Horsehead Lake

Oneida County, Wisconsin

Comprehensive Management Plan

January 2020

Sponsored by:

Horsehead Lake Protection & Rehabilitation District No. 1

WDNR Grant Program

LPL-1644-17

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Onterra, LLC
Lake Management Planning

Horsehead Lake

Oneida County, Wisconsin

Comprehensive Management Plan

January 2020

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Funded by: Horsehead Lake Protection & Rehabilitation District No. 1
Wisconsin Dept. of Natural Resources
(LPL-1644-17)

Acknowledgements

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

Horsehead Lake Planning Committee

Dennis Batchelet	Linda Delius	Beverly Fagen
Kris Batchelet	Joseph Helmuth	James Watters
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Wisconsin Dept. of Natural Resources

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1.0 INTRODUCTION

According to the 1968 recording sonar WDNR Lake Survey Map, Horsehead Lake is 366.5 acres. The WDNR website lists the lake as 377 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in summer of 2015. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 386 acres. Horsehead Lake, Oneida County, is a headwater drainage lake with a maximum depth of 11 feet and a mean depth of 8 feet. This eutrophic lake has a relatively small watershed when compared to the size of the lake. Horsehead Lake contains 28 native plant species, of which flat-stem pondweed is the most common plant. Two exotic plant species are known to exist in Horsehead Lake.

Field Survey Notes

Clear water and abundance of aquatic vegetation made driving a boat difficult at times but overall a beautiful lake.

Photograph 1.0-1. Horsehead Lake, Oneida County

Lake at a Glance - Horsehead Lake

Morphology	
Acreage	386
Maximum Depth (ft)	11
Mean Depth (ft)	8
Shoreline Complexity	4.3
Vegetation	
Curly-leaf Survey Date	June 21, 2017
Comprehensive Survey Date	July 18 & 19, 2017
Number of Native Species	28
Threatened/Special Concern Species	-
Exotic Plant Species	Curly-leaf pondweed, Pale yellow iris
Simpson's Diversity	0.77
Average Conservatism	5.5
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	10.3
Sensitivity to Acid Rain	Low Sensitivity

In the summer of 2003, staff from the WDNR verified the presence of curly-leaf pondweed (*Potamogeton crispus*; CLP) in Horsehead Lake. In 2007, Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was also confirmed within Horsehead Lake. Due to the possible negative effects associated with these exotic species, including loss of important native plant communities and their associated habitat value, water quality degradation, reductions in recreational opportunities, decreased aesthetic value, and loss of economic vitality, CLP and EWM have continued to be monitored within the lake.

The presence of aquatic invasive species (AIS) in Horsehead Lake, along with abundant native plant biomass, has led to concerns within the Horsehead Lake Protection and Rehabilitation District No. 1 (HLPRD) regarding the current and future condition of their highly valued lake. The HLPRD completed a comprehensive management plan in 2011 and applied for an AIS-EDR grant in 2012 to aid in the continued monitoring and control of AIS and to update the management 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 the lake group as a whole or a focus group called a Planning Committee and the completion of a stakeholder survey.

The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

General Public Meetings

The general public meetings were used to raise project awareness, gather comments, create the management goals and actions, and deliver the study results These meetings were open to anyone interested and were generally held during the summer, on a Saturday, to achieve maximum participation.

Kick-off Meeting

At the request of the Horsehead Lake Protection & Rehabilitation District No. 1, a kick-off meeting was not conducted because this is a management plan update project.

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. The first meeting is completed following the completion of the draft report sections of the management plan. The planning committee members were supplied with the draft report sections prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of the first meeting was to fortify a solid understanding of their lake among the committee members. The second planning committee meeting was held a few weeks after the first and concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

On June 20, 2018, Tim Hoyman of Onterra, LLC met with the HLPRD Planning Committee for 3.5 hours. The primary objective of this meeting was to present the results of the current and historical studies completed on Horsehead Lake. The committee was provided the report sections included below prior to the meeting. A great deal of discussion occurred during the meeting and all committee questions were answered.

Planning Committee Meeting II

The HLPRD Planning Committee was again convened on July 11, 2018. Tim Hoyman began the meeting by going through the conclusions of the studies completed on Horsehead Lake. Mr. Hoyman also detailed the results of the stakeholder survey that was completed as a part of the project. The group then moved on to create the framework of the implementation plan found in Section 5.0, below.

Stakeholder Survey

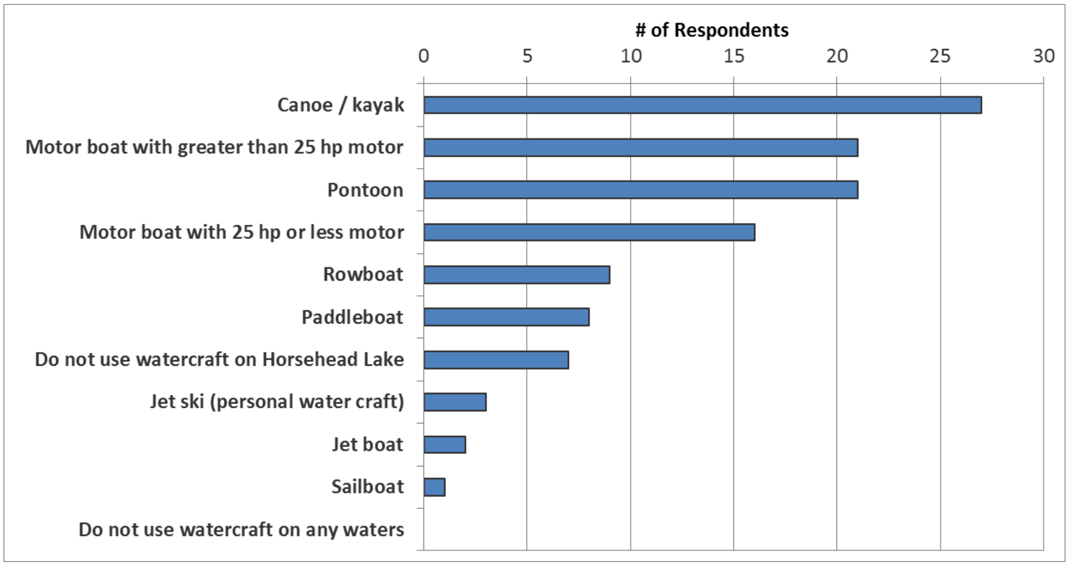
As a part of this project, a stakeholder survey was distributed to district members around Horsehead Lake. The survey was designed by Onterra staff and the HLPRD planning committee and reviewed by a WDNR social scientist. During April 2018 the nine-page, 39-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a HLPRD volunteer for analysis. Forty-nine percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the 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 below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Horsehead Lake. Thirty-three percent of stakeholder respondents are year-round residents, while 29% visit on weekends throughout the year, 22% live on the lake during the summer months only, 4% have undeveloped property, and 2% have resort properties. Forty-six percent of stakeholder respondents have owned their property for over 15 years, and 25% have owned their property for over 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 this survey. More than half of survey respondents indicate that they use either a canoe or kayak (Question 14). Larger motor boats, pontoons, and smaller motor boats were also popular options. On a relatively small lake such as Horsehead Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 17, two of the top recreational activities (open water fishing and motor boating, ranked 2nd and 4th, respectively) on the lake involve boat use. Although unsafe watercraft practices and excessive watercraft traffic are listed as factors potentially impacting Horsehead Lake in a negative manner (Question 23), they were ranked 8th and 9th, respectively, on a list of stakeholder's top concerns regarding the lake (Question 24).

A concern of stakeholders noted throughout the stakeholder survey (see Question 18 and survey comments – Appendix B) was excessive aquatic plant growth in Horsehead Lake. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question 14: What types of watercraft do you currently use on Horsehead Lake?



Question 17: Please rank up to three activities that are important reasons for owning your property on Horsehead Lake.

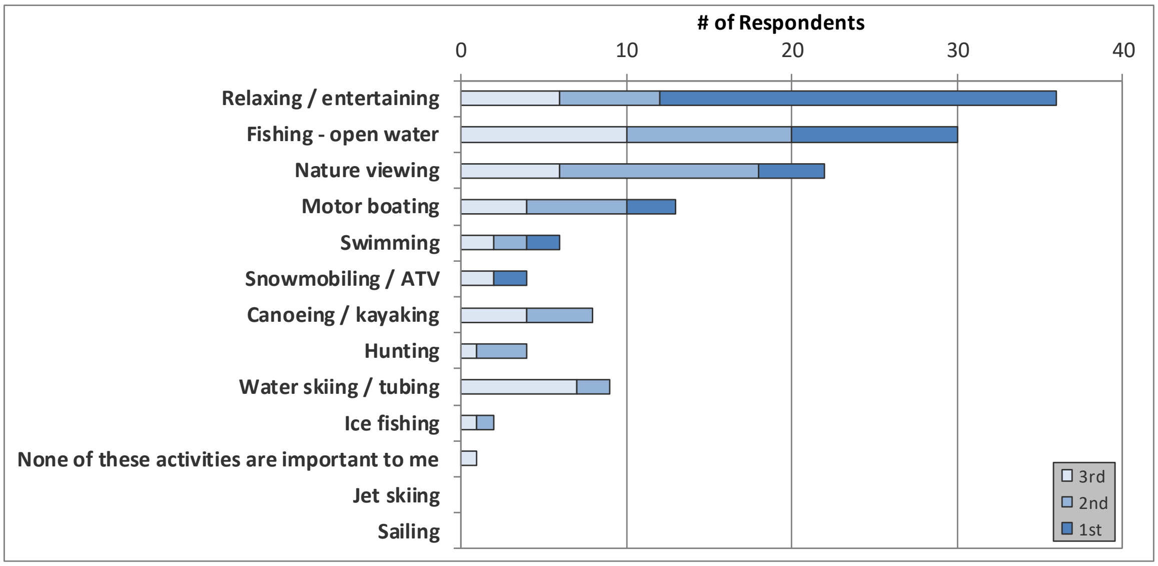
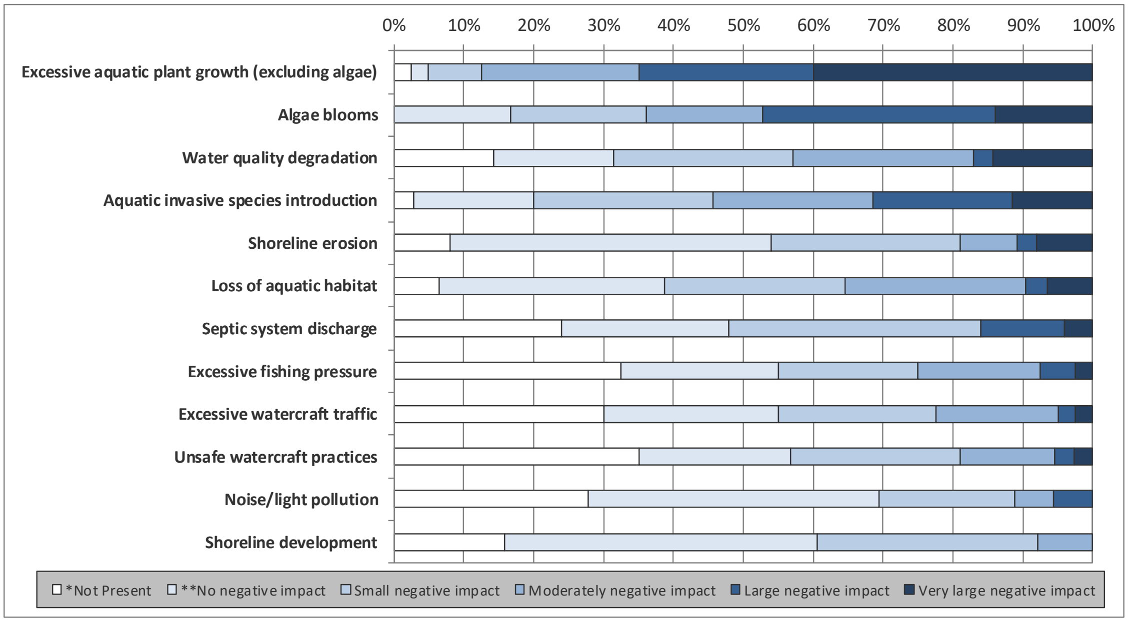


Figure 2.0-1. Select survey responses from the Horsehead Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 23: To what level do you believe these factors may be negatively impacting Horsehead Lake?



Question 24: Please rank your top three concerns regarding Horsehead Lake.

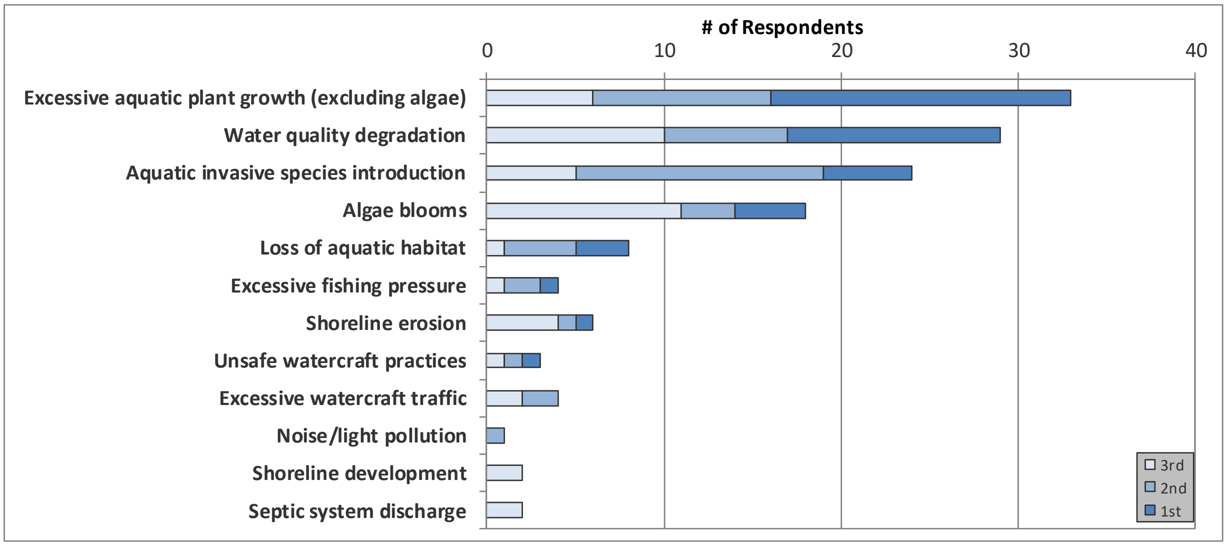


Figure 2.0-2. Select survey responses from the Horsehead Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

In early-November 2018, the HLPRD was provided with a draft of the full implementation plan. Many members provided comments and all were integrated into a second draft. The Planning Committee voted to pass that draft onto the HLPRD Board of Commissioners for its consideration. The HLPRD Board of Commissioners voted to accept the updated Horsehead Lake Management Plan on April 6, 2019 barring any major changes requested by the WDNR.

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 Horsehead Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). 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 Horsehead Lake's 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

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.

> 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.

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, fish kills 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 stratification, whether throughout the summer or periodically between mixing events, 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 turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks at a time).
- Lakes with hypolimnetic total phosphorus values less than 200 μg/L.

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations 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, two possibilities exist: 1) shoreland septic systems, and 2) internal phosphorus cycling. If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) 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 Horsehead Lake 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.

Because of its depth, small watershed and hydrology, Horsehead Lake is classified as a shallow headwater drainage lake (category 2 on Figure 3.1-1).

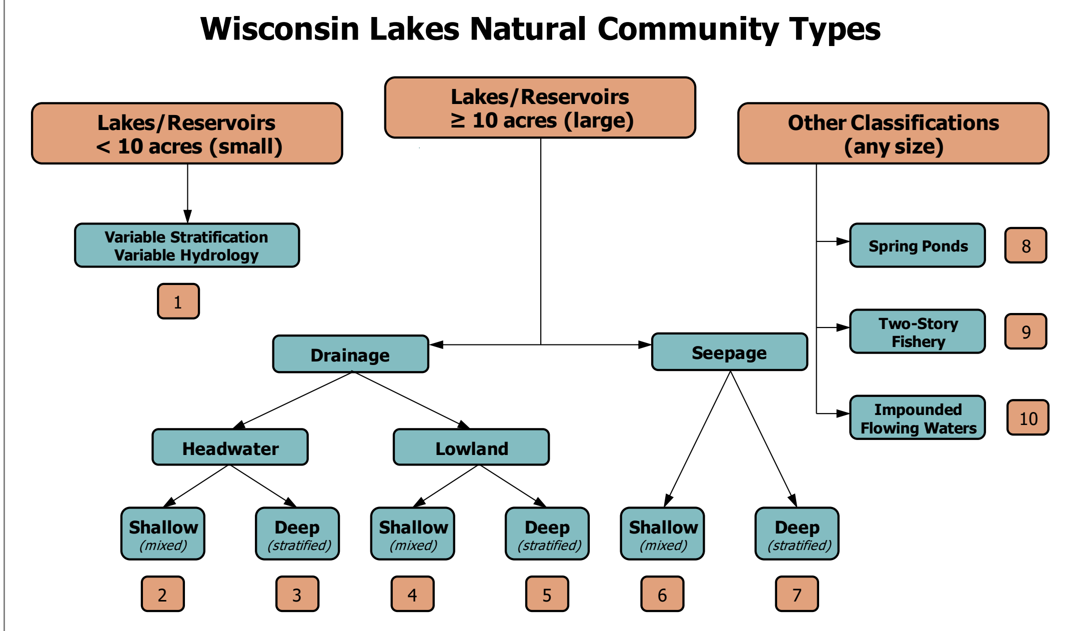


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Horsehead Lake is within the Northern Lakes and Forests (NLF) ecoregion.

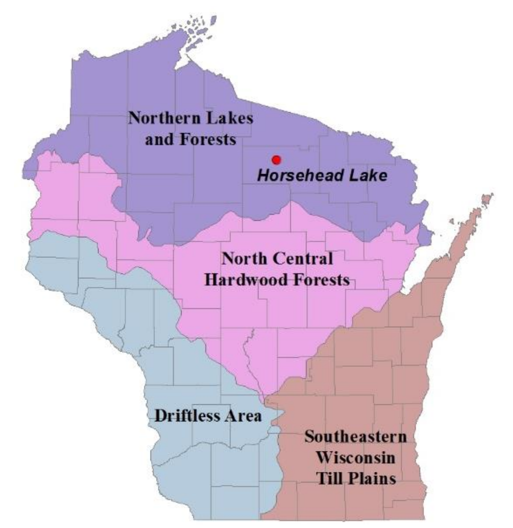


Figure 3.1-2. Location of Horsehead Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2018 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.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Horsehead Lake is displayed in Figures 3.1-3 - 3.1-13. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Horsehead Lake Water Quality Analysis

Horsehead Lake Long-term Trends

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Historic water quality data was available from a continual dataset from numerous past studies completed on Horsehead Lake. The data incorporates results collected for reports completed by Lumberjack (1974), Northern Lakes Services (1977 & 1993), Onterra (2007 & 2017), and from the HLPRD Citizens Lake Monitoring Network (CLMN) program.

Total Phosphorus

Near-surface total phosphorus data from Horsehead Lake are available annually from 2000 to 2017 (Figure 3.1-3). Near-surface total phosphorus data from Horsehead Lake are also available from 1973 and 1974; however, these data are suspect and is not believed to be representative of conditions in the lake. For that reason, those data were excluded from this analysis. Average summer total phosphorus concentrations ranged from 25 µg/L in 2012 to 67 µg/L in 2015. The weighted summer average total phosphorus concentration is 39 µg/L, which falls into the *good* category for Wisconsin's shallow headwaters drainage lakes. Phosphorus concentrations are variable between years with 2002, 2009, and 2015 having the highest growing season and summer mean concentrations. The years with the lowest concentrations were 2004 and 2012. The lake's weighted summer average total phosphorus concentration is higher than the majority of other shallow headwater drainage lakes in the state and is almost two times higher than the majority of all lake types within the NLF ecoregion. As illustrated in Figure 3.1-3, average annual growing season and summer near-surface phosphorus concentrations have been variable; however, a regression analysis indicated that there was no significant overall trend occurring from 2000 to 2017.

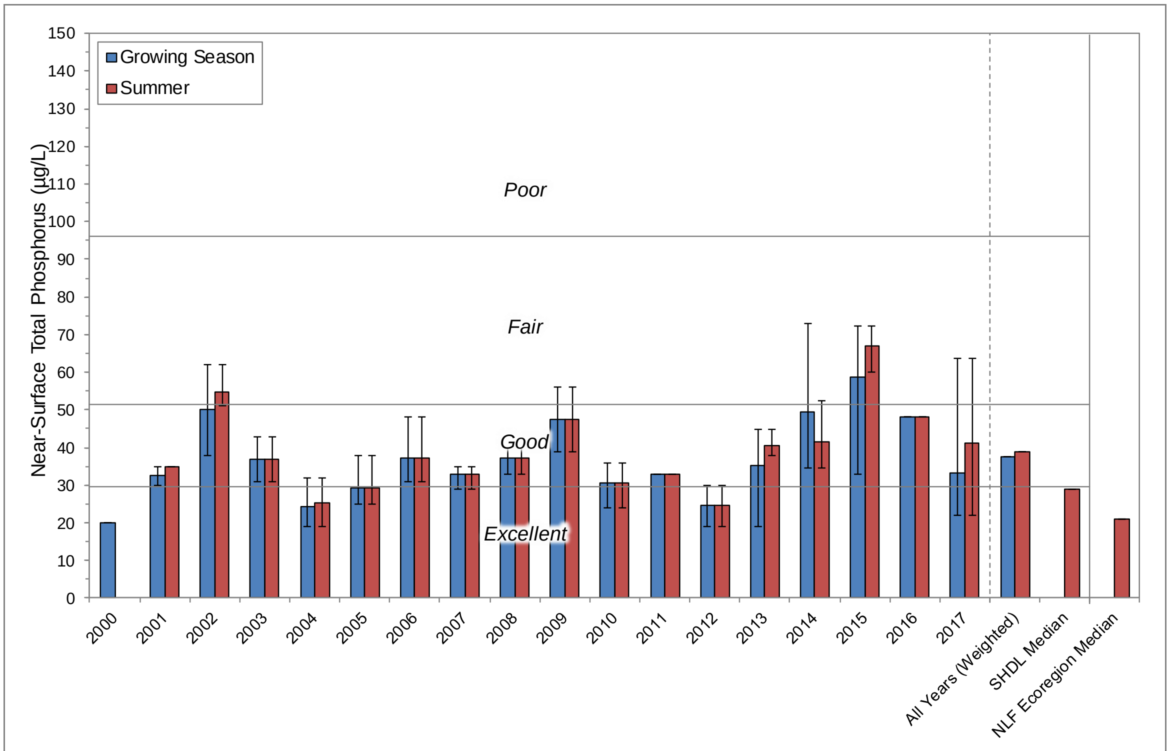


Figure 3.1-3. Horsehead Lake, shallow headwater drainage lakes, and Northern Lakes and Forests (NLF) total phosphorus concentrations. Mean values calculated with summer month surface sample data. Data from 1973 and 1974 were not included. Water Quality Index values adapted from WDNR PUB WT-913.

Figure 3.1-4 displays the change in total phosphorus concentration between the spring and summer months. Phosphorus concentrations, on average are much higher in the summer. This pattern of increasing phosphorus concentrations over the course of the growing season is an indication that *internal nutrient loading* is likely occurring; a phenomenon often observed in shallow lakes. Lakes typically act as phosphorus 'sinks', meaning that less phosphorus leaves the lake than the amount that entered from its watershed. Most of the phosphorus that enters a lake tends to eventually become bound within bottom sediments. Typically, in deep lakes, phosphorus concentrations tend to be higher in the spring when precipitation and runoff are higher, lower in the summer as phytoplankton consume phosphorus, die, and sink to the bottom, and higher again in the fall following fall turnover.

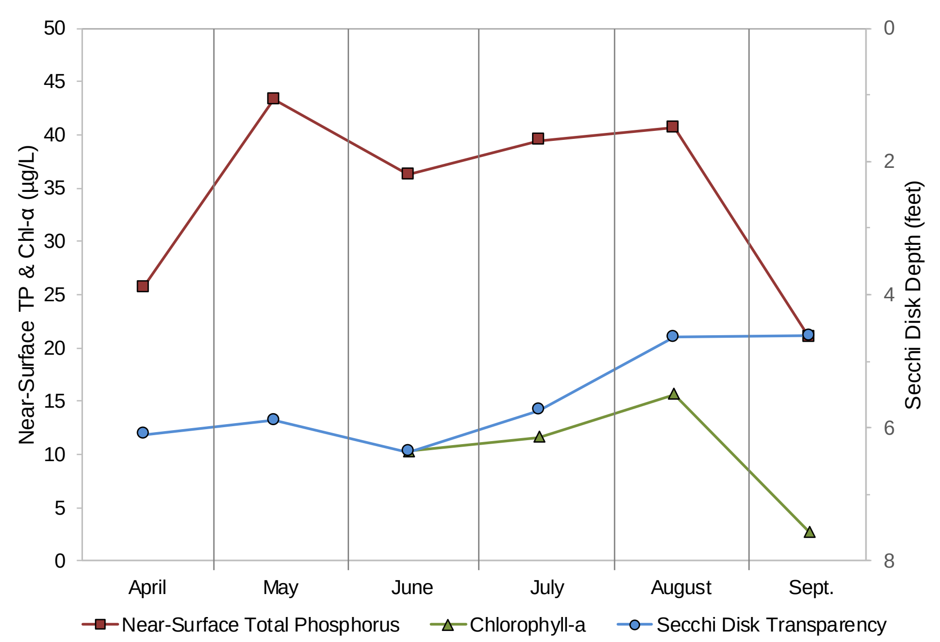


Figure 3.1-4. Horsehead Lake average monthly near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency using all available data. Data from 1973 and 1974 were not included.

Internal nutrient loading, or internal nutrient recycling, involves the release of phosphorus once bound in the lake sediment back into the overlying water column. The release of phosphorus from bottom sediments into the overlying water occurs under two primary environmental conditions: 1) anoxia and/or 2) elevated water pH. In the presence of oxygen, phosphorus remains bound to ferric iron within the sediment. When the overlying water becomes anoxic, or devoid of oxygen, the iron is reduced to ferrous iron and the bond with phosphorus is broken resulting in both iron and phosphorus being released into the water (Pettersson 1998).

Phosphorus can also be released from bottom sediments into the overlying water when water pH becomes elevated to 9.0 or above. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be found in some acid bog lakes and higher than 8.4 in some marl lakes and highly productive lakes (Shaw and Nimphius 1985).

Carbon dioxide dissolves in and reacts with lake water to form carbonic acid which lowers the water's pH. However, during the day, photosynthesizing phytoplankton and *macrophytes* consume carbon dioxide and water pH rises. When phytoplankton and/or macrophytes become overly abundant they have the capacity to raise a lake's pH to 9.0 or greater during the day. When pH reaches these levels, the tendency of phosphorus to remain bound within the sediment is reduced, and phosphorus can be released from sediment under these conditions even in the presence of oxygen (Solim and Wanganeo 2009).

Macrophytes are larger aquatic plants that can be seen with the naked eye and include flowering plants such as pondweeds and milfoils and macroalgae like muskgrasses among others.

In Horsehead Lake, it is believed that phosphorus is being released from bottom sediments during the summer due to both anoxia and elevated pH. The anoxic conditions in Horsehead Lake are not resulting from thermal stratification, but are likely arising from a different process. Horsehead Lake is shallow with a large surface area, and thus is classified as a polymictic lake.

The temperature and dissolved oxygen data collected in 2017 show that Horsehead Lake's temperature and dissolved oxygen were fairly uniform throughout the water column during every sampling event, an indication that the lake was not thermally stratified. While the development of anoxia due to thermal stratification is likely not occurring in Horsehead Lake, it is believed that anoxia may be developing at the sediment-water interface within areas of dense aquatic plant growth, and consequently, phosphorus is being released from bottom sediments in these areas.

Studies involving aquatic plants and sediment phosphorus release have found that some aquatic plants with deep root systems, like wild celery (*Vallisneria americana*), oxygenate the sediments and prevent phosphorus release, while others with shallow root systems such as common waterweed (*Elodea canadensis*) and Eurasian watermilfoil (*Myriophyllum spicatum*), or those with no root systems, like coontail (*Ceratophyllum demersum*), caused reductions in oxygen at the sediment-water interface and increased the release of phosphorus into the water (Wigand et al. 1997; Boros et al. 2011; Dai et al. 2015). Wigand et al. 1997 found that when the water column was occupied by 80-100% coverage of these shallow-rooted aquatic plants, phosphorus was released from bottom sediments. Horsehead Lake contains many areas with dense aquatic plant growth, and the 2017 whole-lake point-intercept survey found that 48% of the aquatic plant community is comprised of common waterweed and coontail, plants that have been shown to cause phosphorus release from bottom sediments in areas with dense growth. As is discussed further in this report, while the dense growth of common waterweed and coontail (among others) in Horsehead Lake is likely causing the observed increases in phosphorus during the summer, the benefits these plants provide to the lake outweigh their effects on the lake's phosphorus concentrations.

The paleoecological study discussed in Section 3.2, found that at the present time the macrophyte community is more dense than it was prior to the settlement of Euro-Americans, first with logging and then with limited agriculture, and now shoreland development. Historically, Horsehead Lake had low phosphorus concentrations and much less macrophytes than it does now. The paleoecological study only compared the present day community with the community prior to Euro-American settlement so it is not possible to know when the lake changed. The diatom community now classifies the lake's biotic integrity as poor while historically it was good.

Elevated pH has also been shown to cause the release of phosphorus from bottom sediments. In 2017, the highest pH recorded in Horsehead Lake was 10.3, indicating that elevated pH may be a significant contributor to phosphorus release from bottom sediments.

Chlorophyll-α

As discussed in the primer section, chlorophyll-*a* is a measure of free-floating algal biomass within a lake and is usually positively correlated with total phosphorus concentrations. Chlorophyll-*a* concentration data are available from Horsehead Lake annually from 2000 to 2017 (Figure 3.1-5). Average summer chlorophyll-*a* concentrations ranged from 7 µg/L in 2010 to 26 µg/L in 2001 The weighted summer chlorophyll-*a* concentration is 13 µg/L, which falls within the *good* category for chlorophyll-*a* concentrations in Wisconsin's shallow headwater drainage lakes. The lake's weighted summer chlorophyll-*a* concentration is almost two times higher than the median concentration for shallow headwater drainage lakes in Wisconsin and just over two times higher than all lake types within the NLF ecoregion. The 2017 average summer chlorophyll-*a* concentration was just below the weighted average, with an average concentration of 11 µg/L. As illustrated in Figure 3.1-4, average annual growing season and summer near-surface chlorophyll-*a* concentrations have been variable; however, a regression analysis indicated that there was no significant trend occurring during the last 20 years.

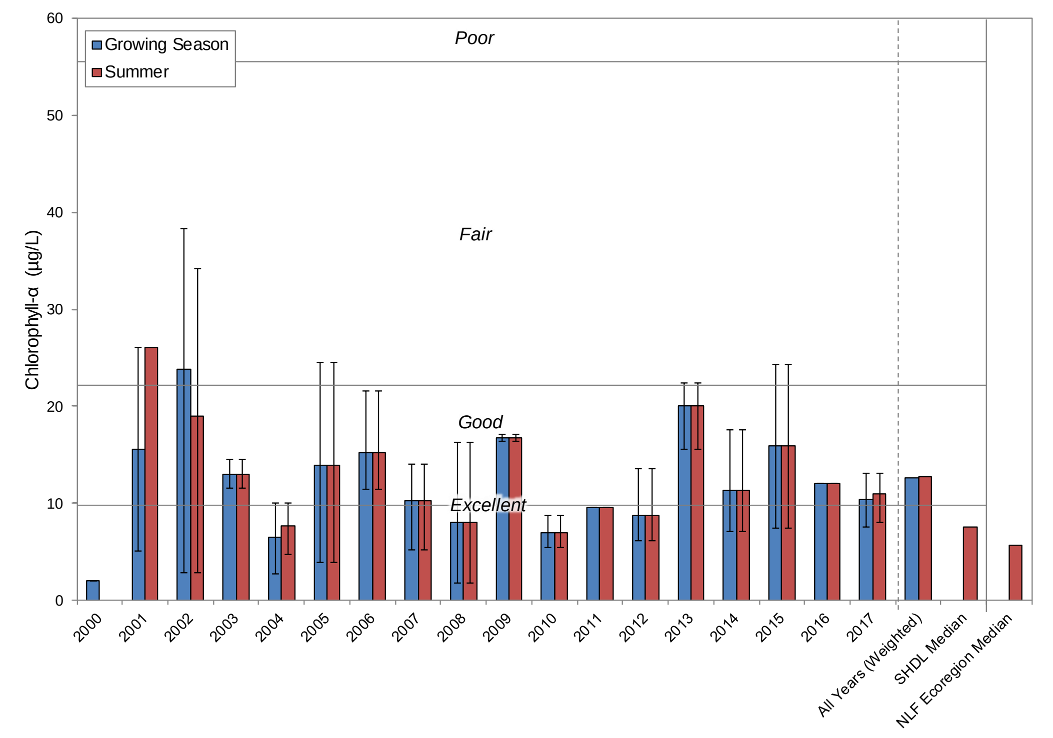


Figure 3.1-5. Horsehead Lake, shallow headwater drainage lakes, and Northern Lakes and Forests (NLF) chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* concentrations were lower than expected in Horsehead lake based on measured total phosphorus concentrations (Figure 3.1-6). The reduced amount of chlorophyll-*a* with the available total phosphorus indicates that another factor(s) other than phosphorus is limiting the growth of phytoplankton in Horsehead Lake.

As is discussed in the Limiting Nutrient of Horsehead Lake Section, the ratio of total nitrogen to total phosphorus is utilized to determine which of these two nutrients is limiting phytoplankton growth. Data collected at the deep hole location indicate phosphorus was the limiting nutrient over the course of the growing season.

Dissolved calcium can reach concentrations at which no additional calcium can be dissolved (saturation point). When this happens, the calcium combines with carbonate forming calcium carbonate, or marl, and it precipitates out of the water. The precipitation of calcium carbonate also absorbs phosphorus, making it unusable by phytoplankton. However, concentrations of calcium measured in Horsehead Lake in 2017 were found to be fairly low, at 11.2 mg/L.

Despite phosphorus being the limiting nutrient in Horsehead Lake and the lower measured concentration of calcium, chlorophyll-*a* concentrations were still lower than predicted. It is believed that the abundance of macrophytes is the primary factor regulating phytoplankton production. Aquatic macrophytes provide zooplankton, small free-floating animals, with refuge from predatory fish. Zooplankton feed on phytoplankton and the abundance of aquatic plants in Horsehead Lake likely allows for a robust zooplankton community which graze and limit the growth of phytoplankton (Moss et al. 2013). Light limitation is not thought to be a limiting factor for phytoplankton production in Horsehead Lake as the lake has good water clarity. Primary production in Horsehead Lake is primarily occurring in macrophyte production, maintaining a clear water state in lieu of a turbid state dominated by phytoplankton.

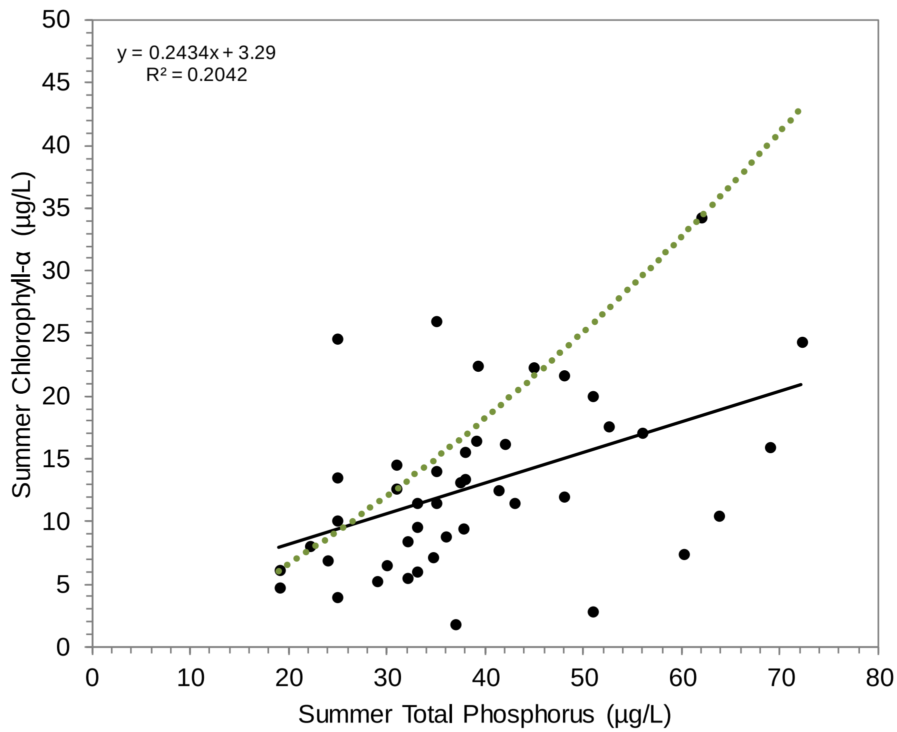


Figure 3.1-6. Simple linear regression of summer total phosphorus concentrations and summer chlorophyll-a concentrations along with predicted chlorophyll-*a* values in Horsehead Lake. Solid black line represents the relationship between total phosphorus and chlorophyll-*a* in Horsehead Lake while the dotted green line represents predicted chlorophyll-*a* concentrations based on measured total phosphorus concentrations.

Water Clarity

Secchi disk transparency data are available from Horsehead Lake intermittently from 1973 to 1997 and annually from 1999 to 2017 (Figure 3.1-7). Average summer Secchi disk depth ranged from 0.2 feet in 1973 to 9.5 feet in 1996. It should be noted that only one summer Secchi disk depth measurement was collected in 1973 and may not be representative of the summer average for that year. The weighted summer average Secchi disk depth is 5.5 feet, which falls just into the *excellent* category for Secchi disk depth in Wisconsin's shallow headwater drainage lakes. The weighted average summer Secchi disk depth is similar to the median value for shallow headwater drainage lakes in Wisconsin and is approximately 1.5 times lower than all lake types within the NLF ecoregion.

As total phosphorus and chlorophyll-*a* concentrations, Secchi disk transparency is variable over the last 20 years and did not display a statistically significant trend and no correlation is observed between Secchi disk depth and precipitation.

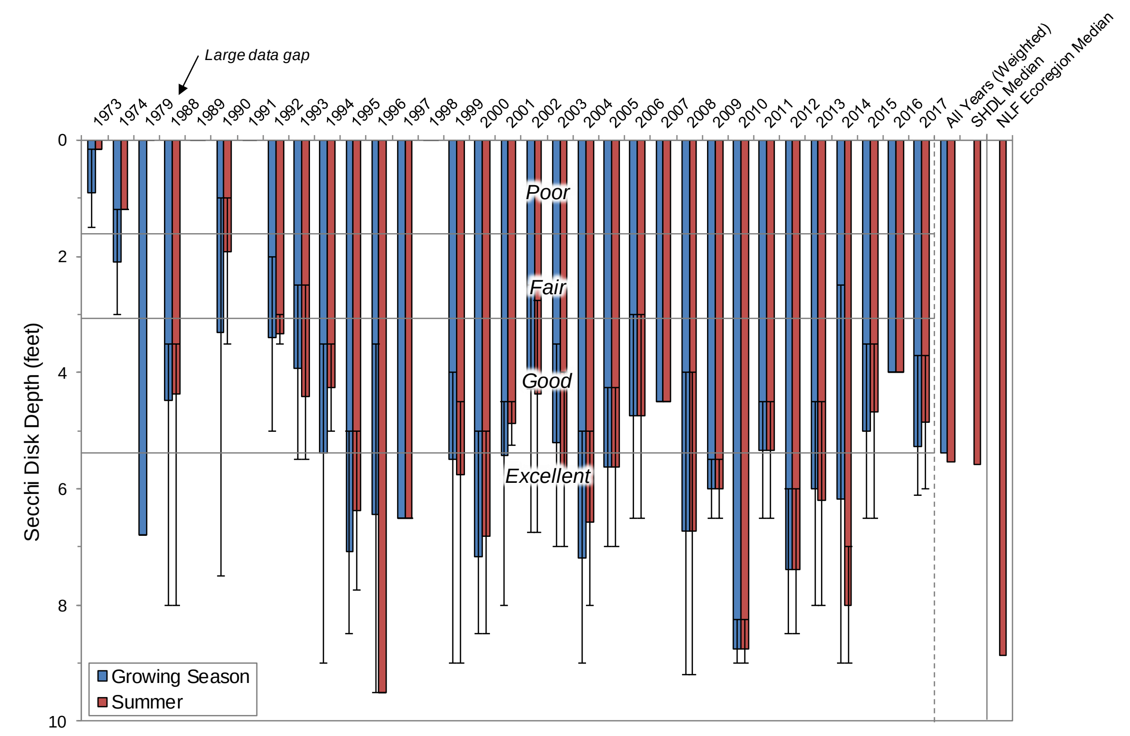


Figure 3.1-7. Horsehead Lake, shallow headwater drainage lakes, and Northern Lakes and Forests (NLF) Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in Horsehead Lake in 2017 with a concentration of 2 mg/L in April, indicating minimal amounts of suspended material within the water. While suspended particles are minimal in the lakes, water clarity can also be influenced by dissolved compounds within the water. Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity.

A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Horsehead Lake in 2017 averaged 12.5 SU (standard units) indicating the lake's water is *slightly colored* and that the lake's water clarity is not influenced by dissolved components in the water (Figure 3.1-8).

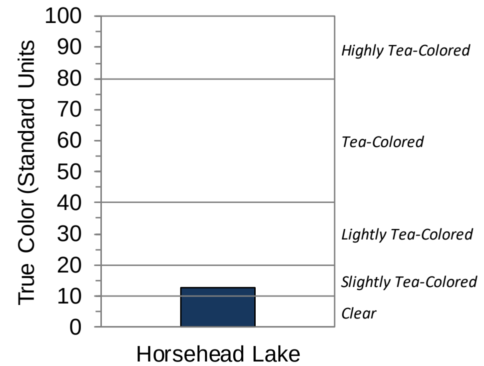


Figure 3.1-8. Horsehead Lake true color value.

Limiting Plant Nutrient of Horsehead Lake

Using midsummer nitrogen and phosphorus concentrations from Horsehead Lake, a nitrogen:phosphorus ratio of 23:1 was calculated. This finding indicates that Horsehead Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Horsehead Lake Trophic State

Figure 3.1-9 contains the weighted average Trophic State Index (TSI) values for Horsehead Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved compounds in the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for Secchi disk depth are nearly all in the eutrophic range with a few in the mesotrophic range and a couple of years in the 1970s in the hypereutrophic range. The weighted TSI values for total phosphorus and chlorophyll-*a* are in the eutrophic range (Figure 3.1-9). Horsehead Lake is more productive than other shallow headwater drainage lakes in Wisconsin and the majority of lakes in the NLF ecoregion. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* values it can be concluded that Horsehead Lake is eutrophic unlike most other lakes in northern Wisconsin.

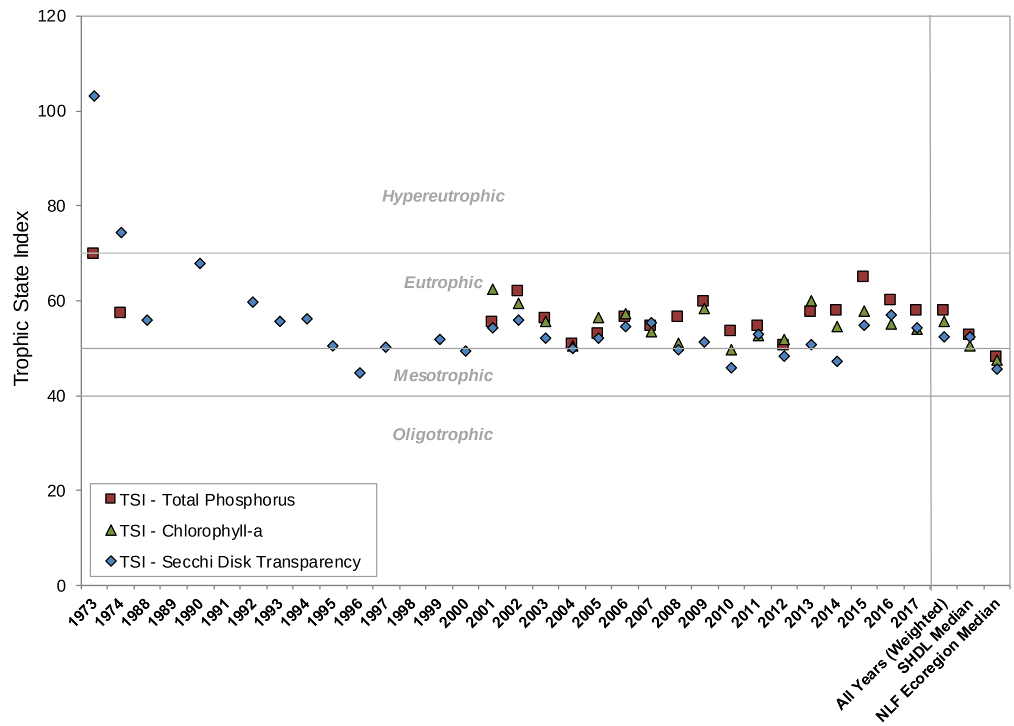


Figure 3.1-9. Horsehead Lake, shallow headwater drainage lakes, and Northern Lakes and Forests (NLF) Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Horsehead Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Horsehead Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-10.

Horsehead Lake is polymictic [lakes that are too shallow to thermally stratify and can mix throughout the growing season] and the temperature at the bottom was over 20°C in July 2017, indicating that the lake frequently mixes (Figure 3.1-10).

During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. The data also indicate that there was very little oxygen throughout most of the water column under the ice during late-winter sampling (Figure 3.1-10). In general, dissolved oxygen levels should be greater than 2-3 mg/L in order to support fish populations. At the surface in the winter of 2018, oxygen levels were already below 2 mg/L.

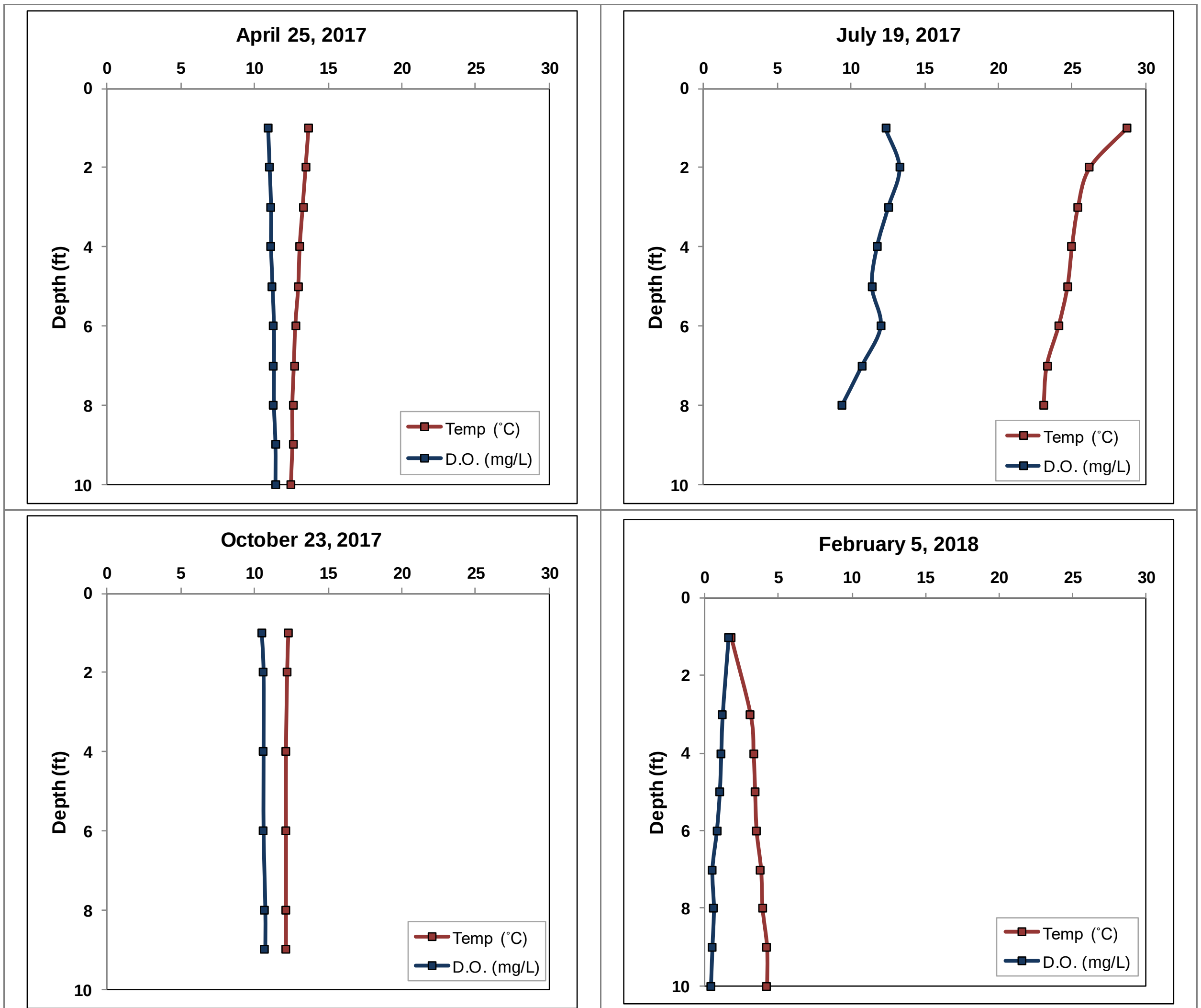


Figure 3.1-10. Horsehead Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Horsehead Lake

The water quality section 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 Horsehead 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 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 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 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 pH of the water in Horsehead Lake was found to be alkaline with a value of 10.3 (Figure 3.1-11, top frame). While the lake's pH falls outside the normal range for most lakes in Wisconsin, this higher pH is due to the large macrophyte community in the lake. During photosynthesis acidic carbon dioxide is removed from the water which causes pH to rise.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against 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 ($CaMgCO_3$). In the absence of photosynthetically induced elevated pH values, a lake's pH is primarily determined by the amount of alkalinity. 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. The alkalinity in Horsehead Lake was measured at 37.8 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain (figure 3.1-11, bottom frame).

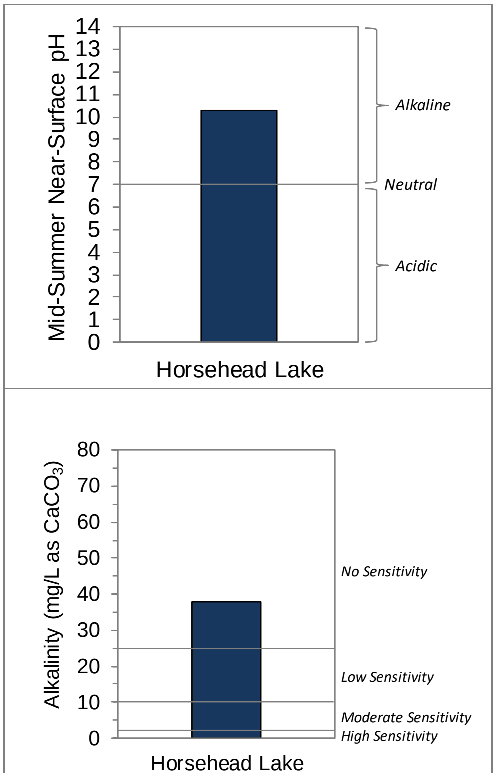


Figure 3.1-11. Horsehead Lake mid-summer near-surface pH value and average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

Like associated alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Horsehead Lake's pH of 10.3 falls outside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Horsehead Lake was found to be 11.2 mg/L, falling just below the optimal range for zebra mussels (Figure 3.1-12).

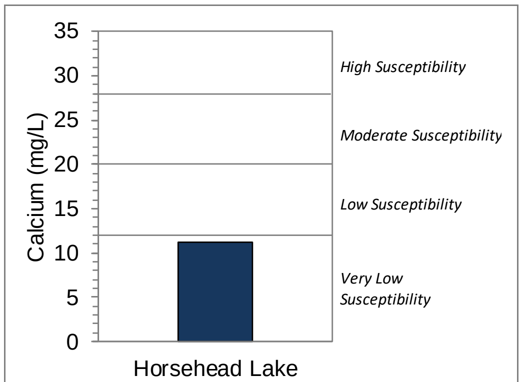


Figure 3.1-12. Horsehead Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

Zebra mussels (*Dreissena polymorpha*) are small bottom dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring. Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Horsehead Lake was considered not suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Horsehead Lake in 2017 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2017 surveys.

Stakeholder Survey Responses to Horsehead Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of Horsehead Lake and how it may have changed over the years. Of the 100 surveys distributed, 49 (49%) were returned. Without a response rate of 60% or higher, the responses to the following questions regarding water quality cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of water quality in Horsehead Lake but cannot be stated with statistical confidence.

Figure 3.1-13 displays the responses of Horsehead Lake stakeholder respondents to questions regarding water quality and how it has changed over their years visiting Horsehead Lake. When asked how they would describe the current water quality of Horsehead Lake the majority of respondents, 41%, indicated *good*, 33% indicated *fair*, 16% indicated *poor*, 6% indicated they were *unsure*, 4% indicated *very poor*.

When asked how they believe the current water quality has changed since they first visited the lake, 41% indicated it has *remained the same*, 21% indicated it has *somewhat degraded*, 14% indicated it has *somewhat improved*, 12% indicated they were *unsure*, 6% indicated it has *greatly improved*, and 6% indicated it has *severely degraded* (Figure 3.1-13). As discussed in the previous section, Horsehead Lake has good water quality. However, as discussed in the Paleoecology Section (3.2), Horsehead Lake's water quality is worse than it was historically, likely due to shoreland development.

18. How would you describe the current overall water quality of Horsehead Lake?

19. How as the overall water quality changed in Horsehead Lake since you first visited the lake?

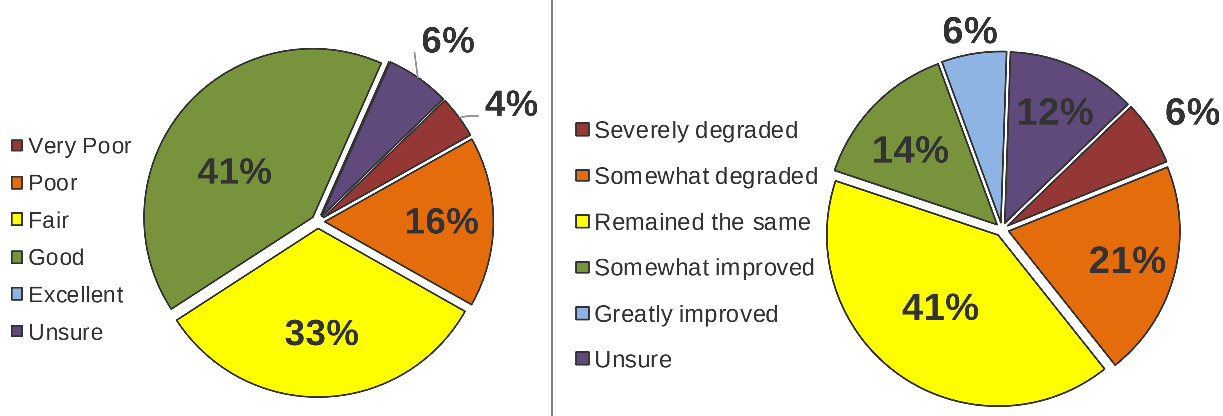


Figure 3.1-13. Horsehead Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

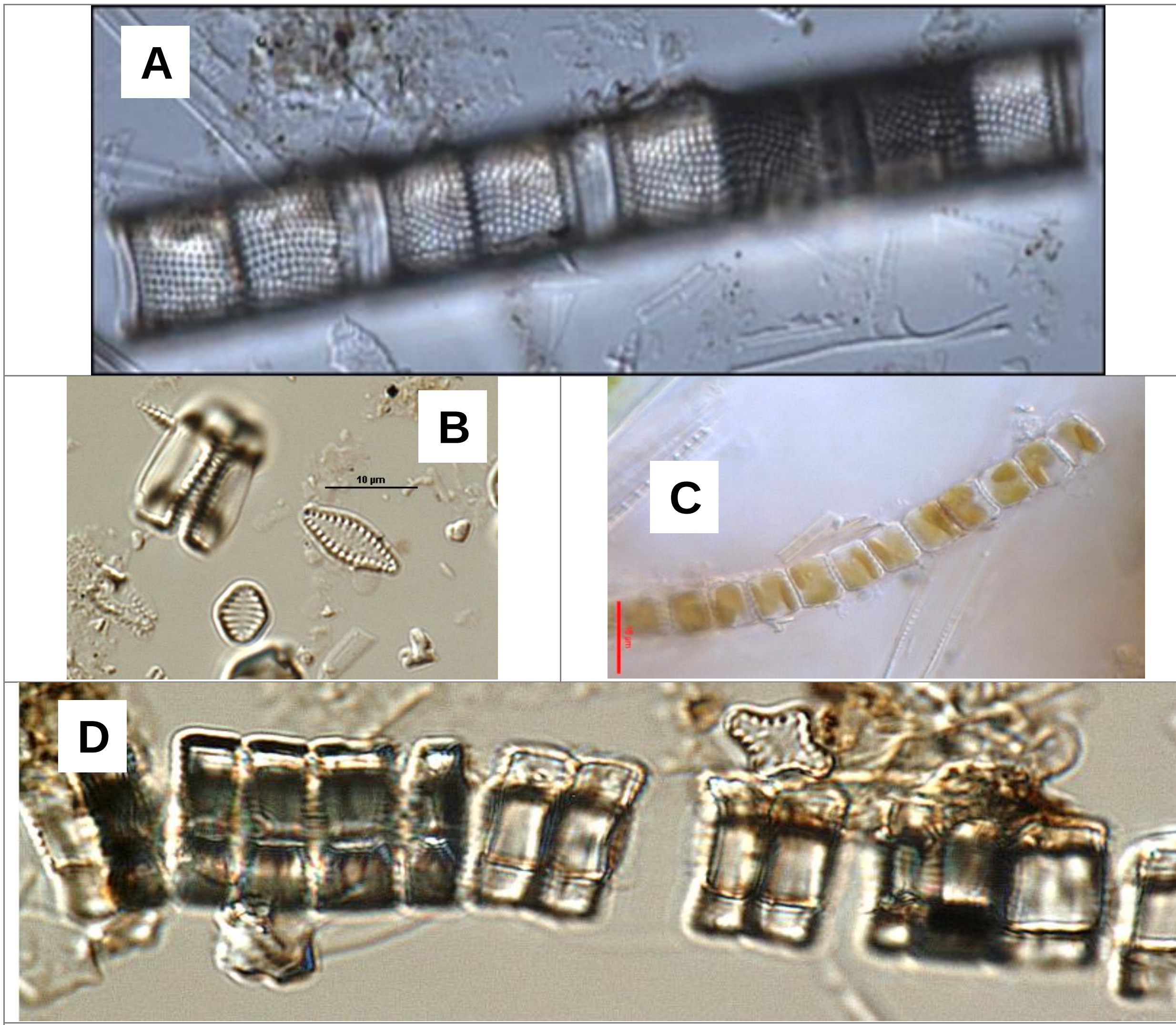
3.2 Paleoecology

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 Photograph 3.2-1, 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.

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.



Photograph 3.2-1. Photomicrographs of the diatoms commonly found in the sediment core from Horsehead Lake. The diatom *Aulacoseira ambigua* (A) is found floating in the open water and was common in the bottom sample. The other diatoms are benthic diatoms which grow attached to macrophytes. *Pseudostaurosira brevistriata* (B) was more common in the top sample while *Staurosirella pinnata* (C) and *Staurosira construens* (D) were equally common in the bottom and top samples.

Horsehead Lake Paleoecological Results

A sediment core was collected from the deep area in Horsehead Lake by Onterra staff on October 23, 2017. The total length of the core was 76 cm. The depth of the water at the coring site was 10 feet.

The top 1 cm was kept for analysis and it is assumed this represents present day water quality conditions in the lake. A bottom sample, 36-38 cm, was analyzed and this is assumed to represent conditions before the arrival Euro-American settlers in the middle of the nineteenth century.

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Horsehead Lake, an exploratory detrended correspondence analysis (DCA) was performed (CANOCO 5 software, ter Braak and Smilauer, 2012). The DCA analysis has been done on many WI lakes to examine the similarities of the diatom communities between the top and bottom samples of the same lake.

The results revealed two clear axes of variation in the diatom data, with 31% and 21% of the variance explained by axis 1 and axis 2, respectively (Figure 3.2-1). 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.

Horsehead Lake is near the top of Figure 3.2-1 because a large part of the diatom community is composed of benthic diatoms unlike many other lakes in this analysis. There is a wide separation between the bottom and top samples indicating the environmental conditions today are much different than they were historically. As will be discussed below, the diatom community has changed from one where there were considerable numbers of planktonic diatoms while now there are none. Horsehead Lake which is at the top of the figure has very few planktonic diatoms in both the top and bottom samples.

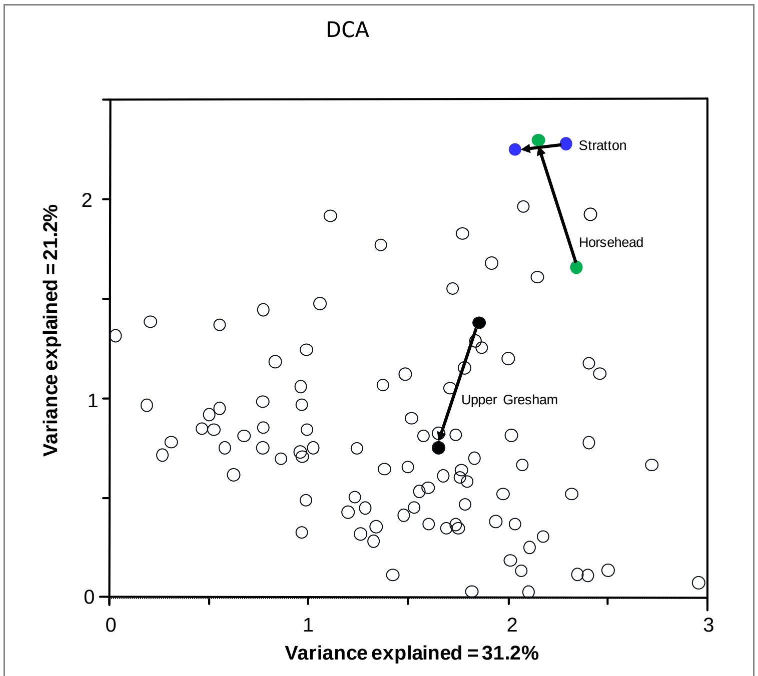


Figure 3.2-1. DCA plot of top/bottom samples from Horsehead Lake. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. Horsehead Lake has changed a significant amount since the arrival of Euro-American settlers over 150 years ago.

Diatom Community Changes

The diatom community in the bottom sample of the Horsehead Lake core was dominated by benthic diatoms especially benthic *Fragilaria* (Figure 3.2-2) which typically grow directly on the sediment or other substrates such as macrophytes. Planktonic diatoms, those that float in the open water, made up about 35% of the diatom community. The dominant planktonic diatom was

Aulacoseira ambigua which is often found in lakes in northern Wisconsin, Michigan, and Minnesota that have low phosphorus levels (Camburn and Kingston 1986, Kingston et al. 1990, Garrison and Fitzgerald 2005). The presence of this diatom in a lake as shallow as Horsehead Lake indicates that historically the lake must have had low phosphorus levels and few macrophytes.

In the top sample there are no planktonic diatoms (Figure 3.2-2). Both benthic *Fragilaria* and small *Fragilaria* (Photograph 3.2-1C) increased in the top sample primarily because of the absence of planktonic diatoms. The lack of planktonic diatoms when they were common historically likely indicates an increase in macrophyte coverage as well as higher phosphorus concentrations. Borman (2007) found that in northwestern Wisconsin, the macrophyte community often changed in seepage lakes, from one dominated by low growing plants to a community dominated by larger macrophytes, as a result of shoreline development. The structure of the macrophyte community changes because the increased runoff of sediment during construction on the shoreline enables the establishment of the larger plants. With the larger plants there is much more surface area available on which diatoms and the other periphytic algae are able to grow.

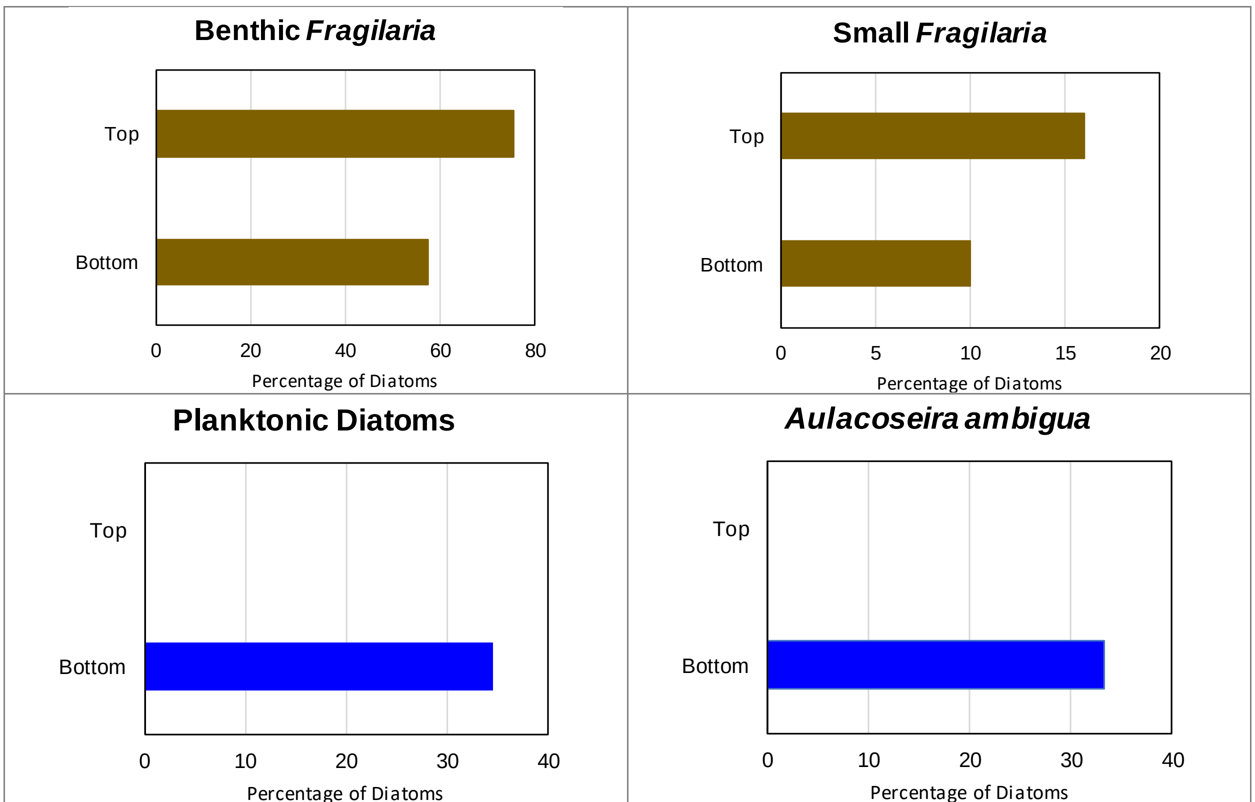


Figure 3.2-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Horsehead Lake. Some planktonic diatoms were found in the bottom sample but not in the top sample indicating that nutrient levels have increased in the lake.

Lake Diatom Condition Index

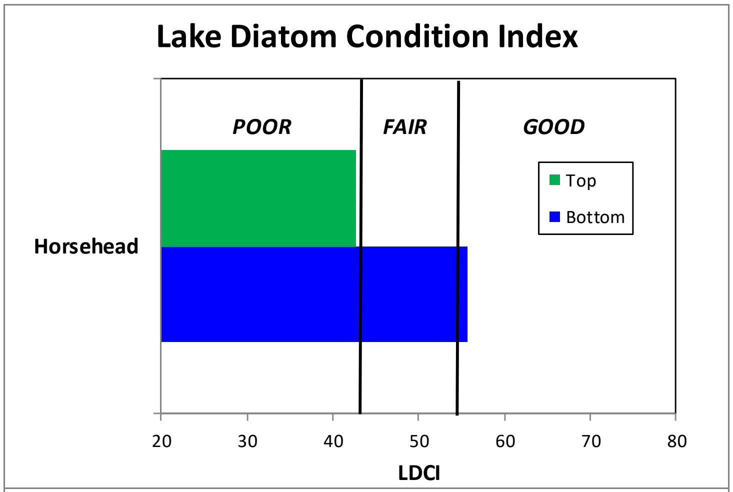


Figure 3.2-3. The Lake Diatom Condition Index (LDCI) for Horsehead Lake. The biotic integrity is poorer in the top sample compared with the bottom sample because historically the lake was oligotrophic with very few macrophytes.

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 in the bottom sample places Horsehead Lake in the good category (Figure 3.2-3) while the top sample has a LDCI in the poor category. This indicates that during the last 150 years the lake's biotic integrity has been degraded.

As mentioned above, nutrients are an important part of the LDCI. As shown in Figure 3.2-4, the percentage of diatoms typically found at higher phosphorus and nitrogen concentrations are more common in the top sample of the core.

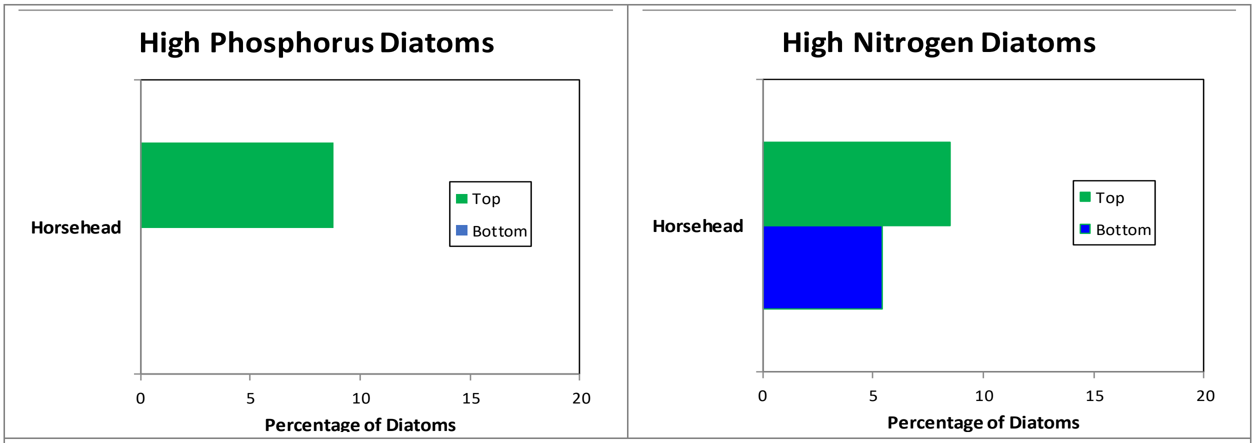


Figure 3.2-4. The amount of diatoms that prefer high phosphorus and nitrogen concentrations that were present in the top and bottom samples from Horsehead Lake. This increase in nutrients in the top sample is consistent with the loss of planktonic diatoms.

Summary

Horsehead Lake has seen a significant degradation of water quality over the last 150 years. Historically, the lake had low phosphorus concentrations and some macrophytes. The presence of significant amounts of planktonic diatoms in this shallow lake historically, indicates this lake must to have had low phosphorus levels. The lake now is deeper than it was when the bottom sample was deposited since there is now a dam on the lake's outlet which raises the lake a few feet.

Often models using the historical diatom community can be used to estimate the historical phosphorus levels. These models are not accurate in lakes like Horsehead Lake where the diatom community is dominated by benthic diatoms. These types of diatoms do not always respond linearly to changes in phosphorus concentrations (Bennion et al. 2001, Juggins et al. 2013). Although we are not able to accurately estimate the phosphorus levels prior to the arrival of Euro-Americans it likely was in the range of 15 to 20 µg/L. This estimate is based upon other similar lakes in northern Wisconsin. This estimated concentration is much lower than the present-day summer phosphorus concentration of 38 µg/L.

At the present time there are no planktonic diatoms which suggests more macrophyte than historically. The increase in macrophytes which increased nutrients is a common occurrence in lakes. Studies have found that the littoral area of a lake often responds earliest to increased nutrient input from the watershed. This is because the littoral zone is the interface between the surrounding watershed and the main body of the lake. The increase in macrophytes experienced in Horsehead Lake has been observed in many other Wisconsin lakes as a result of shoreland development. The few lakes that have been cored that do not have cottages or homes do not generally show an increase in diatoms that are indicative of increased macrophyte growth. This trend of increased macrophyte cover with shoreland development has also been seen in lakes in northeastern US (Vermaire and Gregory-Eaves 2008). To be clear, the impact of development considered here is not just the 'presence' of the cottages and homes on the lake. It is the act of creating the development on the lakes, which includes the land clearing to create the structures, but also the roads leading to them and of course in many cases, the roads leading to those roads.

At the present time with higher phosphorus levels and more macrophytes, the lake's biotic integrity is worse than it was historically. Prior to the arrival of Euro-Americans the lake's condition was good but now the diatom community indicates that it is poor.

3.3 Watershed Assessment

Watershed Modeling

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.

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 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, increased sedimentation, and/or overabundant macrophyte populations. For these reasons, it is important to maintain as much natural land cover (forests, wetlands, etc.) as possible within a lake's watershed to minimize the amount runoff (nutrients, sediment, etc.) from entering the lake.

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. In fact, 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 sheer amount of land draining to the lake. Situations actually occur where lakes with completely 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 sufficiently to see a change in plant production. Both of these situations occur frequently in impoundments.

Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper lake with a greater volume can dilute more phosphorus within its waters than a less voluminous lake and as a result, the production of a lake is kept low. However, in that same lake, because of its low flushing rate (a residence time of years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time and lead to a problem such as internal nutrient loading. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

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). 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. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, 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.

Horsehead Lake Watershed Assessment

Horsehead Lake's watershed encompasses an area of approximately 1,022 acres, yielding a watershed to lake area ratio of approximately 2:1 (Map 2). In other words, approximately two acres of land drain to every one acre of Horsehead Lake. According to WiLMS modeling, the lake's water is completely replaced approximately once every 110 days (residence time) or 3 times per year (flushing rate).

Approximately 48% of Horsehead Lake's watershed is composed of forest, 38% of the lake's surface, 7% of wetlands, and 7% of pasture/grass (Figure 3.3-1). The remaining portions of Horsehead Lake's watershed are composed of rural residential areas.

As discussed earlier, the land cover within watersheds of lakes with watershed to lake area ratios of 10-15:1 or less has a greater influence on the water quality of the lake. Utilizing the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Horsehead Lake's watershed. It was estimated that approximately 178 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.3-2). Phosphorus loading from septic systems was also estimated using data obtained from the 2018 stakeholder survey of riparian property owners. Of the estimated 178 pounds of phosphorus being delivered annually to the lake, 58% is estimated to originate from direct atmospheric deposition into the lake, 22% from forest, 10% from pasture/grass, 6% from riparian septic systems, and 4% from wetlands.

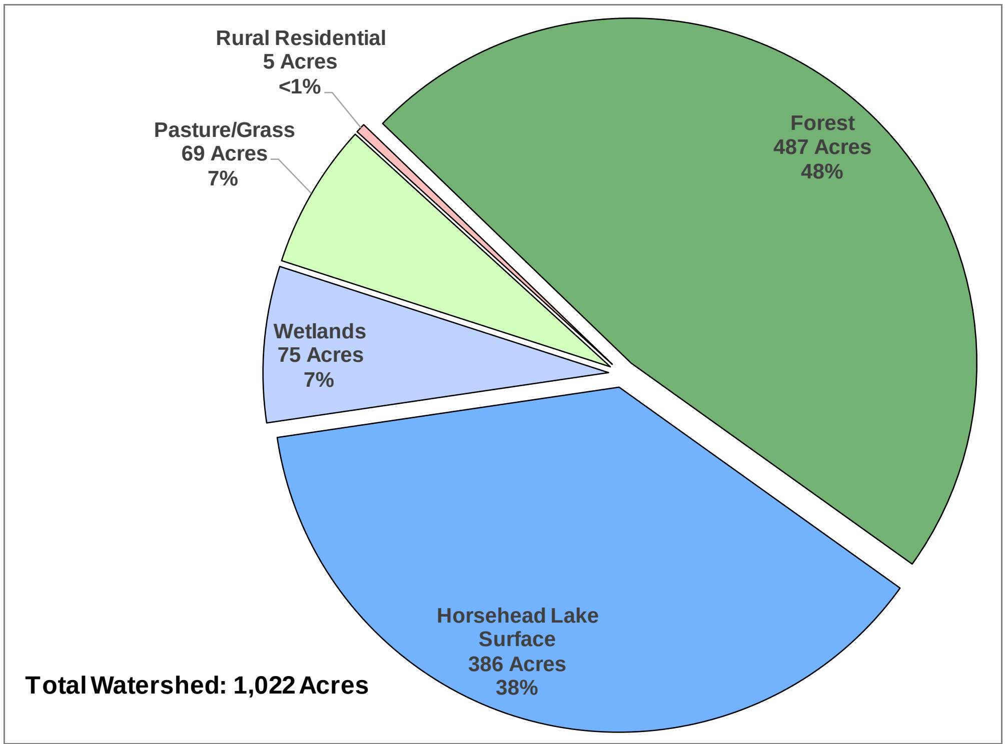


Figure 3.3-1. Horsehead Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

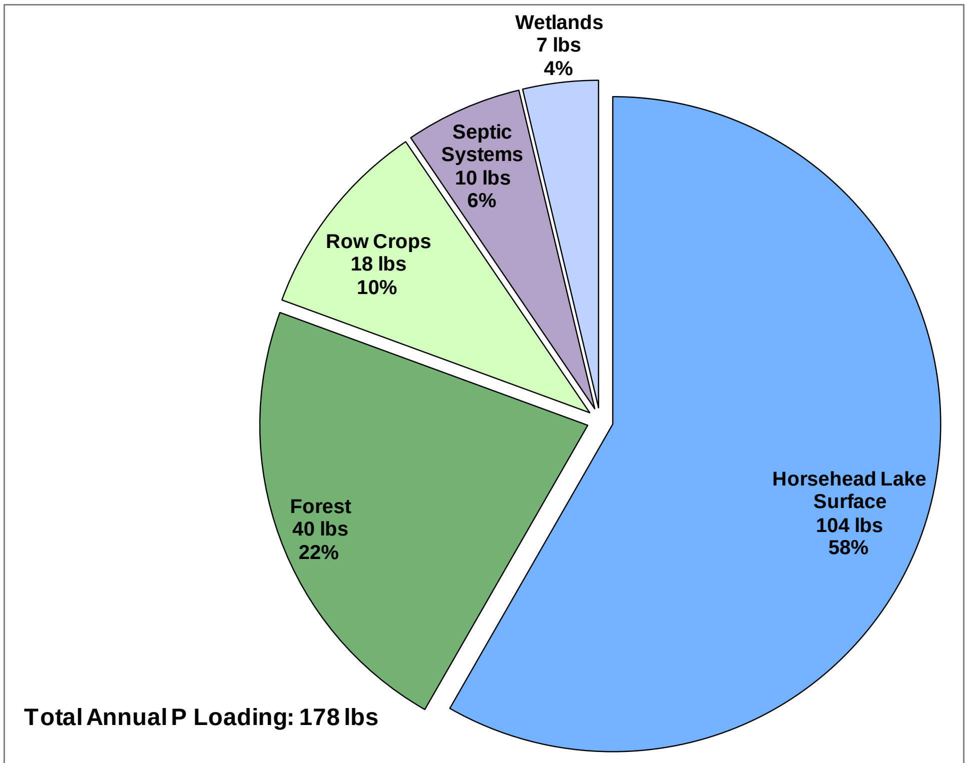


Figure 3.3-2. Horsehead Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

As mentioned above, modeling completed as a part of this project indicated that very little phosphorus (roughly 10 lbs) enters Horsehead Lake from septic systems. Past water quality studies completed on Horsehead Lake in 1977 and 1993 by Northern Lakes Services included specific components looking at septic system impacts and found that inputs from shoreland systems was minimal.

Using predictive equations, WiLMS estimates that based on potential annual phosphorus load, Horsehead Lake should have a growing season mean (GSM) total phosphorus concentration of approximately 23 µg/L. This predicted concentration is lower than the measured GSM total phosphorus concentration of 38 µg/L. As discussed in the Lake Water Quality Section (3.1), internal nutrient loading is occurring in Horsehead Lake and likely explains the discrepancy between the predicted and measured GSM total phosphorus concentration. As discussed in the paleoecology section, the present day phosphorus concentrations are higher than they were prior to the arrival of Euro-American settlers.

As discussed previously, in systems with lower WS:LA ratios like Horsehead Lake, small changes in the watershed can lead to significant changes in water quality. To illustrate this, a scenario was modeled converting 50% of the forest in the lake's watershed to row crop agriculture. WiLMS estimates that the annual phosphorus load would increase from 178 pounds to approximately 374 pounds annually and that the GSM total phosphorus concentration would increase to be approximately 48 µg/L. Currently, Horsehead Lake's average GSM total phosphorus concentration correlates to a TSI value of 56, falling into the eutrophic category. Should 50% of the lake's forested land in the watershed be converted to row crop agriculture, it is estimated that the lake would have a TSI value of 60, still falling into the eutrophic category. Using predictive equations developed by Carlson (1977), average chlorophyll-*a* and Secchi disk transparency values can be estimated using the average growing season surface phosphorus value. If 50% of forested land were converted to row crop agriculture, the estimated GSM concentration for chlorophyll-a could increase to 23 µg/L, which is almost double the average measured GSM chlorophyll-a concentration of 13 µg/L. The estimated GSM Secchi disk depth is estimated to decline to approximately 3.6 feet, which is almost a 2-foot reduction in the average measured GSM Secchi depth of 5.4 feet.

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 nott 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.

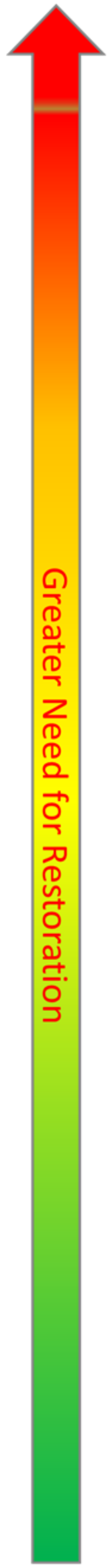
Advantages	***Disadvantages***

• 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 3-4 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.

Horsehead Lake Shoreland Zone Condition

Shoreland Development

Horsehead Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.4-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.



Urbanized: This type of shoreline has essentially no natural habitat. Areas that are mowed or unnaturally landscaped to the water's edge and areas that are rip-rapped or include a seawall would be placed in this category.

Developed-Unnatural: This category includes shorelines that have been developed, but only have small remnants of natural habitat yet intact. A property with many trees, but no remaining understory or herbaceous layer would be included within this category. Also, a property that has left a small (less than 30 feet), natural buffer in place, but has urbanized the areas behind the buffer would be included in this category.

Developed-Semi-Natural: This is a developed shoreline that is mostly in a natural state. Developed properties that have left much of the natural habitat in state, but have added gathering areas, small beaches, etc. within those natural areas would likely fall into this category. An urbanized shoreline that was restored would likely be included here, also.

Developed-Natural: This category includes shorelines that are developed property, but essentially no modifications to the natural habitat have been made. Developed properties that have maintained the natural habitat and only added a path leading to a single pier would fall into this category.

Natural/Undeveloped: This category includes shorelines in a natural, undisturbed state. No signs of anthropogenic impact can be found on these shorelines. In forested areas, herbaceous, understory, and canopy layers would be intact.

Figure 3.4-1. Shoreland assessment category descriptions.

On Horsehead Lake, the development stage of the entire shoreland was surveyed during fall of 2017, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.4-2.

Horsehead Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.1 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.4-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.2 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Horsehead Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

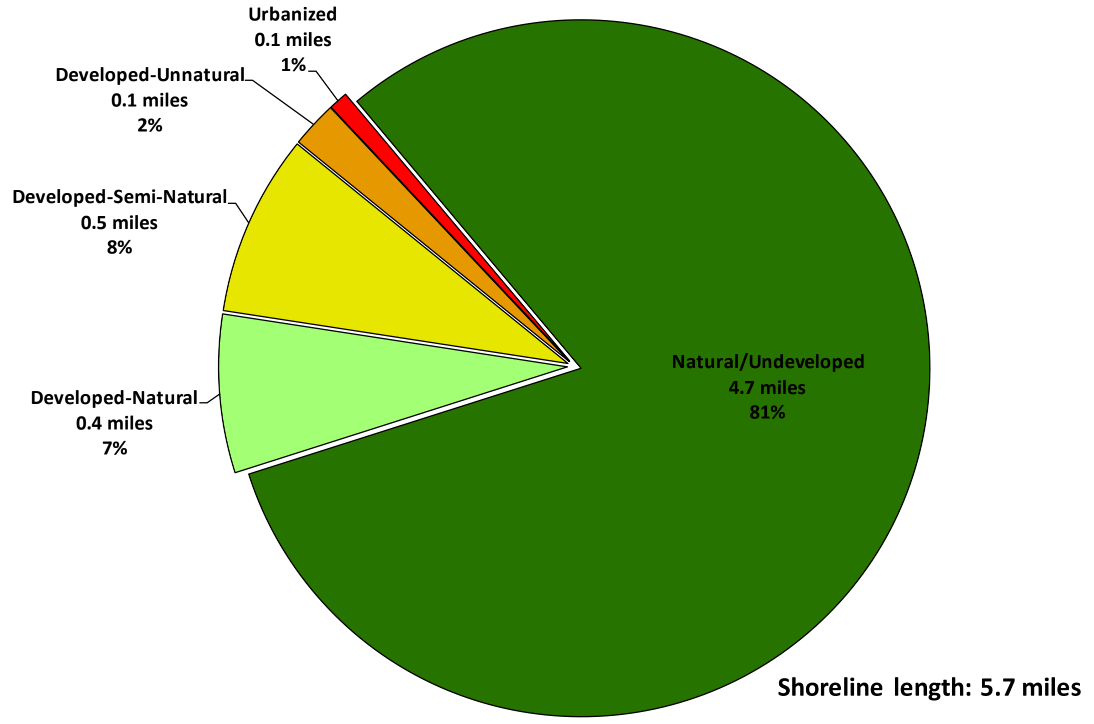


Figure 3.4-2. Horsehead Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map 3.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, un-sloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

As part of the shoreland condition assessment, Horsehead Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters of pieces) 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).

During this survey, 246 total pieces of coarse woody habitat were observed along 5.7 miles of shoreline (Map 4), which gives Horsehead Lake a coarse woody habitat to shoreline mile ratio of 43:1 (Figure 3.4-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Two hundred and two pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, 44 pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Horsehead Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Horsehead Lake falls above the 75th percentile of these 75 lakes (Figure 3.4-3).

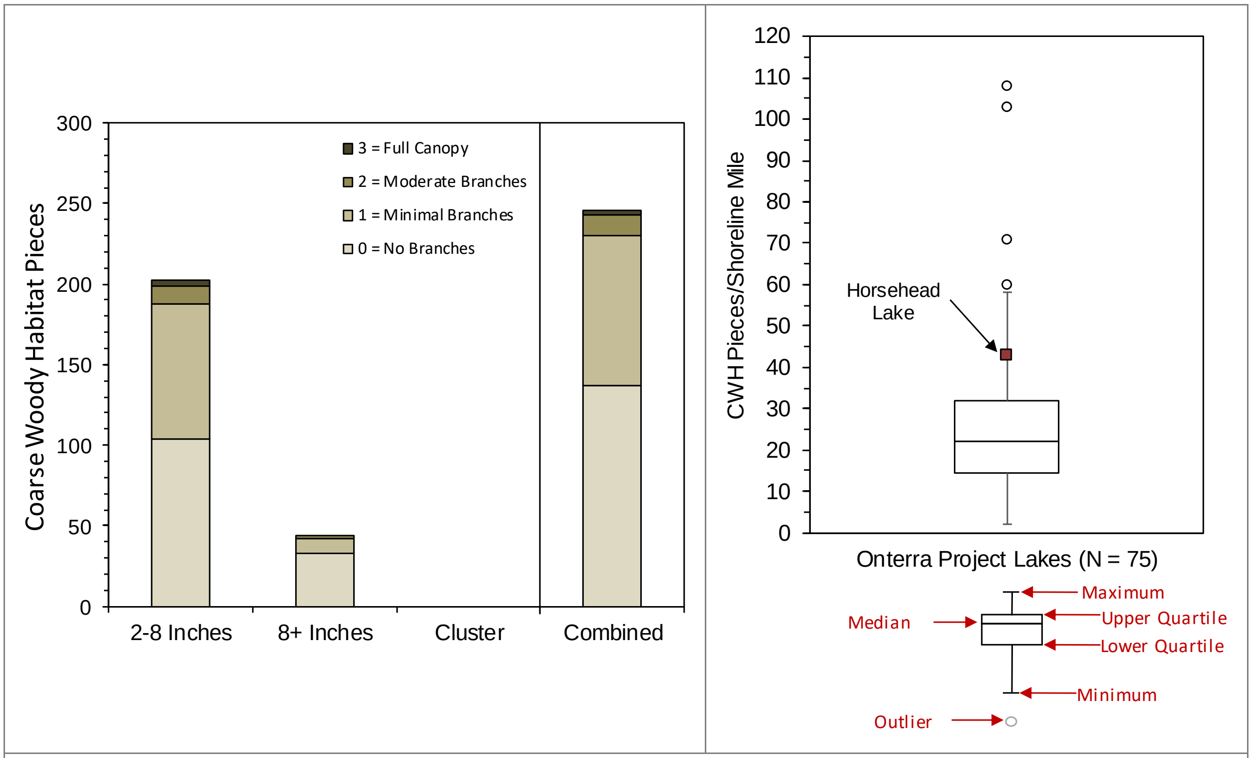


Figure 3.4-3. Horsehead Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Horsehead Lake coarse woody habitat can be found on Map 4.

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 shoreland 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 species will be discussed further in depth in the Aquatic Invasive Species section. 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.

Aquatic Plant Management and Protection

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Important Note:
Even though most of these techniques are not applicable to Horsehead Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake. The techniques applicable to Horsehead Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Manual Removal

Photograph 3.5-2. Example of aquatic plants that have been removed manually.

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width. Please note that the use of powered cutters may require a mechanical harvesting permit to be issued by the WDNR.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost

Commercially available hand-cutters and rakes range in cost from \$85 to \$150. Power-cutters range in cost from \$1,200 to \$11,000.

Advantages	*Disadvantages*
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant colonization on top of the screen. Please note that depending on the size of the screen a Wisconsin Department of Natural Resources permit may be required.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation cost can vary largely, but may roughly cost $750 to have 1,000 square feet of bottom screen installed. Maintenance costs can also vary, but an estimate for a waterfront lot is about $120 each year.

Advantages	*Disadvantages*
• Immediate and sustainable control. • Long-term costs are low. • Excellent for small areas and around obstructions. • Materials are reusable. • Prevents fragmentation and subsequent spread of plants to other areas.	• Installation may be difficult over dense plant beds and in deep water. • Not species specific. • Disrupts benthic fauna. • May be navigational hazard in shallow water. • Initial costs are high. • Labor intensive due to the seasonal removal and reinstallation requirements. • Does not remove plant biomass from lake. • Not practical in large-scale situations.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive. If a hydro-electric facility is operating on the system, the costs associated with loss of production during the drawdown also need to be considered, as they are likely cost prohibitive to conducting the management action.

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian watermilfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant effects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed and reed canary grass. • Permitting process may require an environmental assessment that may take months to prepare. • Non-selective.

Mechanical Harvesting


Photograph 3.5-3. Mechanical harvester.

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Cost

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages	***Disadvantages***
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact. • Plants are not completely removed and can still provide some habitat benefits. • Opening of cruise lanes can increase predator pressure and reduce stunted fish populations. • Removal of plant biomass can improve the oxygen balance in the littoral zone. • Harvested plant materials produce excellent compost.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required. • Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Herbicide Treatment

Photograph 3.5-4. Granular herbicide application.

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially-targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Treatments occurring roughly each year before June 1 and/or when water temperatures are below 60°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides and an extensive list can be found in Appendix F of Gettys et al. (2009).

Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if, "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high water mark require herbicides specifically labeled by the United States Environmental Protection Agency

Aquatic herbicides can be classified in many ways. Organization of this section follows Netherland (2009) in which mode of action (i.e. how the herbicide works) and application techniques (i.e. foliar or submersed treatment) group the aquatic herbicides. The table below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

The arguably clearest division amongst aquatic herbicides is their general mode of action and fall into two basic categories:

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Herbicides that target submersed plant species are directly applied to the water, either as a liquid or an encapsulated granular formulation. Factors such as water depth, water flow, treatment area size, and plant density work to reduce herbicide concentration within aquatic systems. Understanding concentration and exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of an ongoing cooperative research project between the Wisconsin Department of Natural Resources, US Army Corps of Engineers Research and Development Center, and private consultants (including Onterra). This research couples quantitative aquatic plant monitoring with field-collected herbicide concentration data to evaluate efficacy and selectivity of control strategies implemented on a subset of Wisconsin lakes and flowages. Based on their preliminary findings, lake managers have adopted two main treatment strategies: 1) whole-lake treatments, and 2) spot treatments.

Spot treatments are a type of control strategy where the herbicide is applied to a specific area (treatment site) such that when it dilutes from that area, its concentrations are insufficient to cause significant affects outside of that area. Spot treatments typically rely on a short exposure time (often hours) to cause mortality and therefore are applied at a much higher herbicide concentration than whole-lake treatments. This has been the strategy historically used on most Wisconsin systems.

Whole-lake treatments are those where the herbicide is applied to specific sites, but when the herbicide reaches equilibrium within the entire volume of water (entire lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire lake or basin. The application rate of a whole-lake treatment is dictated by the volume of water in which the herbicide will reach equilibrium. Because exposure time is so much longer, target herbicide levels for whole-lake treatments are significantly less than for spot treatments.

Cost

Herbicide application charges vary greatly between $400 and $1,500 per acre depending on the chemical used, who applies it, permitting procedures, and the size/depth of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian watermilfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Advantages	***Disadvantages***
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian watermilfoil density.

Wisconsin has approved the use of two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These beetles were imported from Europe and used as a biological control method for purple loosestrife. Many cooperators, such as county conservation departments or local UW-Extension locations, currently support large beetle rearing operations. Beetles are reared on live purple loosestrife plants growing in kiddy pools surrounded by insect netting. Beetles are collected with aspirators and then released onto the target wild population. For more information on beetle rearing, contact your local UW-Extension location.

In some instances, beetles may be collected from known locations (cella insectaries) or purchased through private sellers. Although no permits are required to purchase or release beetles within Wisconsin, application/authorization and release forms are required by the WDNR for tracking and monitoring purposes.

Cost

The cost of beetle release is very inexpensive, and in many cases is free.

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations many lead to long-term control.	• Although considered “safe,” reservations about introducing one non-native species to control another exist. • Long range studies have not been completed on this technique.

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 Horsehead Lake; 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 aquatic plant species, both native and non-native, that were located during the surveys completed in Horsehead Lake in 2017. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common 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 growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant 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 whole-lake point-intercept survey completed on Horsehead Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

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 surveys (equation shown below). This assessment allows the aquatic plant community of Horsehead Lake to be compared to other lakes within the region and state.

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

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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.

The Simpson's Diversity Index value from Horsehead Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Horsehead Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

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 3.5-1). 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 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.

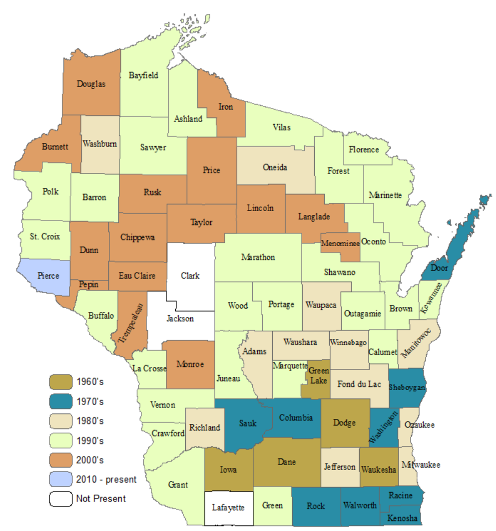


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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.

Horsehead Lake Aquatic Plant Survey Results

As mentioned previously, numerous plant surveys were completed as a part of this project. On June 21, 2017, an Early-Season AIS survey was completed on Horsehead Lake that focused on locating and mapping any occurrences of curly-leaf pondweed. This meander-based, visual survey revealed that CLP was found to be widespread throughout the lake, but the population was mainly comprised of single plant and clump occurrences with a few larger areas designated as *highly scattered*. Because of this plant's potential effects on Horsehead Lake's ecology, water quality, recreation, and aesthetics, the CLP population is discussed in more detail within the subsequent Non-Native Aquatic Plants Section.

The whole-lake aquatic plant point-intercept survey was conducted on Horsehead Lake on July 18 and 19, 2017 by Onterra, and the emergent and floating-leaf aquatic plant community mapping survey was conducted by Onterra on July 19, 2017. During these aquatic plant surveys completed on Horsehead Lake in 2017, a total of 30 species of plants were located in Horsehead Lake, two of which are considered non-native, invasive species: curly-leaf pondweed and pale-yellow iris (Table 3.5-1). While the non-native plant Eurasian watermilfoil was discovered in Horsehead Lake in 2007, Onterra ecologists did not observe any occurrences of this plant in 2017. The aquatic plant species list also contains species recorded during whole-lake point-intercept surveys completed in 1976, 1992, and 2007. Changes in Horsehead Lake's aquatic plant community over this time period are discussed later in this section.

Lakes in Wisconsin vary in their morphometry, water chemistry, substrate composition, recreational use and management, all of which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants and generally leads to a higher number of aquatic plant species within the lake. During the 2017 whole-lake point-intercept survey

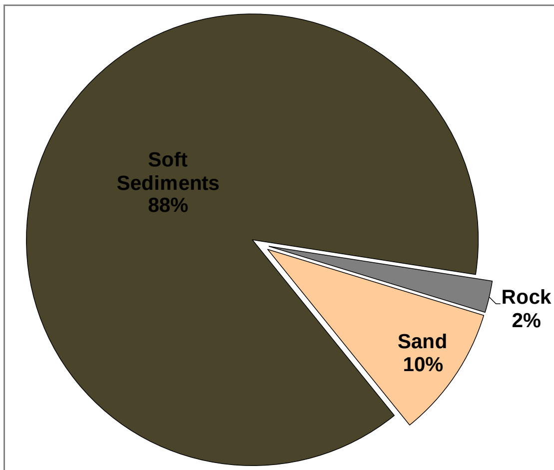


Figure 3.5-2. Horsehead Lake proportion of substrate types within littoral areas. Created using data collected during 2017 whole-lake point-intercept survey (N= 486). Spatial distribution of sediment types in Horsehead Lake are displayed in Map 5.

on Horsehead Lake, information regarding substrate type was collected at locations sampled with a pole-mounted rake. These data indicate that the majority (88%) of sampling locations contained soft sediments, 10% contained sand, and 2% were found to contain rock (Figure 3.5-2 and Map 5). The majority of the aquatic plants located in Horsehead Lake in 2017 are most often found growing in soft sediments.

Horsehead Lake is shallow with moderate water clarity, and aquatic plants were found growing out to a maximum depth of 11 feet, indicating the entire area of the lake is comprised of the littoral zone. Of the 486 point-intercept sampling locations sampled in 2017, 92% contained aquatic vegetation (Figure 3.5-3 and Map 6), indicating the majority of the lake supports aquatic plant growth. The occurrence of aquatic plants in 2017 was slightly lower than the occurrence of 96% recorded in 2007 (Figure 3.5-3).

Table 3.5-1. Aquatic plant species located on Horsehead Lake during 1976, 1992, 2007 and 2017 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	1976 (NLS)	1992 (NLS)	2007 (Onterra)	2017 (Onterra)
Emergent	*Alisma trivale*	Northern waterplantain	4			X	
	Calla palustris	Water arum	9			X	I
	Carex comosa	Bristly sedge	5			X	I
	Carex utriculata	Common yellow lake sedge	7				I
	Eleocharis palustris	Creeping spikerush	6				I
	Iris pseudacorus	Pale yellow iris	Exotic				I
	Iris versicolor	Northern blue flag	5				I
	Juncus effusus	Soft rush	4				I
	Pontederia cordata	Pickerelweed			X		
	Sagittaria latifolia	Common arrowhead	3	X	I	X	I
	Schoenoplectus acutus	Hardstem bulrush	5				I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I	X	I
	Sparganium eurycarpum	Common bur-reed	5			X	
	Typha latifolia	Broad-leaved cattail	1	X	I	X	
	Typha spp.	Cattail spp.	1				I
FL	*Brasenia schreberi*	Watershield	7			X	X
	Nuphar variegata	Spatterdock	6	X	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X	X
	Persicaria amphibia	Water smartweed	5	X	X	X	I
	Sparganium angustifolium	Narrow-leaf bur-reed	9			X	I
FL/E	*Sparganium* sp. (sterile)	Bur-reed sp. (sterile)	N/A				I
Submergent	*Ceratophyllum demersum*	Coontail	3			X	X
	Chara spp.	Muskgrasses	7				X
	Elodea canadensis	Common waterweed	3	X	X	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X		X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic			I	
	Nitella spp.	Stoneworts	7			X	
	Potamogeton amplifolius	Large-leaf pondweed	7			X	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic		X	X	X
	Potamogeton gramineus	Variable-leaf pondweed	7			X	
	Potamogeton natans	Floating-leaf pondweed	5				I
	Potamogeton pusillus	Small pondweed	7		X	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X		X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X		X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A				X
	Stuckenia pectinata	Sago pondweed	3	X		X	X
	Vallisneria americana	Wild celery	6	X		X	X
S/E	*Juncus pelocarpus*	Brown-fruited rush	8			X	
FF	*Lemna minor*	Lesser duckweed	5	X	X	X	

FL = Floating-leaf; FL/E = Floating-leaf and Emergent; S/E = Submergent and Emergent; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidental Species

Aquatic plant total rake fullness (TRF) data collected in 2017 show 24% of the 486 sampling locations contained vegetation with a TRF rating of 1, 26% had a TRF rating of 2, and 42% had a TRF rating of 3 (Figure 3.5-3). The high proportion of TRF ratings of 2 and 3 is an indication of high aquatic plant biomass in Horsehead Lake. When compared to data collected in 2007, the proportion of TRF ratings of 2 and 3 declined from 93% in 2007 to 74% in 2017 indicating a likely reduction in aquatic plant biomass between these two surveys.

Of the 30 aquatic plant species located during the 2017 surveys, 15 species were physically sampled on the rake during the point-intercept survey while the remaining fifteen species were located *incidentally*. An incidentally-located species means the plant was not directly sampled on the rake during the point-intercept survey, but was observed in the lake by Onterra ecologists and was recorded/collected. The majority of incidentally-located plants typically include emergent species growing along the lake's margins and submersed species that are relatively rare within the lake's plant community. Of the 15 species encountered on the rake in 2017, flat-stem pondweed, common waterweed, coontail, and fern-leaf pondweed were the four-most frequently encountered (Figure 3.5-4). These four species were the most frequently-encountered species during the 2007 survey as well.

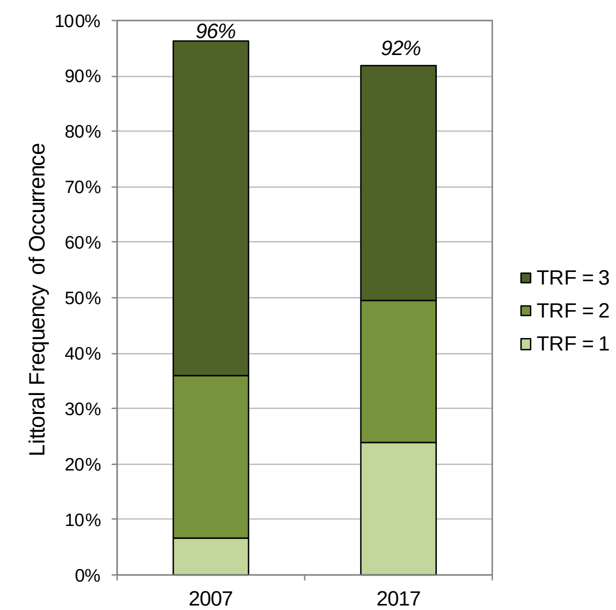


Figure 3.5-3. Horsehead Lake 2007 and 2017 frequency of vegetation and aquatic plant total rake fullness (TRF) ratings. Created using data from 2007 and 2017 whole-lake point intercept surveys. 2007 N = 494 and 2017 N = 486.

The most frequently encountered species in Horsehead Lake in 2017 was flat-stem pondweed with a littoral frequency of occurrence of 54% (Figure 3.5-4). Flat-stem pondweed is often more abundant in productive lakes with soft sediments like Horsehead Lake. Flat-stem pondweed, as its name implies, can be distinguished from other thin-leaved pondweeds by its conspicuously flattened stem. While flat-stem pondweed was the most frequently-encountered species in 2017, its occurrence declined by 23% when compared to 2007 (Figure 3.5-4).

Common waterweed, the second-most frequently-encountered aquatic plant in 2017 with a littoral frequency of occurrence of 49%, is an aquatic plant species with a wide distribution across North America (Figure 3.5-4). While common waterweed can be found growing in many of Wisconsin's waterbodies, abundant growth of this plant is often observed in more productive waterbodies which contain higher levels of nutrients. Common waterweed is tolerant the lower-light conditions in productive systems and can out-compete less tolerant species. The 2017 occurrence of common waterweed was 13% lower when compared to its occurrence in 2007 (Figure 3.5-4).

Coontail, arguably the most common aquatic plant in Wisconsin, was the third-most frequently encountered aquatic plant in Horsehead Lake in 2017 with a littoral frequency of occurrence of 38% (Figure 3.5-4). Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Lacking roots, coontail derives most of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in eutrophic waterbodies with higher nutrients. The 2017 occurrence of coontail was 23% lower when compared to the 2007 survey (Figure 3.5-4).

Fern-leaf pondweed was the fourth-most abundant aquatic plant in Horsehead Lake in 2017 with a littoral frequency of occurrence of approximately 25%. As its name indicates, this plant resembles a terrestrial fern frond in appearance, and is often a dominant species in plant communities of northern Wisconsin lakes. Fern-leaf pondweed is generally found growing in thick beds over soft substrates, where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. Fern pondweed declined in occurrence by 61% when compared to the 2007 survey (Figure 3.5-4).

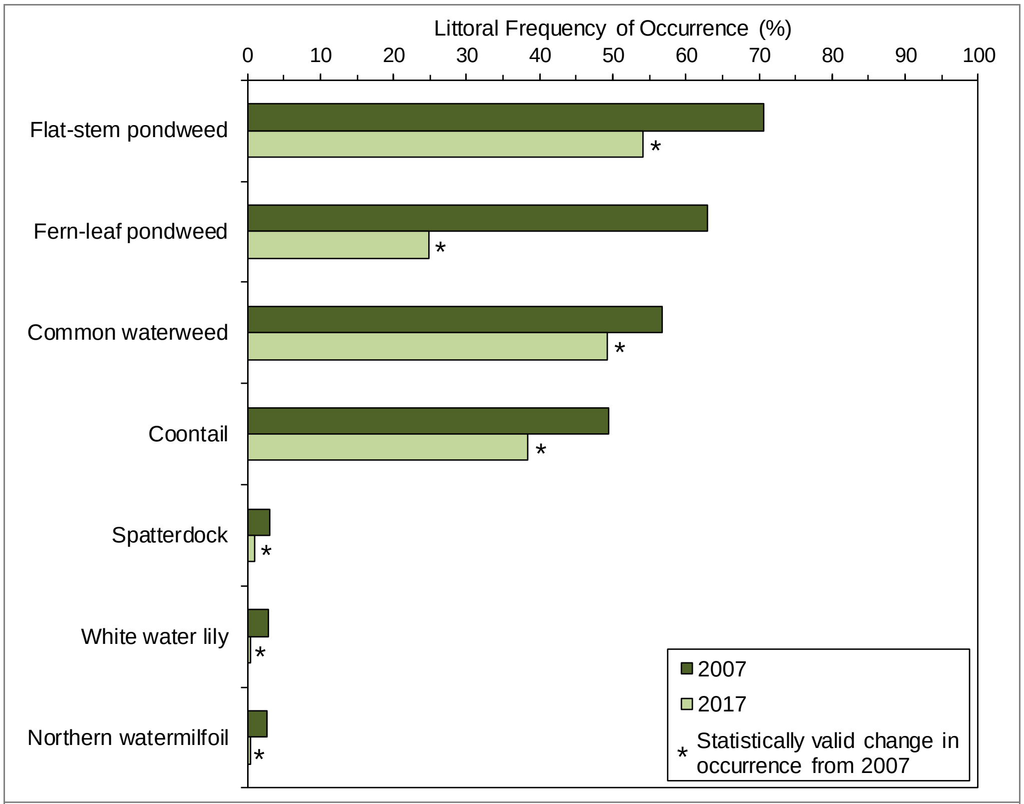


Figure 3.5-4. Horsehead Lake aquatic plant littoral frequency of occurrence. Created using data from 2007 and 2017 surveys. Only species with a littoral frequency of occurrence of 5% of more in one of the two surveys are displayed.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, disease, and management among other factors. Ongoing research on Wisconsin's lakes shows that native aquatic plant populations can fluctuate over short- and long-term periods which are believed to be driven be natural variations in climate, growing season, water levels, etc. The differences in species abundance measured between 2007 and 2017 are not concerning and are believed to be responses by these plant populations to natural variations in environmental conditions. However, these differences could also be partly influenced by the aquatic plant mechanical harvesting that occurs in Horsehead Lake.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while 30 native aquatic plant species were located in Horsehead Lake during the 2017 surveys, only 14 were encountered on the rake during the point-intercept survey. Horsehead Lake's native aquatic plant species richness in 2017 is below the 25th percentile for lakes within the Northern Lakes and

Forests (NLFL) ecoregion and below the median for lakes within the state of Wisconsin (Figure 3.5-5).

The average conservatism of the 14 native aquatic plants recorded on the rake in 2017 was 5.7, falling below the median value (6.7) for lakes within the NLFL ecoregion and for lakes throughout Wisconsin (6.3) (Figure 3.5-5). This indicates that Horsehead Lake supports fewer environmentally-sensitive aquatic plant species when compared to other lakes in the region, or species given a higher conservatism value. Using Horsehead Lake's 2017 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a value of 21.3, falling below the 25th percent quartile for lakes within the NLFL ecoregion as well as lakes throughout the state (Figure 3.5-5). The reasons for Horsehead Lake's lower Floristic Quality are discussed further in this section.

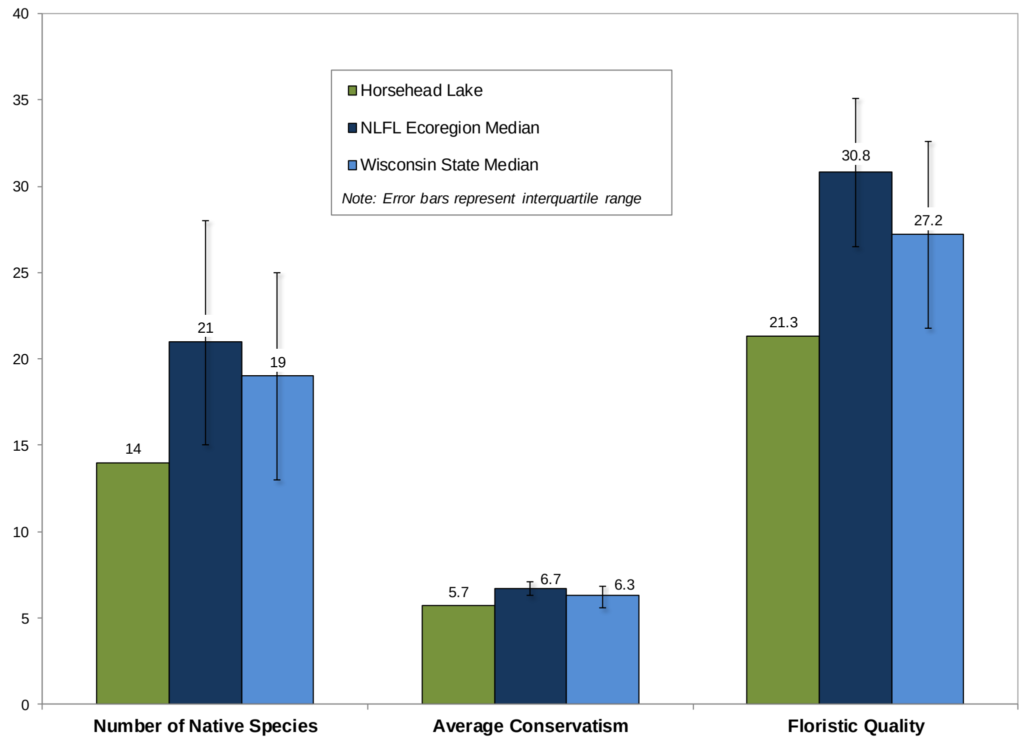


Figure 3.5-5. Horsehead Lake Floristic Quality Assessment. Created using data from the 2017 whole-lake point-intercept survey. Analysis following Nichols (1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Horsehead Lake contains a lower number of native aquatic plant species, one may assume the aquatic plant community also has lower species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.
While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Horsehead Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for

212 lakes within the NLFL ecoregion (Figure 3.5-6). The data collected from the 2017 point-intercept survey yielded a Simpson's Diversity Index value of 0.77, similar to the 0.78 measured in 2007. Horsehead Lake's 2017 Simpson's Diversity remains lower than the majority of lakes within the ecoregion and the state.

The diversity of Horsehead Lake's aquatic plant community is low for two reasons: 1) the lake contains a relatively low number of aquatic plant species and 2) the species within the community have uneven abundance. In other words, Horsehead Lake's aquatic plant community is dominated by just a few species. One way to visualize Horsehead Lake's low species diversity is to look at the relative occurrence of aquatic plant species (Figure 3.5-7). 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). For instance, while flat-stem pondweed had a littoral frequency of occurrence of 54%, its relative frequency of occurrence was 30%. Explained another way, if 100 individual plants were sampled from Horsehead Lake in 2017, 30 would have been flat-stem pondweed. The relative frequency of occurrence illustrates the uneven abundance of aquatic plant species within Horsehead Lake's plant community. The four-most abundant plant species comprise 92% of the community while the remaining 11 species comprise just 8%.

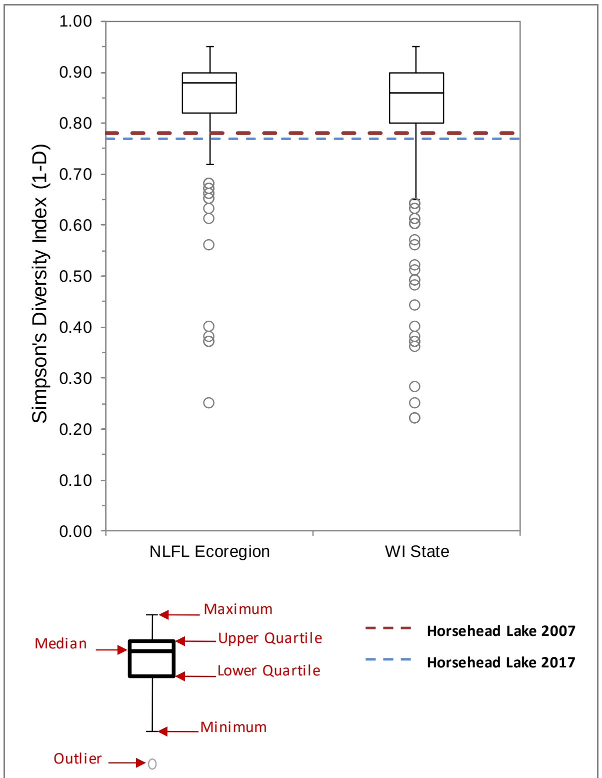


Figure 3.5-6. Horsehead Lake species diversity index. Created using data from 2007 and 2017 aquatic plant surveys. Ecoregion data from 212 NLFL lakes collected by WDNR Science Services and Onterra.

Studies have shown that aquatic plant species richness and diversity tend to decline with increasing levels of nutrients, primarily phosphorus and nitrogen (Jeppesen et al. 2000). As discussed in the Water Quality Section (Section 3.1), Horsehead Lake is eutrophic with higher nutrient concentrations than the majority of lakes within the NLF ecoregion. In shallow, productive lakes like Horsehead Lake, Capers et al. (2009) found that aquatic plant communities were often dominated by one or few species and had low species diversity. These productive lakes tend to have higher nutrient concentrations within the water and sediment, and it is believed these high-nutrient conditions favor the dominance of competitive species and result in the decline of species that are intolerant of competition (Keddy 2000). Horsehead Lake supports aquatic plant species that flourish in high-nutrient conditions, and more sensitive species are unable to compete. These conditions result in a plant community with fewer species, lower diversity, and lower Floristic Quality.

The 2017 emergent and floating-leaf aquatic plant community mapping survey delineated approximately 14.7 acres of these communities in Horsehead Lake (Table 3.5-2 and Map 7). Seventeen floating-leaf and emergent species were located on Horsehead Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. The acreage mapped in 2017 represents an approximate 1.0-acre increase over what was mapped in 2007. The change in acreage was lake-wide with areas of floating-leaf plant communities expanding the northern and southern bays of the lake. Expansion and contraction of these communities over time is not uncommon, and the 1.0-acre expansion in size mapped in 2017 may be due to fluctuations in water levels over this period. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

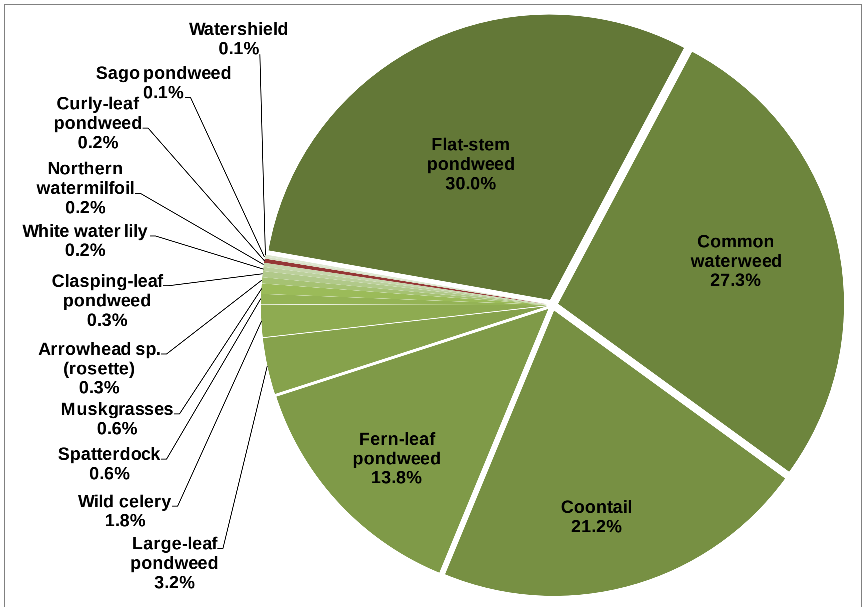


Figure 3.5-7. Relative frequency of occurrence of aquatic plant species in Horsehead Lake. Exotic species indicated with red. Created using data from July 2017 whole-lake point-intercept survey.

Table 3.5-2. Horsehead Lake acres of plant community types. Created from 2007 and 2017 community mapping survey.

	Acres	
Plant Community	**2007**	**2017**
Emergent	0.4	0.3
Floating-leaf	0.8	12.8
Mixed Emergent & Floating-leaf	12.5	1.7
Total	**13.7**	**14.7**

Because the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Horsehead Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-Native Plants in Horsehead Lake

Curly-leaf pondweed

Curly-leaf pondweed (CLP; Photograph 3.5-5) was first documented in Horsehead Lake in 1992 during the whole-lake point-intercept survey but was not verified by the WDNR until 2000. Since its discovery within the lake, no management actions specifically targeting CLP have been taken to control this invasive plant. While the Horsehead Lake Protection and Rehabilitation District employs mechanical harvesting to improve navigation within the lake annually, this harvesting takes place in late-July following the natural senescence of the CLP population. Waiting to initiate mechanical harvesting until most of the CLP population has senesced is believed to help reduce its spread within the waterbody. However, as is discussed further, CLP was found to be widespread throughout Horsehead Lake in the early summer of 2017.

During the Early-Season AIS Survey completed in late-June 2017 in Horsehead Lake, Onterra ecologists mapped approximately 62 acres of highly scattered curly-leaf pondweed (Map 8). While 62 acres may seem significant, these areas represent the lowest density rating Onterra ecologists attribute to these colonies, and highly scattered represents a collection of point-based CLP occurrences (i.e. single or few plants) that were just above a density at which each plant could be represented by a single point. While CLP is widespread throughout Horsehead Lake, the 2017 survey indicated the majority of the population is low-density and there were no monotypic, dominant colonies observed. The curly-leaf pondweed in Horsehead Lake has been monitored occasionally by Onterra since 2007, and the population has never been found to be at levels which interfere with recreation and navigation within the lake.

Eurasian watermilfoil

Eurasian watermilfoil (EWM; Photograph 3.5-5) was first documented in Horsehead Lake in 2007 by Onterra ecologists during an Early-Season AIS survey aimed at mapping CLP. This initial discovery was comprised of a few plants located right near the public boat landing on the lake's south end. Onterra ecologists came out to survey the population in subsequent years and made an effort to hand-pull every EWM occurrence.

In the years since 2007, EWM was never observed outside of the small bay near the boat landing where it was originally discovered. Prior to 2017, the most recent survey completed for EWM in Horsehead Lake was in 2013, and that survey located a few EWM occurrences. During the aquatic plant surveys completed over the course of the summer in 2017, Onterra ecologists did not locate any EWM occurrences in Horsehead Lake. It is highly probably that EWM is still present in Horsehead Lake, but in 2017 was at a level which escaped detection. Ongoing monitoring for EWM in Horsehead Lake should continue so any potential increases in its population can be detected early.

Pale-yellow iris

Pale yellow iris (*Iris pseudacorus*; Photograph 3.5-6) 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. During the 2017 surveys on Horsehead Lake, pale-yellow iris was observed growing in shoreline areas mainly on the eastern shore, but a few occurrences were also found in other areas around the lake (Map 7). Control strategies for pale-yellow iris in Horsehead Lake will be discussed in the Implementation Plan Section.

Curly-leaf Pondweed	***Eurasian watermilfoil***	***Pale-yellow Iris***
		

Photograph 3.5-5. Non-native, invasive plants located in Horsehead Lake. Photo credit Onterra.

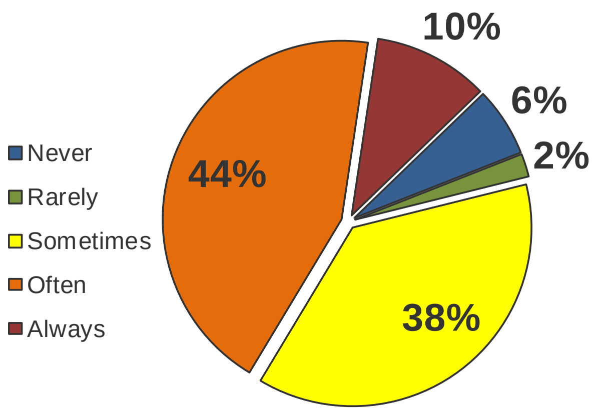
Stakeholder Survey Responses to Aquatic Vegetation within Horsehead Lake

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 3.5-8 displays the responses of members of Horsehead Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed.

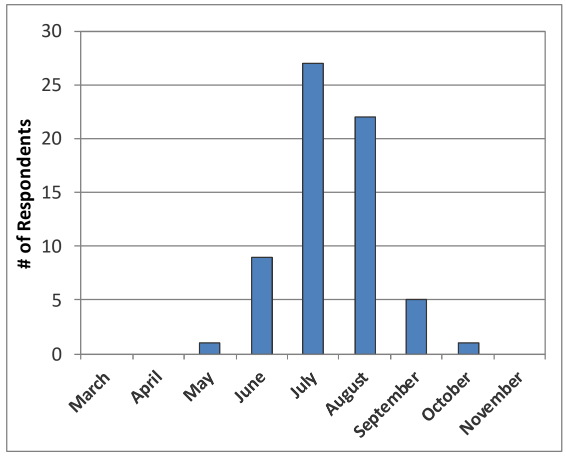
When asked how often aquatic plant growth during the open water negatively impacts enjoyment of Horsehead Lake, the majority of stakeholder survey respondents (44%) indicated *often*, 38% indicated *sometimes*, 10% indicated *always*, 6% indicated *never*, and 2% indicated *rarely* (Figure 3.5-8). When asked which months they have been displaced from Horsehead Lake due to aquatic plant growth, 100% of respondents indicated July, 82% indicated September, 33% indicated June, 19% indicated September, 4% indicated May, and 4% indicated October. These survey questions indicate that the majority of Horsehead Lake stakeholder respondents believe recreational use of Horsehead Lake is hindered by excessive aquatic plant growth and use of the lake is primarily restricted during the summer months of July and August.

Given the excessive aquatic plant growth in Horsehead Lake, the majority (89%) of stakeholder survey respondents indicated that they believe aquatic plant control is *definitely* or *probably* needed in Horsehead Lake, while 9% indicated they were *unsure*, and 2% indicated aquatic plant control is *definitely not* needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating nuisance aquatic plant growth. The management strategy that will be taken to manage nuisance aquatic plant growth in Horsehead Lake is discussed within the Implementation Plan section.

25. During the open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Horsehead Lake?



27. In which months have you been displaced from Horsehead Lake due to aquatic plant growth?



28. Do you believe aquatic plant control is needed in Horsehead Lake?

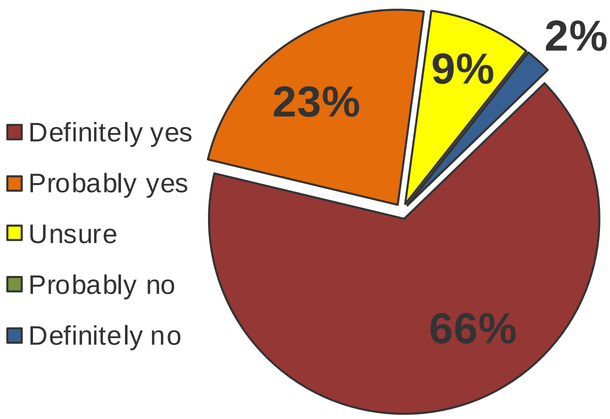


Figure 3.4-8. Horsehead Lake stakeholder survey response questions regarding nuisance aquatic plant growth. N = 23 respondents.

3.6 Aquatic Invasive Species in Horsehead Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Horsehead Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are five AIS present (Table 3.6-1).

Table 3.6-1. AIS present within Horsehead Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.5 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.5 – Aquatic Plants
	Pale-yellow iris	*Iris pseudacorus*	Section 3.5 – Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.6 - Aquatic Invasive Species
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.6 - Aquatic Invasive Species

Figure 3.6-1 displays the 11 aquatic invasive species that Horsehead Lake stakeholder respondents believe are in Horsehead Lake. Only the species present in Horsehead Lake are discussed below or within their respective locations listed in Table 3.6-1. While it is important to recognize which species stakeholder respondents believe to be present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

- http://dnr.wi.gov/topic/invasives/
- https://nas.er.usgs.gov/default.aspx
- https://www.epa.gov/greatlakes/invasive-species

Aquatic Animals

Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

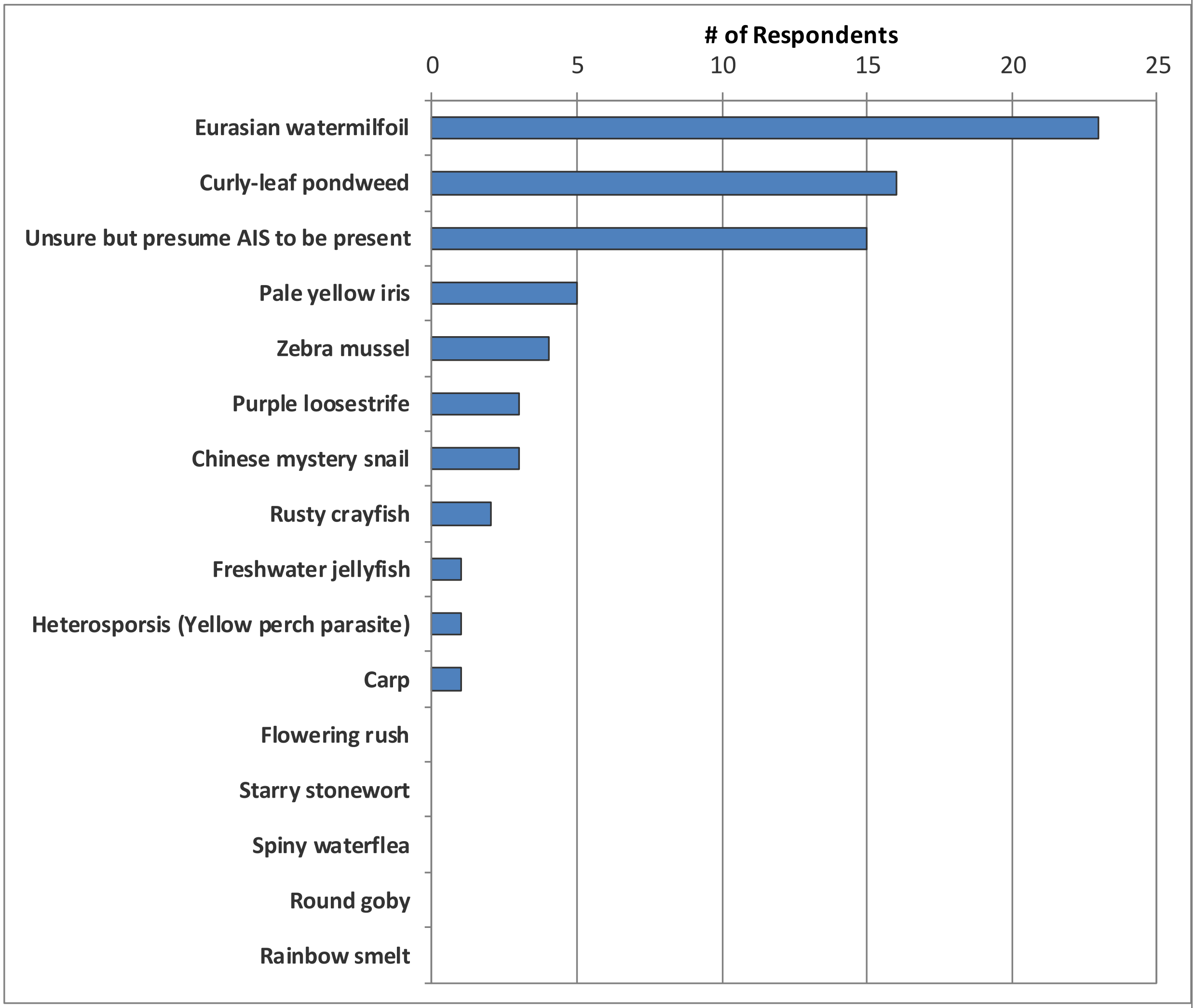


Figure 3.6-1. Stakeholder survey response Question #22. Which aquatic invasive species do you believe are in Horsehead Lake?

3.7 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 a 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 fisheries biologists overseeing Horsehead Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC).

Horsehead Lake Fishery

Energy Flow of a Fishery

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 Horsehead 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 piscivorous 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 3.7-1.

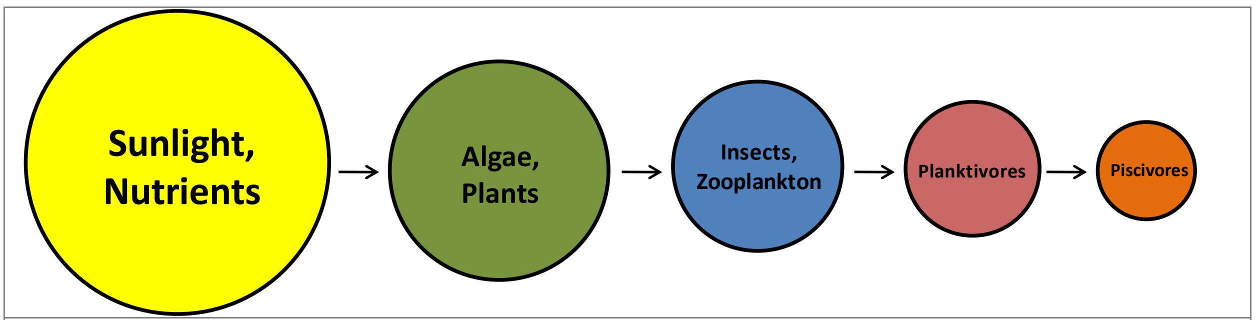


Figure 3.7-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Horsehead Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Horsehead Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.7-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past surveys of Horsehead Lake include white sucker (*Catostomus commersonii*) and the golden shiner (*Notemigonus crysoleucas*).

Table 3.7-1. Gamefish present in Horsehead Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (*Ameiurus 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
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)
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

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.7-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electroshocking (Photograph 3.7-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 3.7-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.7-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Horsehead Lake has been stocked from 1976 to 2016 with largemouth bass, walleye, northern pike X muskellunge and northern pike (Table 3.7-2).

Photograph 3.7-2. Fingerling largemouth bass.

Table 3.7-2. Stocking data available for Horsehead Lake (1976-2016).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
2012	Largemouth Bass	Unspecified	Large Fingerling	17980	3
2013	Largemouth Bass	Unspecified	Large Fingerling	16950	3.25
2014	Largemouth Bass	Unspecified	Large Fingerling	9150	3.2
2015	Largemouth Bass	Unspecified	Large Fingerling	14327	1.9
2016	Largemouth Bass	Unspecified	Large Fingerling	18850	2.2
1981	Walleye	Unspecified	Fry	500000	
1984	Walleye	Unspecified	Fingerling	12800	3
1985	Walleye	Unspecified	Fingerling	18000	2
1976	Northern Pike X Muskellunge	Unspecified	Fingerling	479	9
1990	Northern Pike	Unspecified	Fry	109605	1
1992	Northern Pike	Unspecified	Fry	117600	1
1993	Northern Pike	Unspecified	Fry	737300	0.5
1994	Northern Pike	Unspecified	Fry	65000	0.4

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second important reason for owning property on or near Horsehead Lake (Question #17). Figure 3.7-2 displays the fish that Horsehead Lake stakeholders enjoy catching the most, with bluegill/sunfish, northern pike and crappie being the most popular. Approximately 68% of these same respondents believed that the current quality of fishing on the lake was either fair or poor (Figure 3.7-3). Approximately 77% of respondents who fish Horsehead Lake believe the quality of fishing is somewhat or much worse since they started fishing the lake (Figure 3.7-4).

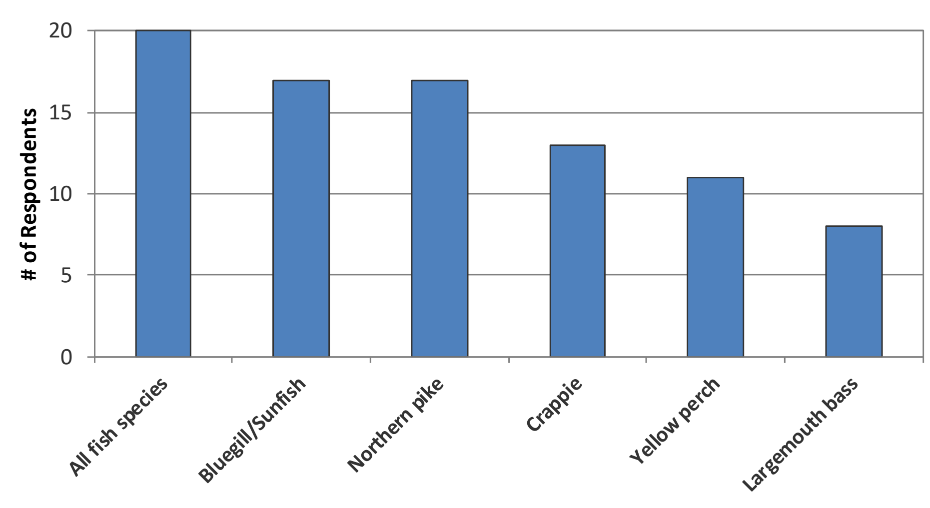


Figure 3.7-2. Stakeholder survey response Question #10. What species of fish do you like to catch on Horsehead Lake?

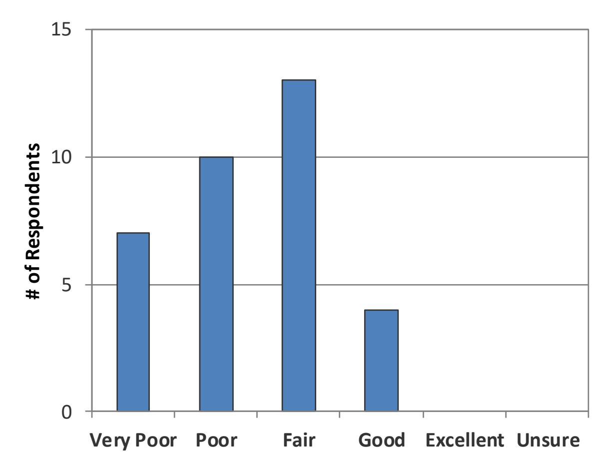


Figure 3.7-3. Stakeholder survey response Question #18. How would you describe the current quality of fishing on Horsehead Lake?

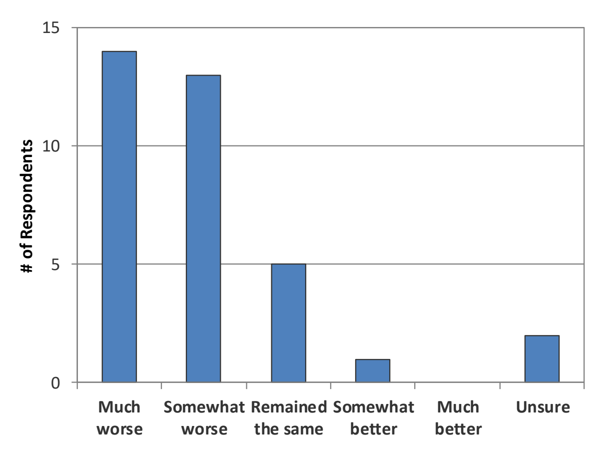


Figure 3.7-4. Stakeholder survey response Question #19. How has the quality of fishing changed on Horsehead Lake since you started fishing the lake?

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on Horsehead Lake represent different population dynamics depending on the species. Brief summaries of popular gamefish present in Horsehead Lake are provided based on the report submitted by WDNR fisheries biologist John Kubisiak following the fisheries survey completed in 2010. Overall**,** northern pike were the dominant gamefish present. The presence of more low oxygen tolerant fish species (e.g., northern pike, black crappie, yellow perch, pumpkinseed and golden shiner) suggests past winter kills, recently documented in 2006, 2008 and 2013 have structured the fish community.

Largemouth bass historically were the dominant gamefish found by the WDNR in 1953, 1954 and 1960. During the 2010 survey, only two bass were captured. It's possible the 2006 and 2008 fish kills decimated the bass population prior to the WDNR 2010 survey. A proposal to re-establish the largemouth bass population through stocking was made following the 2010 survey. Following the survey large fingerling bass were stocked from 2012 to 2016 (Table 3.7-2).

Northern Pike were the dominant gamefish during the 2010 WDNR fisheries survey. Despite poor growth rates, size structure was considered in good condition. The northern pike population was estimated to be 5,760 or 15.7 per acre, which is considered very high.

Panfish

Yellow perch dominated the catch during the April netting. It is typical for April nets to capture higher densities of yellow perch with bluegill and pumpkinseed catch increasing with warmer June temperatures. Nets were again set in June which were dominated by pumpkinseed and bluegill X pumpkinseed hybrids. Bluegill typically represent the more dominated catch in June. This may be another reflection showing how winter fish kills are shaping the fisheries in Horsehead Lake as pumpkinseed are more tolerant to lower oxygen levels than bluegill.

The high panfish densities associated with Horsehead Lake is a contributor to poor size structure and slower than average growth rates. Bluegill and pumpkinseed strongly prefer vegetated areas to feed, spawn and hide from predators. Excessive aquatic plant growth promotes a higher panfish population in turn creating forage competition and possible poor growth rate/size structure consequences. The abundance of aquatic vegetation may be the cause of a highly abundant but slow growing panfish population.

Horsehead Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.7-5). Horsehead Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory.

Horsehead Lake has not historically experienced a tribal harvest. Spearing efforts are more likely to be concentrated on other larger lakes in the region which have higher established populations of walleye or muskellunge.

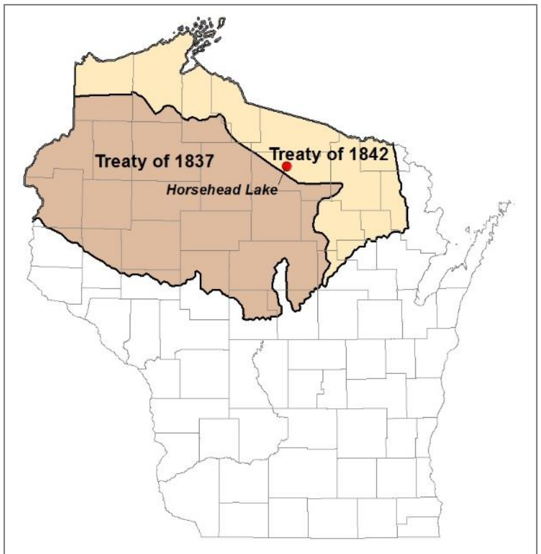


Figure 3.7-5. Location of Horsehead Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Horsehead Lake Fish Habitat

Substrate Composition

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

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is 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 are 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 and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in 2017, 88% of the substrate sampled in the littoral zone of Horsehead Lake were soft sediments, 10% was composed of sand and 2% was composed of rock.

Woody Habitat

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. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass

2006). A fall 2017 survey documented 246 pieces of coarse woody along the shores of Horsehead Lake, resulting in a ratio of approximately 43 pieces per mile of shoreline.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.7-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


Photograph 3.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a fish habitat structure that is placed on the lakebed. Installing fish cribs may be cheaper than fish sticks; however some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (WDNR 2004).

Placement of a fish habitat structure in a lake does not require a permit if the project meets certain conditions outlined by the WDNR's checklists available online:
(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested. The HLPRD should work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Horsehead Lake.

Regulations and Management

Regulations for Horsehead Lake gamefish species as of April 2018 are displayed in Table 3.7-3. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.7-3. WDNR fishing regulations for Horsehead Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	5	14"	June 16, 2018 to March 3, 2019
Largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks, baits, or lures maximum per boat.

Following the 2010 WDNR fisheries survey a proposal to repopulate the largemouth bass population was made. Beginning in 2012 stocking of large fingerling largemouth bass began to assist the predator population in Horsehead Lake.

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.7-6. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways		
	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 3.7-6. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three objectives;

1) Collect baseline data to increase the general understanding of the Horsehead Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil and curly-leaf pondweed.
3) Collect sociological information from Horsehead Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the Horsehead Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Horsehead Lake is a shallow system that has a moderate amount of development on its shores and in its watershed. These two facts must be considered when evaluating the past and current health of the lake and also when considering how the lake should be managed. Water quality analysis indicates that overall, at least through the first 17 years of this century when data are available, that Horsehead Lake has good water quality for this type of lake with low algal abundance and good water clarity. The paleoecological study of a Horsehead Lake sediment core indicates that the lake's phosphorus values have increased since before Euro-Americans settled the area. This is not unexpected for a shallow lake in a watershed that has been impacted serval times by deforestation and has a moderate amount of development in it. Horsehead Lake has been subjected to 'cultural eutrophication', which is the acceleration of a lake's aging (nutrification) by human activities.

The paleocore analysis also indicated that Horsehead Lake contains much more vascular plant growth now than it did in the past. This is expected for a lake that has seen increasing phosphorus concentrations. While the HLPRD wrestles with over abundant plants in some areas of the lake in some years, it is much better to be dealing with that issue than the high algal concentrations with which some shallow lakes contend. Much research has shown that shallow lakes typically exist in either a *turbid* state or a *clear* state. Turbid state lakes are dominated by algae, while clear state lakes are dominated by macrophytes (vascular plants). Horsehead Lake would of course be considered a clear state lake. While competition between the two plant groups for light and nutrients definitely has an impact, a large factor in this equation is the abundance of zooplankton in the lake. Zooplankton is composed of microscopic animals, mostly crustaceans, that graze on algae like cows graze on grass. The zooplankton hide among the macrophytes to avoid predation by small fish; without that cover, the zooplankton population is greatly diminished and algae are able to take over the lake, ultimately shading out much of the macrophyte population and leading to a turbid lake state. So, in Horsehead Lake, the aquatic plant population is very important in maintaining water quality and overall lake health.

While the abundant vegetation in Horsehead Lake is critical to the lake's healthy water quality, it can also impact recreation on the lake by impeding navigation, making angling difficult, and bringing about anoxic (no oxygen) conditions under winter ice due to the decomposition of plant biomass. Fortunately, the HLPRD has options for minimizing these negative impacts without compromising the positive impacts brought on by aquatic plants. These options are elaborated on within the Implementation Plan (Section 5.0) below.

Also covered in the Implementation Plan are goals and actions related to maintaining water quality in the lake and increasing the district's ability to inform and communicate with its members. Further, the district's plan for maintaining important partnerships is also included along with steps to improve fishing opportunities in Horsehead Lake.

5.0 IMPLEMENTATION PLAN

Completion of nearly every action described below relies on dedicated volunteers. The commissioners will make every effort to encourage and engage those volunteers, upon whose involvement successful realization of the goals will depend. It represents the path the HLPRD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Horsehead Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders.

Implementing the Plan

The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the following factors:

- *Condition of Horsehead Lake*. The implementation plan detailed below was constructed with the current state of Horsehead Lake in mind. It contains several actions that will assure important data are collected at regular intervals so management decisions can be made with current information.
- *Availability of funding*. The Horsehead Lake Protection & Rehabilitation District No. 1 has the ability to raise revenue through taxation of district properties; however, that funding source is limited by law and the preference of the district members. Where applicable, the implementation plan includes possible funding sources through WDNR grant programs.
- *Level of volunteer involvement.* **This is the most important factor driving the district's ability to implement the plan.** Nearly every action described below relies on the involvement of dedicated volunteers. Without those volunteers, the HLPRD will not be able to complete many of the actions and therefore not be able to meet the management goals.

Management Goal 1: Preserve and Enhance the Ecological Integrity of Horsehead Lake

Management Action:	Monitor water quality through the WDNR Citizen Lake Monitoring Network
Timeframe:	Continuation of current effort
Facilitator:	HLPRD Board of Commissioners
Prospective Grant:	Funded by WDNR at no cost to district
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Volunteer water quality monitoring is currently being completed annually by Horsehead Lake riparians through the Citizen Lake

	Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The HLPRD currently monitors the deep hole site in the lake as a part of the advanced CLMN program, including collecting Secchi disc transparency and sending in water chemistry samples (chlorophyll-a, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The samples are collected once during the spring and three times during the summer. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). It will be the Board of Commissioners responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples each year. The WDNR maintains a waiting list of lake groups that would like to participate in the CLMN program. Groups that do not consistently participate are often dropped from the program to allow other groups to participate. Having several volunteers properly trained and active through the program is an excellent way to ensure that the HLPRD will have people ready to continue the program and maintain a consistent dataset.
Action Steps:	
	See description above.

Management Action:	Inform Horsehead Lake riparian property owners regarding the importance of natural shorelines and septic system maintenance.
Timeframe:	2019
Facilitator:	HLPRD Board of Commissioners
Description:	As discussed in the Water Quality Section 3.1 and Watershed Section 3.3, Horsehead Lake has a small watershed; therefore, the immediate watershed around the lake, which includes all shoreland properties, is very important in determining the lake's water quality. Further, paleocore analysis indicate that the water quality of Horsehead Lake has worsened over the decades and these changes were likely brought on in part by shoreland development. Natural and near-natural shorelands buffer the lake from shoreland runoff while providing important habitat at the water-land interface. The HLPRD will work to inform district members about the importance of maintaining a natural shoreline. An important part of this action will be getting information out to district members regarding the WDNR Healthy Lakes Initiatives

	program that provides easily accessible funding for shoreland restoration.
Action Steps:	
1.	Review information available from Oneida County, WDNR, and UW-Extension Lakes Program regarding these topics.
2.	Create newsletter articles utilizing information from above.
3.	Recruit speakers from these agencies and others to present this information at district annual meeting.

Management Action:	Work with WDNR fisheries staff to increase proper fish habitat and determine appropriate stocking routine.
Timeframe:	2019
Possible Grant:	WDNR Healthy Lakes Initiative Grant (Fishsticks)
Facilitator:	HLPRD Board of Commissioners
Description:	Fishing is an important activity sited by respondents to the stakeholder survey distributed as a part of this project. Open water fishing ranked second only to "relaxing/entertaining" as the reason for owning property on Horsehead Lake. Over 71% of respondents had fished the lake in the past three years and of those people, 77% believe that the quality of fishing has gotten somewhat worse or much worse since they began fishing on the lake. The HLPRD will work with local fisheries biologists to determine what type of fish structure improvements could be made to the lake to improve its fishery. Further, once those improvements are made, determine a stocking routine that will provide quality fishing opportunities on the lake.
Action Steps:	
1.	See description above.

Management Action:	Work with WDNR fisheries staff to determine if current aeration system is sufficient to prevent winter fish kills in Horsehead Lake.
Timeframe:	2019
Possible Grant:	WDNR Small-scale Planning Grant
Facilitator:	HLPRD Board of Commissioners
Description:	As described in the action above, fishing is an important activity on Horsehead Lake. At present, the HLPRD is unsure if the aeration system installed in the mid-1970s is sufficient to prevent winter fish kills, partial or full, in Horsehead Lake. Many Horsehead Lake riparians believe there was a significant fish kill during the winter of 2013-14. A sufficiently sized aeration system with its diffusers

	properly placed should be able to prevent major fish kills from occurring on Horsehead Lake. The HLPRD will contact the Oneida County fisheries specialist with the WDNR (see contact table on page 100) to design and implement a winter dissolved oxygen monitoring program on Horsehead Lake. This program would include monitoring dissolved oxygen levels through the ice around the open water area created by the current aeration system. Multiple samplings throughout the winter months would be made. Unless dissolved oxygen can be measured in the open water area, it would be assumed that levels would be sufficient to support fish in that area. The results of the monitoring would be used to determine if a sufficient volume of water is being aerated by the system. If it is found that the current aeration system is not working effectively in Horsehead Lake, the Board of Commissioners will work with WDNR staff and a contractor to establish whether current system can be modified to increase its effectiveness or if an updated system will be required. A WDNR Small-scale Planning Grant would be appropriate to fund the purchase of a district-owned dissolved oxygen probe and meter for the study. The volunteer monitoring time would offset much of the local share. If a new aeration system is required or major changes to the existing system are needed, the district may be able to obtain partial funding through a WDNR Lake Protection Grant.
Action Steps:	
1.	See description above.

Management Goal 2: Manage Current Aquatic Invasive Species Populations in and Prevent Further Introductions to Horsehead Lake

Management Action:	Perform Clean Boats Clean Waters watercraft inspections at public access location.
Timeframe:	Initiate 2019
Facilitator:	HLPRD Board of Commissioners
Potential Grant:	WDNR AIS-Clean Boats Clean Waters Grant
Description:	Horsehead Lake is a somewhat popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that originated in Horsehead Lake. The goal is to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. The HLPRD will work with the Oneida County Land and Water Department and/or Lumberjack RC&DC (see contact table on page 100) to develop this program.
Action Steps:	
	See description above.

Management Action:	Conduct periodic qualitative and quantitative vegetation monitoring on Horsehead Lake.
Timeframe:	Early-Season AIS Survey, 2019-2021, then every 3 years Point-Intercept Survey every 3-5 years Community Mapping every 7-10 years
Possible Grant:	Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning in <$10,000 category.
Facilitator:	HLPRD Board of Commissioners
Description:	As part of the ongoing AIS and nuisance native management program, the HLPRD will continue to monitor aquatic plants within Horsehead Lake utilizing the same methodologies as those used in the development of this management plan. The HLPRD is unsure if Eurasian watermilfoil in Horsehead Lake is expanding or remaining at a low occurrence; therefore, the district will sponsor early-season AIS surveys on the lake during 2019, 2020, and 2021 to map the population, The early timing of this survey will also allow for the continued monitoring of curly-leaf pondweed within the lake as well as provide guidance for professional hand-harvesting of

	Eurasian watermilfoil should the district decide to take that action (see below). The HLPRD will decide in 2021 whether to continue monitoring annually or less frequently and every 3 years or every 5 years. A whole-lake point-intercept survey will be conducted at a minimum once every 3-5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Horsehead Lake. A point-intercept survey was conducted on Horsehead Lake in 2017; therefore, the next point-intercept survey will be completed between 2020 and 2022, depending on the level of Eurasian watermilfoil in the lake during the early-season AIS surveys described above. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Horsehead Lake, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on Horsehead Lake in 2017 as a part of this management planning effort. The next community mapping survey will be completed between 2024 and 2027 depending on the results of the surveys discussed above.
Action Steps:	
	See description above.

Management Action:	Manage Eurasian watermilfoil in Horsehead Lake.
Timeframe:	Dependent on plant survey findings
Facilitator:	HLPRD Board of Commissioners
Description:	Eurasian watermilfoil was first discovered in 2007 near the boat landing in Horsehead Lake. During subsequent surveys, it was mapped in other areas around the lake as well. The HLPRD has used professional hand-harvesters to search for and remove Eurasian watermilfoil in the past. During the aquatic plant surveys completed over the course of the summer in 2017, Onterra ecologists did not locate any Eurasian watermilfoil occurrences in Horsehead Lake. It is highly probable that Eurasian watermilfoil is still present in Horsehead Lake, but in 2017 was at a level which escaped detection. The HLPRD intends to keep the level of Eurasian watermilfoil in Horsehead Lake very low, and as mentioned in the previous action, intends to sponsor early-season surveys to search the lake for the exotic during 2019-2021. Completing the survey early in the season, as mentioned above, would also allow for the mapping of curly-leaf pondweed and leave time for professional hand-harvesting later in the summer if deemed appropriate. The HLPRD has utilized professional divers and snorkelers in the past to remove Eurasian watermilfoil in known locations. This practice will continue every-other-year

	beginning in 2019. Each year, the practice will be reevaluated regarding need and frequency of implementation.
Action Steps:	
	See description above.

Management Goal 3: Maintain Navigation and other Recreational Opportunities on Horsehead Lake

Management Action:	Create HLPRD Harvesting Committee to manage mechanical harvesting on Horsehead Lake.
Timeframe:	2019
Facilitator:	HLPRD Board of Commissioners with sufficient volunteer effort to create committee.
Description:	Managing the mechanical harvesting program on Horsehead Lake has traditionally fell on the shoulders of a few district members, typically consisting of the district chairperson and occasionally another volunteer. Performing these tasks not only takes a great deal of time, but also often subject the decisionmakers to ridicule by neighbors and other lake users. To avoid tasking the same individuals with this important aspect of HLPRD business, the HLPRD will create a standing committee; the Horsehead Lake Harvesting Committee. The Harvesting Committee will perform the following functions with concurrence from the HLPRD Board of Commissioners: 1. Bidding and contracting for mechanical harvesting services. 2. Communications with WDNR and harvesting contractor regarding permits and annual harvesting reports. 3. Complete annual lake survey in late June or early July to determine the areas of Horsehead Lake that require harvesting based upon the conditions in the following management action. One of the primary objectives of forming this committee is to spread the work and decision making involved in managing the harvesting operations for Horsehead Lake among many members of the district. To meet that objective, the following guidelines will be used in creating the committee and maintaining its membership: 1. The committee membership will consist of the HLPRD Chairperson and two at large members of the district. 2. The district chairperson will serve on the committee for the extent that he or she is the district chairperson. 3. No member other than the chairperson can occupy consecutive terms. 4. The two district members will serve for two consecutive years, but to maintain some continuality among membership beyond just that of the district chairperson, the two district member terms will be staggered. When the committee is first formed, or if both members must resign at the same time and the committee must be reformed, one of the committee members will serve a three-year term and the second will serve the standard two-year term. This will be decided first by volunteering to fill the three-year term position and second, if

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	either member volunteers, by a coin flip. The district may also direct the HLPRD Chair to appoint new members as well.
Action Steps:	
	See description above.

Management Action:	Utilize contracted mechanical harvesting services to maintain reasonable navigation on Horsehead Lake.
Timeframe:	Initiate 2019
Facilitator:	HLPRD Harvesting Committee
Description:	For over a decade, the HLPRD has contracted to have harvesting of primarily native plants completed on Horsehead Lake. The harvesting normally occurs in July or August and is completed in areas specified by the district. The purpose of the harvesting is to increase navigability in certain areas of the lake that contain dense, nuisance levels of native aquatic plants while opening fish cruising lanes for predators. Over the past decade, members of the 2018 planning committee agreed that during the years harvesting was needed, the harvesting did provide improved navigation within Horsehead Lake. The areas of Horsehead Lake requiring mechanical harvesting change from year-to-year in terms of areas that require harvesting and total acreage of harvesting; therefore, the harvesting plan must remain flexible. The WDNR permitting process requires specifics regarding areas of the lake that are slated for harvesting. To accommodate the WDNR permitting process and the flexible harvesting needs of the HLPRD, the 2011 Horsehead Lake Management Plan included a method for determining and reporting annual harvesting needs by the district. The HLPRD will continue to use this methodology in the coming years. Map 9 includes 144 acres of Horsehead Lake that are available for harvesting based upon past harvesting needs of the district. Harvesting only occurs in areas with developed shoreline, with the exception of the lane that extends to the public boat landing on the southern end of the lake. The need for harvesting is defined by the submergent plants in the area being within 1-2 feet of the surface. The vast majority of the northern portion of the lake is considered a conservation area; therefore, no harvesting is considered in that area except as indicated on the harvest map near properties on Duck Road. While 144 acres of the lake may be considered as a part of the annual harvest plan, no more than 75 acres can actually be harvested in a single year. GPS technology exists to more easily and accurately determine the areas for harvesting by the district. Essentially, a background map can be loaded on a standard handheld GPS unit which would allow district

volunteer to know exactly where they are in relation to the lake's shore and the harvesting grid found on Map 9. The volunteers could also collect points within the grid squares they believe would be included in that year's harvesting. The points could then be downloaded to a computer and emailed to the harvesting contractor for use in the contractor's GPS. The amount of harvesting completed would be reported by the contractor in their annual harvesting record.

Action Steps:

1. HLPRD Harvesting Committee surveys the lake and marks quarter-acre squares with submersed plants within 1-2 feet of the surface on Map 9 for harvesting.
2. Squares are tallied and the sum acreage of that year's harvesting is calculated.
3. Harvesting map and estimated acreage are provided to WDNR 14 days prior to expected harvesting dates.
4. Harvesting contractor completes harvest record at end of year per WDNR permit requirements.

Management Goal 4: Increase the Horsehead Lake District's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use information to promote lake protection and enjoyment through stakeholder education
Timeframe:	2019
Facilitator:	HLPRD Board of Commissioners with sufficient volunteer effort to create committee.
Description:	Education represents an effective tool to address many lake issues. The HLPRD annually distributes a newsletter to its membership and maintains a website. As a part of this action the HLPRD will also complete the following: 1. Further develop and maintain a district member email list. 2. Develop and distribute a *New Neighbor Package* (see below). 3. Consider creating a specific standing committee (see below). Maximizing the level of communication is important within a lake management group because it facilitates the spread of important district news, educational topics, and even social happenings. The HLPRD will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. The *New Neighbor Package* will be distributed to new property owners on Horsehead Lake and contain information regarding the lake, its ecology, district membership, good lake property owner habits, mechanical harvesting, boating safety and regulations, and reducing noise and light pollution. When first created, the packet will be distributed to all existing property owners. Further, the district will communicate with area realtors to let them know the packet and other information is available to them and their clients. As a part of this action, the HLPRD Board of Commissioners will consider creating a standing committee, with an annual budget, that will be tasked with producing educational materials, maintaining media such as the website and newsletter, and developing a diverse group of volunteers. The chair of the new *Horsehead Lake Education, Communication, and Volunteer Committee* would be appointed by the president. *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic invasive species identification

	• Pale yellow iris identification and management • Basic lake ecology • Advantages and disadvantages of mechanical harvesting • Sedimentation • Boating safety (promote existing guidelines, Lake Use Information handout) • Shoreline habitat restoration and protection • Noise and light pollution • Swimmers itch • Lake water levels • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lake
Action Steps:	
	See description above.

Management Action:	Participate in annual Wisconsin Lakes Partnership Convention.
Timeframe:	Annually
Facilitator:	HLPRD Board of Commissioners
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events within the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the state and is specifically suited to the needs of lake associations and districts. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/district. The HLPRD will sponsor the attendance of 3-5 district members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of commissioners regarding topics that may be applicable to the management of Horsehead Lake and operations of the HLPRD. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the district membership at the annual meeting. Information about the convention can be found at:

	https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/convention/default.aspx.
Action Steps:	
	See description above.

Management Action:	Continue HLPRD's involvement with other entities that have responsibilities in managing (management units) Horsehead Lake
Timeframe:	Continuation of current efforts
Facilitator:	HLPRD Board of Commissioners
Description:	The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the HLPRD actively engage with all management entities to enhance the district's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table below:
Action Steps:	
	See guidelines in Table 5.0-1.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Lake Tomahawk	Town Clerk (715.277.2257)	Horsehead Lake falls within this township.	Once a year or more as issues arise.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Lumberjack Resource Conservation & Development Council	Staff (715.396.9886)	Nonprofit organization that covers central WI	Once a year, or more as issues arise.	Provide information on conservation and natural resource preservation
Oneida County Lakes and Rivers Association	Secretary (Connie Anderson – 715.282.5798)	Protects Oneida Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oneida Co. waterways.
Oneida County Land & Water Conservation Department/Committee	County Conservationist (Michele Sadauskas - msadauskas@co.oneida.wi.us) AIS Coordinator (Stephanie Boismenue - sboismenue@co.oneida.wi.us)	Oversees conservation efforts for land and water projects and AIS education in county.	Continuous as it relates to lake, watershed, and AIS activities.	Can aid with shoreland restorations, habitat improvements, and AIS monitoring and education.
Wisconsin Department of Natural Resources	Fisheries Biologist (Zach Woiak – Zachariah.Woiak@wisconsin.gov 715.369.8848)	Manages the fishery of Horsehead Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Scott Van Egeren – Scott.VanEgeren@wisconsin.gov)	Oversees management plans, grants, all lake activities.	Continuous as it relates to lake management activities	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Early spring: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
University of Wisconsin – Extension Lakes Program	Eric Olson, Director and Lakes Specialist (715.346.2192) Patrick Goggin, Rhinelander, Lake Specialist (715.365.8943) Paul Skawinski, Citizens Lake Monitoring Network Educator (715.346.4853)	Provide general information regarding lakes and lake districts. Assist in CLMN training and education.	As needed.	The UW-Ext Lakes Program is a resource for educational materials and guidance regarding lakes, lake monitoring, and the operations of lake management districts.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	HLPRD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Horsehead Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by HLPRD members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall and winter. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (SLOH). The parameters measured, sample collection timing, and designated collector are contained in the table below.

	Spring		**June**	**July**		**August**	**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**S**	**B**	**S**	**B**
Total Phosphorus	■	■	♦	■	■	♦	■	■	■	■
Dissolved Phosphorus	■	■							■	■
Chlorophyll-*a*	■		♦	■		♦	■			
Total Nitrogen	■	■	●	■		●			■	■
True Color	■			■						
Laboratory Conductivity	■	■		■	■					
Laboratory pH	■	■		■	■					
Total Alkalinity	■	■		■	■					
Hardness	■									
Total Suspended Solids	■	■					■	■		
Calcium	■									

♦ indicates samples collected as a part of the Citizen Lake Monitoring Network.
● indicates samples collected by volunteers under proposed project.
■ indicates samples collected by consultant under proposed project.

Watershed Analysis

The watershed analysis began with an accurate delineation of Horsehead Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. 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

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Horsehead Lake during a June 21, 2017 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Horsehead Lake to characterize the existing communities within the lake and include 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 (WDNR PUB-SS-1068 2010) was used to complete this study on July 18-19, 2017. A point spacing of 52 meters was used resulting in approximately 500 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Horsehead Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T 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 the lake.

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered for the University of Wisconsin – Steven's Point Herbarium.

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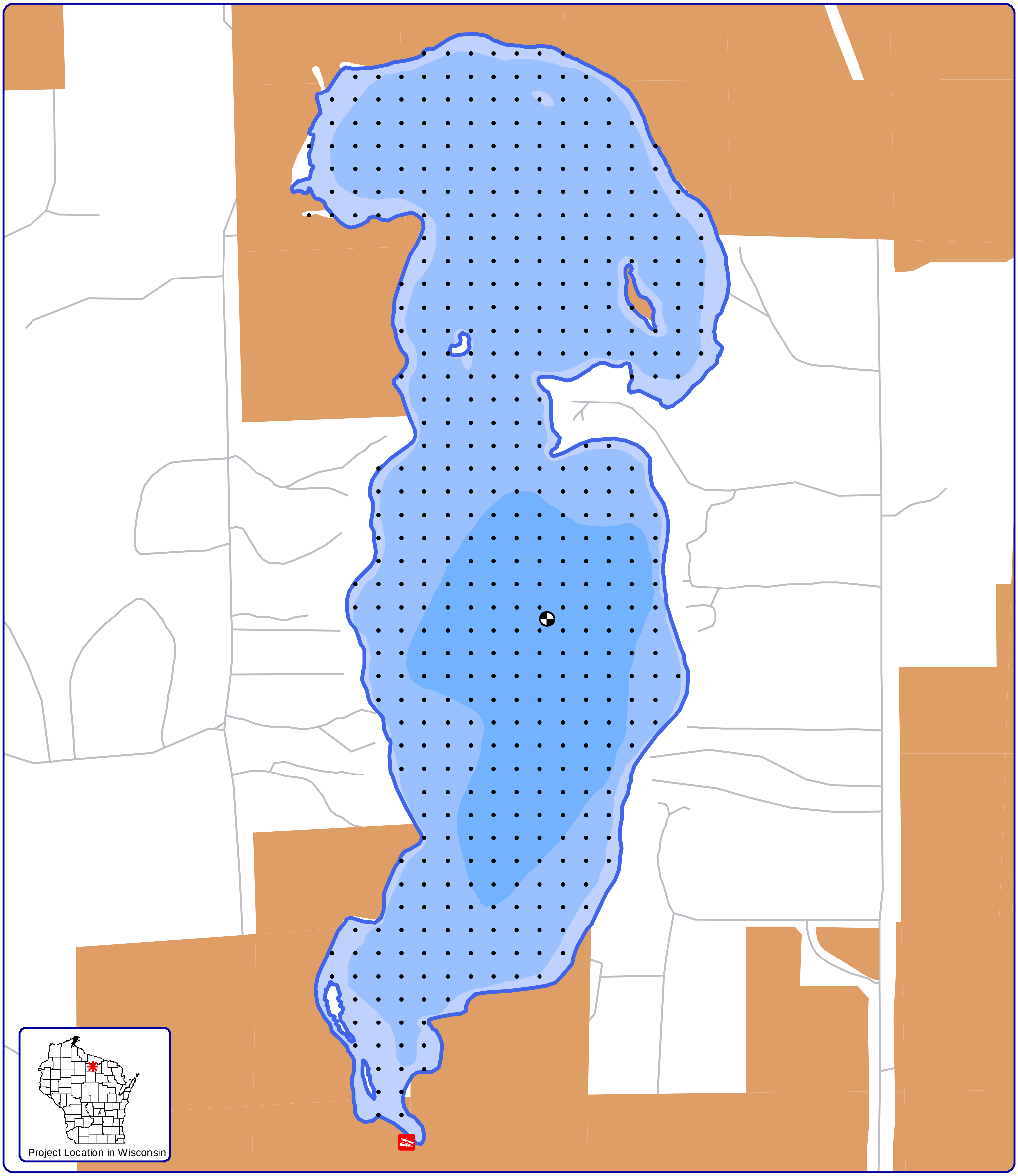

N
W E
S

1,000
Feet

Legend

- Horsehead Lake ~390 Acres
  WDNR Definition
- Point-intercept Sample Location
  55 meter points
- Public Access
- WDNR Managed Lands
- Water Quality Sampling Location

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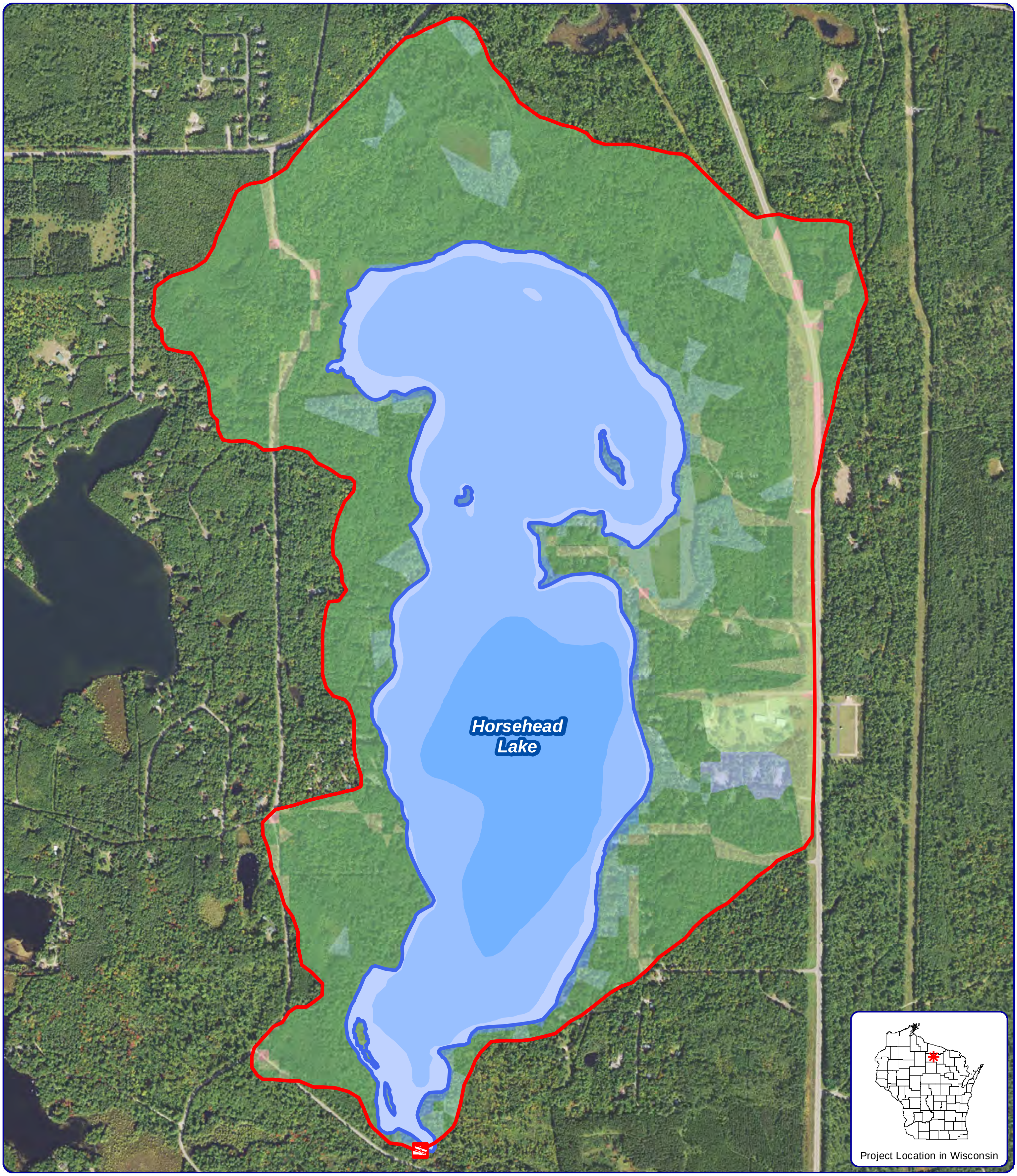
Sources:
Roads and Hydro:WDNR
Map Date: April 16, 2018
Filename: Map1_Horsehead_Location.mxd

Map 1
Horsehead Lake
Oneida County, Wisconsin
Project Location & Lake Boundaries



N W E S

1,200
Feet

Legend

- Horsehead Lake Watershed
- Forest
- Forested Wetlands
- Pasture/Grass
- Rural Open Space
- Rural Residential
- Non-Forested Wetlands
- Open Water

Map 2

Horsehead Lake

Oneida County, Wisconsin

Watershed Boundaries & Land Cover Types

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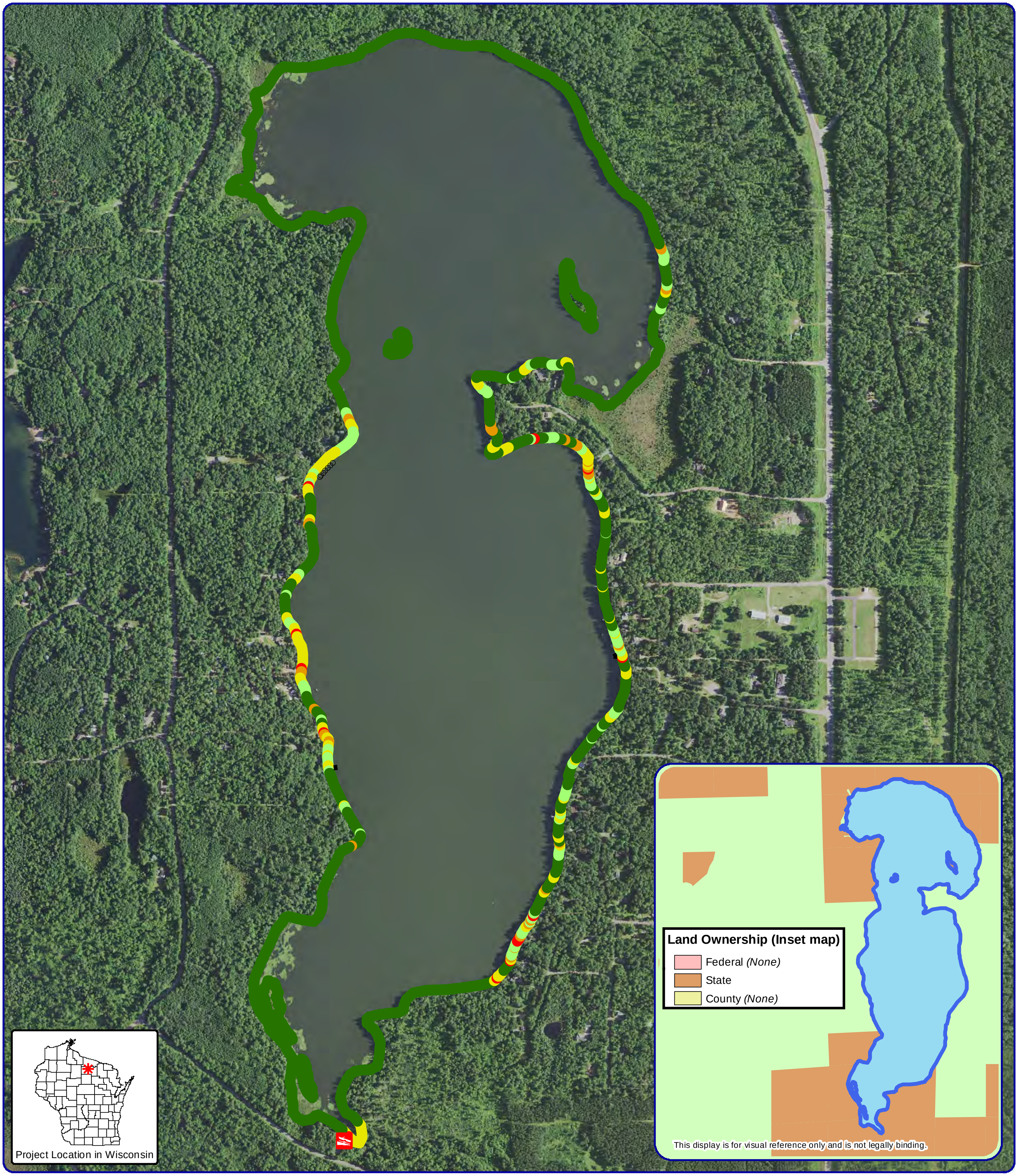
Sources:
Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: NAIP 2017
Land Cover: NLCD 2011
Watershed Boundaries: Onterra 2017
Map Date: October 30, 2017
Filename: Map2_Horsehead_WS.mxd



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Feet

Legend

Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized

Seawall
Masonry/Wood/Metal
Rip-Rap

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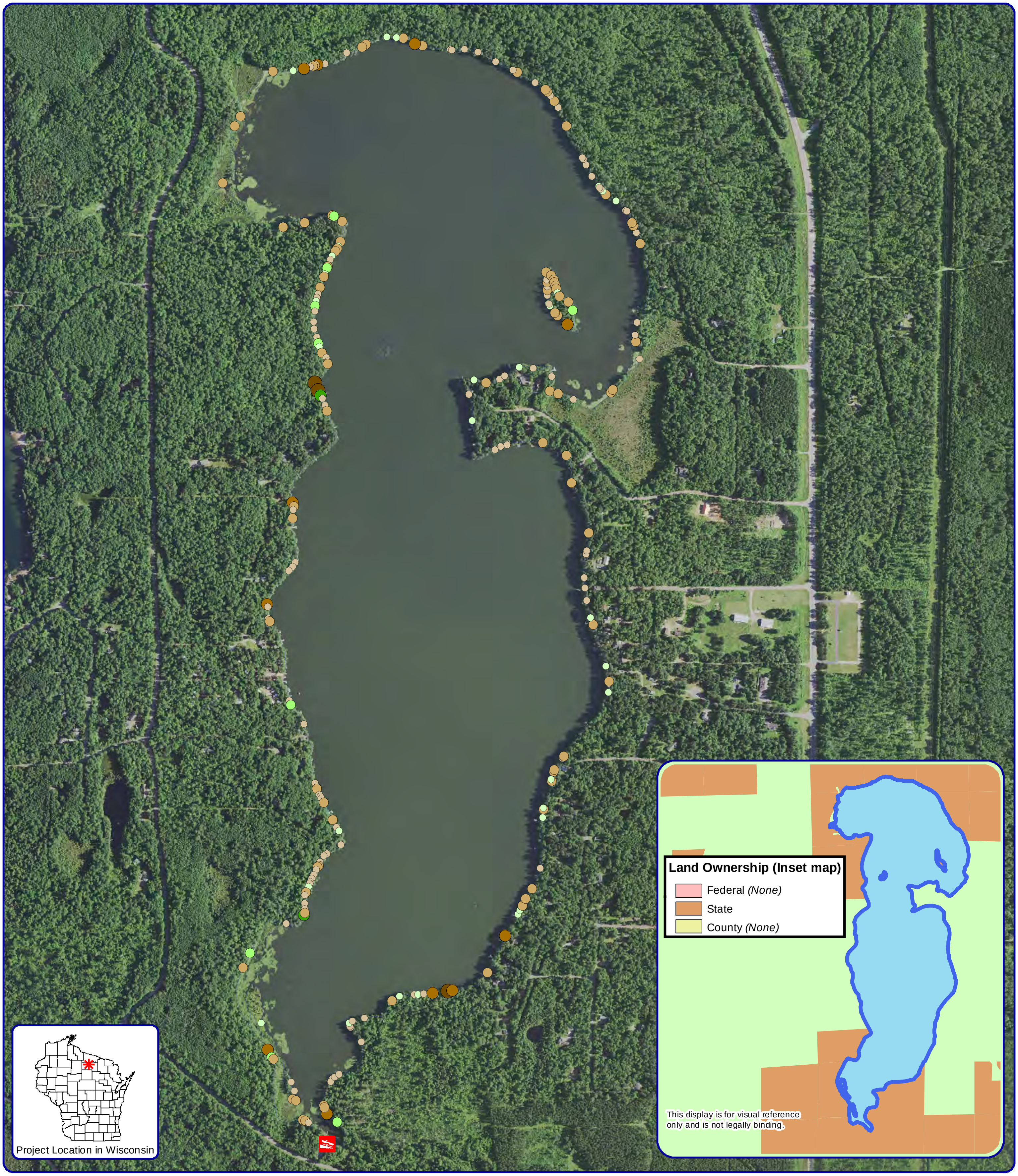
Sources:
Roads and Hyrdo: WDNR
Shoreline Assessment: Onterra, 2017
Map Date: October 17, 2017
Filename: Map3_Horsehead_ShorelandCondition_2017.mxd

Map 3
Horsehead Lake
Oneida County, Wisconsin
2017 Shoreline Condition Assessment



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Feet

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches *(None)*
Minimal Branches	Minimal Branches	Minimal Branches *(None)*
Moderate Branches	Moderate Branches	Moderate Branches *(None)*
Full Canopy	Full Canopy *(None)*	Full Canopy *(None)*

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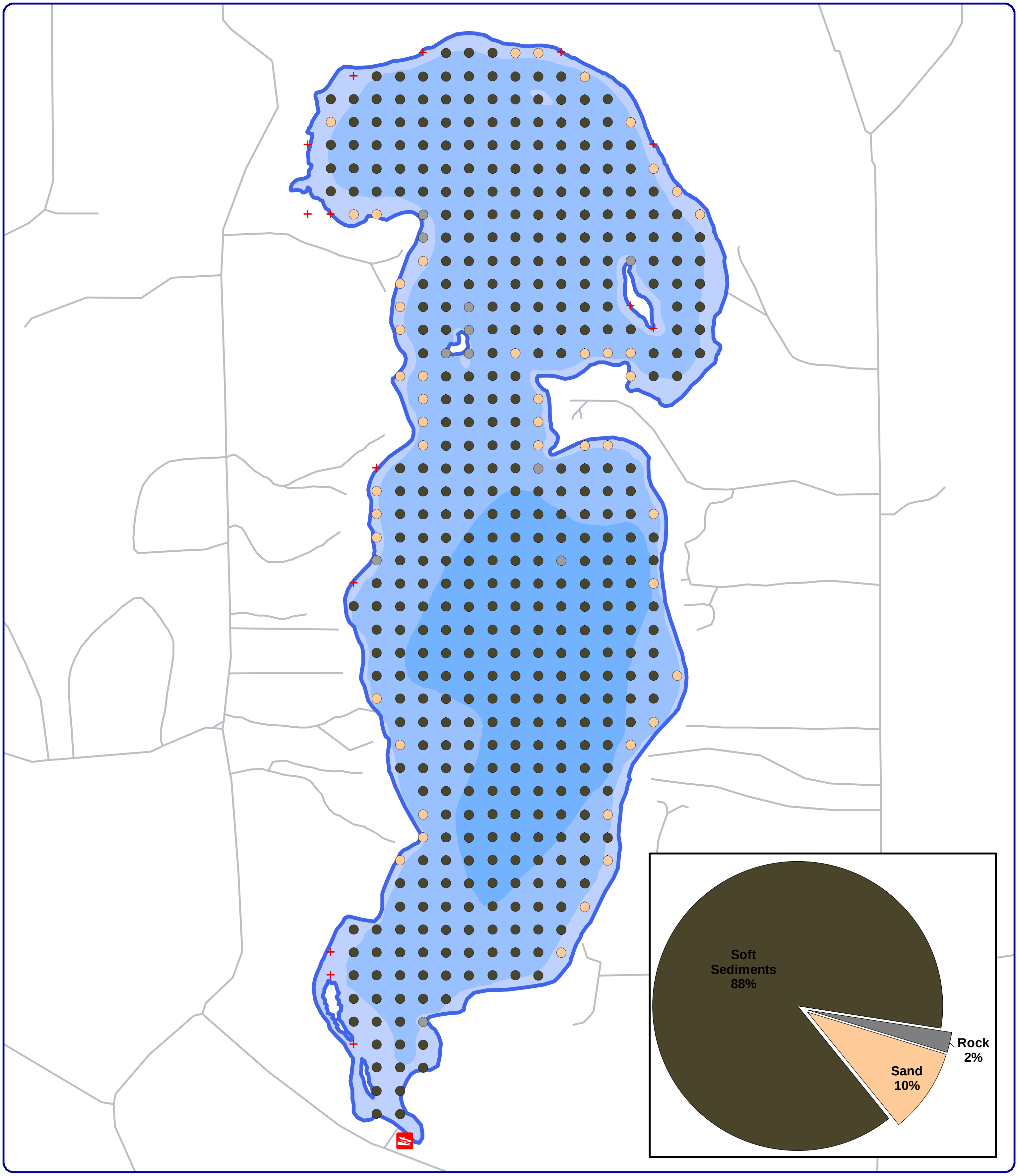
Sources:
Roads and Hyrdo: WDNR
CWH Survey: Onterra, 2017
Map Date: October 17, 2017
Filename: Map4_Horsehead_CWH_2017.mxd

Map 4

Horsehead Lake
Oneida County, Wisconsin

2017 Coarse Woody Habitat Survey Results



1,000
Feet

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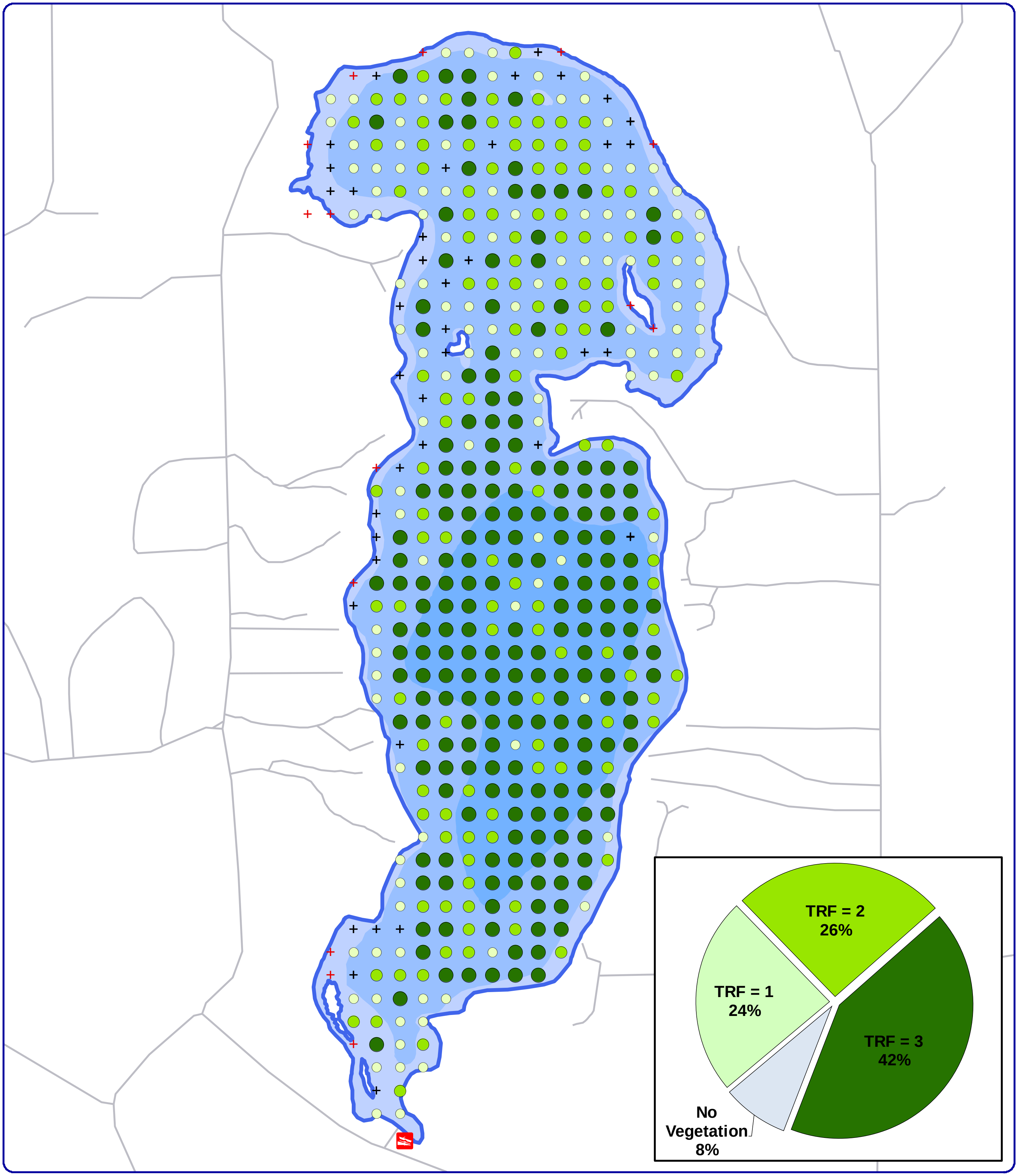
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: WDNR, 2017
Map Date: November 16, 2017
Filename: Map5_Horsehead_SedimentPI_2017.mxd

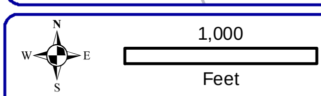
Project Location in Wisconsin

Legend

Soft Sediments
Rock
Sand
No Data
Non-Navigable

Map 5
Horsehead Lake
Oneida County, Wisconsin
2017 PI Survey: Substrate Types





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Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2017
Map Date: November 16, 2017
Filename: Map6_Horsehead_TRFPI_2017.mxd

Project Location in Wisconsin

Legend

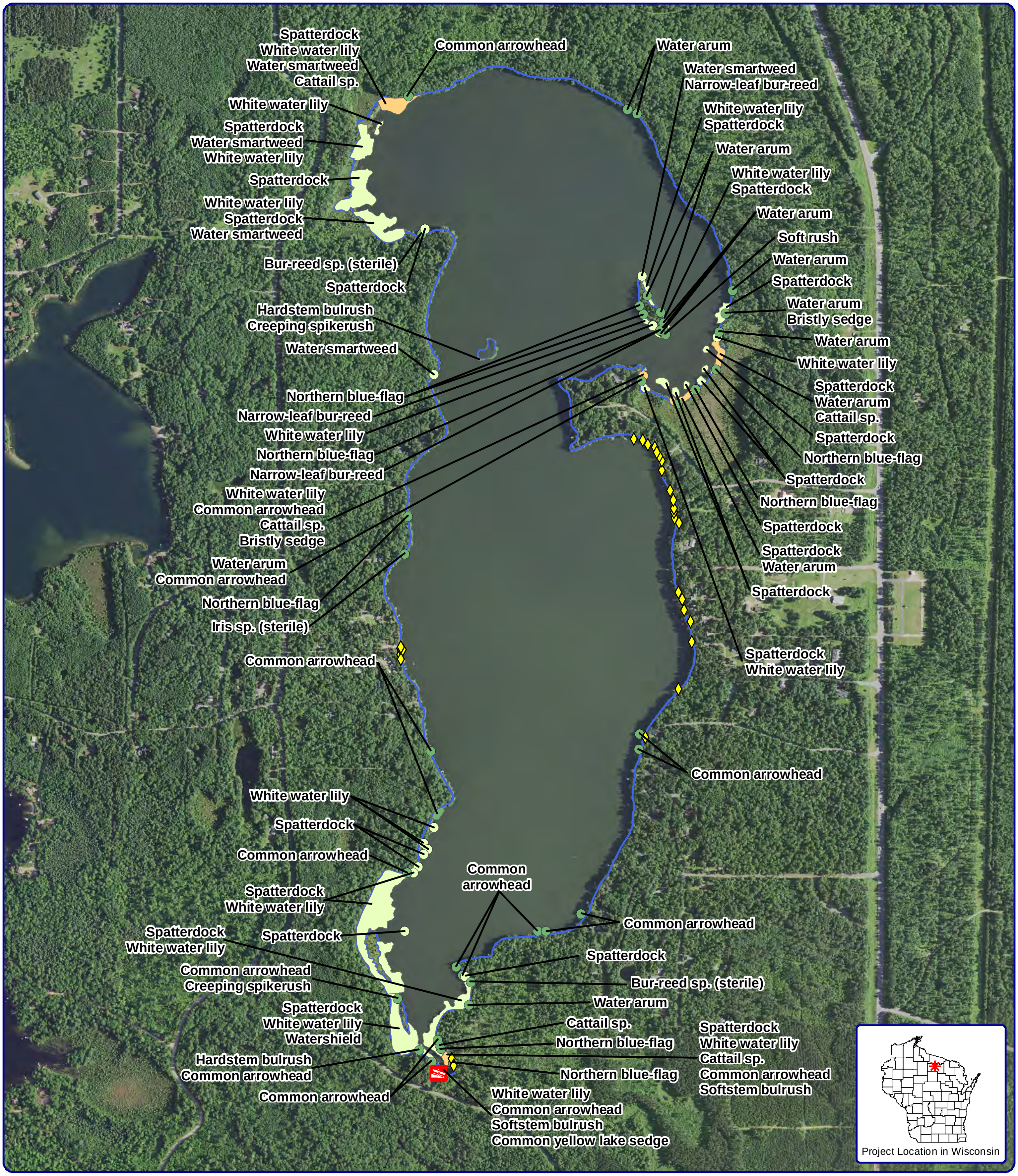
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- + No Vegetation
- + Non-Navigable

Map 6

Horsehead Lake

Oneida County, Wisconsin

2017 PI Survey: Aquatic Plant Distribution



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1,100

Feet

Legend

Large Plant Communities	Small Plant Communities	Exotic Plant Communities
Emergent	Emergent	Pale Yellow Iris
Floating-leaf	Floating-leaf	
Mixed Floating-leaf & Emergent	Mixed Floating-leaf & Emergent	

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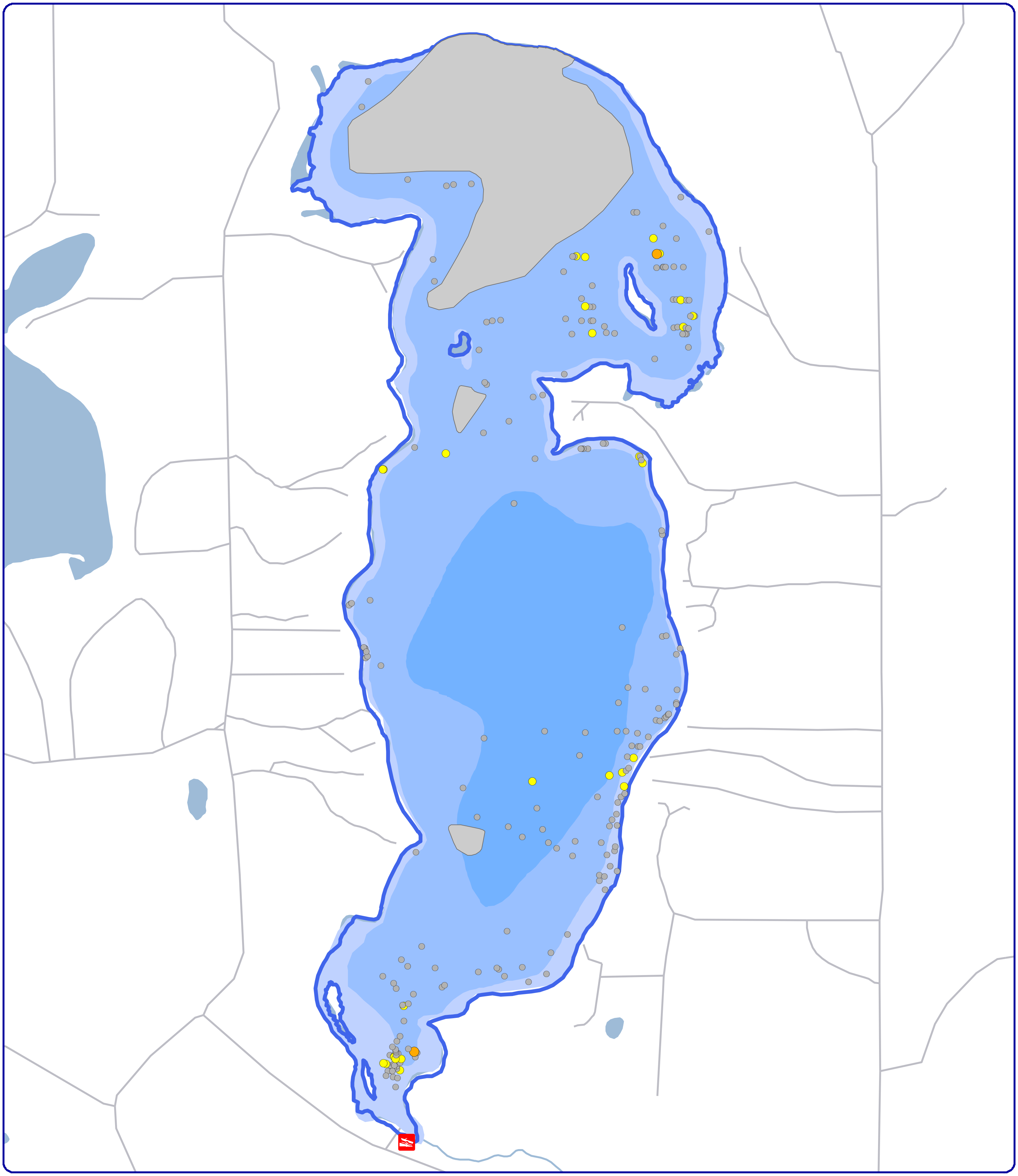
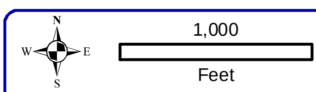
Sources:
Roads and Hyrdo: WDNR
Orthophotograph: NAIP, 2015
Aquatic Plants: Onterra, 2017
Map Date: August 15, 2017
Filename: Map7_Horsehead_Comm_2017.mxd

Map 7

Horsehead Lake
Oneida County, Wisconsin

2017 Plant Survey: Community Mapping





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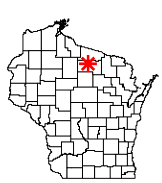
Sources:
Roads and Hydro: WDNR
Aquatic Plant Survey: Onterra, June 2017
Map Date: July 5, 2017
Filename: Map8_Horsehead_CLP_June17.mxd



Project Location in Wisconsin

Legend

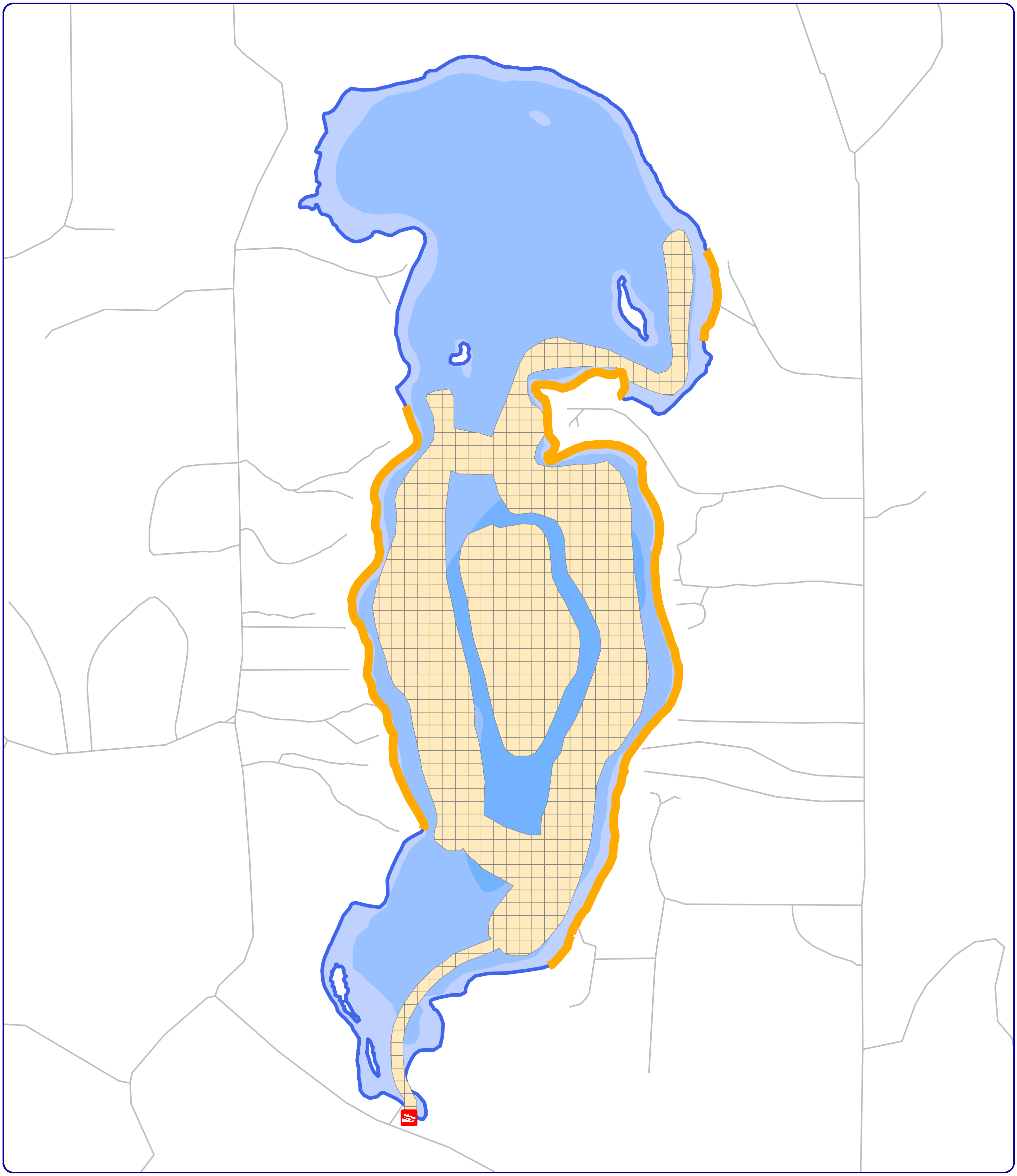
- Highly Scattered
- Scattered (None)
- Dominant (None)
- Highly Dominant (None)
- Surface Matting (None)
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Map 8

Horsehead Lake

Oneida County, Wisconsin

June 2017 CLP Survey Locations



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1,000

Feet

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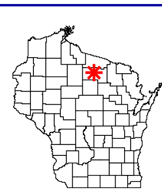
Sources:
Roads and Hydro:WDNR
Bathymetry: WDNR, digitized by Onterra
Map Date: November 6, 2018 JLW
Filename: Map9_Horsehead_HarvPlan.mxd



Project Location in Wisconsin

Legend

Public Access

Potential Harvesting
Areas *(~144 acres)*

Developed Shoreline

Map 9

Horsehead Lake

Oneida County, Wisconsin

Harvesting Plan