structures. A non-conforming structure is any building or structure that was legally established prior to the effective date of the adopted shoreland zoning code. In particular, Long Lake has several primary dwelling units that are well within the 75 feet of the OHWM. Therefore, impervious surfaces did not include the primary dwelling unit in this survey. Secondary structures and patios were included.

Three zones were assessed to document practices within varying distances from the OHWM. Scores from each Zone (A, B, and C) were added to give a final parcel score. Scoring parameters are detailed in Table 3.4-1. A frequency distribution table was used to define scoring categories. A "Healthy" score includes scores greater than 8, and reflect minimum impacts of these parcels on water quality. These parcels tended to provide habitat along the littoral transition zone and have minimal development. A parcel received a "Good" score if it scored 4 – 7. Many parcels that scored "Fair" (0-3) or "Priority" (less than zero) were well developed (Figure 3.4-2). "Priority" parcels are excellent opportunities to advance small land use practices to improve shoreland habitat.

Final scores were entered into ArcMap and several "Shoreline Health" maps were created from the data. The maps can be viewed at http://www.co.calumet.wi.us/index.aspx?NID=318.

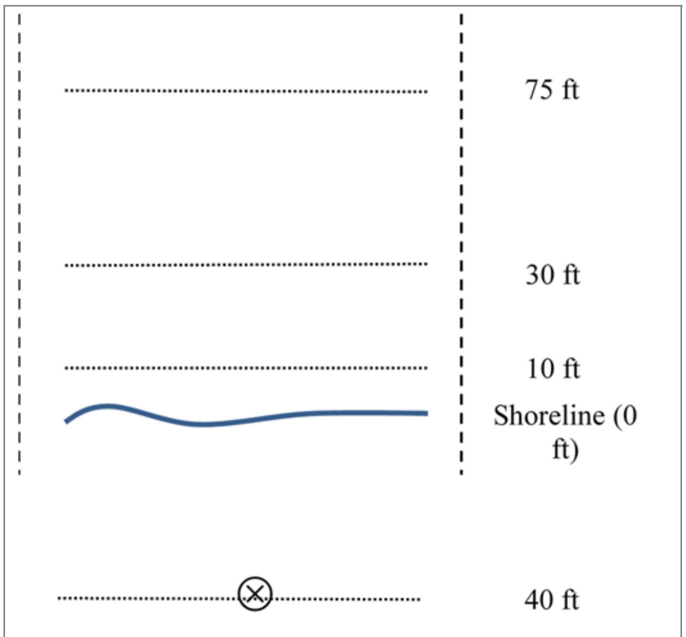


Figure 3.4-1. Parcel Score Stations.

Table3.4-1. Scoring Parameters

Scoring Parameters

	Distance from OHWM								
	<10 feet			10 - 30 feet			> 30 feet		
	Presence	Dominant	Max Score	Presence	Dominant	Max Score	Presence	Dominant	Max Score
Vegetation for Buffer: Forbs, Shurbs, or Trees	1	3	3	1	2	2	1	2	2
Mowed Vegetation, Barren Soil (Susceptible to Erosion)	-1	-2	-2	0	-1	-1	0	0	0
Rip Rap	-1	-2	-2	-2	-2	-2	-3	-3	-3
Wetland Species/Near Shore Emergents	1	2	2	1	2	2	1	2	2
Impervious or Seawall	-1	-2	-2	-1	-2	-2	-1	-2	-2
New Shoreland Restoration	1	2	2						
Invasives	-1	-2	-2	-1	-2	-2	-1	-2	-2
Total			Sum			Sum		Sum	Total Score

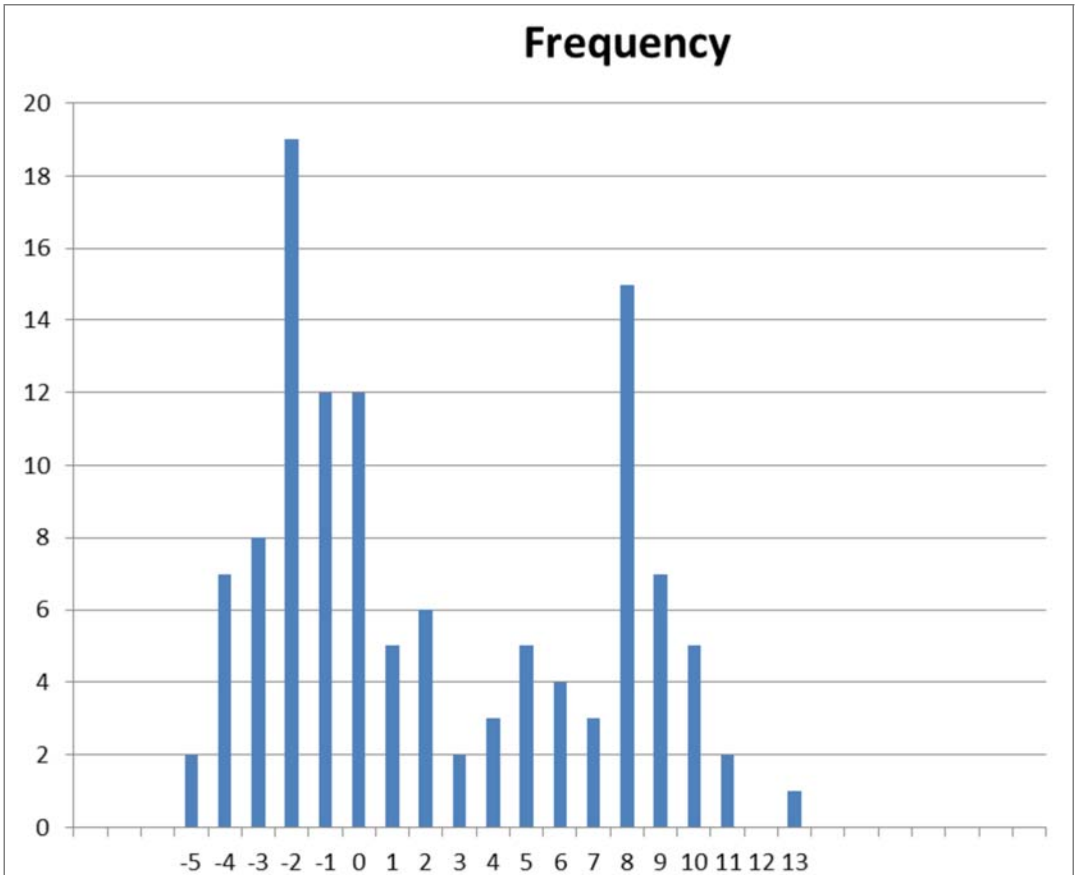


Figure 3.4-2. Frequency Distribution of Parcel Scores.

Coarse Woody Habitat

The CalMan Lakes were surveyed by Onterra staff in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

To date, Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012. Figure 3.4-3 displays the number of coarse woody habitat pieces per shoreline mile from the CalMan Lakes and how they compare with data from the 98 lakes surveyed. The number of coarse woody habitat pieces per mile ranged from 51 in Boot Lake to 33 in Long Lake. Boot and Becker Lakes have coarse woody habitat per shoreline mile values that fall above the 75th percentile for these 98 lakes and the number of coarse woody habitat pieces per shoreline mile in Round and Long Lakes fell above the median value. Locations of coarse woody habitat are displayed on Map 3.

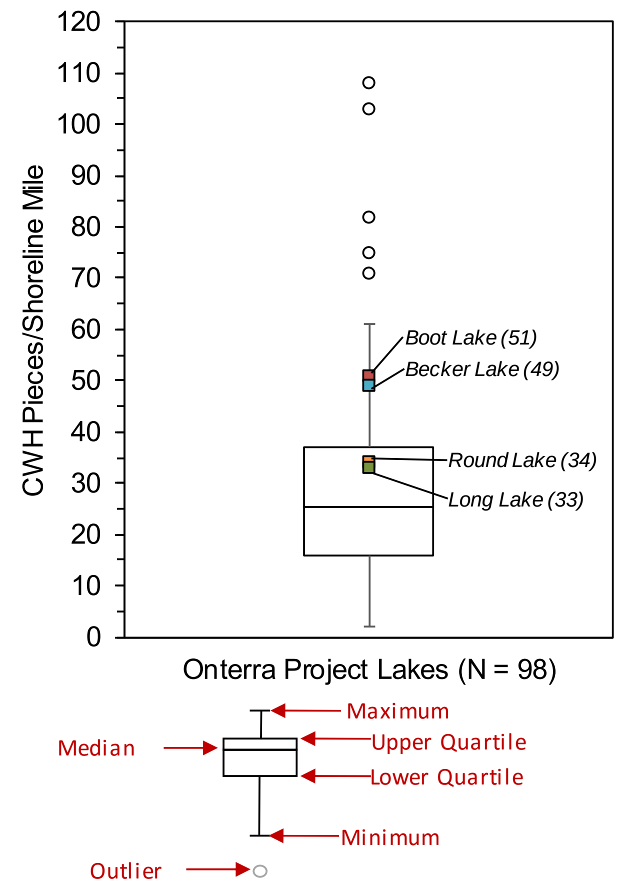


Figure 3.4-3. CalMan Lakes total number of coarse woody habitat (CWH) pieces per shoreline mile. State-wide comparative data available from 98 lakes surveyed by Onterra since 2012. Locations of coarse woody habitat can be found on Map 3.

3.5 Aquatic Plants

Introduction

Although the occasional lake user considers aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, the plants are actually an essential element in a healthy and functioning lake ecosystem. It is very important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Photograph 3.5-1. Example of emergent and floating-leaf communities.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No aquatic plant management plan should only contain methods to control plants, they should also contain methods on how to protect and possibly enhance the important plant communities within the lake. Unfortunately, the latter is often neglected and the ecosystem suffers as a result.

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergents or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on the CalMan Lakes; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the CalMan Lakes, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity and Richness

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Simpson's diversity index is used to determine this diversity in a lake ecosystem. Simpson's diversity (1-D) is calculated as:

$$D = \sum (n/N)^2$$

where:
n = the total number of instances of a particular species
N = the total number of instances of all species and
D is a value between 0 and 1

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to the CalMan Lakes. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of the CalMan Lakes will be compared to lakes in the same ecoregion and in the state (Figure 3.5-1).

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept survey and does not include incidental species or those encountered during other aquatic plan surveys.

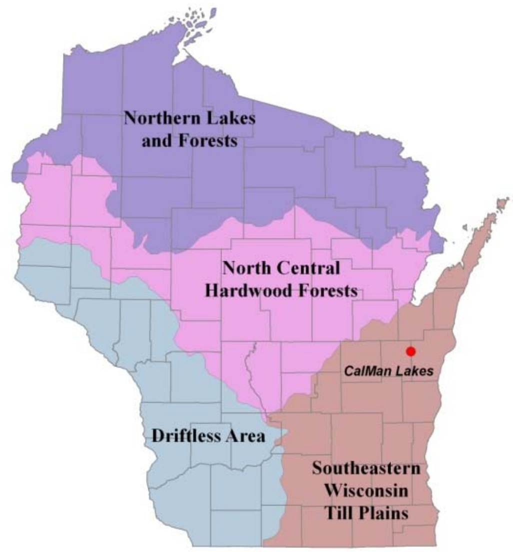


Figure 3.5-1. Location of the CalMan Lakes within the ecoregions of Wisconsin. After Nichols 1999.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian watermilfoil are the primary targets of this extra attention. Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.5-2). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and

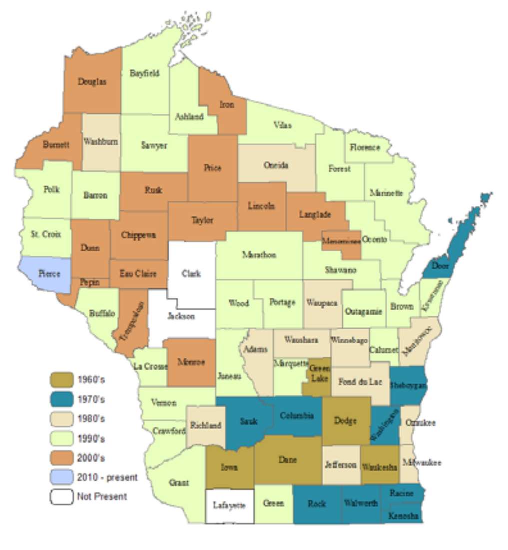


Figure 3.5-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly –leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native vegetation. Like Eurasian watermilfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian watermilfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

CalMan Lakes Aquatic Plant Survey Results

Numerous plant surveys were completed as a part of this project. Because of the collaborative nature of this project, surveys were conducted at different times and also by different agencies. A description of each survey type is presented below.

Early Season Aquatic Invasive Species Survey

An Early-Season Aquatic Invasive Species (ESAIS) survey was conducted in June of 2013 on each of the four CalMan Lakes by Onterra staff. During this meander based survey, aquatic invasive species are mapped using point-based or polygon-based methodologies, with notes taken on the density, depth and extent of each location that is mapped. There are several benefits of mapping species at this time of year. First, curly-leaf pondweed is at its peak growth so its full community may be realized. Also, Eurasian watermilfoil is actively growing and is visible above other native plants in the water column. If Eurasian watermilfoil was mapped during this survey, these sites were reassessed and the plants remapped later in the summer when Eurasian watermilfoil was at its peak biomass. On some project lakes, an emergent invasive plant – pale yellow iris (*Iris pseudacorus*) was spotted and its geospatial locations marked.

Point-Intercept Survey

The point-intercept survey is a grid based survey methodology created by WDNR research scientists (Hauxwell, 2010). The point intercept survey is used to sampling the submergent aquatic plant community. During this survey, a boat is navigated to each sampling point on the lake and a rake is thrown over the side to sample the aquatic vegetation. The vegetation is identified and an estimate of abundance is made. Additional variables such as depth and substrate type are noted.

WDNR staff have completed a point-intercept survey on Long Lake each year from 2008-2012 as part of a long-term monitoring project. WDNR staff and Calumet County staff visited Becker and Round Lakes in 2013, while Boot Lake will be visited in 2014. Aquatic plant point-intercept survey data may be viewed in Appendix D.

Community Mapping Survey

While the point-intercept survey is an excellent tool to characterize the submergent aquatic plant community, sometimes emergent and floating-leaf plants may be under represented. This can occur when shallow depths or dense plant growth prevents navigation into areas of the lake. To further understand these plant communities, Onterra staff completed community mapping surveys in August 2013 on all four CalMan Lakes. The methodology for this survey was similar to that of the aquatic invasive species mapping surveys; data was collected on emergent and/or floating-leaf plant communities in a point-based or polygon-based manner.

Eurasian Watermilfoil Peak Biomass Survey

Eurasian watermilfoil was known to exist in Long Lake, and hybrid watermilfoil, a cross between Eurasian watermilfoil and the native northern watermilfoil, was known to exist in Becker Lake. These locations were first mapped during the ESAIS survey. In August, when Eurasian watermilfoil and hybrid watermilfoil reaches its peak growth (biomass), the mapping efforts of that June were reassessed to update colony size and extents.

Aquatic Plant Survey Results

A total of 17 native plant species were identified from the CalMan Lakes, while seven non-native plant species were located (Table 3.5-1). Purple loosestrife and coontail were identified on all four of the CalMan Lakes. Four species, cattail, spatterdock, curly-leaf pondweed, and sago pondweed, were identified within three of the four lakes. This is a testament to the individuality of the lakes; even though they are in close proximity to each other and at high water times even flow into one another, there are substantial differences in substrate, water quality and morphology that can result in different aquatic plant communities. This relationship will be examined further throughout this section.

Table 3.5-1. Aquatic plant species located in the CalMan Lakes. Species identified during 2012, 2013 and 2014 WDNR/Calumet County point-intercept surveys and Onterra 2013 community mapping surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism	Becker Lake	Boot Lake	Round Lake	Long Lake
Emergent	Acorus calamus	Sweetflag	Exotic			I	
	Decodon verticillatus	Water-willow	7				I
	Eleocharis sp.	Spikerush sp.	N/A		I		
	Iris pseudacorus	Pale yellow iris	Exotic				I
	Iris versicolor	Northern blue flag	5			I	
	Lythrum salicaria	Purple loosestrife	Exotic	I	I	I	I
	Phragmites australis subsp. australis	Giant reed	Exotic	I			
	Sagittaria latifolia	Common arrowhead	3		I	I	
	Sparganium eurycarpum	Common bur-reed	5	I			
	Typha spp.	Cattail spp.	1	I	I		I
FL	*Nuphar variegata*	Spatterdock	6	I		X	X
	Nymphaea odorata	White water lily	6	X			X
	Persicaria amphibia	Water smartweed	5	I			
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X	X	X
	Chara spp.	Muskgrasses	7				X
	Elodea canadensis	Common waterweed	3			X	
	Elodea nuttallii	Slender waterweed	7			X	
	Myriophyllum sibiricum X M. spicatum	Hybrid watermilfoil	Exotic	X			
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic				X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X		X	I
	Potamogeton zosteriformis	Flat-stem pondweed	6	X			
	Stuckenia pectinata	Sago pondweed	3		X	X	X
FF	*Lemna minor*	Lesser duckweed	5		I		I
	Spirodela polyrhiza	Greater duckweed	5			X	

FL = Floating Leaf; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species

In the CalMan Lakes, the number of species observed per lake was notably low in the 2012, 2013 and 2014 surveys. Figure 3.5-3 displays the number of plants found within the point-intercept survey, as well as the additional species found incidentally. The total number of species is a combination of those recorded on the rake during the point-intercept survey and those located incidentally; however, in comparing the CalMan lakes to ecoregion and state medians and computing conservatism values, only the plants located during the point-intercept survey are considered. All CalMan Lakes held fewer species that the median species richness for lakes in the SWTP ecoregion and at the state-wide level. The maximum depth of plants in Becker Lake was three feet in 2013, two feet in Boot Lake in 2014, six feet in Round Lake in 2013, and nine feet in Long Lake in 2012. Aquatic plants are restricted to shallow areas of the CalMan Lakes primarily due to low water clarity resulting in low light availability. In addition, substrates in some areas may be too flocculent to support rooted aquatic plants.

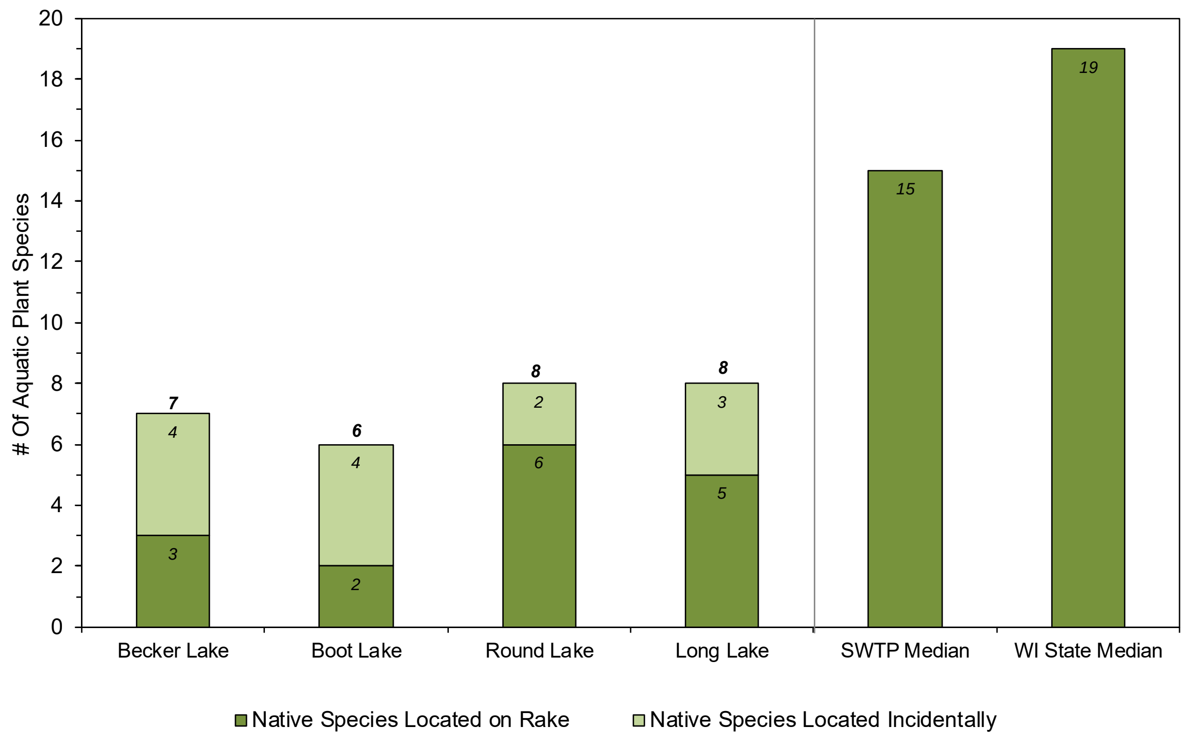


Figure 3.5-3. CalMan Lakes native species richness. Created using data from summer point-intercept and community mapping surveys. Chart includes species sampled directly during the point-intercept study (dark green) and species found incidentally (light green). Note that STWP is the Southeastern Till Plains ecoregion after Nichols (1999).

In addition to determining the species composition of a lake, the point-intercept survey is able to produce data that tells managers the distribution and frequency of occurrence of species in the lake. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). This distribution can be observed in Figure 3.5-4. The pie graphs depicted tell managers if one or two species are much more abundant than the other species, or if all species are well-distributed throughout the lake system. In Long Lake, Eurasian watermilfoil accounts for a large portion of the aquatic plant community, while in Round Lake the species that are present are more evenly distributed.

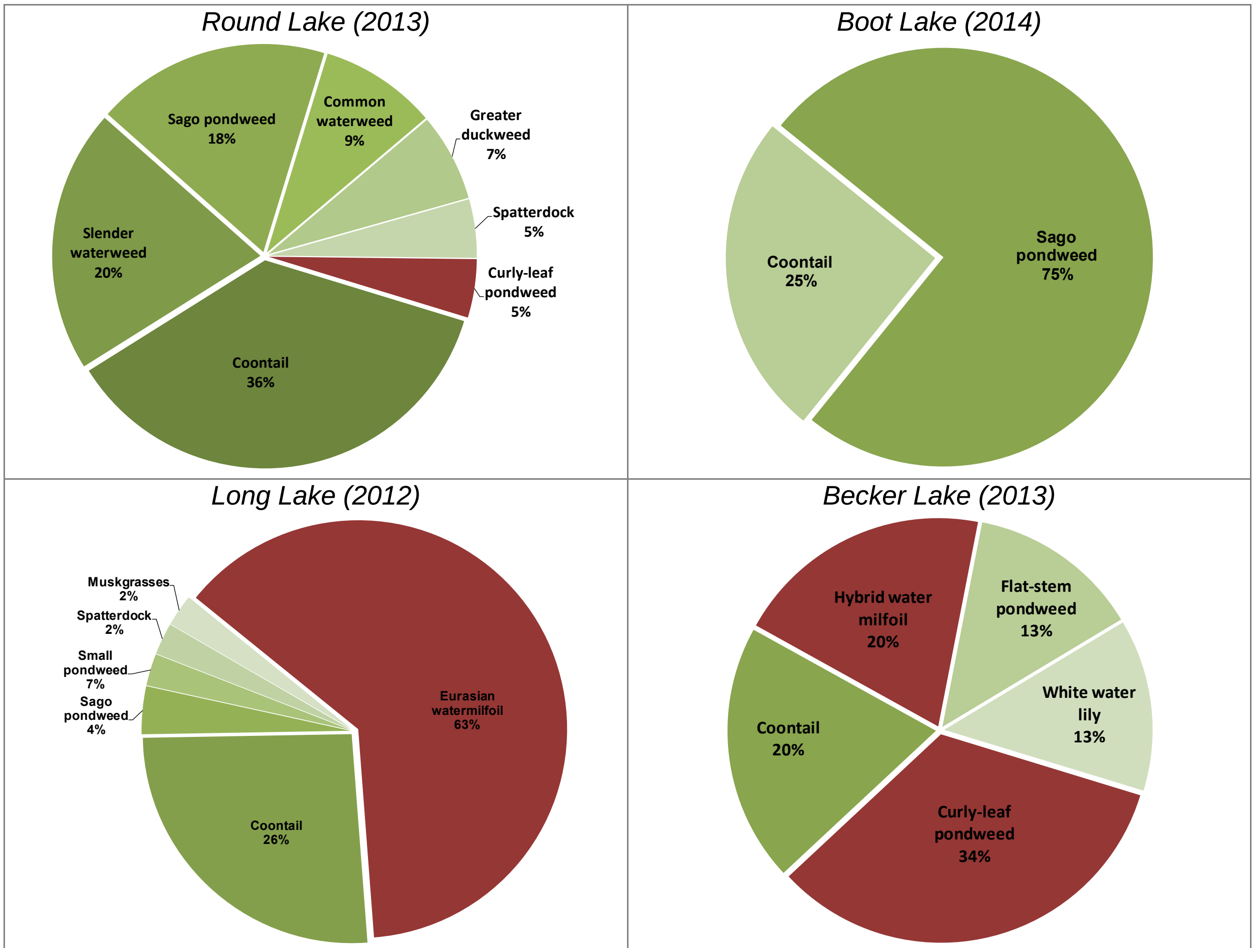


Figure 3.5-4. CalMan Lakes aquatic plant relative frequency of occurrence. Created using data from WDNR and Calumet County summer point-intercept surveys.

As discussed earlier, how evenly the species are distributed throughout the system and species richness together influence species diversity. In other words, a lake with many species is not necessarily diverse, and a lake with few species is not necessarily lacking diversity. Simpson's diversity index (1-D) is used to make this distinction. Species diversity ranged from 0.38 to 0.78 in the CalMan Lakes (Figure 3.5-5). Round Lake, even with the presence of curly-leaf pondweed, has a relatively high diversity given the higher number of species in the community. In contrast, Boot Lake's plant community was comprised of just two species, one of which comprised 75% of the community. The low number of species in combination with an uneven distribution of species in Boot Lake results in low species diversity value of 0.38.

While a method of characterizing diversity values as fair or poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the CalMan Lakes scores rank. Using data obtained from WDNR Science Services, median values and upper/lower quartiles were calculated for 68 lakes within the Southeastern Wisconsin Till Plain ecoregion (Figure 3.4-6). All of the CalMan Lakes hold diversity that is below the NCSE ecoregion median.

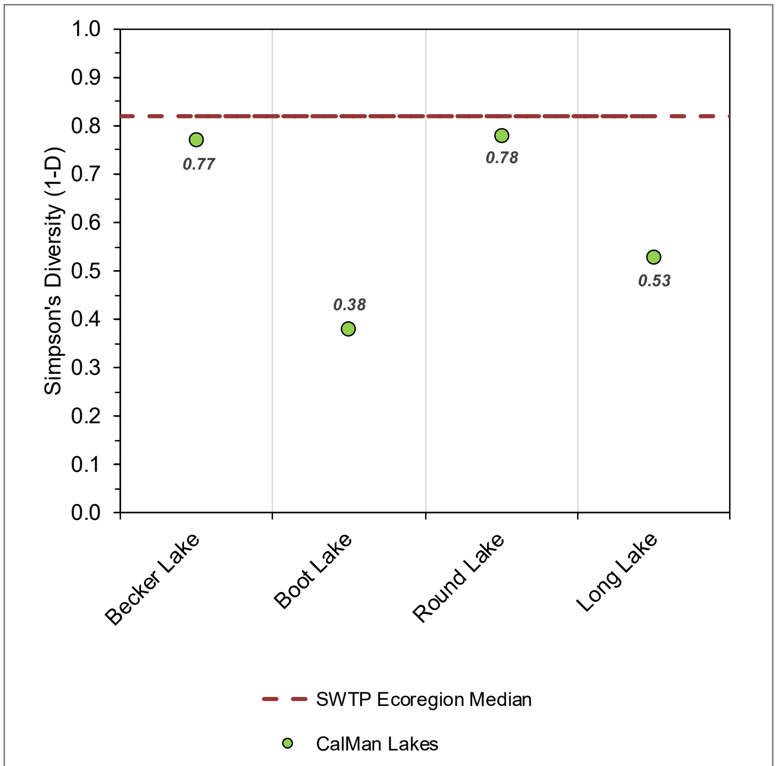


Figure 3.5-5. CalMan Lakes species diversity index. Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

The quality of a lakes aquatic plant species can be indicated by the conservatism value of the species. Data collected from the aquatic plant surveys indicate that the conservatism values of the CalMan Lakes' plant communities are lower than both the ecoregion and state values (Figure 3.5-6). This means the project lakes have plant communities that are more indicative of disturbed conditions than those found in the state and the ecoregion. It also suggests the lakes play host to disturbance-tolerant plant species only (e.g., coontail, non-native species) and fewer or no environmentally-sensitive species.

By combining the species richness and average conservatism values for each project lake, the Floristic Quality Index (FQI) value is obtained (equation shown below) (Figure 3.5-7). All of the project lakes fall below the state and ecoregion median FQI value. Again, this illustrates that the CalMan Lakes have low quality plant communities.

FQI = Average Coefficient of Conservatism * √ Number of Native Species

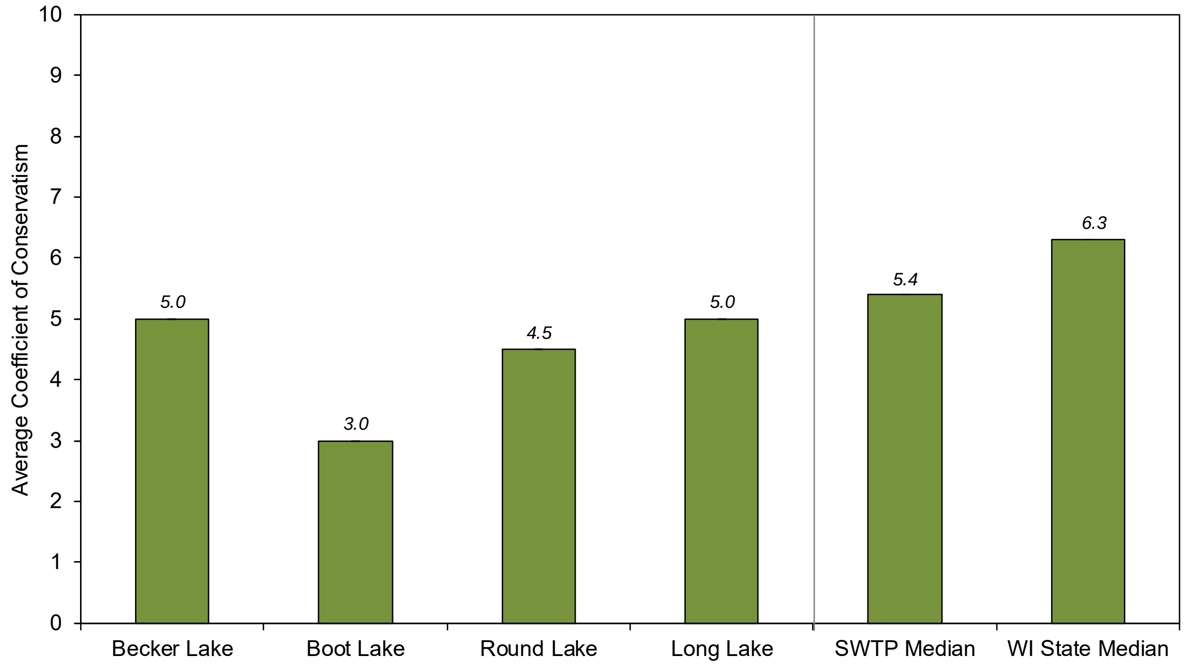


Figure 3.5-6. CalMan Lakes average native species' coefficients of conservatism. Created using data from summer point-intercept surveys.

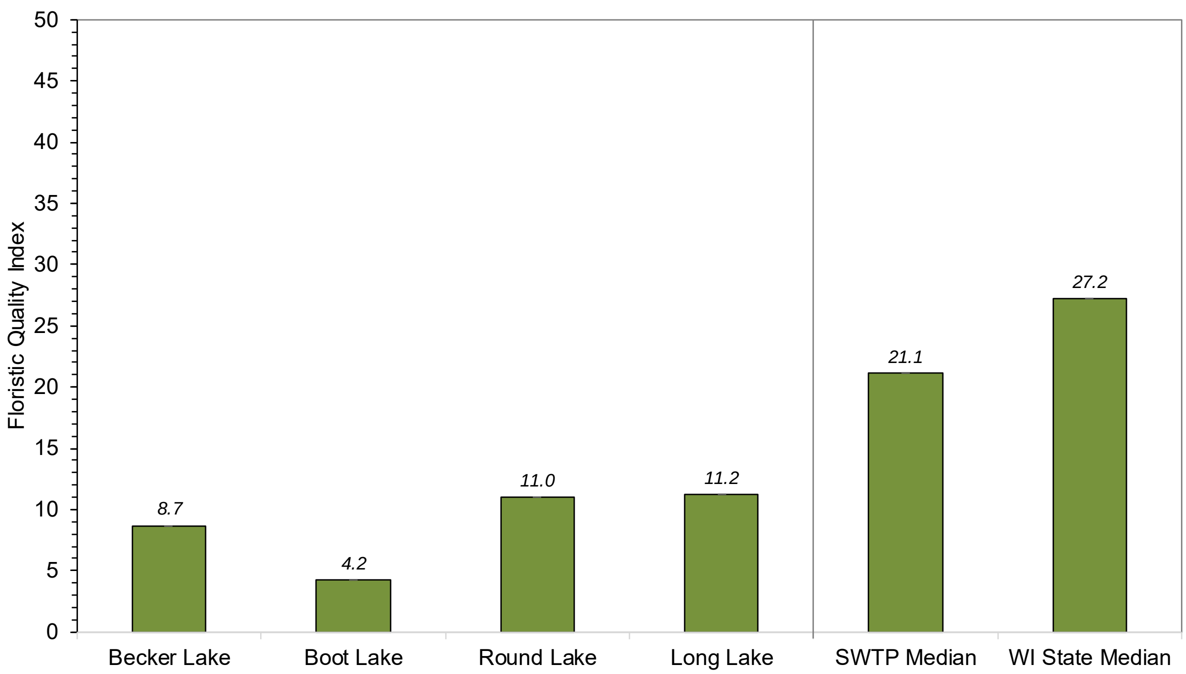


Figure 3.5-7. CalMan Lakes Floristic Quality Assessment. Created using data from summer point-intercept surveys.

Amongst other benefits, a healthy aquatic plant community in a lake provides habitat value for a variety of wildlife. Areas of emergent and floating-leaf plant communities provide valuable fish and wildlife habitat important to the ecosystem both inside and outside of the lake. These areas are utilized by adult fish for spawning, by juvenile fish as a nursery, and by forage fish for protection from predators. Wading birds can be found in these areas hunting fish and insects, and escaping dangerous predators. Finally, these communities protect shorelines from eroding, as they temper the energy on the waves approaching the shoreline from the interior of the lake.

The CalMan Lakes contain minimal areas of these plant communities when compared to the total acreage of the lake (Maps 4, 5, 6 and 7). Figure 3.5-8 displays the acreage of emergent, floating-leaf, or a combined emergent and floating-leaf plant communities. The presence of these communities is dependent upon several factors, including water depth and substrate type. Water clarity and general quality plays a role as well. Often, when disturbance of a waterbody occurs, the emergent and floating-leaf communities are impacted in terms of either the species that are present or their areal extents. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes.

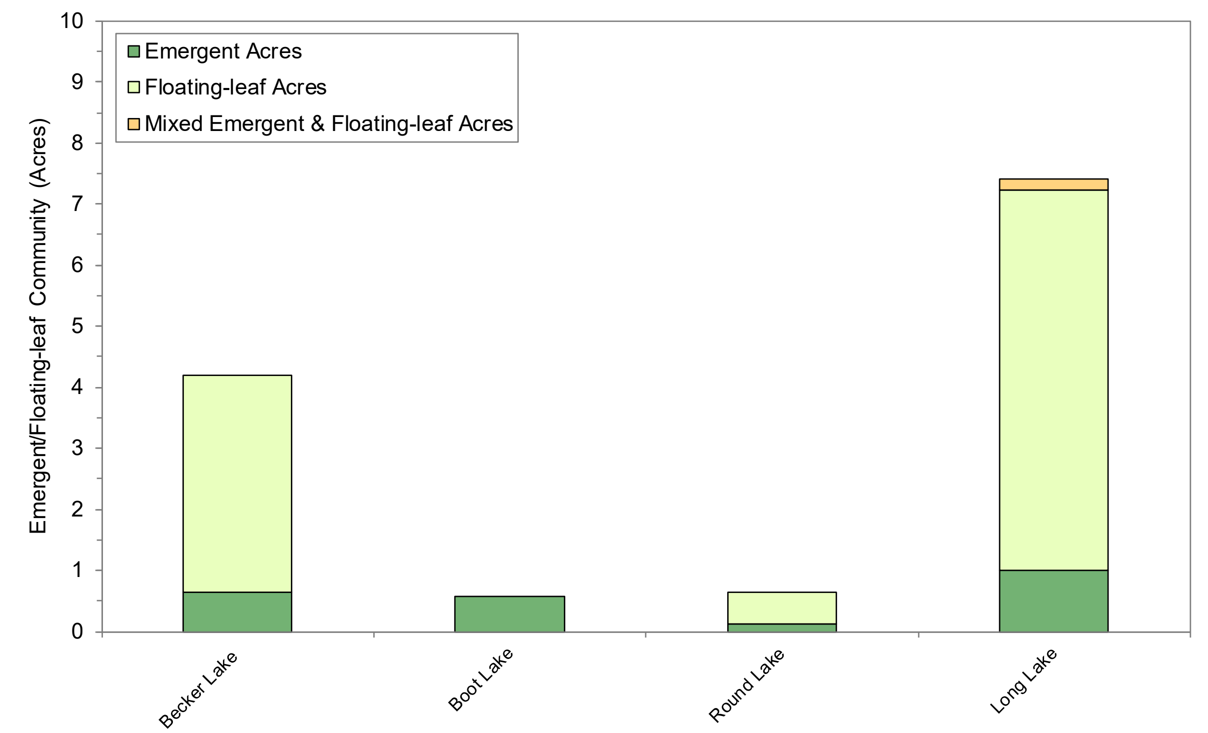


Figure 3.5-8. CalMan Lakes acres of emergent and floating-leaf aquatic plant communities. Created using data from summer community mapping surveys.

Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. These data are displayed in Figure 3.5-9 for each lake.

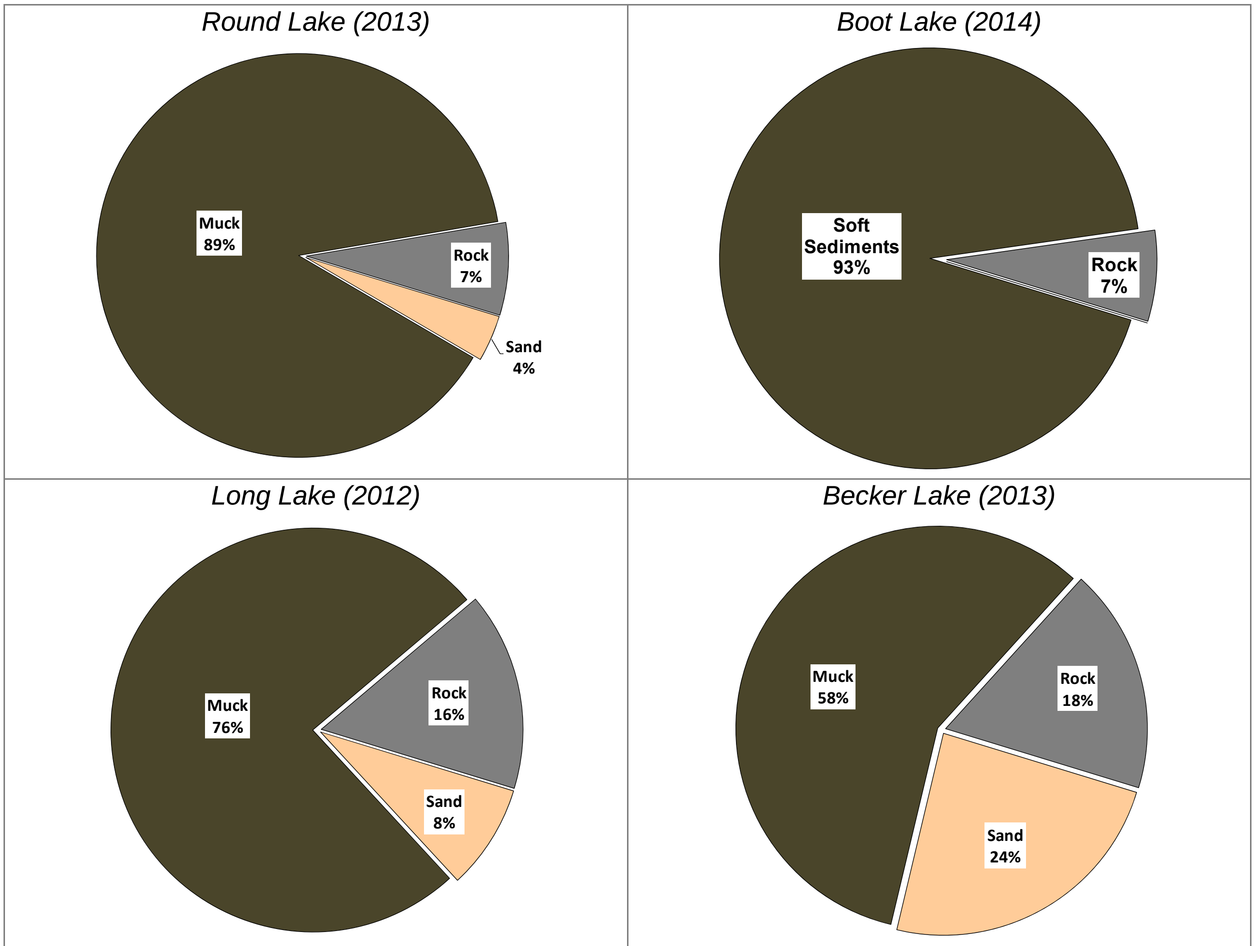


Figure 3.5-9. CalMan Lakes littoral substrate types. Created using data from WDNR and Calumet County summer point-intercept surveys.

Long Lake Aquatic Plant Community Trends

Long Lake has been included within the WDNR's long term lakes monitoring, which means that point-intercept studies have been conducted on the lake several times in recent years. This gives an indication of changes that may be occurring in the lake's aquatic plant community. Onterra or WDNR staff conducted point-intercept surveys on the lake in 2008, 2010, 2011 and 2012.

Figure 3.5-10 displays changes in littoral frequency of occurrence for individual species from the 2008, 2010, 2011, and 2012 surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the four surveys are displayed. Coontail and exhibited a statistically valid decrease from 2008 to 2012 (Figure 3.5-10). Eurasian watermilfoil and sago pondweed exhibited statistically valid increases from 2008 to 2012 (Figure 3.5-10).

Figure 3.5-11 displays the lake-wide frequency of occurrence of aquatic vegetation from 2008, 2010, 2011, and 2012. Overall, the lake-wide abundance of aquatic plants has not changed over the four years in question. The large increase seen in EWM in 2010-2012 has, however, affected the composition of vegetation found within Long Lake. In 2008, EWM only made up 0.5% of the lake and increased to 12-13% in 2010-2012. This can also be seen in the statistically valid increases in the littoral frequency of EWM in Figure 3.5-10. Eurasian watermilfoil was found within Long Lake in 2003 but before 2008, little is known about its presence within the lake. After

2012, EWM has not been monitored so it is unclear what caused the large increase from 2008 to 2010. It is possible that 2008 was just a poor year for EWM growth but without further studies, no conclusions can be made.

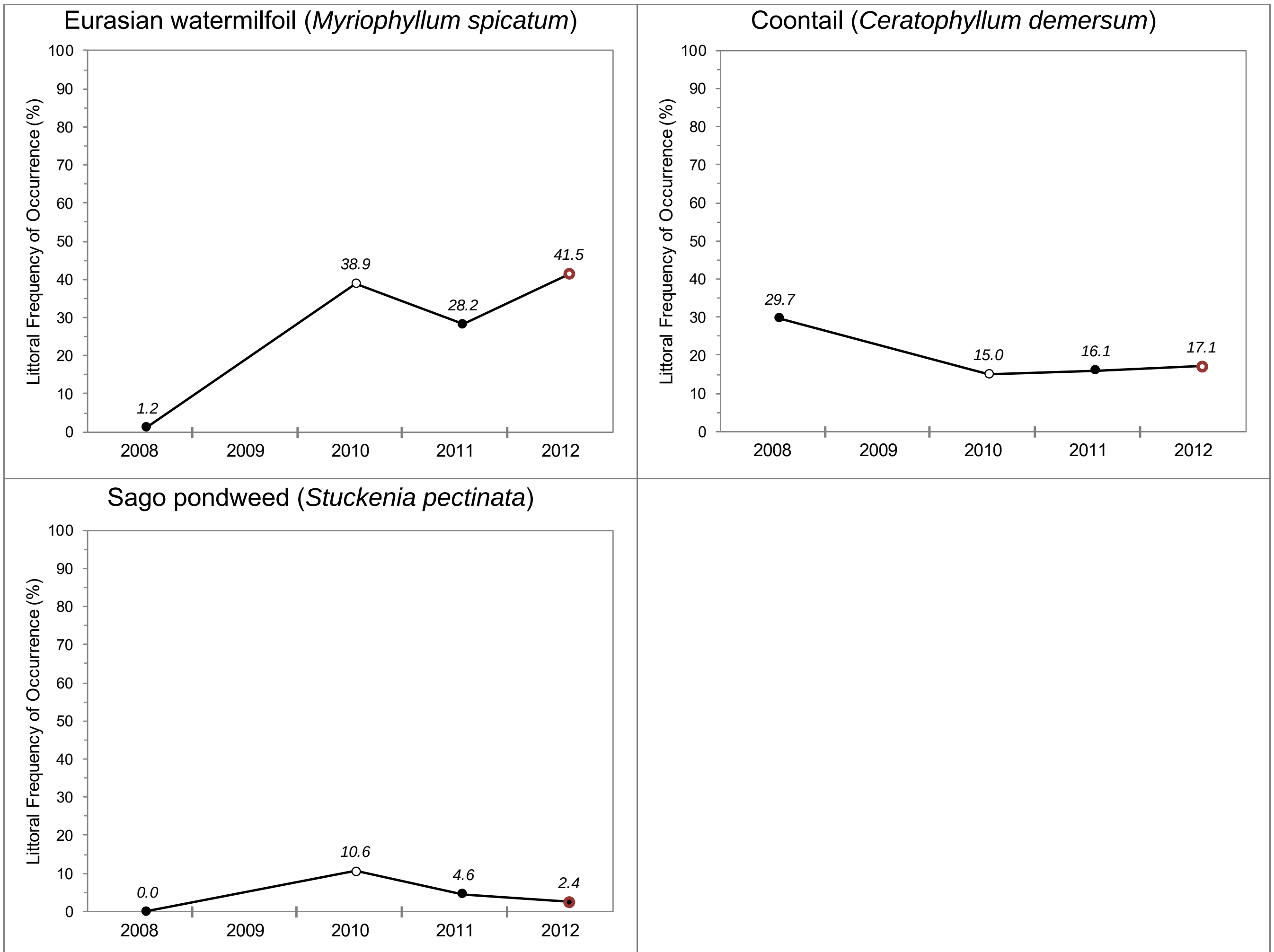


Figure 3.5-10. Littoral frequency of occurrence of select native aquatic plant species in Long Lake from 2008-2012. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2012 littoral occurrence was statistically different from littoral occurrence in 2008 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the four surveys. Created using data from Onterra 2008 (N = 172), Onterra 2010 (N = 113), WDNR 2011 (N = 174), and WDNR 2012 (N = 123) whole-lake point-intercept surveys.

Aquatic plant communities are dynamic, and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, water quality and disease among other factors. It is not known which factor(s) caused the detected changes in occurrence of plant species in Long Lake between 2008 and 2012. It is known however that fluctuations in occurrence of certain species over time are to be expected. However, if large reductions in occurrence or a complete loss of a species were observed, it may indicate an environmental disturbance such as pollution or displacement from invasive species.

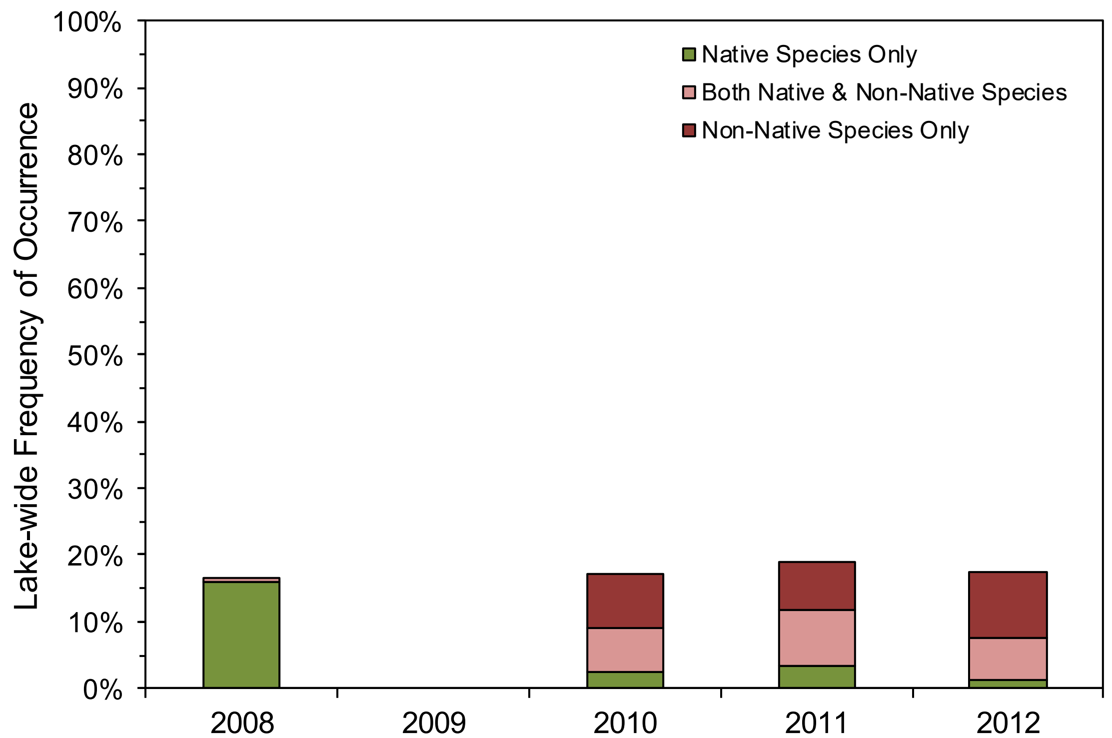


Figure 3.5-11. Lake-wide frequency of occurrence of aquatic vegetation from 2008, 2010, 2011, and 2012. Created using data from Onterra 2008 (N = 172), Onterra 2010 (N = 113), WDNR 2011 (N = 174), and WDNR 2012 (N = 123) whole-lake point-intercept surveys.

Non-Native Aquatic Plant Species

As with most Wisconsin lakes, there is great concern with the CalMan Lakes stakeholders over the threat of aquatic invasive species. Calumet County staff, Long Lake Advancement Association, and the Brillion Conservation Club have put forth much effort in educating area stakeholders and CalMan Lakes visitors about the threat that invasive species pose. Table 3.5-2 presents the known aquatic invasive species found in the CalMan Lakes.

Table 3.5-2. Aquatic Invasive Species located in the CalMan Lakes. Information obtained from a WDNR internet database (http://dnr.wi.gov/lakes/invasives/BySpecies.aspx).

Lake	AIS and Year Confirmed
Round Lake	Curly-leaf pondweed (2014) Purple loosestrife
Boot Lake	Purple loosestrife
Long Lake	Curly-leaf pondweed (1988) Eurasian watermilfoil (2003) Pale yellow iris Purple loosestrife
Becker Lake	Curly-leaf pondweed (1993) Eurasian watermilfoil (2009) Hybrid Eurasian/Northern watermilfoil (2012) Purple loosestrife Phragmites

Eurasian watermilfoil and Hybrid watermilfoil

The beginning of this section discusses the spread of Eurasian watermilfoil throughout Wisconsin and its ill effects on aquatic ecosystems and recreational opportunity. It is now known that a hybrid species between Eurasian watermilfoil and the native northern watermilfoil (hybrid watermilfoil) exists in Wisconsin and elsewhere. In many cases, this species was originally determined to be Eurasian watermilfoil, as morphological traits are very similar between this invasive plant and what is now known to be its hybrid relative. Often genetic testing is required to determine with certainty if a hybrid milfoil is present.

Control of Eurasian watermilfoil is often attempted through herbicide applications, typically with the chemical 2,4-D. Though conditions to reach success (plant mortality) can be difficult to achieve, chemical applications to control Eurasian watermilfoil have been documented to be successful, albeit often with regrowth of the targeted species after a period of time (years). In recent years, there had been anecdotal and scientific reports by lake managers indicating that herbicide applications failed to control hybrid watermilfoil colonies where conditions should have produced control. It is now believed that hybrid watermilfoil not only grows faster than Eurasian watermilfoil, but also displays less sensitivity to herbicide (2,4-D) applications (LaRue et. al. 2013).

Of the CalMan Lakes, Long Lake is known to hold Eurasian watermilfoil while Becker Lake is believed to hold Eurasian watermilfoil as well as hybrid watermilfoil. During 2013, a sample of Long Lake milfoil was confirmed to be pure strain Eurasian watermilfoil through genetics. Genetic analysis was conducted upon a Becker Lake milfoil sample in July of 2012 to confirm the presence of hybrid watermilfoil.

Long Lake was surveyed first during the 2013 ESAIS survey and later in August to map Eurasian watermilfoil at its peak growth. Eurasian watermilfoil was found to occur through much of the littoral zone in substantial density (Map 8). In all, nearly 20 acres of Eurasian watermilfoil was mapped throughout the lake. During this same time, hybrid watermilfoil was mapped on Becker Lake. Hybrid watermilfoil was found in the littoral zone in several areas of the lake, with highly dense colonies being found in the along the northern and southern as well as southeast and southwest shorelines (Map 9). In all, roughly 2.5 acres were delineated within the lake.

Curly-leaf pondweed

Curly-leaf pondweed was mapped during the 2013 ESAIS survey on Becker, Round and Long Lakes. The curly-leaf pondweed on Round Lake covered the vast majority of the littoral zone in varying densities; in all, about 3.6 acres of colonized curly-leaf pondweed were observed (Map 10). Only two occurrences of curly-leaf pondweed were documented in Long Lake in June 2013. Data from a previous aquatic invasive species survey (in which the same methodology was used) indicated that in 2009 curly-leaf pondweed plants could be found around much of the lake's littoral zone (Maps 11). The reason for this apparent decline is unknown, but perhaps may be related to competition with Eurasian watermilfoil or changes in environmental conditions. Becker Lake held densely matted curly-leaf pondweed in June 2013, occurring intermingled with Eurasian watermilfoil (Map 12).

Purple Loosestrife, Giant Reed and Pale Yellow Iris

These three non-native species are emergent, wetland species that may be found along the shorelines of Wisconsin's lakes. Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Populations of purple loosestrife were observed along much of the Boot Lake shoreline (Map 5), within several colonies on Long Lake's northern shoreline (Map 6) and to a minimal extent along Becker and Round Lakes (Maps 3 and 6).

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around the CalMan Lakes.

Giant reed (*Phragmites australis*) is a tall, perennial grass that was introduced to the United States from Europe. While a native strain of this species exists in Wisconsin, it is believed that the plants located on Becker Lake are of the non-native, invasive strain. Giant reed forms towering, dense colonies that overtake native vegetation and replace it with a monoculture that provides inadequate sources of food and habitat for wildlife. Giant reed was found growing in a single location on Becker Lake's shoreline in 2013 (Map 7). Because this species has the capacity to displace the valuable wetland plants along the exposed shorelines of the lake and elsewhere, it is recommended that these plants be removed by cutting and bagging the seed heads and applying herbicide to the cut ends. This management strategy is most effective when completed in late summer or early fall when the plant is actively storing sugars and carbohydrates in its root system in preparation for over-wintering. The giant reed infestation is in its very early stages, and eradication is likely a realistic outcome if control actions are taken quickly.

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Pale yellow iris was observed growing on the shoreline of Long Lake in several locations (Maps 6). At this time, the only means of controlling pale-yellow iris populations is continual hand removal and monitoring.

Stakeholder Survey Response Regarding Aquatic Vegetation

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to the aquatic vegetation within the CalMan Lakes. Figure 3.5-12 displays the responses of CalMan stakeholders regarding aquatic vegetation and its impacts to recreation. When asked how often aquatic plant growth, including algae negatively impacts their recreation, respondents indicated often (29%), always (27%), sometimes (24%) relatively evenly. Thirteen percent rarely have aquatic vegetation impact their enjoyment and 7% indicated that aquatic vegetation never impacts their enjoyment of the lakes. The data collected from 2012-2014 indicates that there are not many submerged aquatic plants within any of the lakes and there are few emergent plants growing along the shoreline of the lakes. The plants that are most likely impacting enjoyment of the lakes are free-floating plants such as duckweed or fragments of plants that have come loose from heavy boat traffic or due to high winds.

Question 22. How often does aquatic plant growth, including algae, negatively impact your enjoyment of the CalMan Lakes?

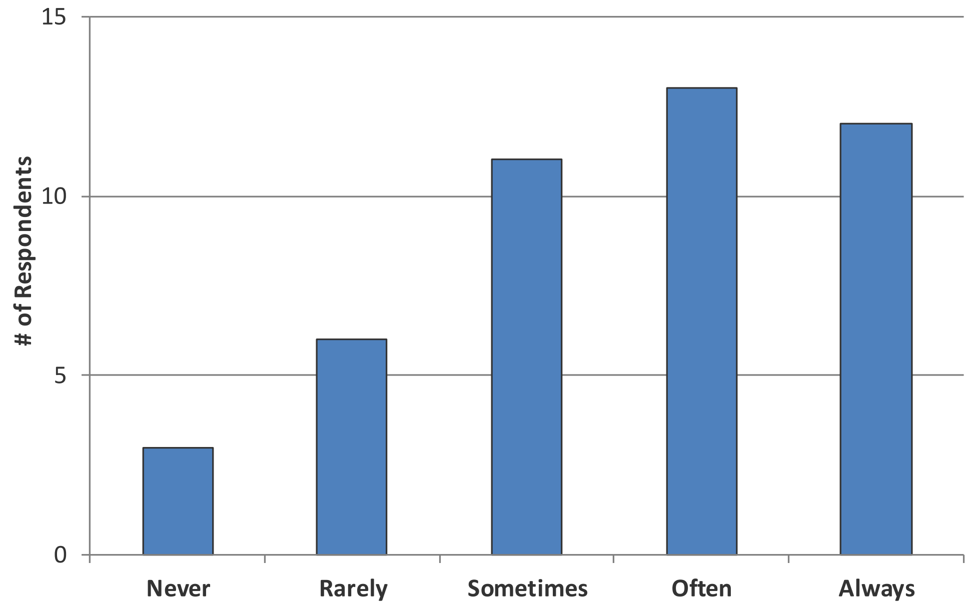


Figure 3.5-12. CalMan Lake stakeholder survey response to questions regarding aquatic vegetation. N = 45 respondents.

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing the CalMan Lakes. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues brought forth by stakeholders within the CalMan Lakes' watershed. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2014).

CalMan Lakes Fishery

CalMan Lakes Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on the CalMan Lakes (Figure 2.0-1). Approximately 47% of these same respondents believed that the quality of fishing on the lake was fair, 44% indicated poor to very poor, and 9% believe the fishing is good (Question #10); and approximately 78% believe that the quality of fishing has gotten somewhat to much worse since they have obtained their property (Question #11).

When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its mass and composition. The gamefish in a lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

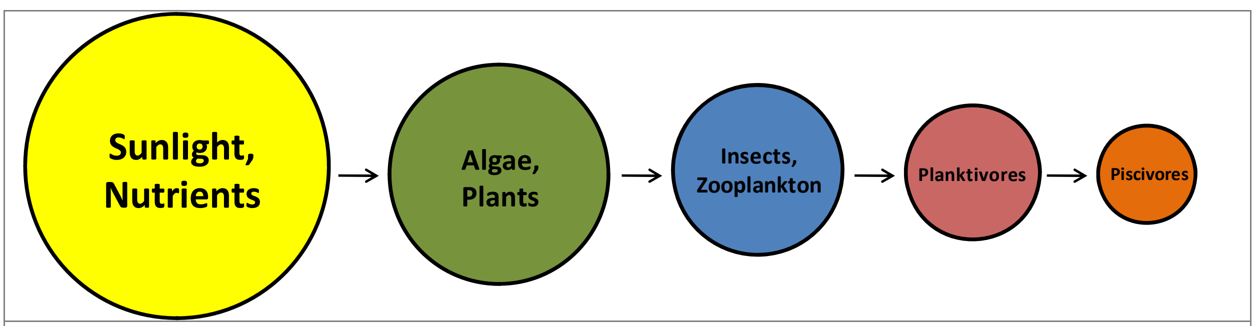


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, the CalMan lakes are eutrophic to hyper eutrophic systems, meaning they have high nutrient content and thus relatively high primary productivity. Simply put, this means the lakes should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. However, as discussed further on within this section, issues associated with this productivity (such as low dissolved oxygen) may impact these fisheries significantly. Table 3.6-1 shows the game fish that are present in these lakes.

Table 3.6-1. Fish species present in the CalMan Lakes with corresponding biological information (Becker, 1983).

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Bullhead	*Ameiurus nebulosus*	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Common Carp	*Cyprinus carpio*	47	April - August	Shallow, weedy areas from 3 - 6 ft	Insect larvae, crustaceans, mollusks, some fish and fish eggs
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Walleye	*Sander vitreus*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

CalMan Lakes Fish Stocking and Management

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. WDNR funded and privately funded stocking records may be found in Appendix E.

The CalMan Lakes, with the exception of Boot Lake, are primarily managed for a bass/panfish fishery with an emphasis on controlling rough fish species. With no public access, Boot Lake is not actively managed by the WDNR, however an aged report indicates the lake was once stocked with northern pike, largemouth bass, bluegill and brook trout (Fassbender, 1971). In Long Lake, walleye and northern pike are stocked by both the WDNR and the LLPA to provide additional angling opportunities for these species. In recent years, bass and northern pike have also been stocked in Becker and Round Lakes. Trout species (brook and brown trout) have been stocked in Round Lake, the deepest lake in Calumet County, in an effort to provide a different fishery opportunity here. According to Fassbender (1971), a bass/bluegill/trout fishery once flourished here, however problems with eutrophication have led to frequent winterkills which has altered this fishery greatly. As a result of these numerous fish kills, trout stocking was halted.

Winterkill, as discussed briefly within the Water Quality Section, has been documented in all four of the CalMan Lakes to various degrees. This may occur more frequently when winter weather is prolonged, which often means that ice cover lasts longer on a lake. There are a variety of factors involved in winterkill including the rate of biological oxygen demand (amount of oxygen needed by organisms to break down organics), as well as the volume and depth of water in the lake. Long Lake, with its depth and larger volume, likely experiences winterkill less frequently than the other three CalMan Lakes. In years past, the LLPA operated an aerator to maintain dissolved oxygen during the winter months however its use was discontinued over a decade ago (Steve Hogler, WDNR, personal communication).

Becker and Round Lakes were visited in early July 2011 by a WDNR electroshocker crew to determine the state of the fishery and also assess winterkill from the previous year. WDNR fisheries biologist Adam Nickel reported that over 100 bluegill, including a strong year class of 6-7-inch fish, were sampled at that time. These fish were likely from a 2011 stocking, which indicates that if Becker Lake did sustain a fish kill in winter of 2013/2014, it was likely small. Mr. Nickel also reported that Round Lake, unfortunately, likely sustained a substantial winterkill in 2013/2014 as one black crappie was sampled along with abundant black bullhead. Although it is not known for certain, it is believed by most that Boot Lake experiences widespread and frequent winter fish kills due to its relatively small volume and exceptionally high productivity.

WDNR biologist Adam Nickel reports that the future fisheries management of the CalMan Lakes, particularly in Becker and Round Lakes, will largely depend on the frequency and severity of winterkill events in the future. The overarching goal would be to produce a self-sustaining largemouth bass and panfish fishery in Becker and Round Lakes, but periodic winterkills that remove entire year classes will likely continue to limit their fishery potential. Therefore, it is important that proactive measures are taken in improving water quality and providing more suitable conditions for sustaining fish populations, such as having more stable dissolved oxygen levels year around.

CalMan Lakes Substrate and Near Shore Habitat

Just as forest wildlife require proper trees and understory growth to flourish, fish prefer certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Indeed, lakes with primarily a silty/soft substrate and much aquatic plants and coarse woody debris may produce a completely different fishery than lakes that are largely sandy and contain few aquatic plant species or coarse woody habitat.

Figure 3.4-9 within the Aquatic Plant Section displays the littoral zone substrate composition within the CalMan Lakes, as determined through the point-intercept survey. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Northern pike are one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone.

CalMan Lakes Fisheries Regulations

Because the CalMan Lakes are located within southern Wisconsin, special regulations may occur that differ from those elsewhere. Table 3.6-2 displays the 2014-2015 regulations for species that may be found in the CalMan Lakes. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.6-2. WDNR fishing regulations for the CalMan Lakes, 2017-2018.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth bass and smallmouth bass	May 6, 2017 to March 4, 2018	The minimum length limit is 14" and the daily bag limit is 5.
Northern pike	May 6, 2017 to March 4, 2018	The minimum length limit is 26" and the daily bag limit is 2
Walleye, sauger, and hybrids	May 6, 2017 to March 4, 2018	The minimum length limit is 15" and the daily bag limit is 5.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rough fish (includes carp)	Open All Year	No minimum length limit and the daily bag limit is unlimited.

4.0 REDUCING PHOSPHORUS LOADS TO THE CALMAN LAKES

Summary of CalMan Loading With and Without an Alum Treatment in Each Lake

All of the lakes act as very efficient phosphorus sinks; therefore, most of what comes into the lakes from the watersheds remains in the lakes. This means that after an alum treatment there would not be a large reduction in the amount of phosphorus leaving each lake. This is, in part, because the loading from the watershed is so large in each lake. For example, Round Lake receives 88 lbs from the watershed and exports 9 lbs. Between Round and Long lakes 285 lbs enter the stream and thus Long Lake. Even though internal loading makes up over 50% of the total load in Round Lake, an alum treatment would only reduce phosphorus export from 9 to 6 lbs.

For the larger picture of the North Branch Manitowoc River Watershed, the most efficient way to reduce the export of phosphorus from Becker Lake would be to concentrate on reducing phosphorus that enters the Becker Lake watershed downstream of Long Lake. There are 155 lbs of phosphorus leaving Long Lake but 506 lbs enter Becker Lake from the stream, an increase of 435 lbs. In the bigger picture, only 96 lbs leaves Becker Lake which is a very minor amount compared to other sources to the North Branch Manitowoc River. If all of the lakes were treated with alum the export from Becker Lake would be reduced from 96 to 72 lbs (Table 4.0-1 and Table 4.0-2).

Table 4.0-1. Phosphorus budget for the CalMan lakes. Units are pounds.

	External	Internal	Export
Round	91	114	9
Boot	180	46	41
Long	724	365	155
Becker	703	332	96

Table 4.0-2. Phosphorus budget for the CalMan lakes following an alum treatment. Units are pounds.

	External	Internal	Export
Round	91	11	6
Boot	180	5	36
Long	716	36	125
Becker	637	33	72

Cost of Alum Treatment

The source phosphorus for internal loading from the sediments is referred to as mobile phosphorus. This component of sediment phosphorus is primarily phosphorus that is bound with iron. In the absence of oxygen, iron changes properties from the insoluble Fe^{+3} form to the soluble Fe^{+2} form, which results in the attached phosphorus moving from the sediments into the overlying water. Other forms of sediment phosphorus that comprise mobile sediment phosphorus are labile organic phosphorus and loosely bound phosphorus. In order to determine the appropriate dosage of alum to add to a lake, the amount of mobile sediment phosphorus in the upper part of the sediments is measured. By measuring the amount of mobile phosphorus, a determination can be made of how much alum to add to permanently bind this phosphorus in the lake's sediment. Additional alum is added to inactivate phosphorus that will settle to the sediments in succeeding years.

The costs below include estimates of lab analysis to determine how much alum to add (Table 4.0-3) and the cost of applying the alum (Table 4.0-4). The application rate could be higher, but the example rate of 50 gAl/m^2 was successfully used in other hardwater lakes similar to the CalMan lakes. Not included are costs for collecting the cores for determining the amount of alum to add or the cost of monitoring that would be necessary during the treatment. A 3-year monitoring plan to determine the success of the treatments is discussed below. The costs below include the mobilization cost if only one lake were treated. It is likely the setup cost would be less if more than 1 lake were treated.

Table 4.0-3. Number of cores to measure mobile sediment phosphorus. A detailed core is 0-6cm/1cm and 6-12cm/2cm and the other cores are a composite of 0-5 cm.

	Number of cores	Number of detailed cores	Number of sections	Cost
Round	6	1	14	$2,310
Boot	3	1	11	$1,815
Long	9	3	33	$5,445
Becker	7	1	15	$2,475

Table 4.0-4. Estimated cost of an alum treatment based upon an application rate of 50 gAl/m2 and the cost of alum of $1.80/gallon.

	Depth of treatment (ft)*	Acres to be treated	Cost of alum	Set of cost
Round	10	6.9	$11,278	$6,000
Boot	5	7.2	$11,887	$6,000
Long	10	68.2	$112,207	$6,000
Becker	10	28.1	$46,248	$6,000

**Alum will be applied at this depth and deeper*

Three-Year Monitoring Plan Following Alum Treatments

If any of the lakes are treated with alum to reduce internal phosphorus loading, it is recommended that a three-year monitoring plan be undertaken to determine if the treatment was successful in improving the lake's water quality. Trophic parameters have been collected in all of the lakes during the last few years and aquatic plant surveys were conducted in each of the lakes in 212, 2013, or 2014.

Trophic parameters would be monitored at the same frequency as they have been in the last few years. Specifically, total phosphorus, and chlorophyll-*a*, samples would be collected at a 3-foot depth during spring turnover (April), June, July, and August. A total phosphorus profile would be collected in October when the maximum amount of phosphorus would be expected in the hypolimnion. Previous studies have shown hypolimnetic phosphorus concentrations to be very high at this time. If an alum treatment is successful these concentrations would be greatly reduced and will be the main determinant of the success of the alum treatment. A near surface chlorophyll-*a* sample would be collected at the same time as the total phosphorus profile. Dissolved oxygen and temperature profiles and Secchi disc transparency would be collected at the same time that phosphorus and chlorophyll-*a* samples are collected.

In the third year of the study, sediment cores would be collected from the lake to determine to what depth the alum layer had settled. Also, the amount of mobile sediment phosphorus will be determined to compare with concentrations prior to the alum treatment.

In the third year, a point-intercept aquatic plant survey would be conducted to determine what effect the alum treatment had on the plant community. If the water clarity improved following the alum treatment we would expect a change in the aquatic plant community.

Table 4.0-5. Sampling schedule for trophic parameters and dissolved oxygen (DO) and temperature profiles.

		Phosphorus	*Chlorophyll-a*	*Secchi Disc*	*DO*	*Temperature*
Round	Near surface	4	4	5	5	5
	Profile	10				
Boot	Near surface	4	4	5	5	5
	Profile	5				
Long	Near surface	4	4	5	5	5
	Profile	8				
Becker	Near surface	4	4	5	5	5
	Profile	9				

Benefits of Improving Shoreland Habitat

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

Studies of nutrient runoff from Wisconsin lake shorelands have found that developed shorelands deliver more phosphorus to a lake compared with undeveloped shorelands. While phosphorus containing fertilizer may not be applied after April 1, 2010, phosphorus containing debris such as leaves and lawn clippings enter the lake at higher rates in developed shorelands. This is primarily because much less infiltration of water occurs on developed shorelands. This means more water from impervious surfaces and the "smoother" textures of lawns enters the lake and thus more phosphorus is also delivered to the lake compared with undeveloped shorelands.

Developed shorelands are much less friendly to wildlife compared with undeveloped shorelands. Numerous studies have documented less natural wildlife, e.g. green frogs and forest birds along urbanized shorelands. The fish community prefers undeveloped shorelands for spawning, refuge, and foraging. The report for the 2007 U.S. EPA National Lake Assessment concluded that poor shoreline habitat condition was the biggest problem with our nation's lakes and this was also true in Wisconsin lakes.

Maps developed from data collected around the CalMan lakes show that much of the shorelands of these lakes are in poor to fair condition. This is most apparent in Long Lake because it is the largest and has the densest development. It is estimated that if shoreland improvements were made around the lake, phosphorus runoff from the shorelands would be reduced from 12 to 7 pounds. More important than the nutrient reduction would be the improvement in habitat. With proper restoration, habitat would be improved for amphibians, native birds, and the fishery. There would be an increase in sites for fish spawning as well as an increase in areas for fish foraging and refuges for small fish.

5.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in the CalMan Lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in each lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included total and dissolved phosphorus, chlorophyll-*a*, total Kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, laboratory conductivity, laboratory pH, total alkalinity, total suspended solids, calcium

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, and dissolved oxygen profile was completed using a Hach LDO 30D.

Watershed Analysis

The watershed analysis began with an accurate delineation of the CalMan Lakes drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. Watershed delineations were determined for each project lake. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003).

Aquatic Vegetation

Early-Season AIS Survey

Surveys of curly-leaf pondweed were completed on the CalMan Lakes during mid to late June in order to correspond with the anticipated peak growth of the curly-leaf pondweed. Please refer to each individual lake section for the exact date in which each survey was conducted. Visual inspections were completed throughout the lake by completing a meander survey by boat. Data was collected using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. AIS colonies were mapped based upon density into categories of point based or polygon based areas.

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on the system to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (Hauxwell 2010) was used to complete the studies. WDNR staff and Calumet County staff completed the studies in 2012 (Long Lake), 2013 (Becker and Round Lake) and Boot Lake (2014).

Community Mapping

During the species inventory work, the aquatic vegetation community types within each lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for each of the lakes.

Eurasian Watermilfoil Peak Biomass Survey

Eurasian watermilfoil colonies were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. This occurred first in June during the ESAIS survey, and the data was refined further with a visit to each CalMan Lake in August of 2013. Eurasian watermilfoil colonies were mapped based upon density into categories of point based or polygon based areas.

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