Kangaroo Lake

Door County, Wisconsin

Comprehensive Management Plan Update

December 2018

Sponsored by:

Kangaroo Lake Association

WDNR Grant Program

LPL-1595-16

Onterra, LLC
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Onterra, LLC
Lake Management Planning

Kangaroo Lake

Door County, Wisconsin

Comprehensive Management Plan Update

December 2018

Created by: Brenton Butterfield, Tim Hoyman, Eddie Heath, Emily Henrigillis, Jessica Wittmann, Todd Hanke, and Josephine Barlament
Onterra, LLC
De Pere, WI

Funded by: Kangaroo Lake Association
Wisconsin Dept. of Natural Resources
(LPL-1595-16)

Acknowledgements

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

Kangaroo Lake Planning Committee

William Andersen
Kari Hagenow
Nari Haig
Lucy Klug
John Leach
Paul Mahlberg
Ed Ritger
Tom Schneider
Cindy Wienkers
Kevin Wienkers

Wisconsin Dept. of Natural Resources

Mary Gansberg
Steven Hogler

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

MAPS

APPENDICES

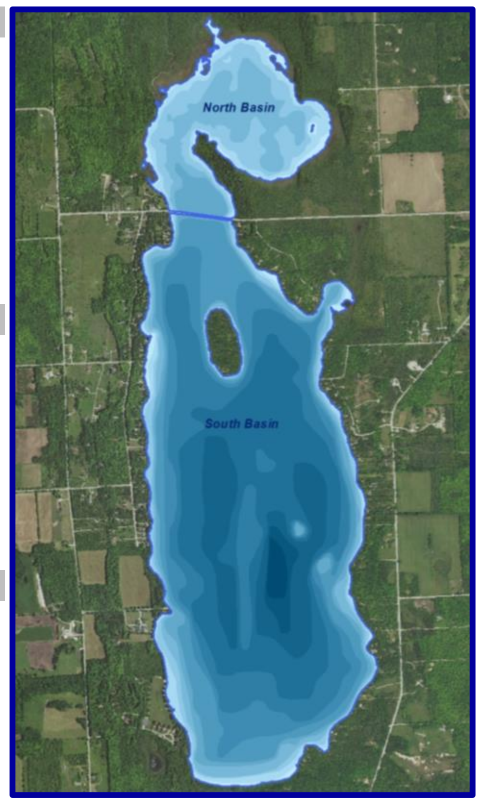
1.0 INTRODUCTION

Kangaroo Lake, the largest inland lake in Door County, is a 1,156-acre meso-oligotrophic, hardwater drainage lake with a maximum depth of 12 feet and a mean depth of 6 feet (Map 1). This shallow lake is divided by the County Hwy E causeway into the smaller north basin and larger south basin. The north basin of the lake was designated as a critical habitat area by the Wisconsin Department of Natural Resources (WDNR) in 1997 and supports a number rare species such as the Hine's emerald dragonfly (*Somatochlora hineana*). The majority of land surrounding the north basin is undeveloped and is within the Kangaroo Lake State Natural Area owned by the Nature Conservancy and the Door County Land Trust. The south basin encompasses the majority of the lake's area and has a higher degree of shoreland development and recreational pressure. The Kangaroo Lake Association (KLA) has undertaken a number of efforts to protect and restore important plant communities within the south basin.

The spring-fed Piel Creek is Kangaroo Lake's primary inflow tributary while the lake drains into nearby Lake Michigan through Heins Creek. Its surficial watershed encompasses approximately 16 square miles and is comprised primarily of pasture/grasslands. In 2016, 27 native aquatic plant species were located in the lake, of which muskgrasses (*Chara* spp.) were the most common. Aquatic invasive species populations documented in Kangaroo Lake are Eurasian watermilfoil and the zebra mussel.

Lake at a Glance - Kangaroo Lake

Morphometry	
LakeType	Shallow Lowland Drainage
Surface Area (Acres)	1,156
Max Depth (feet)	12
Mean Depth (feet)	6
Perimeter (Miles)	11.3
Shoreline Complexity	5.5
Watershed Area (Acres)	10,079
Watershed to Lake Area Ratio	8:1
Water Quality	
Trophic State	Oligo-mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	13
Avg Summer Chl-α (µg/L)	4
Avg Summer Secchi Depth (ft)	5.8
Summer pH	8.6
Alkalinity (mg/L as $CaCO_3$)	179
Vegetation	
Number of Native Species	27
NHI-Listed Species	None
Exotic Species	Eurasian watermilfoil (*Myriophyllum spicatum*)
Average Conservatism	6.4
Floristic Quality	28.0
Simpson's Diversity (1-D)	North Basin 0.61; South Basin 0.65



In 2004, the KLA completed a comprehensive management plan for Kangaroo Lake. That management plan has since guided the KLA's activities including multiple hardstem bulrush restoration and protection projects, volunteer monitoring of Eurasian watermilfoil, and the establishment of mandatory and voluntary slow-no-wake areas. The 2004 planning project focused solely on Kangaroo Lake's south basin and no studies were completed in the north basin. In an effort to update Kangaroo Lake's management plan and collect ecological data from the north basin, the KLA was awarded a WDNR Lake Planning Grant in 2015. This grant aided the KLA in funding a number of studies to collect ecological data on both the north and south basins of Kangaroo Lake in 2016 along with sociological data through an anonymous stakeholder survey.

The KLA realized the value of reassessing the Kangaroo Lake ecosystem and developing an updated management plan. The studies completed in Kangaroo Lake in 2016 included water quality, watershed, shoreland habitat, and aquatic plant community assessments. This report discusses the results of these studies and also includes an updated management plan which the KLA will utilize to protect and enhance the Kangaroo Lake ecosystem. The 2016 studies indicate that Kangaroo Lake is in overall good health. The water quality parameters assessed in Kangaroo Lake rate as excellent for shallow lowland drainage lakes in Wisconsin, and the lake has low nutrient and free-floating algal abundance. While water clarity is often reduced from the suspension of bottom sediments during wind events, average water clarity is still high when compared to other shallow lakes in the state.

Kangaroo Lake's native aquatic plant community is of higher quality when compared to other lakes in the region and is comprised of species typically found in hardwater lakes with good water quality. The north basin of the lake was found to support large communities of emergent and floating-leaf aquatic plants largely comprised of hardstem bulrush, spatterdock, and white water lily. Studies in the south basin found that the hardstem bulrush population declined slightly when compared to studies completed in 2004, but the KLA is continuing their effort to restore and protect this ecologically-important species.

The shoreland assessment surveys completed in 2016 found that the majority of the shoreland surrounding the north basin is undeveloped. However, approximately 29% of shoreland zone within the lake's south basin was found to have a higher degree of human development. The shoreland development in the lake's south basin is likely one of the largest stressors to the Kangaroo Lake ecosystem, and management goals and actions were developed with the KLA to address shoreland development in the south basin. While the majority of Kangaroo Lake's watershed is largely developed in agriculture, the watershed assessment indicated this development is having little impact on the lake's water quality. Given the fast-draining soils and karst landscape found in Door County, much of the precipitation that falls in Kangaroo Lake's watershed percolates through the soil and into the groundwater rather than running across the surface into the lake. This geology has served to protect Kangaroo Lake's water quality from the higher degree of development within its watershed.

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, the completion of a stakeholder survey, and updates within the lake group's newsletter and on the association's website. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting

On July 9, 2016, a project kick-off meeting was held at the Baileys Harbor Town Hall during the KLA's annual meeting to introduce the project to the general public. The meeting was announced through the KLA's newsletter. The approximately 40 attendees observed a presentation given by Brenton Butterfield, an aquatic ecologist with Onterra. Mr. Butterfield's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I

On June 28, 2017, Brenton Butterfield of Onterra met with nine members of the Kangaroo Lake Planning Committee for approximately three hours. In advance of the meeting, attendees were provided an early draft of the study result sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. During this meeting, the results pertaining to Kangaroo Lake's water quality, watershed, shoreland condition, and native aquatic plant community were presented and discussed. For time considerations, a discussion surrounding the lake's population of Eurasian watermilfoil and its management in Wisconsin was postponed until the second planning meeting.

Planning Committee Meeting II

On August 23, 2017, Brenton Butterfield met with eight members of the Planning Committee to discuss Kangaroo Lake's Eurasian watermilfoil population and the ongoing research regarding its management in Wisconsin. In addition, the committee reviewed the stakeholder survey results and the framework for the implementation plan was developed.

Project Wrap-up Meeting

A project wrap-up meeting was held to present the study results and updated Implementation Plan on July 7, 2018 at the Bailey's Harbor Town Hall. Over 50 people attended the meeting that included a presentation by Tim Hoyman and was followed by a question and answer session.

Management Plan Review and Adoption Process

As discussed previously, prior to the first Planning Committee Meeting, a draft of the Results and Discussion Sections (3.0) were provided to the meeting attendees to aid in the delivery of these materials at the meeting. Based upon the discussions that occurred at the two Planning Committee Meetings, a draft of the Implementation Plan Section (5.0) was created by Onterra and provided to the Planning Committee for review.

In January 2018, the first draft of the KLA's Comprehensive Lake Management Plan Update for Kangaroo Lake was distributed for official review to the WDNR. Review comments from WDNR staff were provided directly to Onterra. This report reflects the integration of all comments received. The KLA Board of Directors voted to approve the plan on June 2, 2018.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners around Kangaroo Lake. The survey was designed by Onterra staff and the KLA planning committee and reviewed by a WDNR social scientist. In November 2016, the nine-page, 41-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 KLA volunteer for analysis.

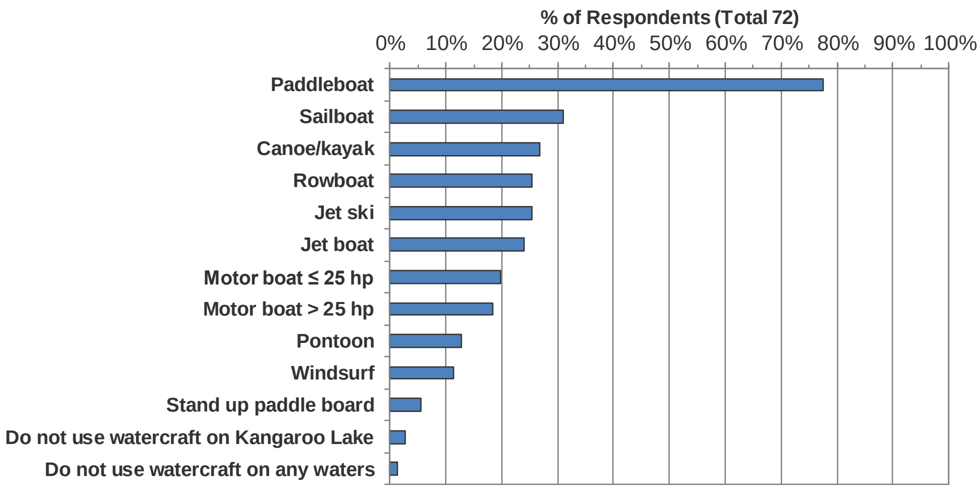
Of the 201 surveys distributed, 72 (36%) were completed. Typically, a benchmark of a 60% response rate is required to portray population projections accurately and to draw conclusions with statistical validity. Given the lower response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Kangaroo Lake but cannot be stated with statistical confidence.

The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. A similar stakeholder survey was also conducted in 2012 by the University of Wisconsin – Stevens Point's Center for Land Use Education. Where appropriate, responses from these two surveys were compared to determine if attitudes towards certain topics may have changed over this time period among Kangaroo Lake stakeholders. The full results of both surveys 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 in this section.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Kangaroo Lake. 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 a canoe/kayak on Kangaroo Lake (Question 18). Larger motor boats, sailboats, pontoons, stand up paddle boards, and paddleboats were also popular options. In 2012, the majority of stakeholders responded that they strongly agreed (37%) or somewhat agreed (44%) that they were knowledgeable about Wisconsin boating laws, while 7% were undecided, 4% somewhat disagreed, and 8% strongly disagreed.

In 2012, survey respondents listed their top concerns/problems on Kangaroo Lake as Eurasian watermilfoil and the loss of hardstem bulrush and aquatic plants. Similarly, top concerns noted throughout the 2016 stakeholder survey (see Question 29 and survey comments – Appendix B) was aquatic invasive species introduction, water quality degradation, and the loss of aquatic habitat and hardstem bulrush populations.

Question 18: What types of watercraft do you currently use on the lake?



Question 22: Please rank up to five activities that are important reasons for owning your property on or near the lake, with 1 being the most important activity.

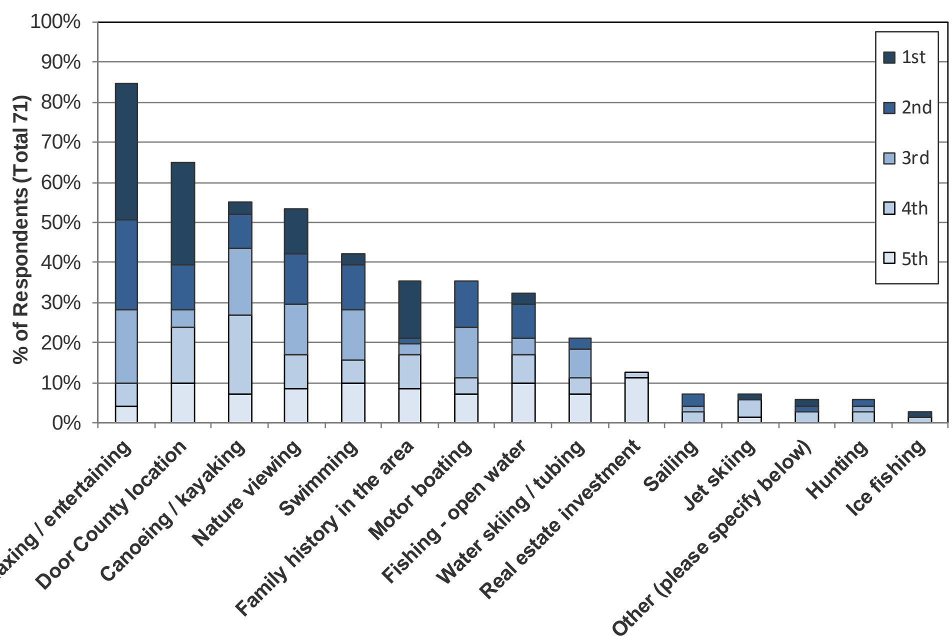
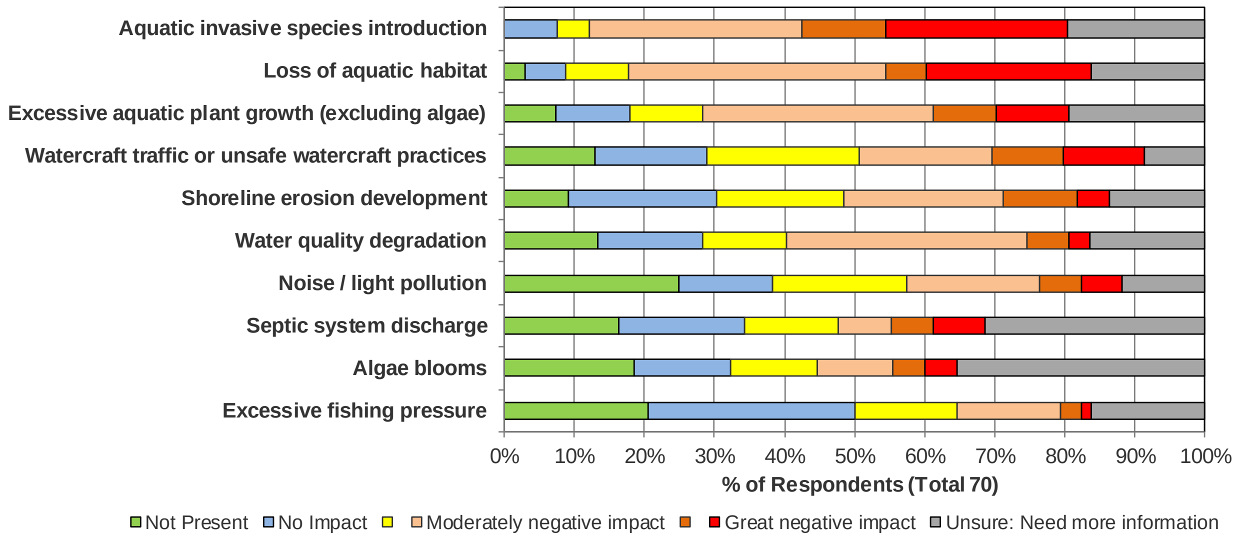


Figure 2.0-1. Select survey responses from the Kangaroo Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 28: To what level do you believe these factors may be negatively impacting Kangaroo Lake?



Question 29: Please rank your top three concerns regarding Kangaroo Lake, with 1 being your greatest concern..

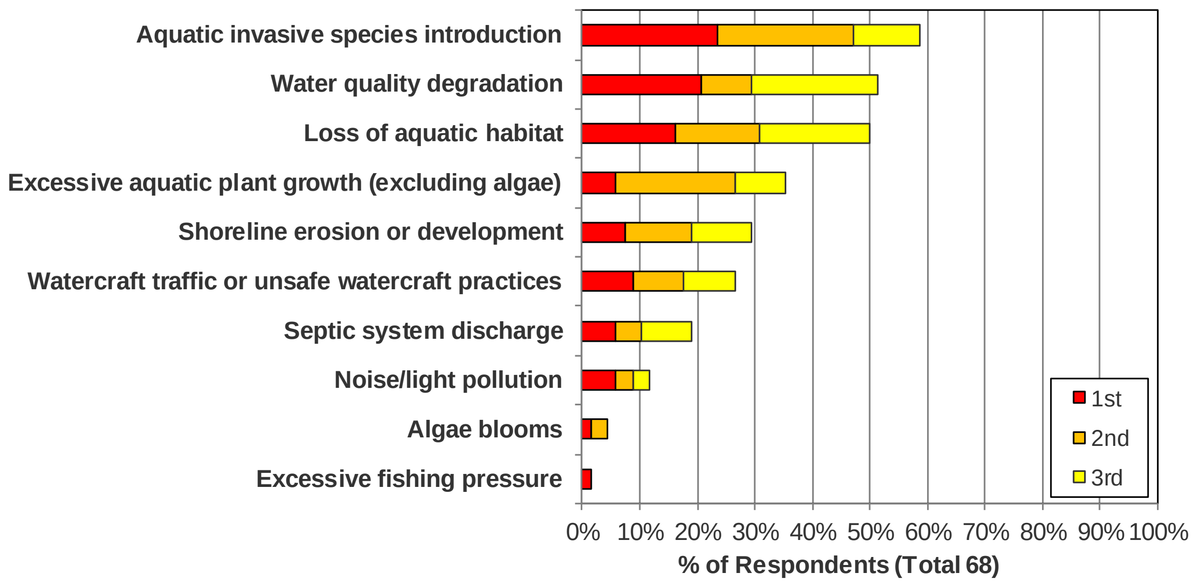


Figure 2.0-2. Select survey responses from the Kangaroo Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on 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 Kangaroo 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 Kangaroo 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 clearer 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 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) 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 Kangaroo 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, hydrology, and watershed size, Kangaroo Lake is classified as a shallow (mixed) lowland drainage lake (category 4 on Figure 3.1-1).

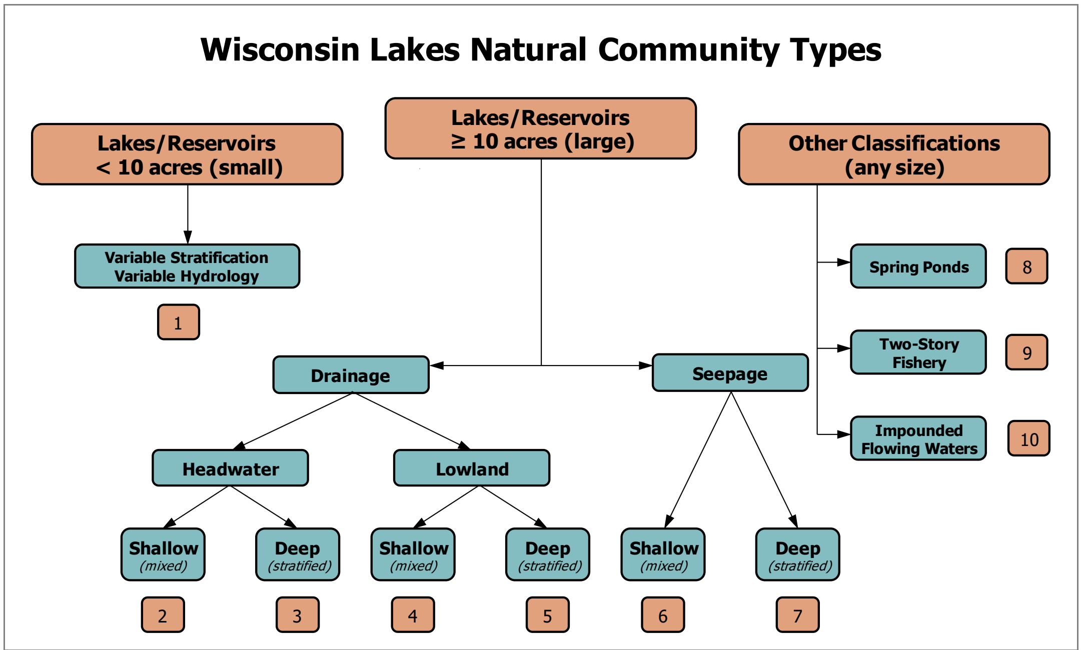


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Kangaroo Lake is within the Southeastern Wisconsin Till Plains ecoregion (Figure 3.1-2).

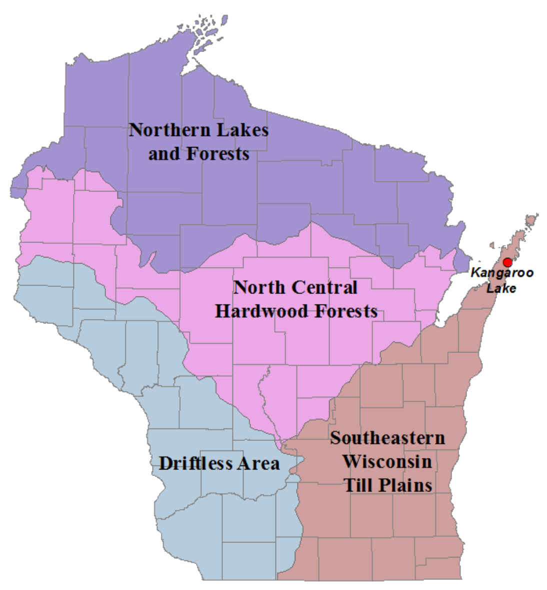


Figure 3.1-2. Location of Kangaroo Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2014 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. Water quality data from Kangaroo Lake along with data from statewide and regional lakes are displayed in Figures 3.1-3 – 3.1-8. The data displayed include both growing season (April – October) and summer (June – August). The data discussed were collected from the deep hole sampling location within the lake's south basin.

Kangaroo Lake Water Quality Analysis

Kangaroo Lake Long-term Trends

Near-surface total phosphorus concentrations are available from Kangaroo Lake from 1973, 1974, 1980-1982, and 1994-2017 (Figure 3.1-3). Near-surface total phosphorus concentrations collected in 1973 and 1974 were significantly higher than any subsequent data. It cannot be said if the 1973 and 1974 data were representative of phosphorus concentrations in the lake at this time or if these data are erroneous due to sampling/processing errors. While the 1973 and 1974 data are included within Figure 3.1-3, these data were not used in the calculation for overall weighted average concentration for Kangaroo Lake.

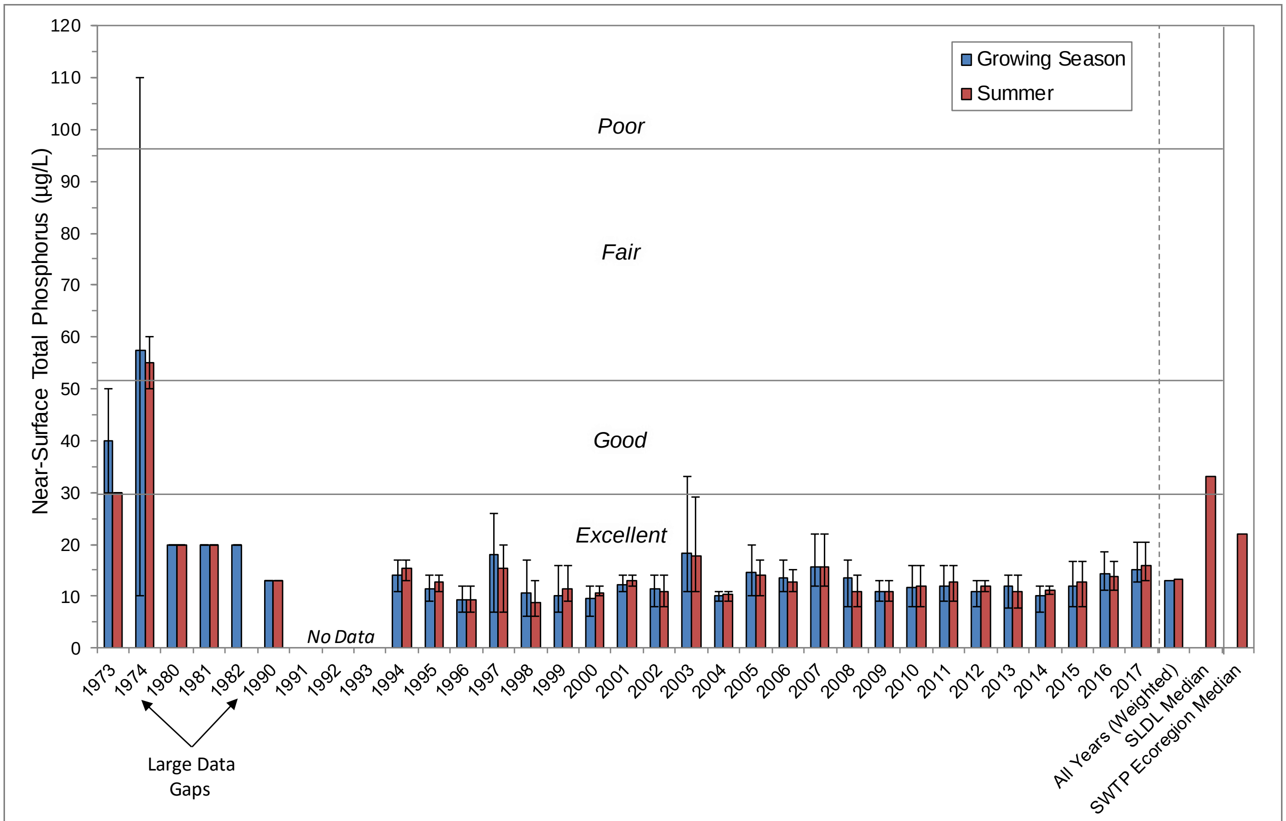


Figure 3.1-3. Kangaroo Lake annual near-surface total phosphorus and statewide shallow lowland drainage lakes (SLDL) and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes median summer total phosphorus. Error bars represent minimum and maximum values. Water quality index values adapted from WDNR PUB WT-913.

Within the near-surface total phosphorus concentration dataset from 1980-2016, average summer concentrations ranged from 20.0 µg/L in 1980 and 1981 to 8.7 µg/L in 1998 (Figure 3.1-3). The weighted summer average near-surface total phosphorus concentration using data from 1980-2016 is 13.2 µg/L, falling well within the *excellent* category for Wisconsin's shallow lowland drainage lakes. Kangaroo Lake's weighted summer near-surface total phosphorus concentration is approximately 2.5 times lower than the median concentration for shallow lowland drainage lakes in Wisconsin and approximately 1.5 times lower than the median concentration for lakes within the SWTP ecoregion. Linear regression of near-surface total phosphorus concentrations in Kangaroo Lake from 1980-2016 indicates that while phosphorus concentrations can be variable from year to year, there is no statistically valid trend (positive or negative) in phosphorus concentration occurring over this time period.

The variability in total phosphorus concentrations from year to year in Kangaroo Lake are likely driven by differences in climatic conditions. There was a weak, negative correlation between annual precipitation (measured at Sturgeon Bay) and average summer total phosphorus concentrations in Kangaroo Lake from 1994-2016. In addition, bottom sediments and nutrients in Kangaroo Lake are easily resuspended during windy periods given the lake's shallow nature in combination with large surface area. The periodic resuspension of bottom sediments and nutrients can also result in variable phosphorus concentrations over shorter periods of time.

Of Wisconsin's 10 classes of lake types, shallow lowland drainage lakes like Kangaroo Lake tend to have the highest phosphorus concentrations as a result of having a large watershed relative to a smaller volume of water. In other words, deeper lakes with larger volumes of water are better able to dilute phosphorus from their watersheds. In addition, shallow lakes tend to have higher phosphorus concentrations when compared to deep lakes as a result of increased sediment resuspension. However, as is discussed further within the Watershed Assessment Section (Section 3.2), phosphorus concentrations in Kangaroo Lake are 248% lower than watershed model predictions. The lower phosphorus concentrations in Kangaroo Lake are the result of geology of the surrounding landscape in which the lake resides, an area mainly comprised of shallow, fast-draining soils overlying karst dolomite bedrock.

The fast-draining soils within the watershed allow the majority of the precipitation which falls within the lake's watershed to percolate into the ground rather than flowing over land and into the lake. Kangaroo Lake has higher concentrations of calcium and magnesium indicating that groundwater rich in these minerals is entering the lake. Groundwater passing through the dolomite bedrock dissolves and carries these minerals into the lake. Lakes with high concentrations of calcium, or *marl lakes*, tend to have lower phosphorus concentrations as phosphate binds to calcium carbonate where it precipitates to the lake bottom and is unavailable for biological use. In addition, the spring-fed Piel Creek, the primary tributary feeding Kangaroo Lake, is largely buffered with intact forests and wetlands which likely intercept and absorb incoming phosphorus from adjacent farm fields. The combination of fast-draining soils in the watershed, calcium-rich water within the lake, and a buffered tributary all work together to maintain low phosphorus concentrations in Kangaroo Lake.

As is discussed in the previous section, internal nutrient loading is a process by which phosphorus (and other nutrients) are released from bottom sediments when bottom waters become devoid of oxygen (anoxic). Internal nutrient loading is more prevalent in deeper lakes which experience summer stratification or in shallow lakes that are highly productive where high rates of decomposition deplete oxygen near the sediment-water interface. To determine if internal nutrient loading of phosphorus is occurring in Kangaroo Lake, phosphorus concentrations were also measured near the bottom in the deepest part of the lake. In lakes which experience high levels of internal nutrient loading, phosphorus concentrations are usually significantly higher near the bottom than those measured near the surface.

In Kangaroo Lake, near-bottom phosphorus concentrations were measured on three occasions in 2016 (Figure 3.4-4). On all three occasions, near-bottom phosphorus concentrations were similar to those at the surface indicating the internal loading of phosphorus is not a significant source of phosphorus to Kangaroo Lake. Historical samples collected in 1994 and 2003 also indicate that near-bottom and near-surface total phosphorus concentrations were similar. As is discussed further in this section, Kangaroo Lake's shallow nature in combination with a large surface area allows wind to mix and deliver sufficient oxygen throughout the water column. In 2016, Kangaroo Lake was not found to have developed thermal stratification and/or anoxic conditions in bottom waters.

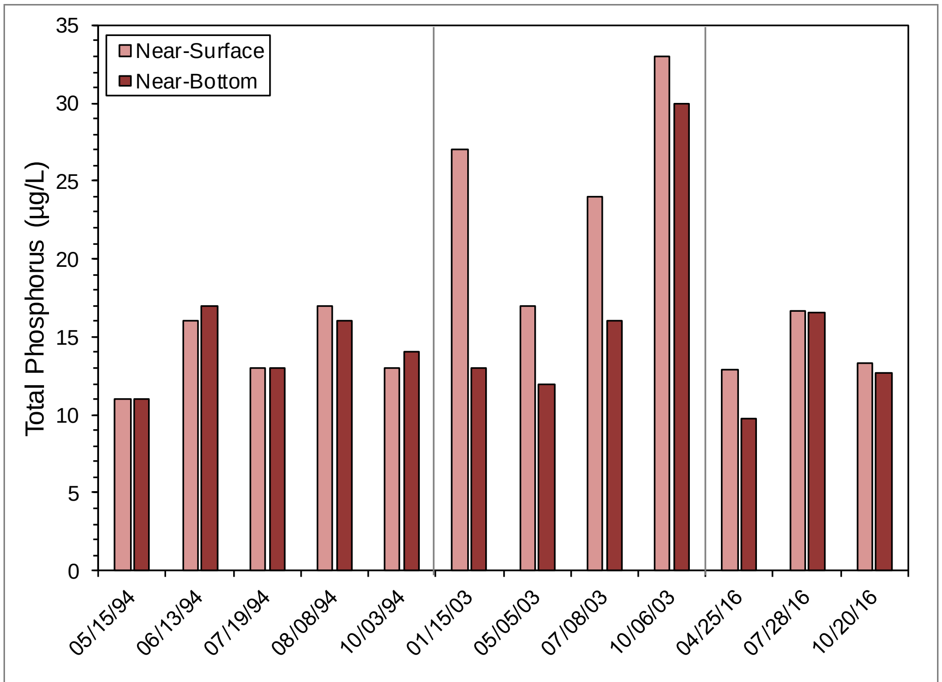


Figure 3.1-4. Kangaroo Lake comparison of near-surface and near-bottom total phosphorus concentrations.

Chlorophyll-*a* concentrations in Kangaroo Lake are available from 1980-1982, 1990, and 1993-2017 (Figure 3.1-5). Within the dataset from 1993-2016, average summer chlorophyll-*a* concentrations ranged from 8.9 µg/L in 1994 to 2.0 µg/L in 2015. The weighted summer average chlorophyll-*a* concentration using all available data was 4.0 µg/L, falling into the *excellent* category for Wisconsin's shallow lowland drainage lakes. Kangaroo Lake's average summer chlorophyll-*a* concentration also falls below the median concentration for shallow lowland drainage lakes in Wisconsin and the median concentration for all lake types within the SWTP ecoregion. The average summer chlorophyll-*a* concentration measured in 2016 and 2017 was 3.2 and 2.8 µg/L, respectively, falling slightly below the historical average.

Chlorophyll-*a* concentrations in Kangaroo Lake are low and are similar to predicted concentrations based on the concentrations of phosphorus. Chlorophyll-*a* concentrations were slightly higher from 1993-1996 before declining in 1997. From 1997-2013 there was a slight increasing trend in chlorophyll-*a* concentration before concentrations declined again from 2014-2017. While there has been an overall negative trend in chlorophyll-*a* concentration over the period from 1993-2017, this trend is relatively weak and the data may suggest a more cyclical rather than linear pattern is occurring over time.

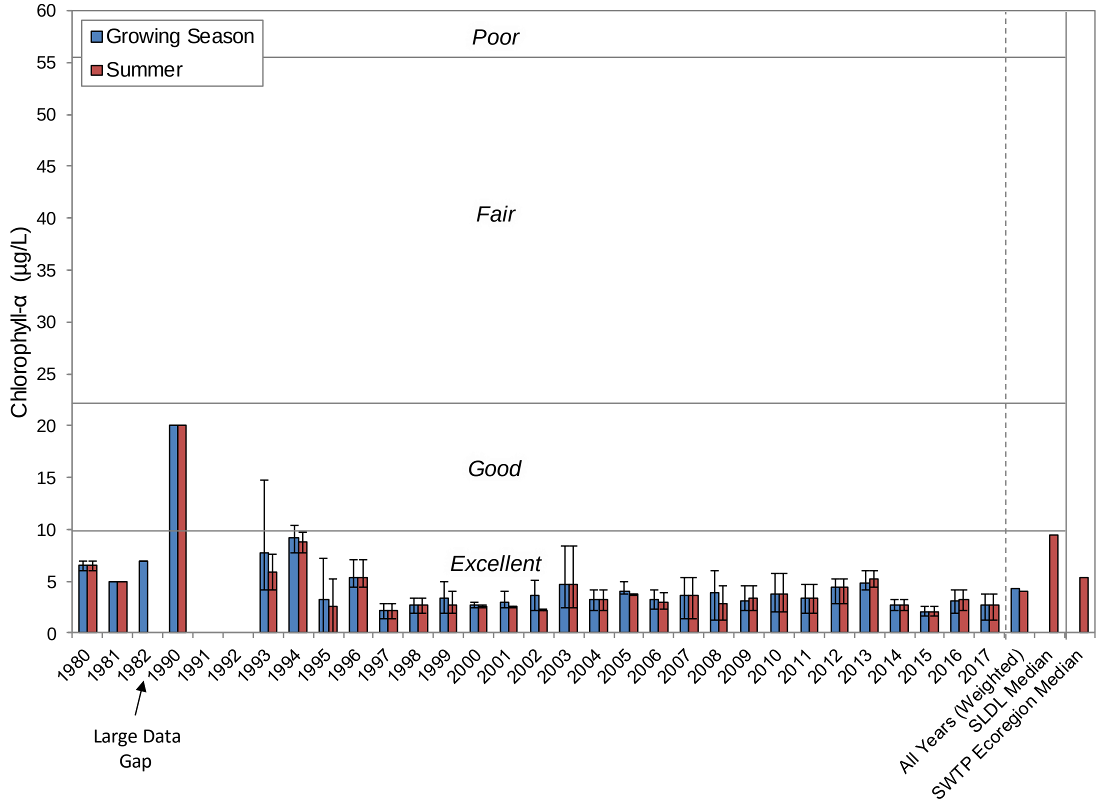


Figure 3.1-5. Kangaroo Lake annual chlorophyll-α and statewide shallow lowland drainage lakes (SLDL) and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes median summer chlorophyll- α. Error bars represent minimum and maximum values. Water quality index values adapted from WDNR PUB WT-913.

Secchi disk transparency data from Kangaroo Lake are available from 1973-1974, 1990, and 1992-2017 (Figure 3.1-6). Within the dataset from 1993-2017, average summer Secchi disk depth ranged from 4.4 feet in 2010 to 9.3 feet in 2017. It must be noted that the Secchi disk was recorded to hit the bottom (11 feet) on two occasions in 2017, and average water clarity was likely higher than 9.3 feet. Based on the average summer chlorophyll in 2017, average summer Secchi disk depth is predicted to be closer to 10 feet. The weighted summer average Secchi disk depth calculated from all available data was 5.9 feet, falling into the *excellent* category for Wisconsin's shallow lowland drainage lakes. Kangaroo Lake's average summer Secchi disk depth is slightly higher than the median value for shallow lowland drainage lakes in Wisconsin but slightly lower than the median value for all lake types within the SWTP ecoregion. However, some of the highest Secchi disk transparency values were recorded in the recent years of 2015, 2016, and 2017 with an average summer value of 8.6 feet.

Despite interannual variability in Secchi disk transparency from 1993-2017, trends analysis indicated no significant trend (positive or negative) in water clarity has occurred over this time period. The relationship between Secchi disk depth and chlorophyll-*a* in Kangaroo Lake is not very strong, and a wide range of Secchi disk depths have been measured at low concentrations of chlorophyll-*a* (Figure 3.1-7). And while measured chlorophyll-*a* concentrations in Kangaroo

Lake align with predicted concentrations based on total phosphorus, measured summer Secchi disk transparency is approximately 3.0 feet lower than predicted based upon measured chlorophyll-*a*. This is an indication that another factor(s) apart from phytoplankton abundance is affecting water clarity in Kangaroo Lake.

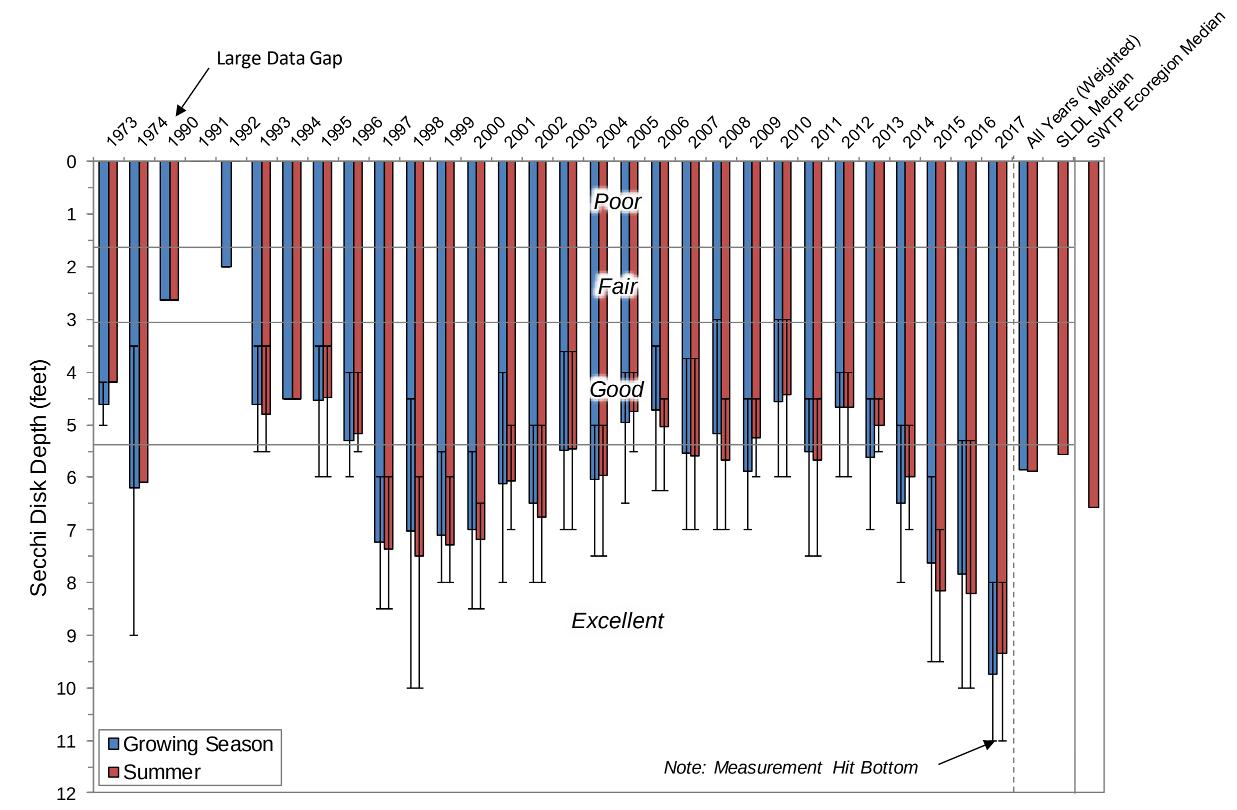


Figure 3.1-6. Kangaroo Lake annual Secchi disk transparency and statewide shallow lowland drainage lakes (SLDL) and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes median summer Secchi disk transparency. Error bars represent minimum and maximum values. Water quality index values adapted from WDNR PUB WT-913.

Water clarity in Wisconsin's lakes is primarily influenced by suspended particulates within the water, mainly phytoplankton. However, abiotic suspended particulates, such as sediment, can also affect water clarity. As mentioned previously, Kangaroo Lake is prone to wind-driven sediment resuspension given its shallow water and large surface area. Total suspended solids, a measure of both biotic and abiotic suspended particles within the water were measured in Kangaroo Lake on two occasions in 2016. The total suspended solids values ranged from 2.0-5.0 mg/L. While these values are relatively low, they are higher given the low concentrations of chlorophyll-*a* and indicate the presence of suspended abiotic particles. Historical data indicate that total suspended solids have measured as high as 11.0 mg/L (1990) in Kangaroo Lake. The total suspended solids data from Kangaroo Lake indicate that resuspended bottom sediments during windy periods reduce water clarity.

In addition to suspended material within the water, water clarity in Wisconsin's lakes can also be affected by dissolved compounds within the water. Many lakes in northern Wisconsin contain higher concentrations of dissolved humic substances and organic acids that originate from decomposing plant material within wetlands and coniferous forests in the lakes' watersheds. In higher concentrations, these dissolved compounds give the water a brown or tea-like color, decreasing water clarity. A measure of water clarity once all of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed true color, and indicates the level of dissolved material within the water. The true color of Kangaroo Lake's water was measured on two occasions in 2016 with an average value of 5.0 SU (standard units) indicating very low concentrations of dissolved compounds and clear water. Stained water was observed flowing into the north basin of Kangaroo Lake from Piel Creek; however, these organic compounds are broken down rapidly by bacteria in lakes with higher concentrations of calcium. Water clarity in Kangaroo Lake is primarily influenced by phytoplankton and suspended abiotic particulates (sediment).

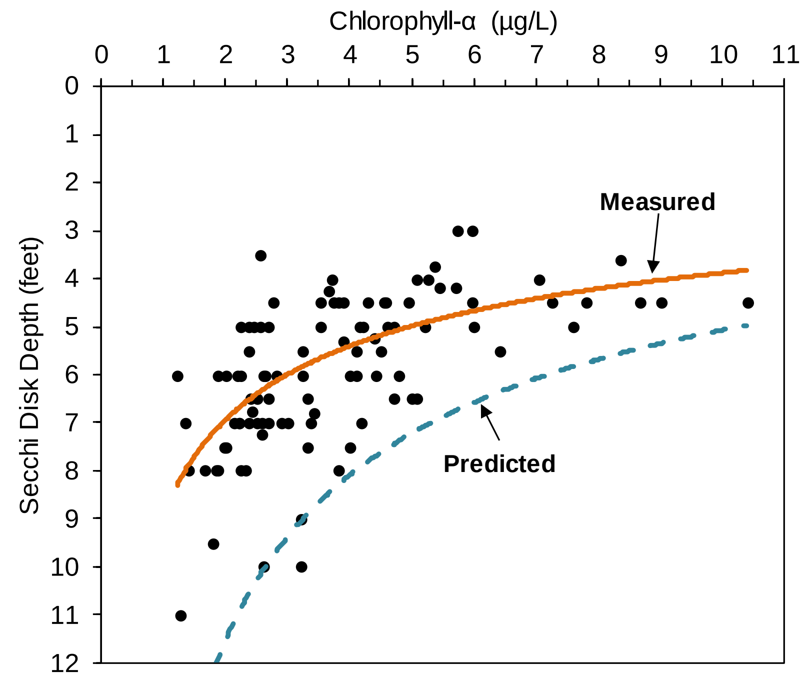


Figure 3.1-7. Kangaroo Lake measured relationship between chlorophyll and Secchi disk depth (orange solid line) and predicted Secchi disk depth based on measured chlorophyll (dashed blue line). Secchi disk depth lower than predicted based on measured chlorophyll due to wind-driven sediment resuspension which reduces water clarity. Predicted Secchi disk depth calculated using predictive equations from Carlson 1977. Data displayed were collected from 1993-2017.

The non-native zebra mussel (*Dreissena polymorpha*) was discovered in Kangaroo Lake in 2008. Numerous studies on lakes invaded by zebra mussels found that water clarity increases as a result of decreased suspended material within the water from the filtering of zebra mussels (MacIsaac 1996; Karatayev et al. 1997; Reed-Andersen et al. 2000; Zhu et al. 2006). Zebra mussels are very efficient filter feeders, and water that has been filtered is almost entirely devoid of suspended particles (Karatayev et al. 1997). Even unwanted particles (e.g. clay particles) that pass through the zebra mussel are deposited to the sediment as pseudofeces (Karatayev et al. 1997). Following zebra mussel invasion, chlorophyll-*a* concentrations tend to decline despite no change in total phosphorus concentrations. It cannot be said if the recent decline in chlorophyll-*a* since 2014 and corresponding increase in water clarity in Kangaroo Lake is the result of zebra mussel establishment or other environmental factors. Continued monitoring of the lake's water quality will reveal if and how chlorophyll-*a* and water clarity change with the presence of zebra mussels in Kangaroo Lake.

Limiting Plant Nutrient of Kangaroo Lake

As discussed previously, phosphorus is the primary nutrient controlling the growth of phytoplankton in the majority of Wisconsin's lakes. To determine whether phosphorus is the limiting nutrient within a lake the concentration of phosphorus is compared to the concentration of nitrogen. Using mid-summer total phosphorus and total nitrogen concentrations from Kangaroo Lake indicates the lake is phosphorus-limited, like the majority of Wisconsin's lakes. The mid-summer nitrogen to phosphorus ratio in 2016 was 42:1. This indicates that potential increases in phosphorus to Kangaroo Lake would likely result in increased phytoplankton production.

Kangaroo Lake Trophic State

Figure 3.1-8 contains the weighted average Trophic State Index (TSI) values for Kangaroo 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 along with 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. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

Kangaroo Lake's weighted TSI values for total phosphorus and chlorophyll-*a* are relatively similar indicating that phytoplankton production is regulated by phosphorus. However, the TSI value for Secchi disk depth is higher than the TSI values for phosphorus and chlorophyll-*a*, and is another indication that another factor in addition to phytoplankton is affecting water clarity. As discussed in the previous section, resuspended bottom sediments during periods of wind are also affecting Kangaroo Lake's water clarity. The TSI values for total phosphorus and chlorophyll-*a* fall on the threshold between an oligotrophic and mesotrophic state, and indicate that Kangaroo is currently in an oligo-mesotrophic state. Kangaroo Lake is of considerably less productive when compared to other shallow lowland drainage lakes in Wisconsin, which on average are eutrophic. Similarly, Kangaroo Lake is of lower productivity when compared to all lake types within the SWTP ecoregion, which on average tend to be meso-eutrophic.

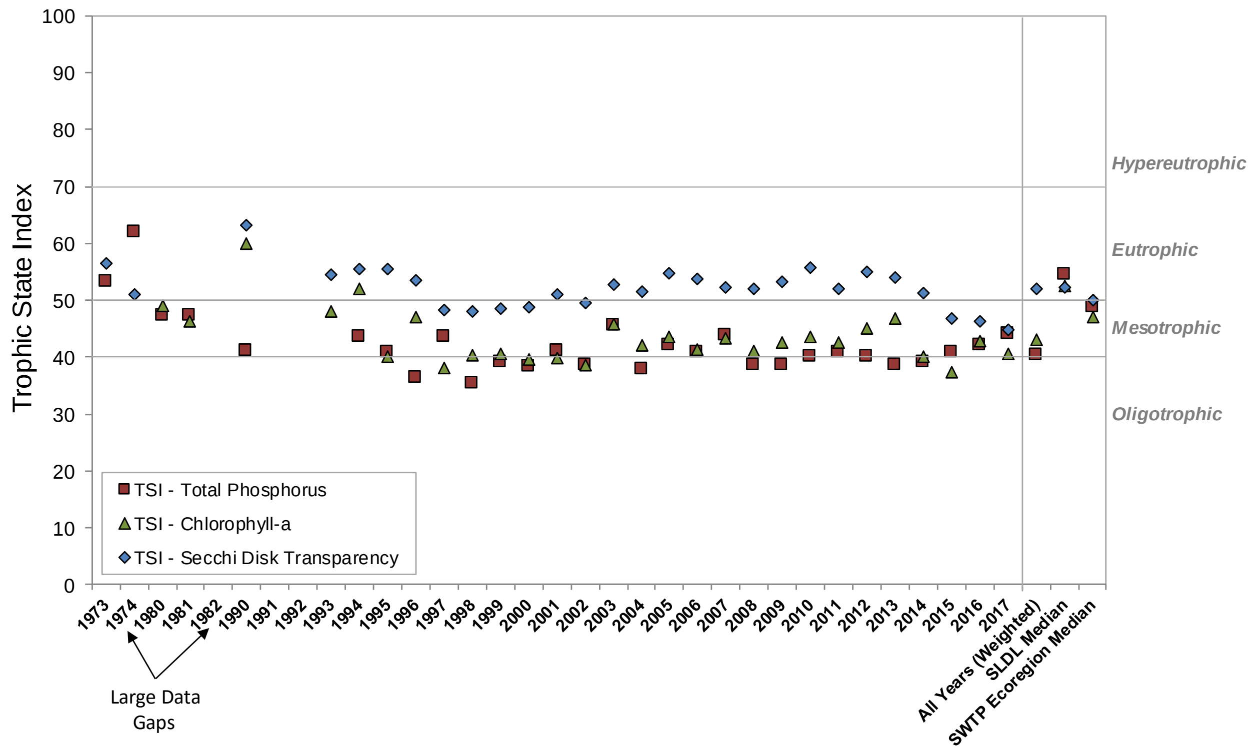


Figure 3.1-8. Kangaroo Lake, statewide shallow lowland drainage lakes (SLDL), and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data (Carlson 1977). Weighted average was calculated using data from years which had measurements for all three parameters.

Dissolved Oxygen and Temperature in Kangaroo Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Kangaroo Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-9. The water in Kangaroo Lake was found to be uniformly mixed during the April, July, and October sampling events. Being a shallow lake with a large surface area, Kangaroo Lake remains mixed over the course of the growing season and does not experience strong thermal stratification. Measurements taken under the ice in February of 2017 indicate Kangaroo Lake maintains sufficient oxygen during the winter to sustain aquatic life, and winter fishkills are not a concern.

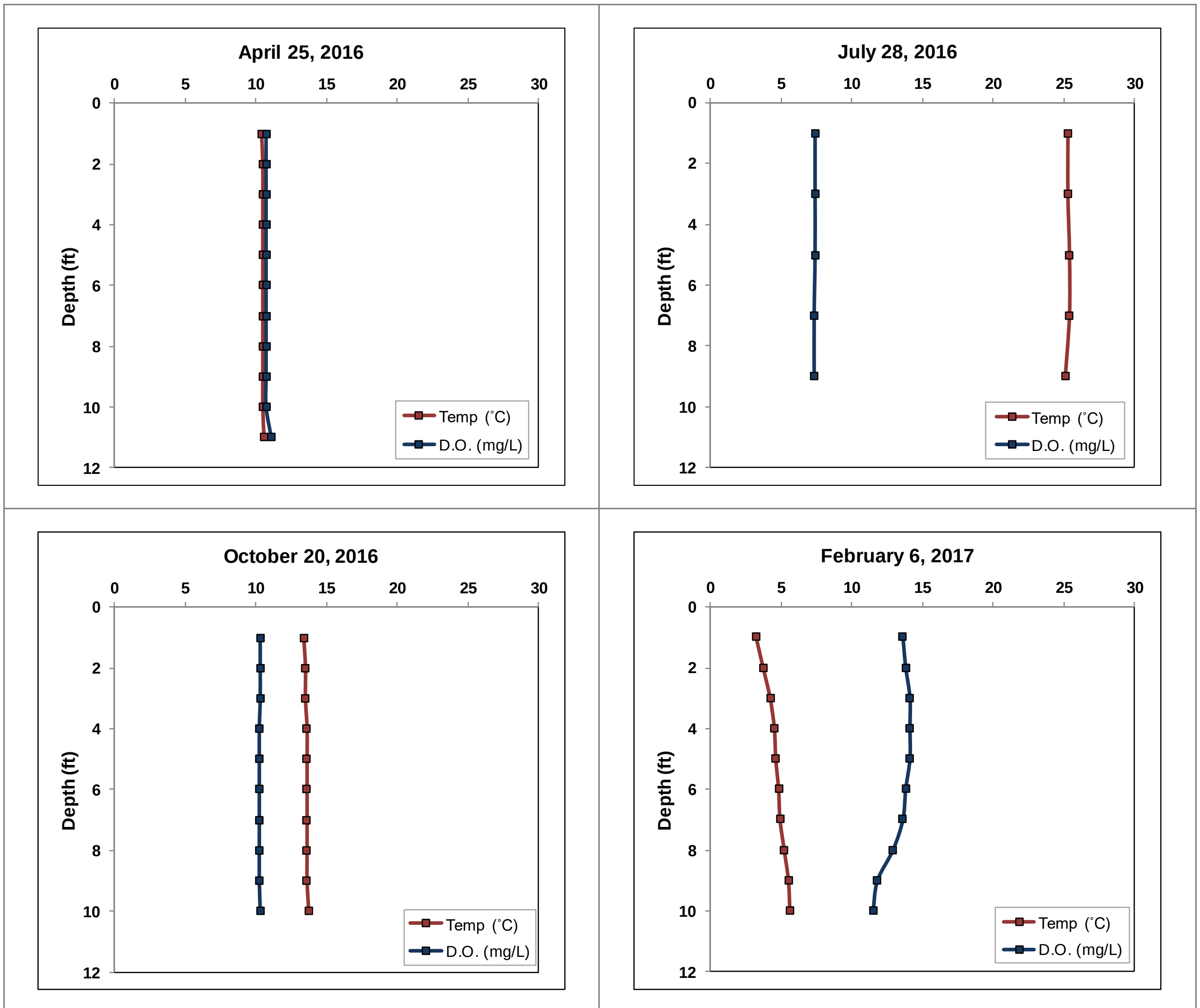


Figure 3.1-9. Temperature and dissolved oxygen profiles collected on Kangaroo Lake in 2016/17. Data were collected from the deep hole sampling location within the south basin.

Additional Water Quality Data Collected at Kangaroo Lake

The previous sections were largely centered on water quality parameters that relate to the lake's trophic state. 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 Kangaroo 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 7.0 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7.0 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7.0 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to

8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985).

The mid-summer pH of the water in Kangaroo Lake was found to be alkaline with a value of 8.6. As discussed in the previous section, Kangaroo Lake is considered to be a marl lake with high concentrations of calcium. While the lake's pH falls outside the normal range for most lakes in Wisconsin, this higher pH is expected given the higher concentration of calcium within the lake.

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 ($CaMgCO_3$). 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 Kangaroo Lake was measured to be high at 179 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and 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 mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Kangaroo Lake's pH of 8.6 falls within 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 Kangaroo Lake was found to be 42 mg/L, indicating a high susceptibility to zebra mussel establishment. As mentioned, zebra mussels were confirmed in Kangaroo Lake in 2008, and this invasive mussel is discussed in detail within the Aquatic Invasive Species in Kangaroo Lake Section (3.5).

Summary of 2007 Sediment Core Analysis

In 2007, a sediment core was collected from the deeper area within the south basin of Kangaroo Lake to undergo analysis to determine how water quality within the lake has changed following Euro-American settlement (Garrison 2007). Fossilized diatoms within the sediment were analyzed to infer changes in water quality. Diatoms are a type of alga which possess siliceous cell walls and are usually abundant, diverse, and well preserved in sediments (Photo 3.1-1). They are especially useful as they are ecologically diverse and their ecological optima and tolerances can be quantified. In other words, certain species thrive in certain conditions, so the past ecological conditions are able to be reconstructed based on the species that were present. For example, some species prefer lower phosphorus concentrations while other species grow attached to benthic substrates such as aquatic plants.

Analysis of the sediment core collected from Kangaroo Lake showed significant changes between the diatom community at the bottom of the core (pre-settlement) and the diatom community at the top of the core (present conditions). The diatom community at the bottom of the core was largely comprised of diatoms that grow attached to aquatic plants, while the community at the top of the core was largely comprised of diatoms which are planktonic, or grow within the water column. The conclusions of this fossilized diatom community analysis were that nutrient levels (phosphorus) in Kangaroo Lake have increased moderately since Euro-American settlement and that the lake, likely the south basin in particular, has seen a decline in abundance of aquatic plants over time.

Development in the form of agriculture and the construction of residential structures along Kangaroo Lake's shoreline are the likely cause of the moderate increase in nutrient levels. The causes of the decline in the aquatic plant community are not known, but likely involve a combination of factors including changes in hydrologic regime with the installation of the dam, increased recreational use, and shoreland development. Kangaroo Lake's aquatic plant community is discussed in detail within the Aquatic Plant Section (Section 3.4).

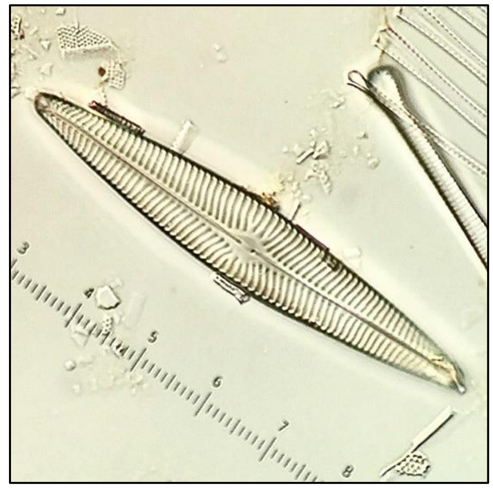


Photo 3.1-1. Fossilized diatom (*Navicula radiosa*) extracted from a lake sediment core. Photo credit Onterra.

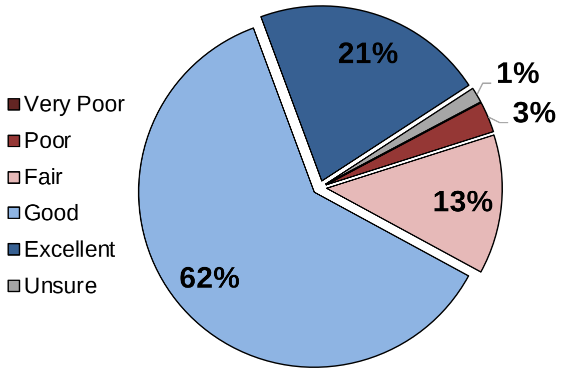
Stakeholder Survey Responses to Kangaroo Lake Water Quality

In 2016, a stakeholder survey was sent to 201 Kangaroo Lake stakeholders. Approximately 36% or 72 surveys were completed. Given the relatively low response rate, the results of the stakeholder survey 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 Kangaroo Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

When asked about the state of Kangaroo Lake's current water quality, the majority of respondents (83%) described the current water quality as *excellent* or *good*, 13% described it as *fair*, 3% described it as *poor*, and 1% indicated *unsure* (Figure 3.1-10). When asked how water quality has changed in Kangaroo Lake since they first visited the lake, approximately 39% of respondents indicated water quality has *remained the same*, 21% indicated it has *somewhat degraded*, 20% indicated it has *somewhat improved*, 4% indicated it has *greatly improved*, 2% indicated it as *severely degraded*, and 14% were *unsure* (Figure 3.1-10).

As is discussed in the previous sections, total phosphorus, chlorophyll-*a*, and Secchi disk transparency in Kangaroo Lake all fall within the *excellent* category for shallow lowland drainage lakes in Wisconsin, and these data align with the majority of stakeholder perceptions of Kangaroo Lake's water quality. While 39% of respondents indicated that the water quality in Kangaroo Lake has not changed since they first visited the lake, approximately 20% indicated water quality has improved while another 21% indicated water quality as degraded. In the previous sections, trends analysis showed that water quality in Kangaroo Lake in terms of water clarity can be variable from year to year, but no trend (positive or negative) was occurring over the time period for which data are available. It is possible that the differences in the perception of change in Kangaroo Lake's water quality is due to differences in the time period for which people have been on the lake.

23. How would describe the current water quality of Kangaroo Lake?



24. How has the water quality changed in Kangaroo Lake since you first visited the lake?

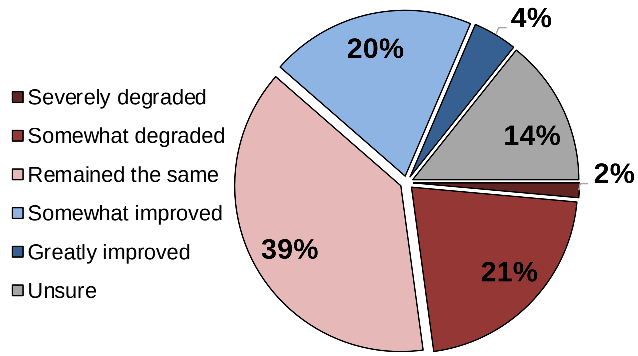


Figure 3.1-10. Kangaroo Lake stakeholder survey responses to questions regarding the lake's current and historical water quality.

3.2 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.

Kangaroo Lake Watershed Assessment

Kangaroo Lake's surficial watershed encompasses approximately 10,079 acres (15.7 square miles), yielding a watershed to lake area ratio of 8:1 (Figure 3.2-1 and Map 2). The WiLMS modeling indicates that Kangaroo Lake's water residence time is approximately 0.68 years, or the water is completely replaced within the lake 1.5 times per year. Approximately 50% (5,001 acres) of the watershed is comprised of areas of pasture/grass/rural open space, 18% (1,859 acres) is comprised of forests, 12% (1,174 acres) is comprised of wetlands, 12% (1,170 acres) is comprised of Kangaroo Lake's surface, 6% (649 acres) is comprised of row crop agriculture, 2% (221 acres) is comprised of rural residential areas, and <1% (5 acres) is comprised of medium density urban areas (Figure 3.2-1).

Using the land cover types and their acreages within Kangaroo Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to the lake from the watershed. In addition, using data obtained from the 2016 stakeholder survey of Kangaroo Lake stakeholders, an estimate of phosphorus loading to the lake from septic systems was also incorporated into the model. The WiLMS model estimated that approximately 2,528 pounds of phosphorus are loaded to Kangaroo Lake from its watershed on an annual basis. Using the estimated annual potential phosphorus load, WiLMS predicted in in-lake growing season mean concentration of phosphorus of 52 µg/L, or 248% higher than the measured growing season mean phosphorus concentration of 13 µg/L.

The large discrepancy between measured and predicted total phosphorus concentrations in Kangaroo Lake indicates that the model is significantly overestimating the amount of phosphorus being loaded to Kangaroo Lake annually from its watershed. Based on the measured growing season mean total phosphorus concentration of 13 µg/L, it is estimated that a lesser amount of approximately 500 pounds of phosphorus are delivered to the lake on an annual basis. Of this 500 pounds, 313 pounds (63%) are estimated to originate from direct atmospheric deposition onto the lake surface, 102 pounds (20%) from pasture/grasslands, 44 pounds (9%) from row crop agriculture, 19 pounds (4%) from riparian septic systems, 11 pounds (2%) from forests, 8 pounds (2%) from wetlands, and 2 pounds (<1%) from rural residential areas (Figure 3.2-2).

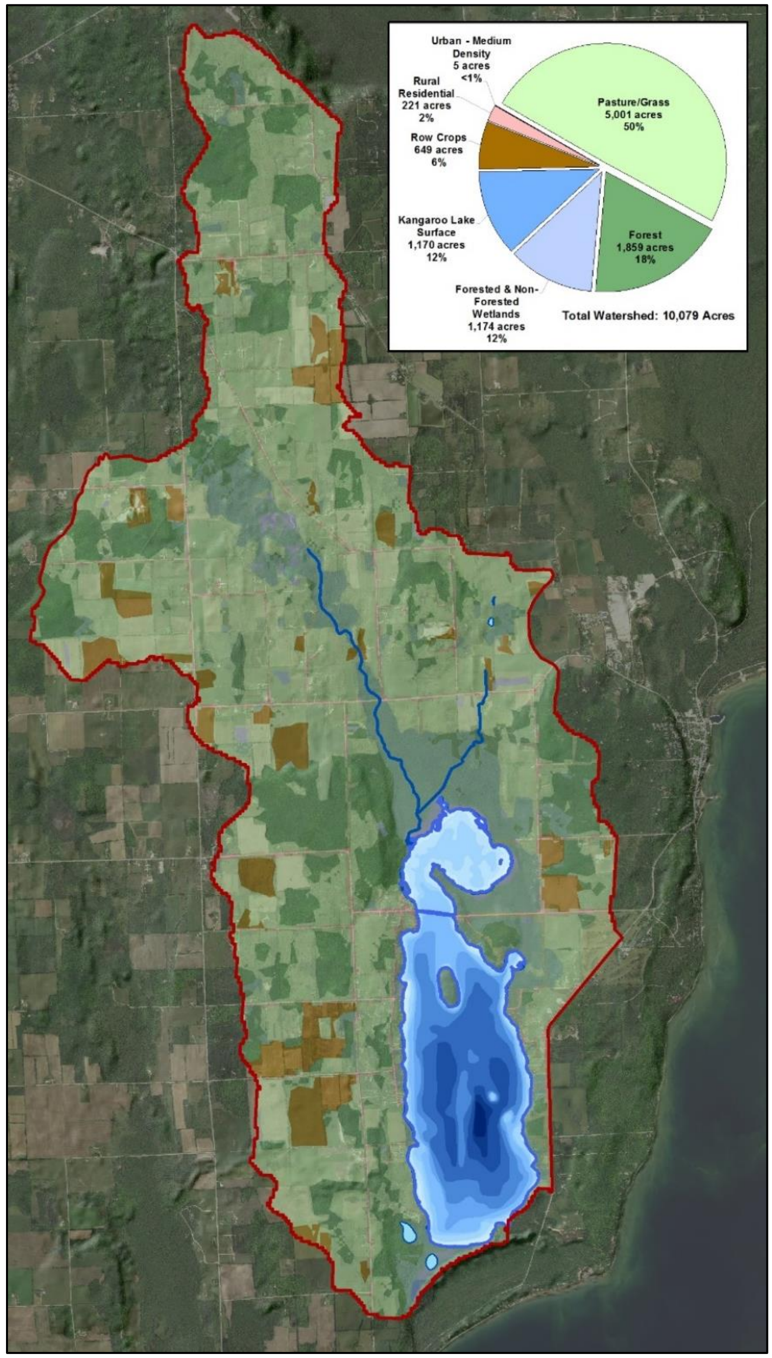


Figure 3.2-1. Kangaroo Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

The lower than predicted phosphorus concentrations in Kangaroo Lake are believed to be the result of the underlying geology of the area in which the lake resides; an area mainly comprised of shallow, fast draining soils on top of dolomite bedrock. Apart from some wetland areas around the northern part of the lake and immediately adjacent to Piel Creek which contain *somewhat poorly* to *poorly drained* soils, the majority of Kangaroo Lake's watershed contains soils categorized as *well drained* (Map 3). The fast-draining soils within the watershed allow the majority of the precipitation which falls in the watershed to percolate into the ground rather flowing over land and into the lake as the WiLMS model assumes.

In addition, Kangaroo Lake has higher concentrations of calcium and magnesium indicating that groundwater rich in these minerals is entering the lake. Groundwater passing through the

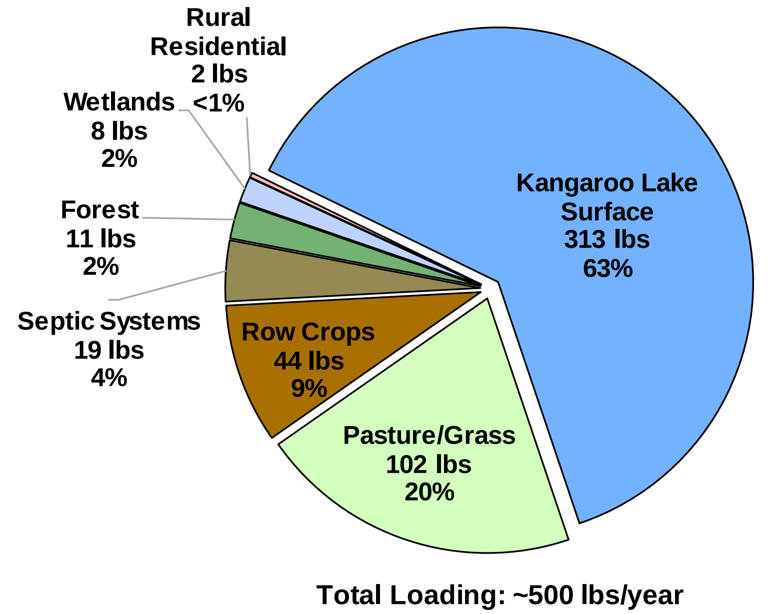


Figure 3.2-2. Kangaroo Lake estimated annual phosphorus loading. Calculated using Wisconsin Lakes Modeling Suite.

dolomite bedrock dissolves and carries these minerals into the lake. Much of the water within Piel Creek originates from alkaline groundwater springs (Wisconsin Wetlands Association). Lakes with high concentrations of calcium, or *marl lakes*, tend to have lower phosphorus concentrations as phosphate binds to calcium carbonate where it precipitates to the lake bottom and is unavailable for biological use. In addition, Piel Creek, the primary tributary feeding Kangaroo Lake, is largely buffered with intact forests and wetlands which likely intercept and absorb incoming phosphorus from adjacent farm fields. Despite a high degree of human development within Kangaroo Lake's watershed, the combination of fast-draining soils, calcium-rich water within the lake, and a buffered tributary all work together to maintain low phosphorus concentrations in Kangaroo Lake.

Using the WiLMS model, scenarios can be developed to gain an understanding of how Kangaroo Lake's water quality may change with changes in land use within its watershed. If the current areas of pasture/grass and row crop agriculture were converted to forests, WiLMS estimated that Kangaroo Lake's average growing season total phosphorus concentrations would decline by approximately 20%, from 14.9 µg/L to 12.0 µg/L. The predicted decline in total phosphorus would reduce growing season chlorophyll-*a* concentrations from 4.1 µg/L to 3.2 µg/L. The predicted reduction in chlorophyll-*a* would be predicted to increase Secchi disk transparency from 5.8 feet to 8.5 feet; however, this does not account for sediment resuspension which also influences clarity in Kangaroo Lake and increases in clarity may not be realized.

Similarly, a scenario was run to determine how Kangaroo Lake's water quality may change if 25% of the forests remaining within its watershed were converted to row crop agriculture. In this scenario, average growing season total phosphorus concentrations are predicted to increase from 14.9 µg/L to 16.0 µg/L, chlorophyll-*a* would increase from 4.1 µg/L to 4.8 µg/L, and Secchi disk transparency would decline from 5.8 feet to 5.1 feet. While the high degree of development within Kangaroo Lake's watershed is not currently having significant impacts to the lake's water quality, future development especially within the immediate areas around Piel Creek and the lake itself could lead to water quality degradation. Efforts to preserve natural land cover within these areas and elsewhere in Kangaroo Lake's watershed should be made to maintain the lake's excellent water quality.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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.

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.

Photograph 3.3-1. Example of coarse woody habitat in a lake.

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 3.3-2. Example of a bio-log 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.

Kangaroo Lake Shoreland Zone Condition

Shoreland Development

Kangaroo 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 3.3-1 displays a diagram of shoreland categories ranging 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.

On Kangaroo Lake, the development stage of the entire shoreland was surveyed in the fall of 2016 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.

Kangaroo Lake has stretches of shoreland that fit all of the five shoreland assessment categories (Figure 3.3-2 and Map 4). Of the 11.3 miles of shoreland around both basins of Kangaroo Lake, 7.4 miles (66%) of natural/undeveloped and developed-natural shoreland were observed during the survey. 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, 2.4 miles (21%) of urbanized and developed–unnatural shoreland were observed. If restoration of the Kangaroo 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. Approximately 1.5 miles (13%) of the shoreline was categorized as being in a developed-semi natural state.

Urbanized: This type of shoreland 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 shorelands 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 shoreland 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 shoreland that was restored would likely be included here, also.

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

Figure 3.3-1. Shoreline assessment category descriptions.

Looking at the northern and south basins of Kangaroo Lake separately shows there is a higher degree of development of the shoreland zone within the south basin (Figure 3.3-2). The majority of the shoreland zone within the north basin (90% or 3.8 miles) was delineated as natural/undeveloped. A large portion of the shoreland within the north basin is part of the Kangaroo Lake State Natural Area. Within the north basin, approximately 0.1 miles (2%) of the shoreland was delineated as developed-natural, 0.1 miles (2%) was delineated as developed-unnatural, and 0.03 miles (1%) was delineated as developed-semi-natural. Approximately 3.5 miles (50%) of the shoreland zone in the south basin was delineated as natural/undeveloped or developed-natural, while approximately 2.1 miles (29%) was delineated as urbanized or developed-unnatural (Figure 3.2-2). Approximately 1.5 miles (21%) was delineated as developed-semi-natural.

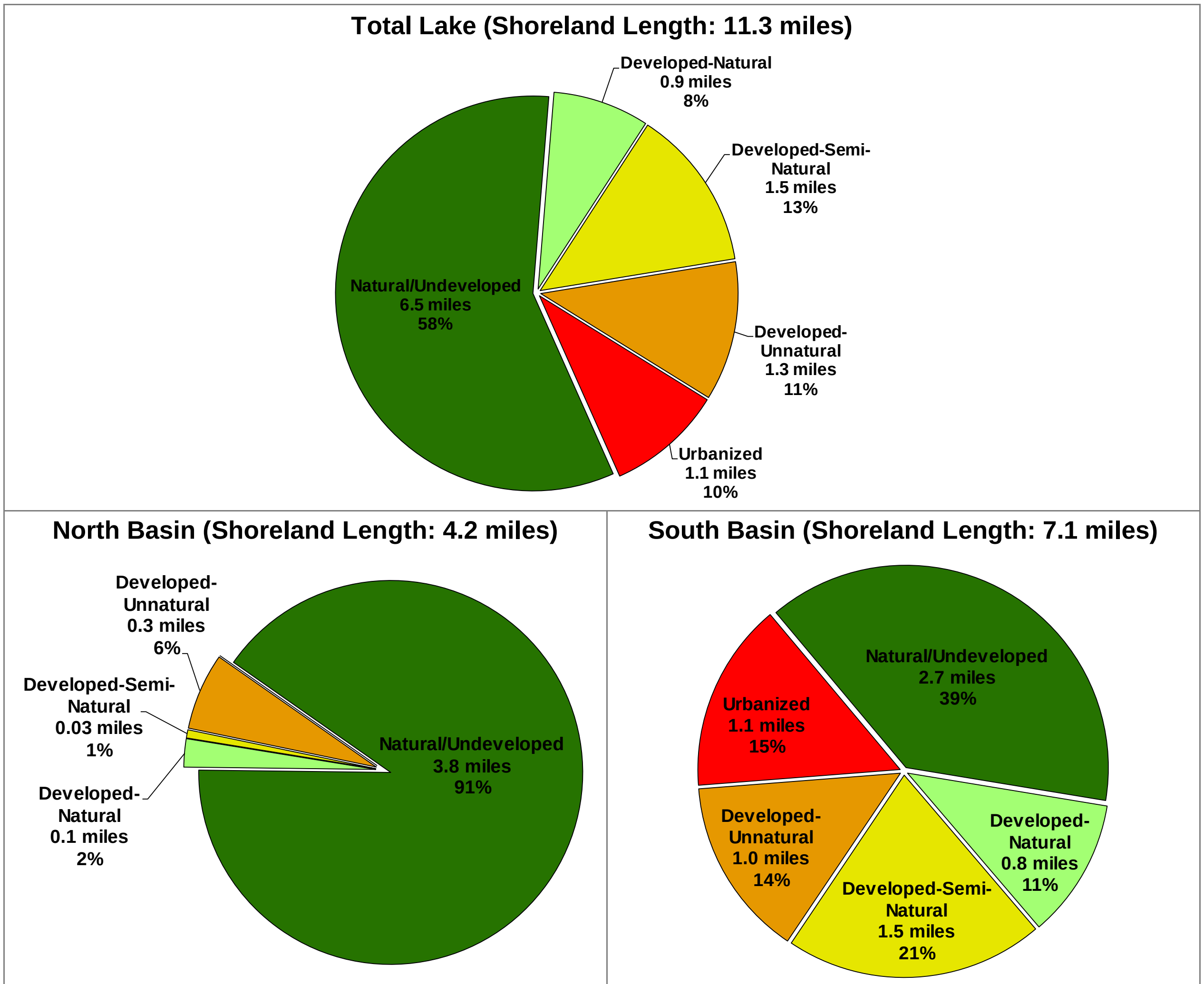


Figure 3.3-2. Kangaroo Lake shoreland categories and total lengths. Based upon a fall 2016 survey. Locations of these categorized shorelands can be found on Map 4.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a riparian property owner'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, unsloped 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

Kangaroo Lake was also surveyed in the fall of 2016 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 356 total pieces of coarse woody habitat were observed along 11.3 miles of shoreline which includes both the northern and south basins. This yields a coarse woody habitat to shoreline mile ratio of 32:1 (Figure 3.3-3 and Map 5). Of the 98 lakes across Wisconsin which Onterra has completed coarse woody habitat surveys on since 2012, Kangaroo Lake falls in the 65th percentile for the number of coarse woody habitat pieces for shoreline mile. The north basin of Kangaroo Lake had a coarse woody habitat to shoreline ratio of 23:1 while the south basin had a ratio of 37:1. The majority of the coarse woody habitat pieces were in the 2-8 inch diameter range and ranged from no branches to moderately branched.

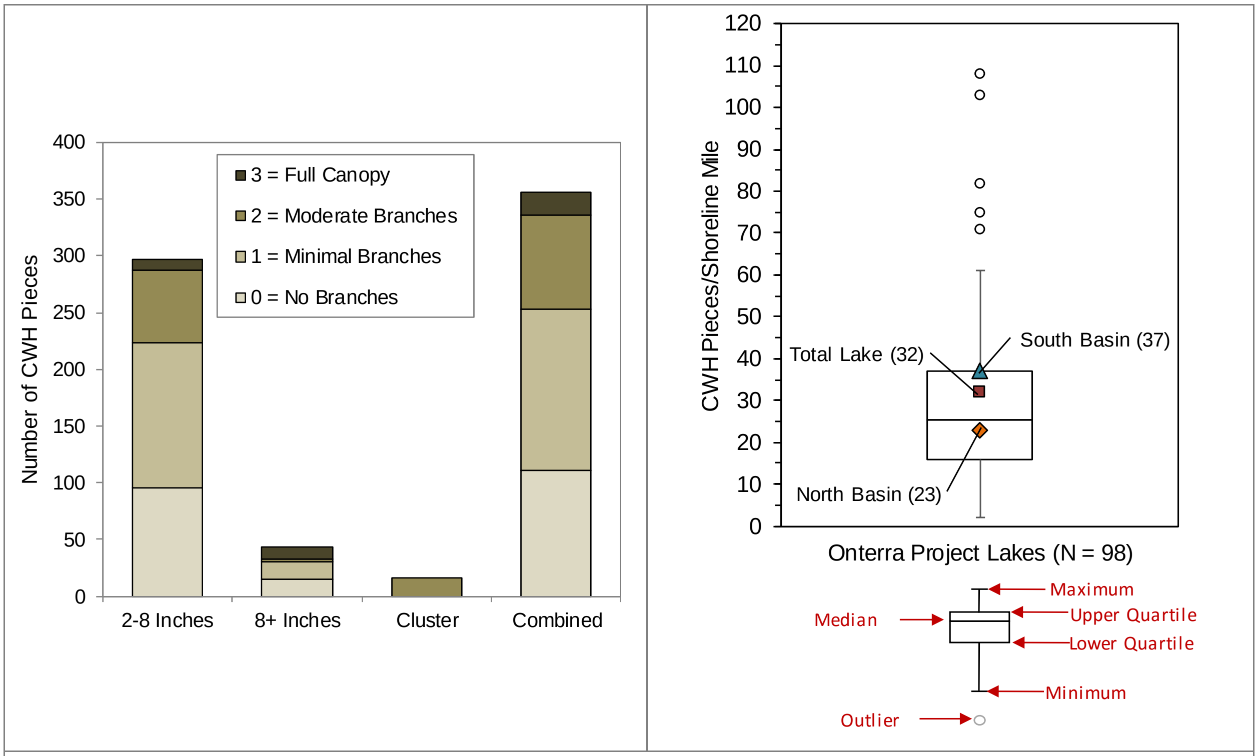


Figure 3.3-3. Kangaroo Lake coarse woody habitat (CWH) size and branching categories (left) and box plot of the ratio of CWH pieces per shoreline mile relative to 98 lakes surveyed by Onterra in Wisconsin since 2012.

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 (WDNR 2014). Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore. 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.

Kangaroo Lake has already participated in this program to enhance coarse woody habitat around the south basin of Kangaroo Lake. Each winter beginning in 2015, KLA volunteers have assisted in placing coarse woody habitat along the shoreline properties of those who volunteered to host these habitat complexes. Since 2015, the KLA has placed 100 trees along the shoreline of the south basin with 28 hosts volunteering portions of their property for these habitat enhancements.

3.4 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 3.4-1. 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

Important Note:
Even though most of these techniques are not applicable to Kangaroo 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 Kangaroo Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

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.

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

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.

Photograph 3.4-2. Example of aquatic plants that have been removed manually.

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 3.4-3. 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 3.4-4. 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)
Contact		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides
Contact		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
Systemic	Auxin Mimics	Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
Systemic	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
Systemic	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
Systemic	Enzyme Specific (ALS)	Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
Systemic	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
Systemic	Enzyme Specific (foliar use only)	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 Kangaroo 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 Kangaroo Lake in 2016. 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 Kangaroo 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 Kangaroo Lake to be compared to other lakes within the region and state.

$$\text{FQI} = \text{Average Coefficient of Conservatism} * \sqrt{\text{Number of Native Species}}$$

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 Kangaroo Lake is compared to data collected by Onterra and the WDNR Science Services on 77 lakes withn the Southeast Wisconsin Till Plain 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 Kangaroo Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Non-Native 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.

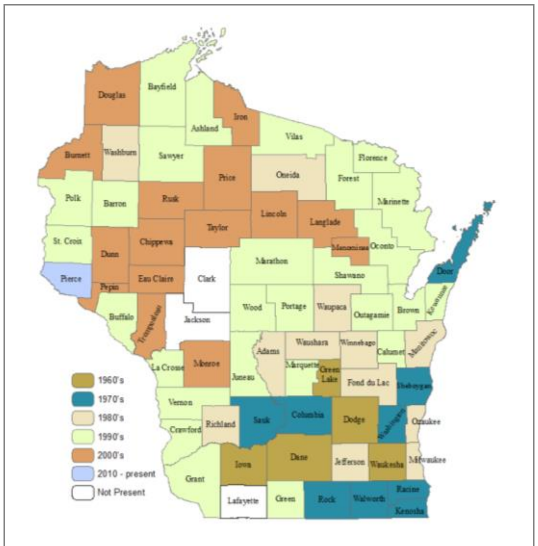


Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

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

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

Aquatic Plant Survey Results

Four surveys aimed at assessing the aquatic plant communities (Photograph 3.4-5) within both the north and south basins of Kangaroo Lake were completed in 2016. During these surveys, a total of 28 aquatic plant species were located (Table 3.4-1). These include 12 emergent and floating-leaf species and 16 submergent species. Of the 28 species located, only one was a non-native, invasive species: Eurasian watermilfoil. Because of its ecological, sociological, and economical significance, the population of Eurasian watermilfoil in Kangaroo Lake is discussed in detail in the subsequent Non-Native Aquatic Plant Subsection. While Door County contains large populations of the non-native grass *Phragmites*, the north basin of Kangaroo Lake was found to contain a population of the native subspecies (subsp. *americanus*). No plants of the non-native subspecies (subsp. *australis*) were located in 2016.

Photo 3.4-5. Floating-leaf and emergent aquatic plant communities in the north basin of Kangaroo Lake. Photo credit Onterra, 2016.

Of the 28 species located, eight were unique to the north basin, four were unique to the south basin, and 16 were located in both. Of the 25 aquatic plant species located by Northern Ecological Services in 2003 in Kangaroo Lake, 19 were re-recorded during the surveys in 2016, while eight were recorded in 2016 that were not recorded in 2003 (Table 3.4-1). None of the native aquatic plants located in 2016 are listed as endangered, threatened, or special concern in Wisconsin.

Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. During the 2016 whole-lake point-intercept survey, aquatic plants were found growing to 12 feet, the maximum depth of the lake. Kangaroo Lake's high water clarity allows adequate light to support aquatic plant growth at these deeper depths. Because the lake supports aquatic plant growth across all water depths, the entire area of the lake is considered to be littoral zone, or the area of the lake which supports aquatic plant growth. Of the 580 locations sampled within the south basin in 2016, approximately 79% contained aquatic vegetation. Similarly, of the 384 locations sampled within the north basin in 2016, approximately 89% contained aquatic vegetation (Map 6 and 7). Total rake fullness data indicate that vegetation in both the northern and south basins is of relatively low density as the largest proportion of aquatic plant total rake fullness ratings had a rating of 1 (Figure 3.4-3).

Table 3.4-1. Aquatic plant species located in Kangaroo Lake in 2003 and 2016.

Growth Form	Scientific Name	Common Name	Coeffecient of Conservatism (C)	South Basin (2003)	South Basin (2016)	North Basin (2016)
Emergent	*Eleocharis palustris*	Creeping spikerush	6	•	I	X
	Equisetum fluviatile	Water horsetail	7	•		
	Iris versicolor	Northern blue flag	5	•	I	I
	Juncus effusus	Soft rush	4		I	
	Phragmites australis subsp. *americanus*	Common reed	5			I
	Sagittaria latifolia	Common arrowhead	3	•	I	
	Sagittaria sp. (sterile)	Arrowhead sp. (sterile)	N/A		I	I
	Schoenoplectus acutus	Hardstem bulrush	5	•	X	X
	Schoenoplectus pungens	Three-square rush	5	•	X	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	•		
	Typha latifolia	Broad-leaved cattail	1	•	I	I
	Zizania palustris	Northern wild rice	8			X
FL	*Nuphar variegata*	Spatterdock	6	•	I	X
	Nymphaea odorata	White water lily	6	•		X
	Sparganium fluctuans	Floating-leaf bur-reed	10	•		
Submergent	*Chara* spp.	Muskgrasses	7	•	X	X
	Heteranthera dubia	Water stargrass	6		X	
	Myriophyllum heterophyllum	Various-leaved watermilfoil	7	•	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	•	X	X
	Najas flexilis	Slender naiad	6	•	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	•	X	
	Potamogeton friesii	Fries' pondweed	8			I
	Potamogeton gramineus	Variable-leaf pondweed	7	•	X	X
	Potamogeton illinoensis	Illinois pondweed	6	•	X	X
	Potamogeton illinoensis X *P. richardsonii*	Ilinois x clasping-leaf pondweed hybrid	N/A			I
	Potamogeton natans	Floating-leaf pondweed	5	•		X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	•		
	Stuckenia pectinata	Sago pondweed	3	•	X	X
	Utricularia intermedia	Flat-leaf bladderwort	9			X
	Utricularia minor	Small bladderwort	10			X
	Utricularia vulgaris	Common bladderwort	7	•	X	X
	Vallisneria americana	Wild celery	6	•	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	•		
FF	*Lemna minor*	Lesser duckweed	5	•		

• = Located during 2003 surveys; X = Located on rake during 2016 point-intercept survey; I = Incidentally located during 2016 surveys
FL = Floating-leaf; S/E = Submergent & Emergent; FF = Free-floating

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 areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available. In the north basin, 97% of the sampling locations contained soft sediments primarily comprised of marl (Figure 3.4-4). Similarly, 75% of the sampling locations within the south basin contains soft, marl sediments while 21% contained sand and 4% contained rock. Areas of sand in the south basin were located in the shallowest areas around the lake.

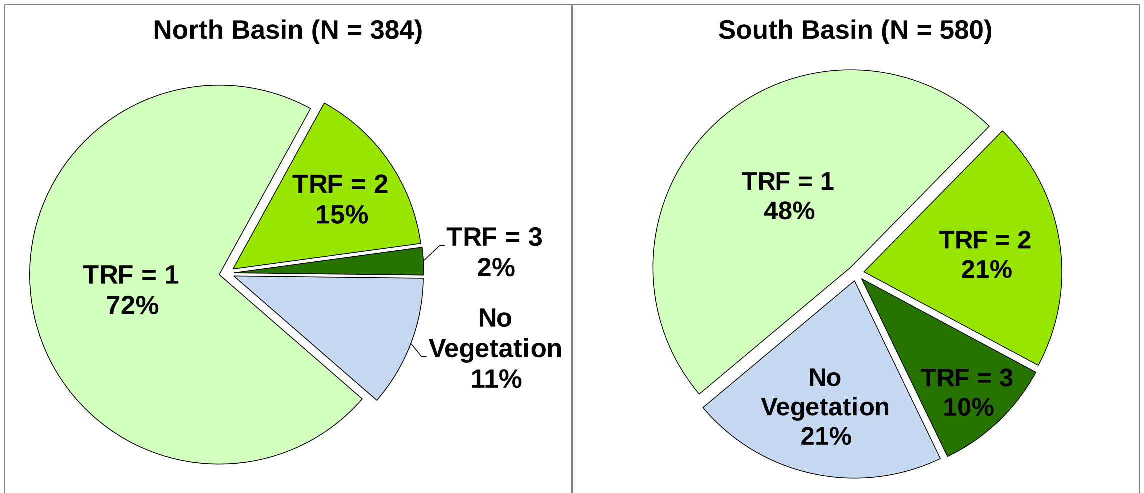


Figure 3.4-3. Kangaroo Lake aquatic vegetation total rake fullness (TRF) ratings. Created using data from 2016 whole-lake point-intercept surveys.

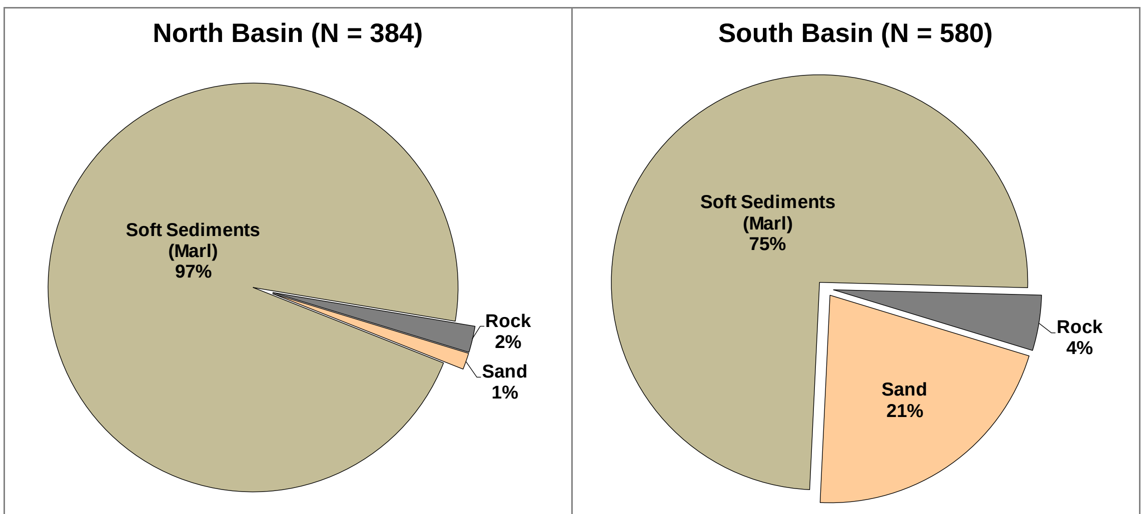


Figure 3.4-4. Kangaroo Lake proportion of substrate types. Created using data from 2016 whole-lake point-intercept surveys.

Of the 23 aquatic plant species located within the north basin of Kangaroo Lake in 2016, 17 were encountered directly on the rake during the whole-lake point intercept survey while six were located incidentally (Figure 3.4-5). Incidental species include those that were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 17 species recorded on the rake in the north basin, muskgrasses, slender naiad, and hardstem bulrush were the three most frequently encountered. Of the 19 species located in the south basing of Kangaroo Lake in 2016, 13 species were recorded on the rake while six were located incidentally (Figure 3.4-6). Of the 18 species recorded on the rake in the south basin, muskgrasses, slender naiad, and common bladderwort were the three most frequently encountered.

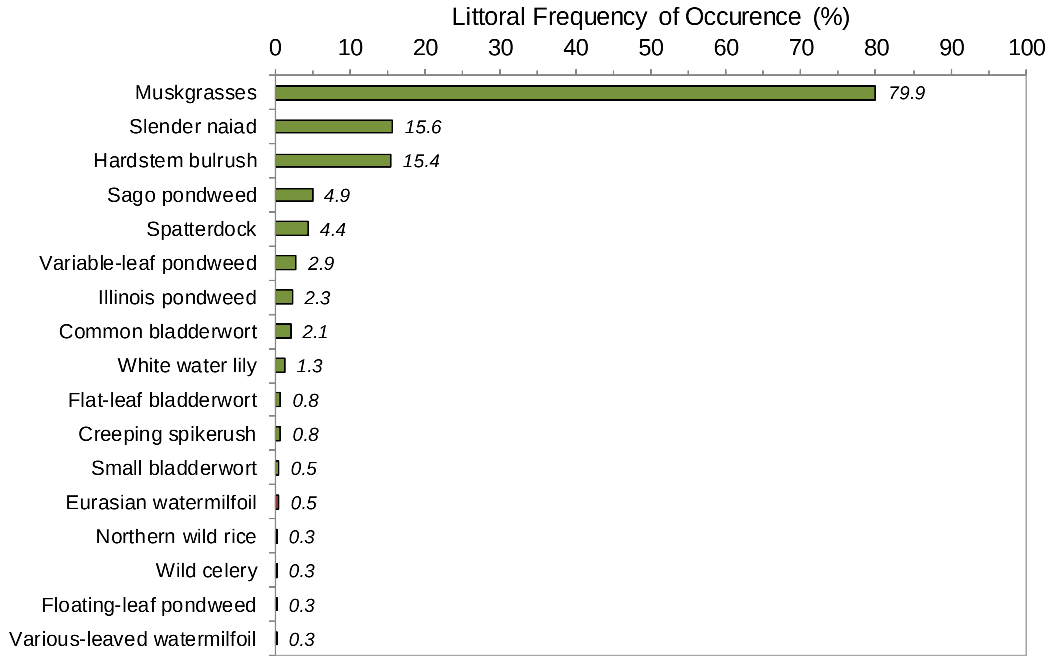


Figure 3.4-5. Littoral frequency of aquatic plant species in the north basin of Kangaroo Lake. Created using data from 2016 whole-lake point-intercept survey. Exotic species indicated with red.

Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin (Photo 3.4-6). In 2016, muskgrasses had a littoral frequency of occurrence of approximately 80% and 71% in the north and south basins, respectively (Figures 3.4-5 and 3.4-6). Dominance of the aquatic plant community by muskgrasses is common in hardwater, marl lakes like Kangaroo Lake, and these macroalgae have been found to more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds help to stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). Muskgrasses were abundant across water depths in both the northern and south basins in 2016.

Slender naiad, the second-most frequently encountered aquatic plant in 2016 in both basins with a littoral frequency of occurrence of 16% and 21% in the northern and south basins, respectively (Figure 3.4-5 and 3.4-6), is a submersed, annual plant that produces numerous seeds (Photo 3.4-6). Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Slender naiad is often abundant in hardwater lakes but can be found across a wide range of alkalinity.

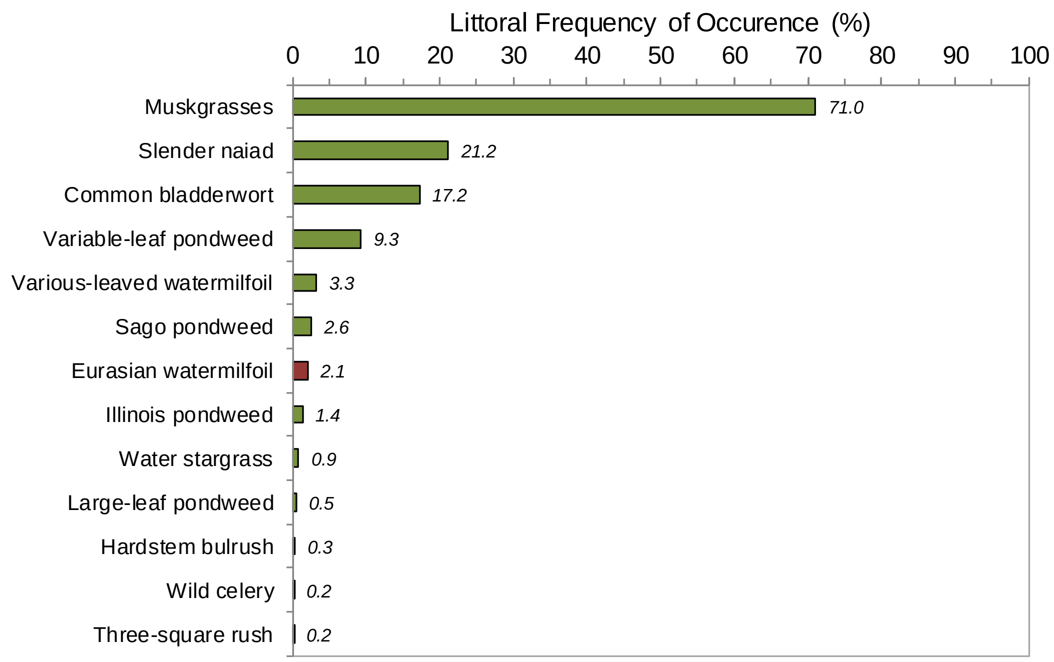


Figure 3.4-6. Littoral frequency of aquatic plant species in the south basin of Kangaroo Lake. Created using data from 2016 whole-lake point-intercept survey. Exotic species indicated with red.

Muskgrasses
(*Chara* spp.)

Slender Naiad
(*Najas flexilis*)

Common bladderwort
(*Utricularia vulgaris*)

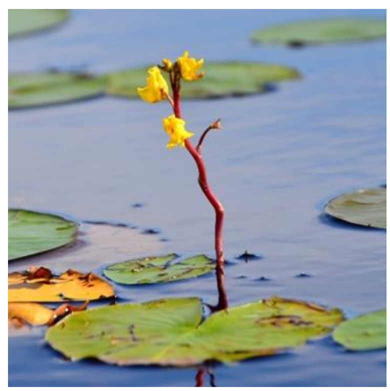


Photo 3.4-6. Common aquatic plants of Kangaroo Lake. Photo credit Onterra, 2016.

Common bladderwort was the third-most frequently encountered aquatic plant species within the south basin of Kangaroo Lake during the 2016 point-intercept survey with a littoral frequency of occurrence of 17% (Figure 3.4-6). Common bladderwort is one of seven species of bladderwort that occur in Wisconsin and one of three bladderwort species located in Kangaroo Lake. Bladderworts are a genus of carnivorous plants which produce bladder-like traps that are used to capture aquatic invertebrates. Common bladderwort is the most prevalent bladderwort species in

Wisconsin and can grow within a wide range of water quality. In summer, common bladderwort produces yellow snapdragon-like flowers on stalks held above the water's surface in areas of shallow, quiet water (Photo 3.4-6).

Hardstem bulrush was the third-most frequently encountered aquatic plant species within the north basin of Kangaroo Lake in 2016 with a littoral frequency of occurrence of 15% (Figure 3.4-5). Anecdotal reports indicate that the hardstem bulrush population in Kangaroo Lake, particularly within the south basin, have been in decline since the mid-20th century. The current and historical hardstem bulrush population in Kangaroo Lake is discussed in further detail later in this section within the discussion surrounding emergent and floating-leaf aquatic plant communities.

As discussed in the primer section, 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. Native aquatic plant species richness is the number of native aquatic plant species located in the rake during the point-intercept surveys. Native species richness in 2016 was 16 in the north basin, 12 in the south basin, and 19 when data from both basins are combined (total lake). Kangaroo Lake's species richness of 19 exceeds the median species richness for lakes within the SWTP ecoregion and is identical to the median species richness for lakes throughout Wisconsin (Figure 3.4-7).

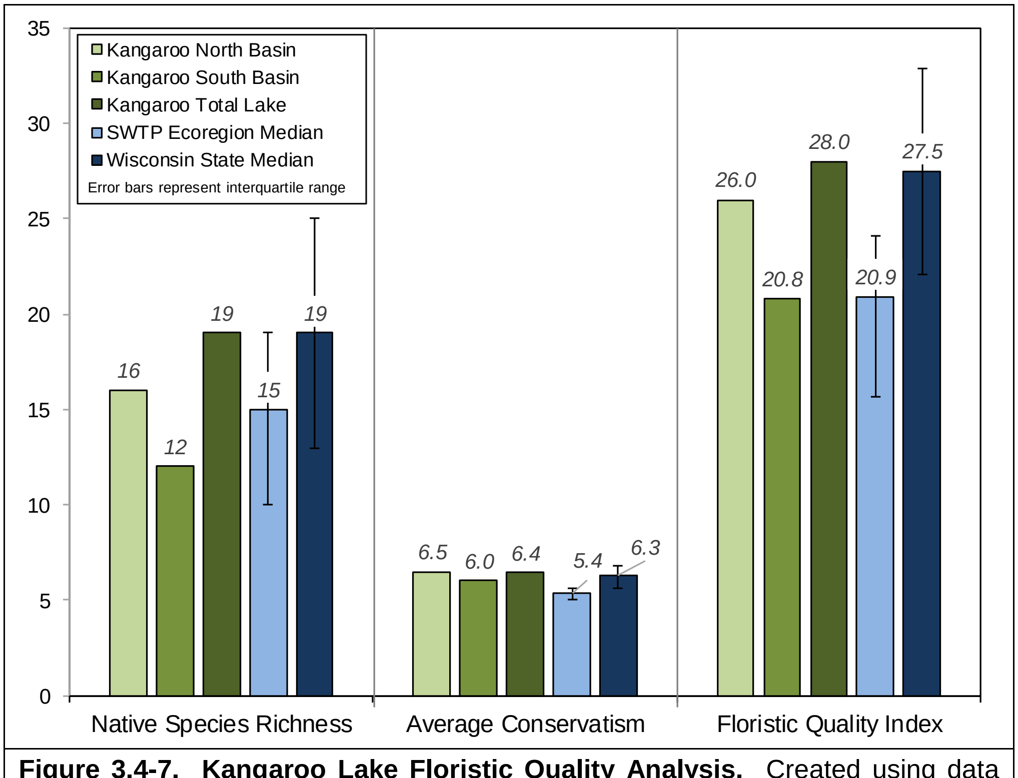


Figure 3.4-7. Kangaroo Lake Floristic Quality Analysis. Created using data from 2016 whole-lake point-intercept survey. Analysis follows Nichols (1999).

The average conservatism of native aquatic plants was 6.5 in the north basin, 6.0 in the south basin, and 6.4 for the lake as a whole (Figure 3.4-7). These average conservatism values all exceed the median value (5.4) for lakes in the SWTP ecoregion, while the average conservatism for the entire lake also exceeds the median average conservatism (6.3) for lakes throughout Wisconsin. These data indicate that the north basin of Kangaroo Lake harbors a higher number of environmentally sensitive aquatic plant species (higher conservatism values) when compared to the south basin, while the lake as a whole has a higher number of environmentally sensitive species than the majority of lakes within the SWTP ecoregion.

Using Kangaroo Lake's native aquatic plant species richness and average conservatism to calculate the FQI yielded values of 26.0 for the north basin, 20.8 for the south basin, and 28.0 for the lake as a whole (Figure 3.4-7). The FQI value for the north basin exceeds the median value for lakes in the SWTP and fell just below the median value for lakes in Wisconsin. The FQI value for the south basin was similar to the median value for lakes in the SWTP ecoregion and lower than the median value for lakes throughout the state. The FQI value for the lake as a whole exceeded the median value for lakes in the SWTP ecoregion and was similar to the median value for lakes in Wisconsin. The FQI analysis indicates that Kangaroo Lake's aquatic plant community is of higher quality when compared to the majority of lakes within the SWTP ecoregion and comparable to most lakes throughout Wisconsin.

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 Kangaroo Lake contains a relatively high number of native aquatic plant species, one may assume the aquatic plant community also has high 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 Kangaroo Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP ecoregion (Figure 3.4-8). Using the data collected from the 2016 point-intercept surveys, aquatic plant diversity in both the north and south basins of Kangaroo Lake was shown to be low with values of 0.61 and 0.65, respectively. Both of these diversity values fall below the 25th percentile for lakes within the SWTP ecoregion and lakes throughout Wisconsin.

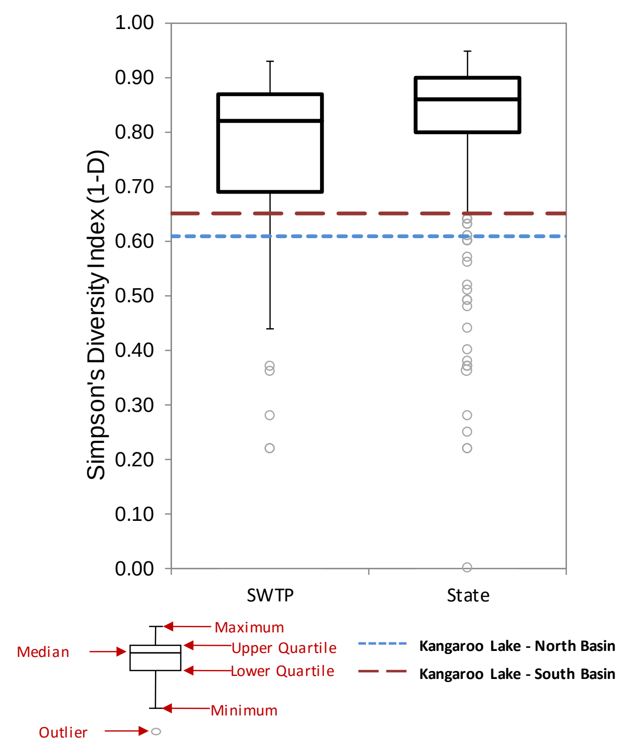


Figure 3.4-8. Kangaroo Lake species diversity index. Created using data from 2016 point-intercept surveys. Ecoregion data from 77 SWTP lakes collected by WDNR Science Services and Onterra.

While Kangaroo Lake contains a relatively high number of aquatic plant species, the majority of the plant community is comprised of just one species: muskgrasses. One way to visualize Kangaroo Lake's lower species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.4-8 displays the relative frequency of occurrence of aquatic plant species in the north and south basin created from the 2016 whole-lake point-intercept surveys and illustrates the relatively uneven distribution of aquatic plant species within the community. In the north basin, muskgrasses account for 60% of the plant community while they comprised 55% of the plant community within the south basin.

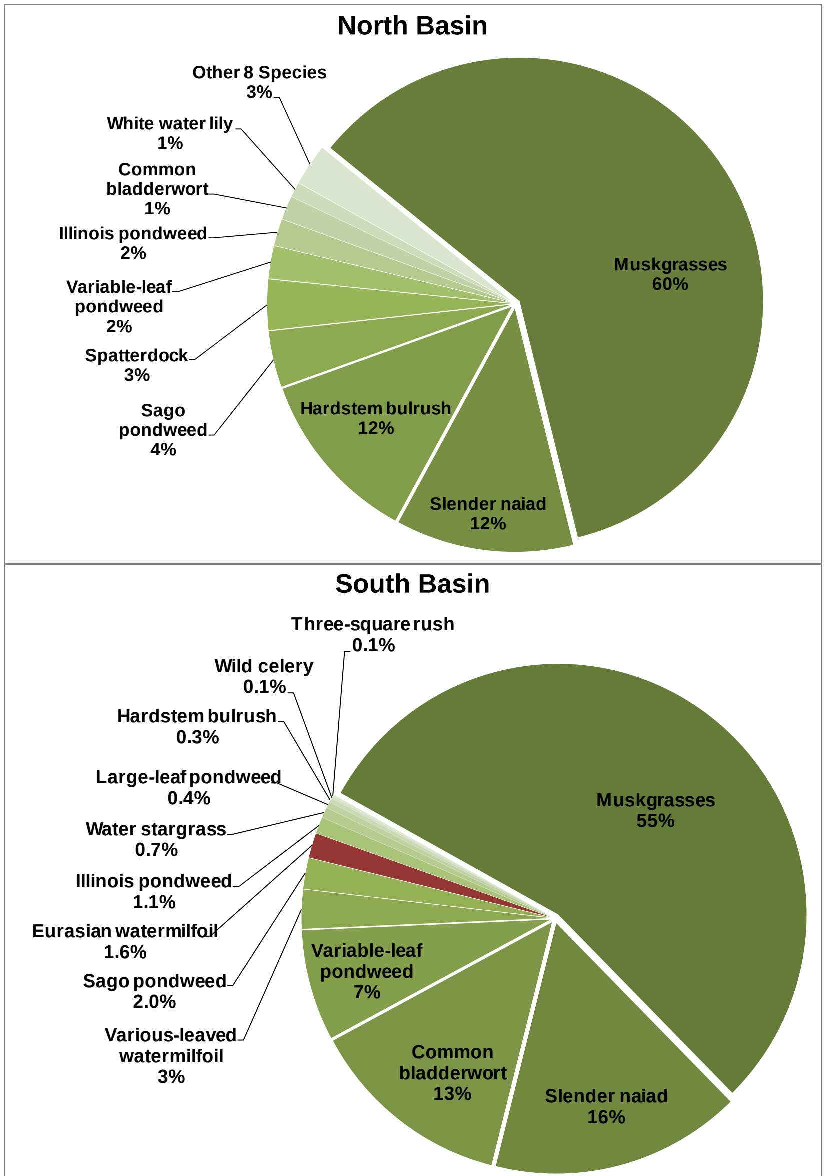


Figure 3.4-9. Relative frequency of occurrence of aquatic plant species in Kangaroo Lake. Created using data from 2016 whole-lake point-intercept surveys.

The dominance of the plant community by a small number of aquatic plant species yields the low species diversity in Kangaroo Lake. As discussed previously, hardwater, marl lakes like Kangaroo Lake are often dominated by muskgrasses which are able to outcompete other plants in these conditions. In addition, the calcium carbonate encrustations which from on submersed aquatic plants make it difficult for certain species to photosynthesize, and only those species which are able to tolerate the calcium-rich conditions are able to persist. The low species diversity in Kangaroo Lake is not an indication of degraded conditions, but is the result the naturally-occurring water quality conditions found in the lake.

The emergent and floating-leaf aquatic plant community mapping survey completed in Kangaroo Lake in 2016 revealed that the lake contains approximately 186 acres of these communities and they are comprised of 12 species. Approximately 92% of the emergent and floating-leaf aquatic plant community acreage was located within the north basin of the lake (Table 3.4-2, Map 8, and Map 9). These communities provide valuable structural habitat for aquatic wildlife, stabilize bottom sediments, and reduce shoreland erosion.

Table 3.4-2. Kangaroo Lake acreage of emergent and floating-leaf aquatic plant communities. Created from 2016 emergent and floating-leaf aquatic plant community mapping survey.

	Acres		
Plant Community	**North Basin**	**South Basin**	**Total Lake**
Emergent	154.9	11.3	166.3
Floating-leaf	15.2	1.6	16.8
Mixed Emergent & Floating-leaf	1.7	1.4	3.1
Total	**171.9**	**14.3**	**186.2**

While the north basin supports a large community of emergent and floating-leaf aquatic plants, information provided by long-term lake residents indicate that the south basin once supported a larger population of emergent plant communities primarily comprised of hardstem bulrush (*Schoenoplectus acutus;* Photo 3.4-7). Hardstem bulrush, one of Wisconsin's largest sedges, is found growing along wet shorelines and in standing water of up to 8.0 feet. Hardstem bulrush is most often found growing over harder substrates, but can also be found growing in marl or peat. Historical locations of hardstem bulrush populations within the south basin provided by Kangaroo Lake residents indicate there was potentially up to 175 acres of these communities in the early to mid-20th century. In 2016, approximately 13 acres of emergent communities containing at least some hardstem bulrush were delineated, representing a 93% decrease in acreage from historical levels (Map 9).

The 2003 Northern Ecological Services study delineated approximately 16.8 acres of emergent and/or floating-leaf aquatic plant communities in the south basin. The same mapping study completed in 2016 indicated that while a few populations of these communities expanded slightly in size, there was an overall reduction of approximately 2.5 acres or 15% of these communities over this 13-year period (Map 9). Many of the emergent plant populations were found to have retracted shoreward, while some completely disappeared. The largest reductions occurred along shoreland areas in the southern, west-central, and northeastern areas of the south

Photo 3.4-7. Hardstem bulrush (*Schoenoplectus acutus*) community in the south basin of Kangaroo Lake. Photo credit Onterra.

basin.

Numerous studies of lakes in North America and Europe have shown that the decline of emergent aquatic plant communities is often attributed to human activity. Emergent aquatic plant communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shoreland areas when compared to undeveloped shoreland areas in Minnesota lakes. Studies completed on Wisconsin lakes have also shown that aquatic plants are susceptible to direct impacts from watercraft such as cutting from the prop and uprooting of plants through scouring of the bottom (Asplund and Cook 1997).

In addition to shoreland development and direct impacts from watercraft, emergent aquatic plant communities have also been shown to decline following alterations to natural hydrologic regimes such as the stabilization and/or heightening of water levels (Coops et al. 2003, Leira and Cantonati 2008, and Zhang, et al. 2014). Emergent plant communities can be completely dependent on slight water level fluctuations for germination and/or flooding seedlings (Coops et al. 2003). However, the response of aquatic vegetation following the alteration of natural water levels can be slow, and the loss of these communities may appear gradually over several decades following water level manipulation (Leira and Cantonati 2008).

Sloey et al. (2016) found that hardstem bulrush seedlings, adult plant biomass, and the biomass of their inflorescences (flower spikes) decreased with increased duration of flooding. In addition, the stems of adult hardstem bulrushes were less rigid and more prone to damage when subjected to longer durations of flooding. Increased duration of flooding of hardstem bulrush plants decreased their vegetation expansion and also limited their reproductive capacity by reducing seed production. Cassanova and Brock (2000) found that the duration and frequency of flooding had a larger influence on plant species establishment compared to the depth of flooding.

According to WDNR records, the small dam located at the outlet of Kangaroo Lake in Heins Creek was installed in 1937 which has a maximum hydraulic height of 3.0 feet. While this small dam does not have gates which can regulate the rate of water flow out of Kangaroo Lake, the dam does artificially raise the water level of the lake. Water level fluctuations of approximately 12 inches between spring and fall still occur in Kangaroo Lake; however, the dam has increased the overall depth of the lake and reduces the ability of the lake to experience extreme low water levels that historically have taken place.

While emergent aquatic plant communities have evolved to tolerate a wide range of water level fluctuations, the installation of the dam represented a hydrologic shift to higher water levels in Kangaroo Lake. While the hardstem bulrush communities likely persisted for some time following the dam's installation, the higher water levels in combination with increased pressure from recreation and shoreland development likely led to the observed decline in bulrush communities within the south basin. Kangaroo Lake residents have also reported Canadian geese foraging on hardstem bulrush plants within the south basin. It is not known how herbivory of bulrush by geese is influencing their growth and survival in the south basin.

The north basin of Kangaroo Lake still supports large colonies of hardstem bulrush with approximately 155 acres of emergent plant communities containing hardstem bulrush delineated in 2016 (Map 8). Human development and recreational pressure is considerably less in the north basin when compared to the south basin. The shoreland areas around the north basin of Kangaroo Lake remain largely undeveloped and motorized watercraft are prohibited. In addition, the north basin represents the most upstream portion of Kangaroo Lake and it is possible that alterations in water level from natural conditions are less pronounced in this area of the lake when compared to downstream areas within the south basin.

In 2005, the KLA initiated an experimental bulrush restoration project in the south basin of the lake. Just prior to initiating this project, the KLA was also successful in implementing a slow-no-wake zone in the southern end of the lake and a voluntary 500-foot slow-no-wake zone round the perimeter of the lake and the island. These slow-no-wake areas were implemented to reduce impacts to shallow plant communities and decrease watercraft sediment resuspension. Both hardstem and softstem (*S. tabernaemontani*) bulrush were planted in eight plots in southern portion of the lake in water ranging from 17.5 to 68.0 inches in depth. A portion of the plots were protected with a wave-break to determine if these plantings would have more success under sheltered conditions. KLA volunteers trained by Onterra ecologists monitored the bulrush plots for three years (2005-2007) by conducting stem counts.

Monitoring showed that bulrush density within the plots continually declined over the three-year monitoring period. By the end of monitoring in 2007, only two of the eight plots contained bulrush plants and the project was deemed unsuccessful. Given a portion of the plots had wave-breaks suggested that excessive wave action was not the primary factor inhibiting the establishment of bulrushes. In addition, the one plot with the highest density of bulrush plants at the end of the study did not have a wave-break.

The KLA received a WDNR planning grant in 2014 to complete a shoreline preservation and restoration plan which included additional experimental hardstem bulrush plantings in 2014, 2015, and 2016 in a number of locations within the south basin (Mahlberg and Eichler 2017). Following the planting of hardstem bulrush seedlings at a number of locations with variations in water depth and substrate type, this study found that successful growth of seedlings occurred when planting occurred in May and June, in areas with marl, sand, or gravel substrates, and planting in shallow water less than one inch deep.

The conditions the KLA found that led to successful hardstem seedling establishment align with a study completed by Sloey et al. (2016) which found that constant inundation was too stressful for young seedlings of hardstem bulrush to survive, and indicate that the soil surface at the restoration site must be exposed to air for a minimum of 40% of the day for successful establishment. Once established, these plants are then able to colonize deeper waters through vegetative propagation. Plants growing in deeper waters are able to receive resources from shallower-growing plants and would otherwise not be able to survive on their own. The results from the KLA restoration project are promising, and the establishment of new bulrush plants in shallower water will hopefully lead to vegetative propagation into deeper areas of the lake.

As is discussed within the Lake Water Quality Section (Section 3.1), paleoecological analysis of a sediment core collected from Kangaroo Lake in 2007 indicated that submersed aquatic plants were more abundant within the south basin prior to Euro-American settlement (Garrison 2007). The 2016 whole-lake point-intercept survey within the south basin indicated a high occurrence of aquatic plants, with approximately 79% of the 580 sampling locations containing aquatic vegetation. While aquatic plants, primarily muskgrasses, were found throughout the south basin in 2016, the sediment core results indicate that the biomass of aquatic plants was likely higher in the past compared to today. The reasons for the apparent decline in aquatic vegetation following Euro-American settlement are not known, but likely involve a combination of factors including alterations to natural hydrologic regimes, increased motorboat activity, and shoreland development.

A study completed on Lake Ripley in southern Wisconsin found that when watercraft were excluded from small experimental plots that aquatic plant biomass, coverage, and shoot height significantly increased compared to experimental plots that were exposed (Asplund and Cook 1997). This study also indicated that the decline in aquatic plants outside of the enclosures was primarily the result of direct impacts from watercraft such as cutting from the prop and uprooting of plants through scouring of the bottom. The authors of this study also noted that taller aquatic plants (e.g. pondweeds) were more susceptible to cutting when compared to shorter plants (e.g. charophytes). Vascular plants in Lake Ripley have been declining since the mid-20th century, and the ones that remain were found to be in areas of the lake that were not subject to high watercraft use (Asplund and Cook 1997). In an effort to protect the lake's aquatic plant community, the KLA implemented a voluntary slow-no-wake zone extending 500 feet from the shoreline into open water. This zone is intended to protect native aquatic plants in shallower areas of the lake and reduce sediment resuspension from watercraft.

Non-Native Aquatic Plants in Kangaroo Lake

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first documented in Kangaroo Lake in the fall of 1994 (Photo 3.4-8). Soon thereafter, the KLA successfully applied to be included in a WDNR-UW-Stevens Point milfoil weevil study where weevils were applied to areas of EWM in Kangaroo Lake. As discussed earlier, the milfoil weevil (*Euhrychiopsis lecontei*) is native to Wisconsin and naturally feeds and reproduces on native milfoil species and it has also been shown to utilize EWM as a host. The application of milfoil weevils in Kangaroo Lake was met with limited success. Milfoil weevils overwinter in shoreland areas around the lake and it was believed that shoreland development decreased overwintering survival and/or the lake's size prevented the weevils from returning to EWM located in the center of the lake. Localized herbicide applications also occurred in 2007 and 2012 in an effort to control EWM around the causeway to prevent further expansion within the north basin of the lake.

Photo 3.4-8. The non-native Eurasian watermilfoil (*Myriophyllum spicatum*; left) compared to the native various-leaved watermilfoil (*M. heterophyllum*; right) in Kangaroo Lake. Photo credit Onterra, 2016.

In addition to these control efforts, the KLA has also been monitoring Kangaroo Lake's EWM population to track its locations and abundance within the lake over time. In 2006, 2008, and 2010, KLA members completed modified point-intercept sampling surveys in the south basin of the lake. This modified point-intercept sampling survey involved the collection of aquatic plant species presence and abundance at a total of 530 sampling locations within the south basin of the lake (Figure 3.4-10). Of these 530 sampling locations, 343 were set at a 100-meter resolution while a subset of 187 sampling locations was set at a 50-meter resolution over an area in the south-central portion of the basin which contained the highest concentration of EWM. The data collected by the KLA in 2006, 2008, and 2010 can be compared with the data collected during the point-intercept survey completed in 2016.

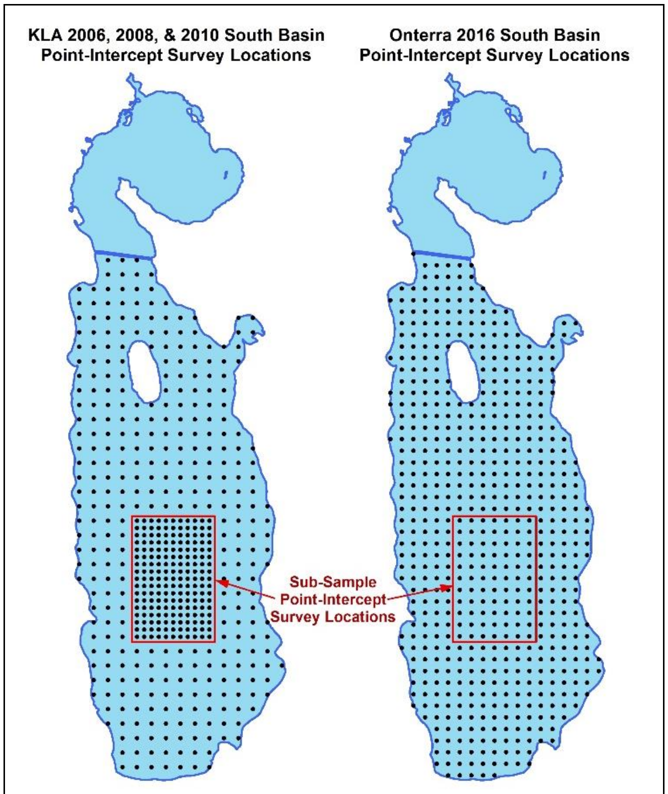


Figure 3.4-10. Kangaroo Lake KLA 2006, 2008, and 2010 point-intercept sampling locations (left) and 2016 Onterra point-intercept sampling locations (right).

Eurasian watermilfoil occurrence within the south basin from 2006, 2008, 2010, and 2016 was calculated by dividing the total number of sampling locations by the number of sampling locations that contained EWM. However, the basin-wide occurrence of EWM calculated using the KLA point-intercept data was likely overestimated because the survey involved the collection of data at a subset of 187 sampling locations with a smaller spacing resolution over the area of the lake with the highest concentration of EWM. To normalize this subset of 187 sampling locations to the rest of the sampling locations throughout the basin, half of the subset sampling locations (94) were removed. This reduced the total number of sampling locations from 530 to 436. In addition, the number of sampling locations containing EWM within the subset of 187 sampling locations was divided in half.

The 2006, 2008, and 2010 normalized datasets show that the frequency of occurrence of EWM within the south basin ranged from 6.2% in 2006 to 4.1% in 2010; however, Chi-square analysis ($\alpha = 0.05$) indicated the occurrence of EWM between these three surveys was not statistically different (Figure 3.4-11). The frequency of occurrence of EWM as determined from the 2016 point-intercept survey was 2.1%, representing a statistically valid reduction in occurrence from the 2006, 2008, and 2010 surveys (Figure 3.4-11).

Similarly, the frequency of occurrence of EWM was calculated within the subset of 187 sampling locations in the south-central portion of the south basin from 2006, 2008, and 2010 (Figure 3.4-10). The frequency of occurrence of EWM was also calculated within this area using a subset of 77 points from the 2016 point-intercept survey (Figure 3.4-10). The subset point-intercept data indicate there was a statistically valid reduction in the occurrence of EWM from

25.7% in 2006 to 18.7% in 2008 (Figure 3.4-11). The frequency of occurrence of EWM in this area in 2010 of 18.2% was not statistically different from 2008. In 2016, EWM had a frequency of occurrence of 9.1% in this area, representing a statistically valid reduction in occurrence of 50% from 2010 and 66% from 2006 (Figure 3.4-11).

The comparison of these datasets indicate that the EWM population within the south basin of Kangaroo Lake has declined over the past six years, and its basin-wide occurrence in 2016 was low. The 2016 data indicate that the EWM population in Kangaroo Lake is currently not a significant stressor to Kangaroo Lake's ecology at the lake-wide level. However, the 2016 EWM mapping survey indicated most of the EWM within the lake is concentrated in a larger colony within the south-central portion of the south basin (Figure 3.4-12). This dense, larger colony of EWM may be causing localized ecological impacts within this area including the displacement of native plants and may also affect recreation in this area.

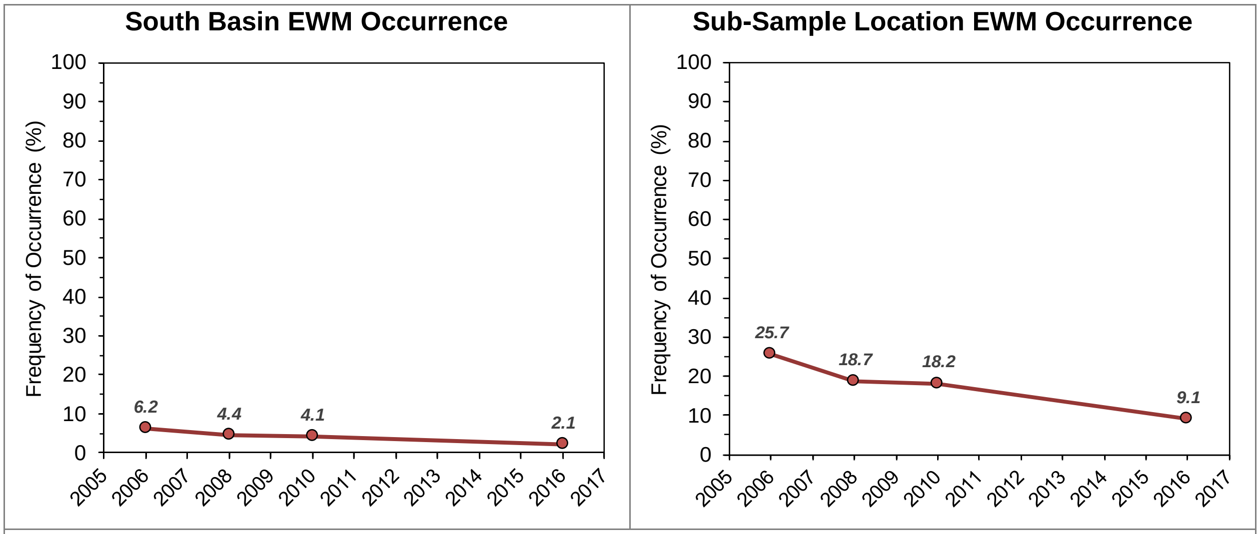


Figure 3.4-11. Eurasian watermilfoil frequency of occurrence within the south basin from 2006-2016 (left) and frequency of occurrence within subset of sample locations in south basin from 2006-2016 (right). Basin-wide occurrence calculated using data from KLA 2006, 2008, and 2010 point-intercept survey data (N = 436) and Onterra 2016 point-intercept survey data (N = 580). Sub-sample occurrence calculated using data from KLA 2006, 2008, and 2010 sub-sample point-intercept survey data (N = 187) and Onterra sub-sample point-intercept survey data (N = 77). Locations of sub-sample locations is in Figure 3.4-10.

During the 2016 EWM mapping survey, a total of approximately 10.8 acres of colonized EWM (polygons) were located (Figure 3.4-12 and Map 10). The majority of the EWM was given a density rating of *dominant*, and 90% of the acreage mapped was located in the south-central portion of the south basin. Apart from the larger colonies of EWM in the south basin, a number of small plant colonies and clumps of plants were mapped throughout the basin. An approximate 1-acre colony comprised mainly of highly *dominant* EWM was mapped in the north basin adjacent to the causeway, while a clump of EWM was located at the tip of the peninsula on the eastern side of the basin.

In an effort to have the most up-to-date picture of the EWM population, another EWM survey was completed in the late-summer of 2017 prior to the finalization of this report. This survey showed that the EWM population in terms of size and density was very similar to what was mapped in 2016. In 2017, approximately 10.5 acres of colonized EWM were mapped in Kangaroo Lake, approximately 0.3 acres less than what was mapped in 2016 (Figure 3.4-12 and Map 11). The proportion of the EWM mapped in 2017 with density ratings of *dominant* and *highly dominant* was also very similar t what was mapped in 2017. Because the EWM population remained relatively unchanged in 2017, the management strategy developed with the planning committee earlier in the summer of 2017 remains unchanged.

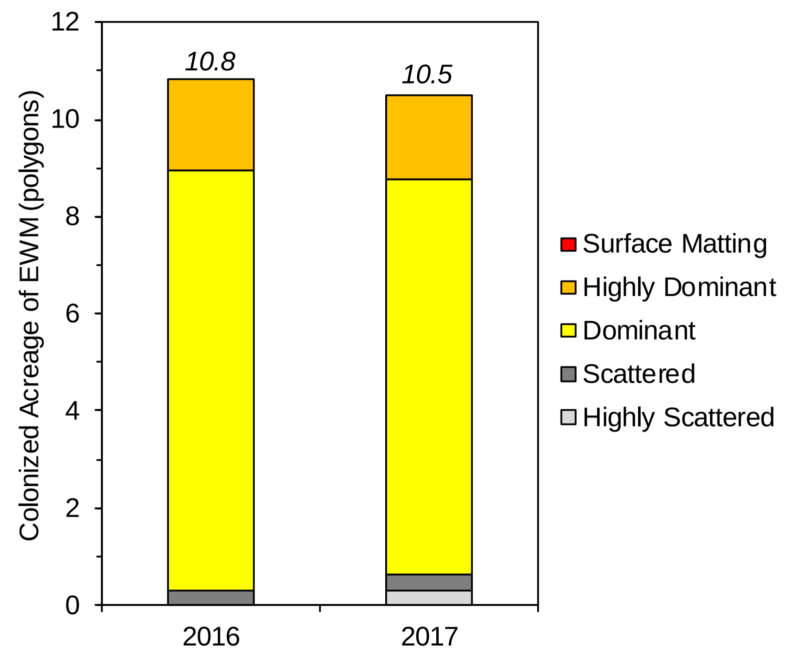


Figure 3.4-12. Acreage and density of EWM colonies mapped in Kangaroo Lake (north and south basins) in 2016 and 2017. Created using data collected from Onterra 2016 and 2017 Late-Summer EWM Peak-Biomass Surveys.

WDNR Long-Term Eurasian watermilfoil Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase. Because the waters of Wisconsin managed for multiple uses (Statue 281.11), the WDNR wanted to understand if EWM populations would increase and cause either 1) ecological impacts to the lake and/or 2) reductions in ecosystem services (i.e. navigation, recreation, aesthetics, etc.) to lake users. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes are not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most intuitive for unmanaged lakes within the Northern Lakes and Forests Ecoregion (Figure 3.4-13). Some lakes, such as Hancock Lake, maintained low EWM populations over the study averaging a littoral frequency of occurrence of 2.3% between 2008 and 2015. At these low levels, there are likely no detectable ecological impacts to the lake and there are no reductions in ecosystem services to lake users. The EWM population of Hancock Lake has increased in recent years to 5.2% in 2015 and over 10% in 2016 (preliminary data not shown in Figure 3.4-13).

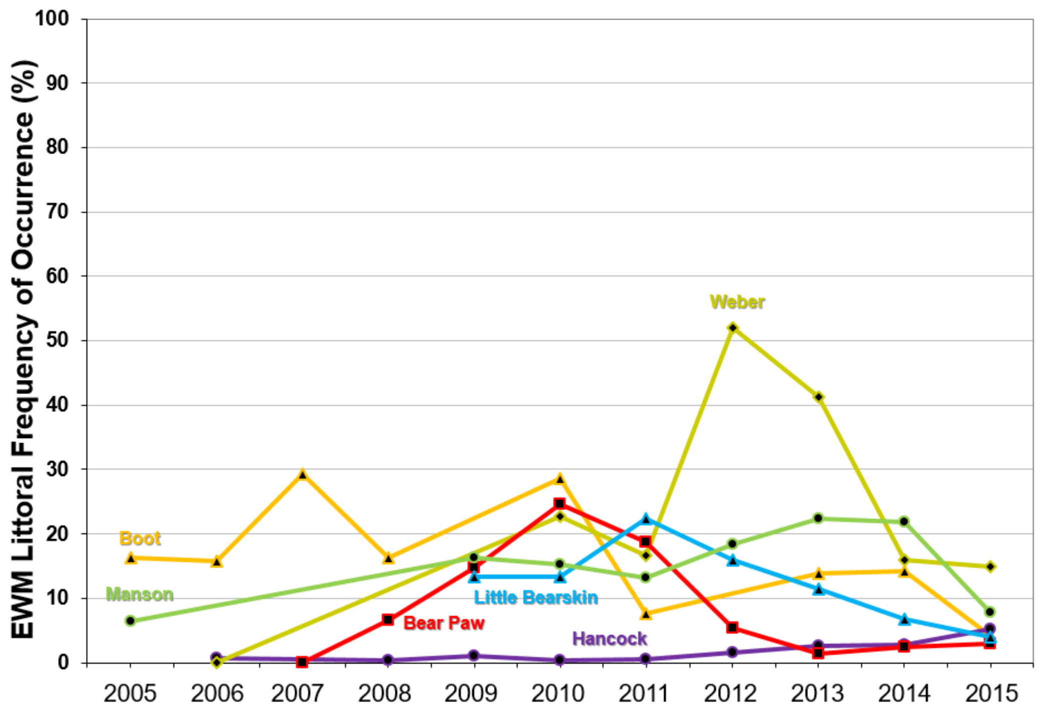


Figure 3.4-13. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from the WDNR Bureau of Science Services.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate widely between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Some lake managers interpret these data to suggest that in some circumstances it is not appropriate to manage the EWM population as in some years as the population may become less. However, even a lowered EWM population of approximately 10% exceeds the comfort level of many riparians because it is potentially approaching a level than can be impactful to the function of the lake as well as not allowing the lake to be enjoyed by riparians as it had been historically.

Some lake groups choose to manage the EWM population to keep it at an artificially lowered level. Following detection of an EWM population within a lake, it is common for a lake group to initiate management activities and not wait to see if the EWM population will become a problem in their lake. In other instances, the management strategy is simply to maintain a lower level population of EWM for the purposes of allowing the ecosystem to function as it had before the exotic was introduced to the lake. And yet other lakes are managed simply to alleviate the lost ecosystem services, most notably to manage for multiple human uses. There are a number of different management techniques used for controlling EWM with the most commonly implemented being hand-harvesting and herbicide control.

In Kangaroo Lake, localized spot treatments were used to control EWM in areas around the causeway. In many lakes, this method is able to slow the spread and population of EWM throughout the lake and may even be able to cause a decline in the EWM population where the activities were conducted. But in other lakes, the EWM population progression is too great for the method to provide effective lake-wide control. Continuing localized spot treatments on these lakes may be able to provide localized EWM reductions where the control strategy is applied and reduce that specific colony from contributing to the overall population increase to the lake. These efforts may also reduce recreational impediments that are caused by dense EWM colonies.

Background on Herbicide Application Strategy

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 dilute herbicide concentration within aquatic systems. Understanding concentration-exposure times (often referred to as CETs) is an important consideration for the use of 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.

A Cooperative Research and Development Agreement between the Wisconsin Department of Natural Resources and U.S. Army Corps of Engineers Research and Development Center in conjunction with significant participation by private lake management consultants have coupled quantitative aquatic plant monitoring with in-lake herbicide concentration data to evaluate efficacy, selectivity, and longevity of chemical control strategies implemented on a subset of Wisconsin waterbodies. Based on the preliminary findings from this research, lake managers have adopted two main treatment strategies: 1) spot treatments, and 2) large-scale (whole-lake) treatments.

Spot treatments (like those conducted in 2007 and 2012 in Kangaroo Lake) 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 effects outside of that area. Herbicide application rates for spot treatment are formulated volumetrically, typically targeting EWM with 2,4-D at 3.0-4.0 ppm acid equivalent (ae). This means that sufficient 2,4-D is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal 3.0-4.0 ppm ae. This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 3.4-14). While lake managers may propose that a particular volumetric dose be used, such as 3.0-4.0 ppm ae, it is understood that actually achieving 3.0-4.0 ppm ae within the water column is not likely due to dissipation and other factors.

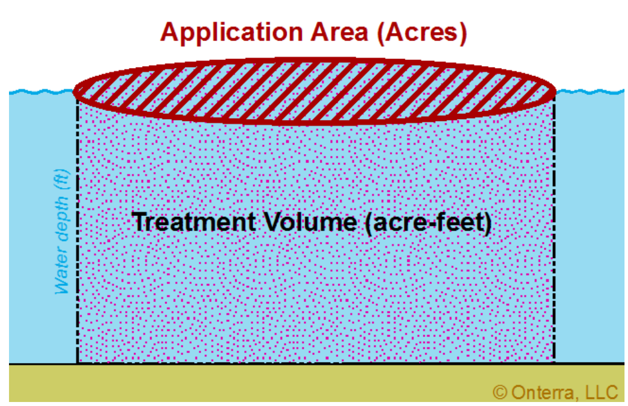


Figure 3.4-14. Herbicide spot treatment diagram.

Ongoing research clearly indicates that the herbicide concentrations and exposure times of large (> 5 acres each) treatment sites are higher and longer than for small sites (Nault 2015). Research also indicates that higher herbicide concentrations and exposure times are observed in protected parts of a lake compared with open and exposed parts of the lake. Areas targeted containing higher water exchange (i.e. flow) are often not able to meet herbicide concentration-exposure time (CET) requirements for control.

Wisconsin Department of Natural Resources administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). From an ecological perspective, large-scale (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 (of the 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 treated volume. In regards to the WDNR's 10% littoral frequency of occurrence threshold discussed above, there is ecological basis in this standard. In general, if 10% of a lake was targeted with 2,4-D at 4.0 ppm ae, the whole-lake equilibrium concentration would be approximately 10% of that rate or 0.4 ppm ae. The target 2,4-D concentration for large-scale EWM treatments is typically between 0.250 and 0.400 ppm ae understanding that the exposure time would be dictated by herbicide degradation and be maintained for 7-14 days or longer. Therefore, spot treatments that approach 10% of a lake's area will become large-scale treatments.

Large-scale treatments have become more widely utilized by many lake managers (and public sector regulatory partners) as they impact the entire EWM population at once. This minimizes the repeated need for exposing the lake to herbicides as is required when engaged in an annual spot treatment program. Properly implemented large-scale herbicide treatments can be highly effective, with minimal EWM, often 0.0% being detected for a year or two following the treatment (Figure 3.4-15). Some large-scale treatments have been effective at reducing EWM populations for five to six years following the application.

Predicting success (EWM control) and native plant impacts from whole-lake treatments is also better understood than for spot treatments. Some native plants are quite resilient to this herbicide use pattern, either because they are inherently tolerant of the herbicide or they emerge later in the year than when the herbicide was active in the lake. Other species, particularly dicots, some narrow-leaved pondweeds (*Potamogeton* spp.), and naiad species (*Najas* spp.), can be impacted and take a number of years to recover. Often during the year of treatment, overall native plant biomass can be lessened but typically (not always) rebounds the following year.

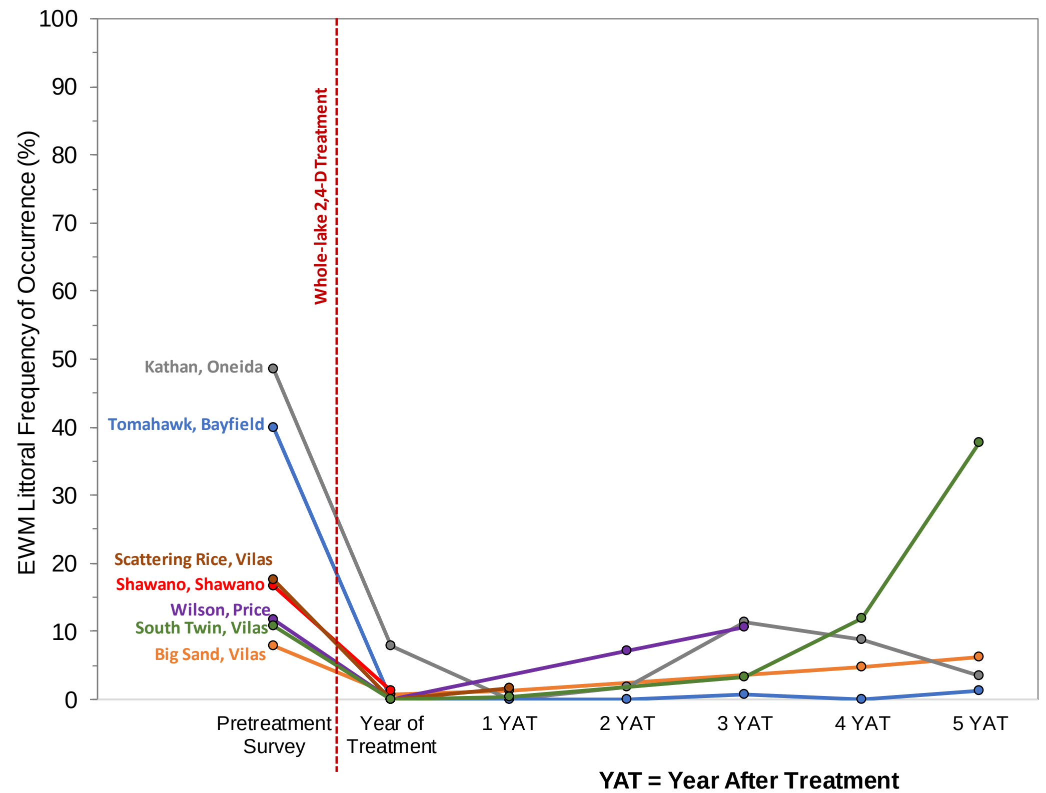


Figure 3.4-15. Littoral frequency of occurrence of EWM in lakes managed with large-scale 2,4-D treatments.

It is also important to note that US EPA registration of aquatic herbicides typically requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with spot-treatment use patterns (high concentrations, short exposure times). Therefore, only limited organismal toxicity data is available for concentrations and exposure times consistent with whole-lake treatment use patterns (low concentrations, long exposure times).

Because of their durability as a laboratory species, fathead minnows are often the subject of organismal toxicity studies. The LC50 (lethal concentration when half die) for fathead minnow exposure to 2,4-D (amine salt) has been determined to be 263 ppm ae sustained for 96 hours, a thousand times higher than fish would be exposed to in a large-scale treatment (target of approximately 0.3 ppm ae). With the assistance of a WDNR AIS-Research Grant, DeQuattro and Karasov (2015) investigated the impacts on fathead minnow of 2,4-D concentrations more relevant to what would be observed in large-scale treatments. The focus of their investigations was on reproductive toxicity and/or possible endocrine disruption potential from the herbicide. The study revealed morphological changes in reproducing male fathead minnows, such that they had lower tubercle scores (analogous to smaller antlers on a male white-tail deer) with some 2,4-D products/use-rates and not with others. This may suggest that the "inert" carrier may be the cause, not the 2,4-D itself.

At a static exposure of 0.5 ppm ae for 58 days (fish exposed for 28 days then eggs they laid were continued to be exposed for 30 more days post fertilization) uncovered a reduction in larval fathead survival from 97% to 83% at the lowest dose of one herbicide that was tested (no reduction at higher doses). While the herbicide concentrations and exposure times that caused the larval fathead minnow survival rates to decline in the study are much higher and longer than would be targeted for large-scale treatments, some 2,4-D treatments that accidentally exceeded the target rates could have approached the target concentrations tested by DeQuattro and Karasov (2015).

As discussed above, large-scale treatments can have potential secondary impacts to the lake in addition to the financial costs to the lake group. Therefore, large-scale EWM treatments are typically postponed until the population exceeds a pre-defined threshold in an attempt to balance these factors. As is discussed in the previous section, the 2016 surveys on Kangaroo Lake indicated EWM occurrence was low, and a whole-lake treatment strategy would not be applicable for controlling EWM in Kangaroo Lake at this time.

Stakeholder Survey Responses to Aquatic Vegetation within Kangaroo Lake

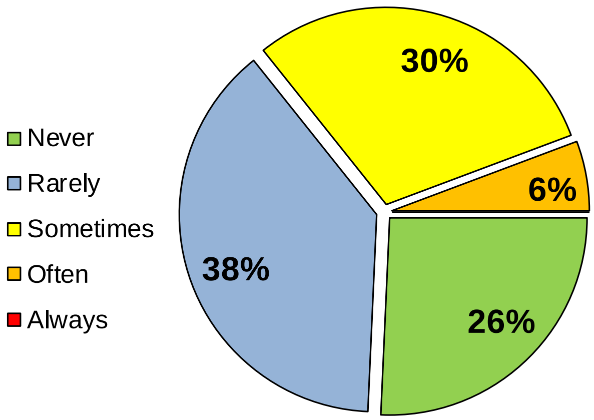
As discussed in the Stakeholder Participation Section (Section 2.0), in 2016, a stakeholder survey was sent to 201 Kangaroo Lake stakeholders. Approximately 36% or 72 surveys were completed. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Kangaroo Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

Figures 3.4-16 and 3.4-17 displays the responses of Kangaroo Lake stakeholder responses to questions regarding aquatic plant growth within the lake. When asked how often does aquatic plant growth, including algae, negatively impact their enjoyment of Kangaroo Lake, 64% indicated *rarely* or *never*, 30% indicated *sometimes*, 6% indicated *often*, and 0% indicated *always*. While aquatic plants are widespread in Kangaroo Lake, the majority are comprised of low-growing plants such as muskgrasses and slender naiad which do not often grow to levels which interfere with recreational use of a lake. The larger colony of EWM located in the south-central area of the south basin may grow close enough to the surface where it could affect recreation in this area. However, the stakeholder survey data indicates that excessive aquatic plant growth is not a significant issue on Kangaroo Lake.

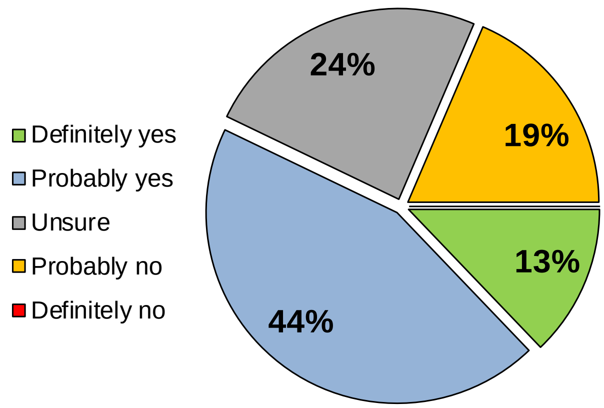
When asked if they believe aquatic plant control is needed on Kangaroo Lake, 57% indicated *definitely* or *probably yes*, 19% indicated *probably no*, and 24% were *unsure* (Figure 3.4-16). While the majority of respondents indicated aquatic plant growth rarely or never negatively impacts their enjoyment of the lake, the majority of respondents believe aquatic plant control is needed on Kangaroo Lake. This seemingly contradictory response is likely a reflection of the fact that 78% of survey respondents were aware of the presence of EWM in Kangaroo Lake. When asked if they believed control of EWM was needed in Kangaroo Lake, 97% of respondents indicated *definitely* or *probably yes* and 3% were unsure (Figure 3.4-16).

When asked what is their level of support for the responsible use of an array of EWM control techniques, the majority of respondents were either highly or moderately supportive of hand-removal by divers, integrated control using many methods, herbicide (chemical) control, and manual removal by property owners (Figure 3.4-17). The majority of respondents were highly or moderately unsupportive of water level drawdown for controlling aquatic plants as well as do nothing (do not manage aquatic plants). The level of support was mixed for biological control (milfoil weevil), mechanical harvesting, and dredging of bottom sediments.

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



Do you believe aquatic plant control is needed in Kangaroo Lake?



Eurasian watermilfoil, an aquatic invasive plant, is known to be present in a relatively small population within Kangaroo Lake. Do you believe Eurasian watermilfoil control is needed on Kangaroo Lake?

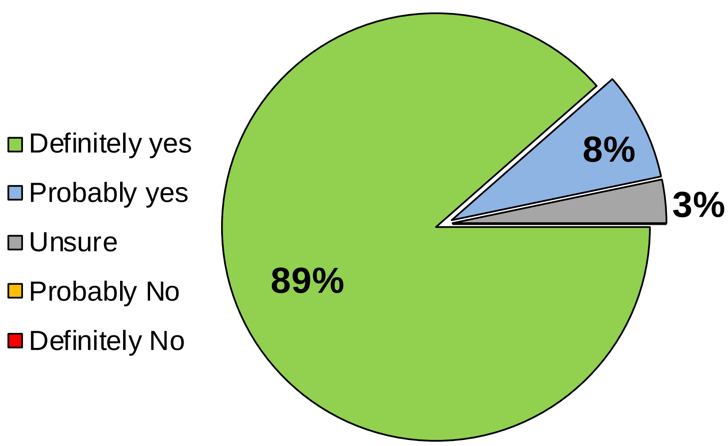


Figure 3.4-16. Kangaroo Lake 2016 stakeholder survey responses to questions to pertaining to aquatic plant growth and control.

Eurasian watermilfoil can be managed using many techniques. What is your level of support for the responsible use of the following techniques on Kangaroo Lake to specifically control Eurasian watermilfoil?

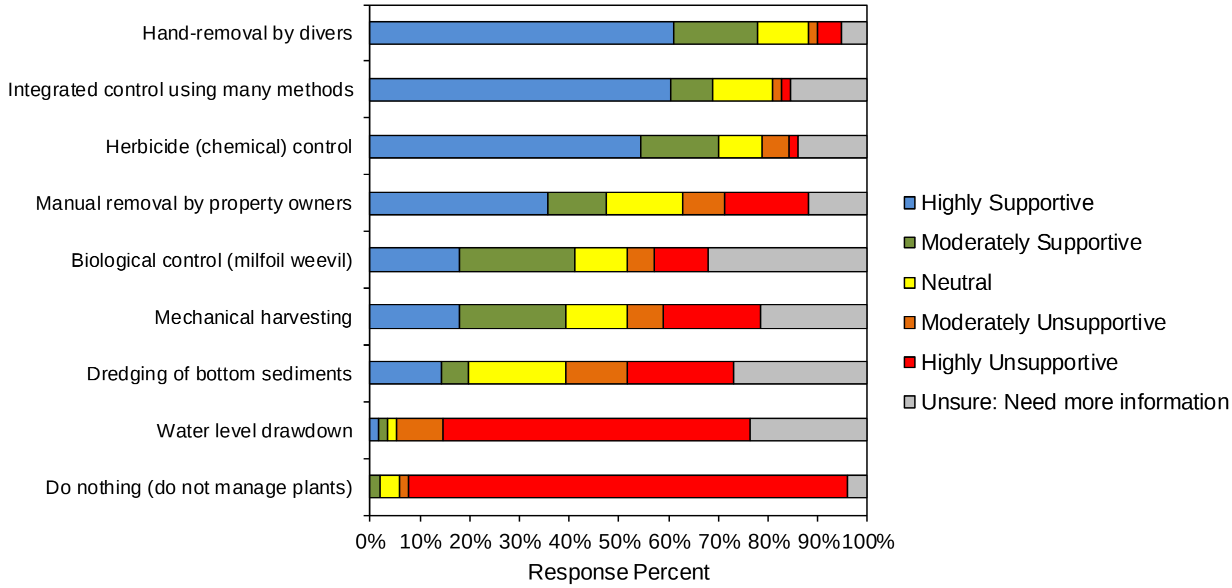


Figure 3.4-17. Kangaroo Lake 2016 stakeholder survey responses to a question pertaining to Eurasian watermilfoil control.

3.5 Aquatic Invasive Species in Kangaroo Lake

As is discussed in detail within the Aquatic Plants Section (Section 3.4), the non-native, invasive plant Eurasian watermilfoil has been present in Kangaroo Lake for over 20 years. The only other non-native, invasive species to be documented in Kangaroo Lake are common carp and zebra mussels (Table 3.5-1). A detailed description of zebra mussels and common carp can be found below. Figure 3.5-1 displays the responses from Kangaroo Lake stakeholders when asked which invasive species they believe are in Kangaroo Lake from the 2016 stakeholder survey.

Of the invasive species that have been confirmed in Kangaroo Lake, 78% of respondents were aware of the presence of Eurasian watermilfoil, 29% were aware of the presence of common carp, and 26% were aware of the presence of zebra mussels. Sixteen percent of respondents indicated the invasive grass *Phragmites* was present in Kangaroo Lake. The 2016 surveys identified the native subspecies of *Phragmites* (subsp. *americanus*) in the north basin of the lake, and no occurrences of the non-native subspecies (subsp. *australis*) were located. Stakeholder survey respondents also indicated they believed rusty crayfish, curly-leaf pondweed, purple loosestrife, *Heterosporosis*, the round goby, spiny water flea, freshwater jellyfish, starry stonewort, and flowering rush are present in Kangaroo Lake. However, none of these invasive species have been documented in Kangaroo Lake. Twenty-six percent of survey respondents indicated they believed invasive species are present within the lake, but they were not sure which species were present.

Table 3.5-1. Confirmed aquatic invasive species in Kangaroo Lake as of June 2017.

Scientific Name	Common Name	Type	Year Confirmed
Cyprinus carpio	Common Carp	Fish	Unknown
Dreissena polymorpha	Zebra Mussel	Invertebrate	2008
Myriophyllum spicatum	Eurasian Watermilfoil	Plant	1994

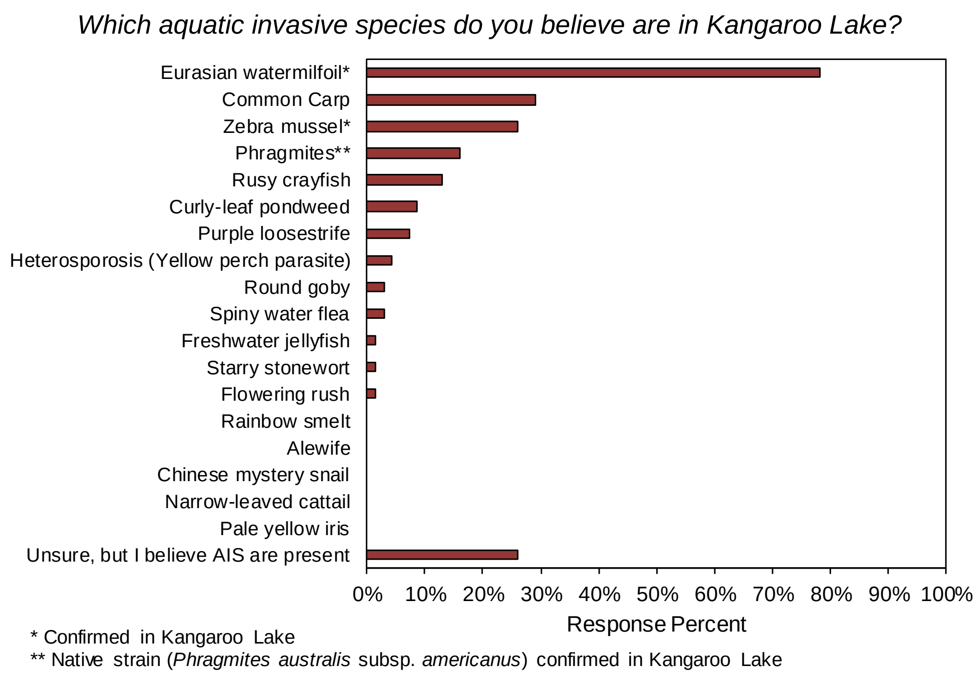


Figure 3.5-1. Kangaroo Lake stakeholder survey response to a question pertaining to aquatic invasive species.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are relatively small mollusks that are native to Europe and Asia. They were unintentionally introduced to the Great Lakes in the mid-1980s through the ballast water of ocean-going vessels. Zebra mussels have the capacity to spread rapidly, and they attach themselves to boats, boat lifts, docks, and aquatic plants and can survive for up to five days out of the water. Zebra mussel veligers, or their plankton larval stage, can also be spread to different waterbodies if live wells, bait buckets, etc. are not properly drained and dried. Adult zebra mussels can be identified their small, D-shaped bivalve shell with yellow-brown striped coloring (Photo 3.5-1). 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.

Zebra mussels often attach to and smother native mussels and are one of the primary reasons for the decline in many of North America's native freshwater mussel species. In addition, numerous studies on lakes invaded by zebra mussels found that many lakes experience an increase in water clarity as a result of decreased suspended material within the water from the filtering of zebra mussels (MacIsaac 1996; Karatayev et al. 1997; Reed-Andersen et al. 2000; Zhu et al. 2006). Zebra mussels are very efficient filter feeders, and water that has been filtered is almost entirely devoid of suspended particles (Karatayev et al. 1997). Even unwanted particles (e.g. clay particles) that pass through the zebra mussel are deposited to the sediment as pseudofeces (Karatayev et al. 1997). Following zebra mussel invasion, chlorophyll-*a* concentrations tend to decline despite no change in total phosphorus concentrations. Zebra (and quagga) mussels have been linked to many ecological changes within the Great Lakes, including increased water clarity, increased benthic algal growth, and changes in fish populations.

As is discussed within the Water Quality Section (Section 3.1), it is not yet apparent if the recent introduction of zebra mussels to Kangaroo Lake have had detectable changes to the lake's water quality. Continued monitoring of Kangaroo Lake's water quality will determine if zebra mussels lead to detectable changes over time.

Photo 3.5-1. Left: Non-native zebra mussels (*Dreissena polymorpha*) attached to a native plain pocketbook mussel (*Lampsilis cardium*). Right: Native giant floater mussel (*Pyganodon grandis*) found in Kangaroo Lake. Photo credit Onterra.

Common Carp

Common carp (*Cyprinus carpio*) are a non-native, invasive fish which originated in Eurasia and have been introduced to waterbodies throughout North America. Numerous studies have documented the deleterious effects these fish have on lake ecosystems. Common carp can survive in a wide range of waterbody conditions, but they reach their greatest densities in shallow, eutrophic systems (Weber et al. 2011). Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber et al. 2011).

Following the introduction of common carp to a waterbody, studies have documented declines in submersed aquatic vegetation and increases in total phosphorus and suspended solids, and a shift from a clear, submersed aquatic plant-dominated state to a turbid, algae-dominated state (Bajer and Sorensen 2015). Common carp directly increase nutrients within the water by physical resuspension of bottom sediments through foraging and spawning behavior as well as through excretion (Fischer et al. 2013). Common carp foraging behavior also creates more flocculent sediments which are more prone to resuspension from wind. In addition, sediments are also more prone to wind-induced resuspension as aquatic vegetation declines through physical uprooting and decline in light availability due to increases in water turbidity (Lin and Wu 2013). Zooplankton which feed on algae also decline as their refuge from predators within aquatic vegetation disappears. Common carp create a positive feedback mechanism: the direct physical resuspension and uprooting of vegetation indirectly increases the susceptibility of bottom sediments to wind-induced resuspension, and the increased turbidity further decreases aquatic vegetation.

The year common carp were confirmed in Kangaroo Lake could not be located. Fisheries data provided by WDNR fisheries biologist Steve Hogler indicates that in seven spring netting surveys completed between 1973 and 2012 the catch of common carp was near 0 in all surveys. This is not unexpected because spring netting surveys are designed to catch early spring spawning fish such as northern pike, walleye and yellow perch that are present in nearshore waters at the time the nets are deployed. Carp at the time of netting surveys are generally found offshore because of unfavorable water temperatures. Electroshocking surveys which are conducted later in spring and early summer are better indictors of carp abundance because they are preformed when water temperatures are closer to the water temperature preferred by carp for spawning. These surveys have been conducted since the early 1980's and have captured carp, but in low abundances (Hogler 2018). In 1970, the KLA implemented a barrier on the dam in an effort to prevent carp from migrating into Kangaroo Lake from Lake Michigan. These efforts appear to have been successful given no carp were documented in any of the fisheries surveys completed on Kangaroo Lake. At this time, the common carp population in Kangaroo Lake appears to be very low and these fish are likely not having significant effects on the lake's ecology.

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a 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 WDNR fisheries biologists overseeing Kangaroo Lake. The goal of this section is to provide an overview 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 WDNR and personal communications with WDNR Fisheries Biologists Steve Hogler and Nick Legler.

Before beginning to summarize available fisheries data, historical fisheries should be taken into consideration. Historical fishery data can provide valuable information as to what the fishery was once like and is currently trending towards. Prior to 1980, Kangaroo Lake was once a bass-bluegill fishery but during the early 1980s walleye emerged as the most abundant sport fish and top predator (Hogler, personal communication). After more than 20 years of stability, walleye populations decreased while smallmouth bass and bluegill abundances increased (Table 3.5-3).

Considering the history of Kangaroo Lakes fishery, this shift in populations indicate the lake is currently in a state of change and beginning to move towards a bass-bluegill fishery once again (Hogler 2012). This may be due to increased submergent plants and temperature changes (Hogler Personal Communication). Another historical aspect to consider is the spillway dam, positioned on the south side of Kangaroo Lake in Heins Creek. The Kangaroo Lake spillway dam was originally built in the early 1920s but replaced in 1937 by the Works Progress Administration (W.P.A.). The original purpose was to raise Kangaroo Lakes' water level (Williamson 2012). However, in 1970 the Kangaroo Lake Association (KLA) was influential in raising the dam 4 inches and installing a common carp barrier screen.

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 Kangaroo 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, higher 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 a large amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and higher plants) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

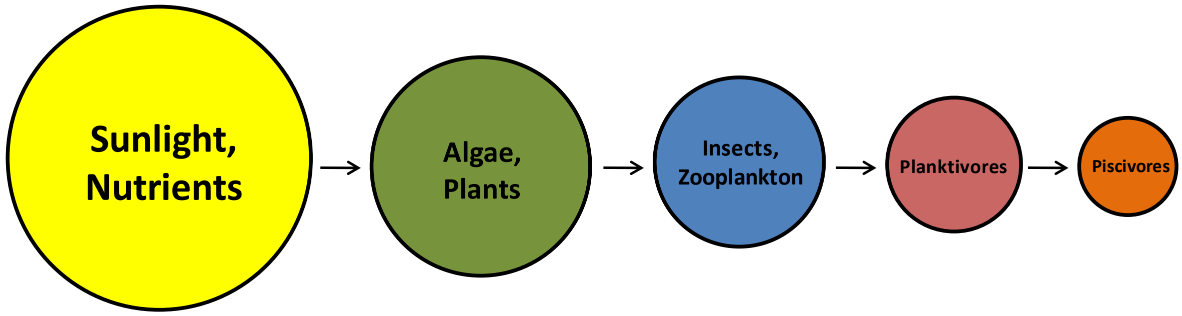


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Kangaroo Lake is an oligo-mesotrophic system, meaning it has lower nutrient content and lower levels of primary productivity. This is in contrast to a eutrophic system which contains more nutrients and consequently has higher primary productivity. Given its productivity, Kangaroo Lake should be able to support a moderately-sized population of predatory fish species. Table 3.5-1 contains a list of the popular game fish present in Kangaroo Lake. Non-gamefish species also found in the lake include bluntnose minnow (*Pimephales notatus*), bowfin (*Amia calva*), common carp (*Cyprinus carpio*), common shiner (*Luxius cornutus*), longnose gar (*Lepisosteus osseus*), longnose sucker (*Catostomus catostomus*), mimic shiner (*Notropis volucellus*) and white sucker (*Catostomus commersonii*).

Table 3.6-1. Gamefish present in Kangaroo Lake with corresponding biological information (Becker, 1983).

Common/Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Bullhead sp. (*Ameiurus*)	6	Dependent on species	Dependent on species	Amphipods, insect larvae and adults, fish, fish eggs, detritus, algae
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
*Brook Trout (*Salvelinus fontinalis*)	6	October - December	Streams or spring-fed tributaries, gravel bottom	Aquatic insects, terrestrial insects, crustaceans, fish and worms
*Brown Trout (*Salmo trutta*)	18	October - December	Large streams to small spring-fed tributaries with gravel bottom	Aquatic invertebrates, terrestrial insects, worms, fish, and crayfish
*Coho Salmon (*Oncorhynchus kisutch*)	3	March - April	Freshwater tributaries/streams, gravel from 0.6 to 3.8 cm.	Freshwater: plankton and insects. Saltwater: Smaller fish
Gar sp. (Lepisosteus)	27	May - June	Dependent on species	Small fish, leeches, crayfish
Green Sunfish (*Lepomis cyanellus*)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
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)
*Rainbow Trout (*Oncorhynchus mykiss*)	11	March - May	Stream for spawning and large lake for development	Aquatic and terrestrial insects and other invertebrates, zooplankton, fish
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

*Species most likely from Lake Michigan and not naturally reproducing in Kangaroo Lake

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 common passive trap used is a fyke net (Photo 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net and 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 and sort the fish that were captured. Fyke nets were used on Kangaroo Lake to assess spring spawning populations of northern pike, walleye and yellow perch (Hogler 2012).

The other commonly used sampling method is electroshocking (Photo 3.6-1). 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. Electroshocking was conducted on Kangaroo Lake to recapture fish marked during spring fyke netting to determine the abundance of young-of-year fish and to depict the general population of fish (Hogler 2012).

Once fish are captured, using the appropriate method, data such as count, species, length, weight, sex, tag number, and aging structures may be recorded or collected and the fish released. Fisheries biologists use this data to make recommendations and informed decisions on managing the future of the fishery.

Photo 3.6-1 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 stock fry, fingerlings, or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photo 3.6-2). 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. Table 3.6-2 displays 1954-1974 stocking efforts of northern pike and walleye in Kangaroo Lake. Stocking efforts discontinued during the mid-1970s because natural reproduction was providing a sufficient fish abundance (Hogler, personal communication).

Photo 3.6-2. Fingerling Walleye. (Source: Global Aquaculture Alliance)

Table 3.6-2. Stocking data available for Kangaroo Lake (1954-1974).

Year	Species	Age Class	# Fish Stocked
1954	Walleye	Fingerling	8,262
1956	Walleye	Fingerling	5,000
1959	Walleye	Fingerling	8,000
1961	Walleye	Fingerling	7,500
1970	Northern Pike	Yearling	500
1972	Northern Pike	Yearling	750
1973	Northern Pike	Yearling	500
1974	Northern Pike	Yearling	1,000

Fish Populations and Trends

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. The following summaries of gamefish and panfish are largely based off the 2012 fisheries report by Steve Hogler.

Gamefish

Since the 1980s, the top predator fish has changed from walleye to smallmouth bass in Kangaroo Lake. The results for the stakeholder survey show landowners, who fish Kangaroo Lake, overall thought the quality of fishing for gamefish has become worse since first starting to fish the lake (Figure 3.6-2). Although this is the perception of stakeholders, the general fish population appears to be in good health (Hogler, personal communication).

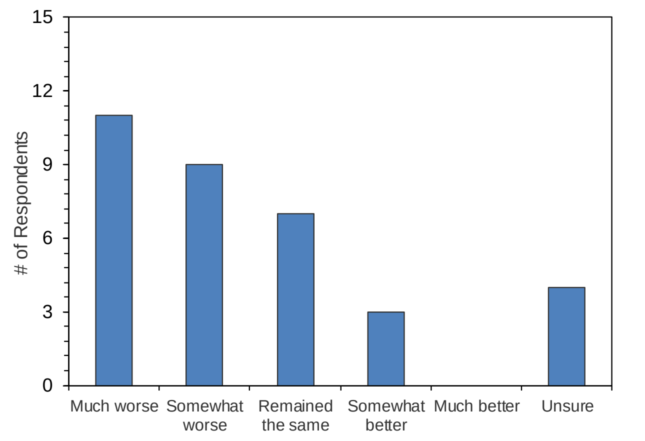


Figure 3.6-2. Stakeholder survey response Question #15. How has the quality of gamefish (i.e. bass, walleye, northern pike) fishing changed on Kangaroo Lake since you have started fishing the lake?

Walleye have increased in abundance from the 2008 to 2012 spring fyke net surveys even though walleye abundance remains less than what it previously was in the 1980s. The YOY (Young of Year) walleye population has decreased from 2008 to 2012 however strong 2 through 4 age classes indicate anglers should find good fishing opportunities in the approaching years. To also improve the population, a new regulation for walleye was made effective in April of 2007 raising the size minimum from 15" to 18" and a previously daily bag limit of 5 was reduced to 3.

Smallmouth bass have increased gradually since 1983 to the recent 2012 survey becoming the co-dominant top predator gamefish with walleye. The WDNR's size and growth distributions indicate smallmouth bass are consistently reproducing and established within the lake.

Largemouth bass population trends were not readily clear by the WDNR. Sporadically between years largemouth bass produce viable year classes.

Northern Pike have maintained a consistent population since the 1980s. Access for Northern Pike to spawn north of the causeway into Peil Creek has perhaps helped the population remain consistent. Spawning activities were documented in Peil Creek by the KLA and Nature Conservancy (Steve Hogler, personal communication).

Panfish

The overall panfish abundance has remained stable since 1980. The results for the stakeholder survey show landowners, who fish on Kangaroo Lake, typically thought the quality of panfish has become worse since first started fishing the lake (Figure 3.6-3). Although this is the perception of stakeholders the general fish population appears to be in good health (Hogler, personal communication).

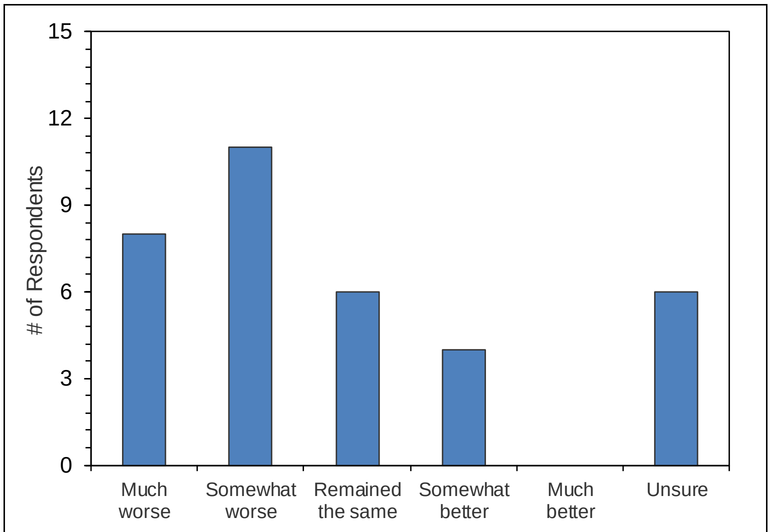


Figure 3.6-3. Stakeholder survey response Question #13. How has the quality of panfish (i.e. bluegill, crappie, perch) fishing changed on Kangaroo Lake since you have started fishing the lake?

Yellow perch particularly increased in abundance from 1983 to 2004 but have markedly decreased during the recent 2008 and 2012 surveys. The WDNR suggests the decrease in 2012 abundance may be due to net placement and unusual weather conditions encountered during spring fyke netting rather than a collapse in the perch population.

Bluegill and rock bass populations have increased overall. A decline in bluegill CPE was seen in 2012 however this was likely due to poor weather conditions during spring fyke netting. For both species scales were collected in 2012 for an age analysis. Growth, measured by length at age, for both species was found to be at or above statewide averages.

Common carp are also present within Kangaroo Lake and have their own effects on the system, see section 3.5 Aquatic Invasive Species in Kangaroo Lake.

Kangaroo 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, 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 2016, 75% of the substrate sampled in the littoral zone of Kangaroo Lake was soft sediments (marl), 21% was sand, and the remaining 4% composed of rock substrate.

Coarse Woody Habitat and Fish Sticks Program

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).

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 (WDNR 2014). Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photo 3.6-3). 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.

These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. During Onterra's 2016 coarse woody habitat survey, Kangaroo Lake had 32 coarse woody pieces/mile of shoreline.

Photo 3.6-3. Fish Stick Example. (Photo courtesy of WDNR 2013).

Kangaroo Lake is an excellent candidate to install coarse woody habitat and the KLA, with the help of volunteers, has already taken advantage of the fish sticks program. During 2015, 2016 and 2017 14, 30 and 33 trees, respectively, were dropped for the fish sticks project.

Regulations and Management

Due to the shallow body of water Kangaroo Lake is, the KLA established a voluntary 500-foot slow/no-wake zone around the edge of the shore and island. Additionally, special fisheries regulations occur, specifically in terms of walleye. Table 3.6-3 displays the 2017-2018 regulations for Kangaroo Lake gamefish species. A minimal size of 18 inches and bag limit of three walleyes has been established. The purpose of this regulation is to allow more walleyes to achieve breeding age and increase populations. For specific fishing regulations, 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 3.6-3. WDNR fishing regulations for Kangaroo Lake (2017-2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	June 17, 2017 to March 4, 2018
Smallmouth bass	Catch and release only	None	May 6, 2017 to June 16, 2017
Largemouth bass	5	14"	May 6, 2017 to June 16, 2017
Muskellunge and hybrids	1	40"	May 27, 2017 to November 30, 2017
Northern pike	5	None	May 6, 2017 to March 4, 2018
Walleye, sauger, and hybrids	3	18"	May 6, 2017 to March 4, 2018

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, but 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 3.6-4. 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 3.6-4. 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/).

Viral Hemorrhagic Septicemia (VHS)

Viral Hemorrhagic Septicemia or VHS, is an infectious disease in fish caused by the *Viral hemorrhagic septicemia* virus. Originally identified in European freshwater trout, the virus was discovered in the Pacific northwest of the United States in the late 1980's and subsequently in the Great Lakes region in 2005. A strain of the VHS virus was discovered in Lake Michigan which is connected to Kangaroo Lake via Heins Creek. The VHS virus is a threat to many fish species in Wisconsin and has caused large scale fish kills since its discovery. The VHS virus has never been associated with human illness and diseased fish caught by anglers may be consumed.

It is important to make efforts to prevent the spread of the VHS virus to other waters in Wisconsin. Specific laws aiming to prevent the spread of VHS in Wisconsin are in place and can be reviewed on the WDNR website at: http://dnr.wi.gov/topic/fishing/vhs/vhs_prevent.html.

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three main objectives:

1) Collect detailed information on Kangaroo Lake's water quality, watershed, shoreland habitat, and aquatic plant community, including within the north basin, a critical habitat area.
2) Collect sociological information from Kangaroo Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.
3) Using the ecological and sociological data, work with the KLA to develop an updated management plan to protect and enhance Kangaroo Lake into the future.

These three objectives were fulfilled during this project and have led to a more detailed picture of the Kangaroo Lake ecosystem, the people who care for it, and the management actions that need to be taken to continue to protect and enhance the Kangaroo Lake ecosystem. The studies completed on Kangaroo Lake indicate that the lake is overall very healthy. All of the water quality parameters that were assessed fell within the excellent category for shallow lowland drainage lakes in Wisconsin, and the lake harbors a native aquatic plant community which is of higher quality than the majority of the lakes within the region.

While the non-native, invasive plant Eurasian watermilfoil (EWM) is widespread throughout the lake's south basin, the 2016 point-intercept survey indicated the population is small with a littoral occurrence of only 2%. In addition, comparisons with previous datasets indicate the EWM population in the south basin has declined by 66% since 2006. Similarly, surveys in Kangaroo Lake's north basin found it to be largely free of EWM, with the majority of the population concentrated in a one-acre colony adjacent to the causeway. As is discussed in depth in the subsequent Implementation Plan (Section 5.0), the KLA will continue to monitor Kangaroo Lake's EWM population and investigate alternative management strategies for controlling the isolated colony within the north basin.

The 2016 studies found that largest stressor to the Kangaroo Lake ecosystem at present is shoreland development within the south basin. It is estimated that the south basin has lost over 90% of its hardstem bulrush population since the mid-20th century. Shoreland development, in combination with increased recreational use and changes in hydrological regimes with the installation of the dam, has likely contributed to the observed decline. The KLA recognizes the important habitat and water quality benefits these emergent plant communities provide, and the Implementation Plan outlines how they will continue their effort to protect and enhance these populations within the south basin. The 2016 surveys found that the north basin of Kangaroo Lake supports large emergent and floating-leaf plant communities. The minimal shoreland development around the north basin along with the restriction of motorized watercraft have allowed these large communities to persist.

The 2016 studies found that Kangaroo Lake continues to be an exceptional water resource for Door County and Wisconsin that is utilized for relaxation, wildlife viewing, swimming, fishing and more. With the data gathered through this project, the KLA has put together a strategic plan to maximize Kangaroo Lake's positive attributes, minimize negative attributes, and effectively and efficiently manage the lake as an ecosystem. The Implementation Plan that follows is a result of the hard work of many Kangaroo Lake stakeholders and WDNR staff. The KLA should consider revisiting and updating this management plan in 5-7 years.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Kangaroo Lake Association (KLA) Planning Committee, ecologist/planners from Onterra, and WDNR staff. It represents the path the KLA 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 Kangaroo 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. This was truly a team-based effort and could not have been undertaken without the efforts of KLA board and planning committee members. Continued volunteer involvement in the KLA and Kangaroo Lake's management will be essential for ongoing protection and enhancement of Kangaroo Lake. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain current water quality conditions

Management Action:	Continue monitoring of Kangaroo Lake's water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Cindy Wienkers or current CLMN volunteer
Description:	Monitoring water quality is an import 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. As discussed in the Water Quality Section (Section 3.1), Kangaroo Lake's water quality is rated as *excellent* for a shallow lowland drainage lake in Wisconsin with low nutrient and algal levels and high water clarity. Continued monitoring will allow for early detection of potential negative trends and may lead to the reason as to why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the KLA have been measuring Secchi disk transparency in Kangaroo Lake annually since 1992 and collecting samples for chlorophyll-*a* and total phosphorus annually since 1993 and 1994, respectively. The KLA recognizes the importance of continuing this monitoring effort which will supply them with valuable data about their lake. When a change in the collection volunteer occurs, Mary Gansberg (920.662.5489) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also 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) by the volunteer.

Action Steps:

1. Cindy Wienkers or KLA Board of Directors appoints/recruits new volunteer(s) as needed.
2. New volunteer(s) contact Mary Gansberg (920.662.5489) with the WDNR as needed.
3. Volunteer(s) reports results to WDNR SWIMS database.

<u>Management Action:</u> Continue monitoring of Peil Creek water quality through the WDNR Water Action Volunteers (WAV) Program.

Timeframe: Continuation of current effort

Facilitator: Lucy Klug or current WAV volunteer

Description: The WAV Program is a collaborative effort between the WDNR and University of Wisconsin – Extension which utilizes citizen volunteers to monitor rivers and streams across Wisconsin. Like the CLMN program discussed previously, regular data collection on Wisconsin's rivers and streams allows for the early detection of potential problems. Peil Creek, which is mainly fed via groundwater springs, is the primary tributary to Kangaroo Lake which empties into the north basin.

Volunteers from the KLA have been collecting water quality data from Peil Creek annually since 2010. Water quality parameters measured monthly between spring and fall include: dissolved oxygen, streamflow, transparency, temperature, and pH. Total phosphorus concentrations are also periodically measured. Continued monitoring of Peil Creek will provide resource managers with valuable information on not only the health of the stream but the health of Kangaroo Lake as well.

Like water quality monitoring in Kangaroo Lake, the KLA recognizes the importance of continuing the monitoring effort in Peil Creek. When a change in the collection volunteer occurs, the statewide WDNR and UW-Extension WAV Program contacts (see information below) will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also 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) by the volunteer.

Action Steps:

1. Lucy Klug or KLA Board of Directors appoints/recruits new volunteer(s) as needed.

2. New volunteer(s) contact UW-Extension statewide WAV Program Coordinator Peggy Compton (608.342.1633), WDNR statewide WAV Program Coordinator Ilana Haimes (608.266.3599), and/or current regional coordinator (Matt Peter) with the Ridges Sanctuary (920.839.2802) as needed.
3. Volunteer(s) reports results to WDNR SWIMS database.

Management Action: Preserve natural and restore highly developed shoreland areas on Kangaroo Lake to improve habitat, reduce erosion, and protect water quality.

Timeframe: Initiate 2018

Facilitator: KLA Board of Directors

Description: The 2016 Shoreland Condition Assessment found that the immediate shoreland zone of Kangaroo Lake's south basin had a higher degree of development when compared to the north basin. Approximately 50% (3.5 miles) of the immediate shoreland zone within the south basin contained little to no development, delineated as either *natural/undeveloped* or *developed-natural*, while approximately 29% (2.1 miles) contained a higher degree of development categorized as *developed-unnatural* or *urbanized*. Approximately 21% (1.5 miles) of the shoreland zone within the south basin contained rip-rap or seawalls.

In the north basin, approximately 91% (3.8 miles) of shoreland were delineated as *natural/undeveloped* or *developed-natural* while 6% (0.3 miles) was delineated as *developed-unnatural*. The only rip-rap observed in the north basin was along the County Highway E causeway which is approximately 0.25 miles in length or 6% of the shoreland zone within the north basin. In total, approximately 66% (7.4 miles) of Kangaroo Lake's shoreland contained little to no development, 21% (2.4 miles) contained a higher degree of development, and 13% (1.5 miles) contained a moderate degree of development.

It is important that the owners of properties with little development are informed on the benefits their shoreland is providing to Kangaroo Lake in terms of maintaining the lake's water quality and habitat, and that these shorelands remain in a natural or semi-natural state into the future. It is equally important that the owners of properties with developed shorelands become educated on the lack of benefits and possible harm their shoreland has to Kangaroo Lake's water quality and contribution to habitat loss.

As is discussed further in this section, the KLA in partnership with the Nature Conservancy has been active in improving shoreland habitat by increasing coarse woody habitat within the south basin of the lake through the WDNR's Fish Sticks Program. The KLA would like to continue improving shoreland habitat in Kangaroo Lake, particularly in the south basin. The KLA board of directors will work with the appropriate entities such as the Nature Conservancy, Door County Soil and Water Conservation Department, and the WDNR to research grant programs and other pertinent information that will aid the KLA in preserving and restoring the shoreland areas of these lakes.

The KLA could reach out to Erin Hanson (920.746.2214) with the Door County Soil and Water Conservation Department to research grant programs, shoreland restoration/preservation techniques, and other pertinent information that will aid in the KLA. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, properties with restoration on their shorelands could serve as demonstration sites. Other lakeside property owners could have the opportunity to view a shoreland that has been restored to a more natural state, and learn about the maintenance, labor, and cost-sharing opportunities associated with these projects.

The WDNR's Healthy Lakes Initiative Grants allow partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county and the WDNR Lake Protection Grant Program. However, for a larger project that may include a number of properties, it may be more appropriate to seek funding through a WDNR Lake Protection Grant. While more funding can be provided through a Lake Protection Grant and there are no limits to where that funding is utilized (e.g. technical, installation, etc.); however, the grant does require that the restored shorelines remain undeveloped in perpetuity.

Action Steps:

1. The KLA Board of Directors gathers appropriate information from entities listed above.
2. The KLA provides property owners with the necessary informational resources to protect or restore their shoreland should they be interested. Interested property owners may contact the KLA and the Door County Soil and Water Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action:	Preserve natural land cover within the Kangaroo Lake watershed beyond the immediate shoreland zone.
Timeframe:	Continuation of current effort
Facilitator:	KLA Board of Directors
Description:	As is discussed within the Watershed Section (Section 3.2), changes in land use beyond the shoreland zone within a lake's watershed can impact water quality. Nearly 60% of Kangaroo Lake's surficial watershed is developed, with the majority of this development comprised of pasture/grasslands and lesser portions comprised of row crop agriculture, rural residential areas, and medium density urban areas. Given this higher level of development, modeling of Kangaroo Lake's watershed predicted an in-lake growing season total phosphorus concentration of 52 µg/L – 248% higher than the measured growing season mean concentration of 13 µg/L. As is discussed in the Watershed Section, the large discrepancy between predicted and measured total phosphorus in Kangaroo Lake is largely due to the fast-draining soils and underlying geology within Kangaroo Lake's watershed. The majority of soils within Kangaroo Lake's watershed are classified as *well drained*, indicating that the majority of the precipitation which falls within the lake's watershed likely percolates quickly into the ground rather than flowing across the surface and into the lake as the watershed modeling assumes. The lake's high concentration of calcium and magnesium are also indications that the lake receives significant sources of groundwater. Peil Creek is largely groundwater-fed, originating from groundwater springs north of Kangaroo Lake. The KLA recognizes the importance of protection natural lands within Kangaroo Lake's watershed beyond the immediate shoreland zone of Kangaroo Lake. The KLA has worked with the Nature Conservancy, the Door County Land Trust, and private landowners to protect land surrounding Piel Creek and the north basin of Kangaroo Lake. In the mid-1990s, the Nature Conservancy purchased 117 acres of land around the north basin and transferred 57 acres to the Door County Land Trust for long-term protection. And in 2005, the Nature Conservancy purchased 42 acres of land surrounding the headwater springs which feed Piel Creek and Kangaroo Lake. In total, the Nature Conservancy manages 367 acres of land around Kangaroo Lake. The KLA continues to work with the Nature Conservancy in an effort to protect the north basin of Kangaroo Lake and protect water quality and habitat in Piel Creek. As of this writing, approximately 7% of the land within Kangaroo Lake's surficial watershed is under some type of protection either

through the Nature Conservancy, the Door County Land Trust, or Door County (Map 12). The KLA should continue to work with agencies such as the Nature Conservancy in an effort to protect additional land adjacent to Peil Creek and immediately surrounding Kangaroo Lake.

Some valuable resources for land owners within Kangaroo Lake's watershed who want to protect their land for future generations can be found below:

- The Nature Conservancy website: (www.nature.org)
- Door County Land Trust website: (www.doorcountylandtrust.org)
- Door County Soil and Water Conservation Department website: (http://www.vilasconservation.com/who_we_are.html)
- Kangaroo Lake Association website: (www.kangaroolake.org)

Action Steps:

1. See description above.

Management Goal 2: Control Existing Aquatic Invasive Species and Prevent New Introductions and Spread from Kangaroo Lake

Management Action: Conduct periodic, lake-wide professional vegetation monitoring in the south basin of Kangaroo Lake.

Timeframe: Initiate in 2020

Facilitator: KLA Board of Directors

Description: This management action discusses continued monitoring of EWM and native aquatic plants within the south basin of Kangaroo Lake. Continued monitoring of EWM within the north basin is discussed in the subsequent management action. As is discussed within the Aquatic Plant Section (Section 3.4), the whole-lake point-intercept surveys completed on Kangaroo Lake in 2016 found that the EWM population in the south basin is relatively small with a littoral frequency of occurrence 2.1%. Comparison of the 2016 data with data from 2006, 2008, and 2010 collected by KLA volunteers showed that the littoral frequency of occurrence of EWM within the south basin declined by 66% from 2010 to 2016.

During the planning meetings with the KLA Planning Committee, the ongoing research on EWM management in Wisconsin being completed by the US Army Corps of Engineers, WDNR, and private consultants was presented. The KLA Planning Committee was able to put the EWM population in Kangaroo Lake into perspective when compared to other Wisconsin Lakes and agreed that herbicide applications to control the EWM population in Kangaroo Lake were not warranted at this time.

However, the KLA would like to continue their active role in monitoring Kangaroo Lake's EWM population over time so that they can act quickly in the event the population expands. The stakeholder survey indicated that Kangaroo Lake stakeholders are highly supportive of actively managing the lake's EWM population with 97% indicating *definitely yes* or *probably yes* when asked if they believe EWM control is needed on Kangaroo Lake (Figure 5.0-1).

Question 25: Eurasian watermilfoil, an aquatic invasive plant, is known to be present in a relatively small population within Kangaroo Lake. Do you believe Eurasian watermilfoil control is needed on Kangaroo Lake?

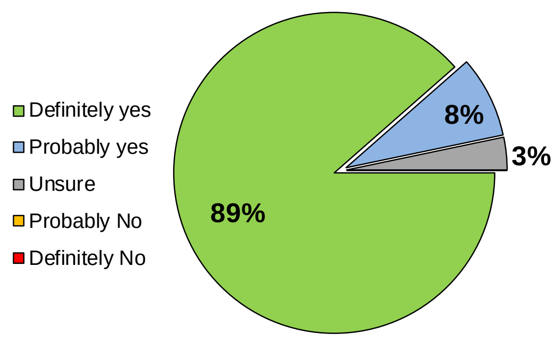


Figure 5.0-1. Kangaroo Lake 2016 stakeholder response to question 25.

Eurasian watermilfoil has been present in Kangaroo Lake for over 20 years, and the fact that its population remains small indicates that the habitat in Kangaroo Lake may not be ideal for this invasive plant. Much of the substrate in Kangaroo Lake is comprised of marl and sand, substrates that are relatively low in nutrients. In addition, marl tends to bind-up phosphorus and make it unavailable for biological use. While it is believed it is unlikely that the EWM population will expand to levels which will impart negative ecological and/or recreational impacts to Kangaroo Lake, the KLA would like to continue monitoring the EWM population over time.

The KLA will actively monitor the EWM population in the south basin by having professional whole-lake point-intercept surveys completed once every five years. Like the whole-lake point-intercept survey completed in 2016, these surveys allow for a quantitative measure of EWM within the lake (littoral frequency of occurrence). In addition, information regarding the south basin's native aquatic plant community can also be gathered to assess its overall health. The data collected during these surveys can be compared to data collected previously to determine if the occurrence of EWM or any native aquatic plant species has changed over time. If the EWM population is found to have increased significantly, feasible management strategies can be discussed and developed.

In addition to completing a whole-lake point-intercept survey, an emergent and floating-leaf aquatic plant mapping survey would be completed on the south basin once every 10 years. The details of this survey are discussed in detail in a subsequent management action.

Action Steps:

1. Retain qualified professional to complete whole-lake point-intercept survey on Kangaroo Lake's south basin in 2021 and once every five years thereafter.
2. Work with qualified professional to develop EWM management strategy if warranted.
3. Update management plan to reflect changes in EWM management/monitoring needs and those of the lake ecosystem.

Management Action: Continue annual monitoring and hand-removal of EWM within the north basin of Kangaroo Lake.

Timeframe: Continuation of current effort

Facilitator: Kari Hagenow (The Nature Conservancy) and KLA Board of Directors

Description: Largely free of development, the north basin of Kangaroo Lake is an important component for the overall health of the Kangaroo Lake ecosystem in terms of habitat and water quality as well as providing lake users with recreational opportunities in a more natural setting. The surveys completed in 2016 and 2017 found that the north basin is largely free of EWM, and apart from a few single plants the population is mainly concentrated in a 1.0-acre colony adjacent to the causeway in the southern area of the basin (Maps 10 and 11).

The Kangaroo Lake Planning Committee indicated that the EWM in the north basin has largely been restricted to this area of the north basin for some time and has yet to spread elsewhere within the basin. It was discussed at the planning meetings that given EWM's capacity for rapid spread and the fact it has been present in Kangaroo Lake for over 20 years, its absence in most of the north basin may be an indication that the habitat is unsuitable for this invasive plant. The substrate within the north basin was found to be comprised primarily of flocculent, low-nutrient marl deposits. Overall, the north basin supports a low occurrence of native submersed aquatic plants with the exception of the macroalgae *Chara*.

While it is unlikely that EWM will expand significantly beyond its current levels in the north basin, the KLA would like to continue annual monitoring and hand-harvesting of EWM within the north basin by partnering with Kari Hagenow, the Nature Conservancy's Door Peninsula Land Steward & Door County Invasive Species Team Coordinator. The KLA should continue to work with Kari to coordinate volunteer efforts to map and hand-remove EWM from the north basin.

These hand-removal efforts should largely be focused on smaller occurrences of EWM found within the basin, such as single plants and clumps. The 1.0-acre colony of dominant EWM mapped along the causeway is likely too large and dense for manual hand-harvesting to be effective. A potential management strategy for controlling this colony of EWM is discussed in the next management action. The continued annual monitoring of EWM within the north basin will provide insight into the dynamics of this population, while continued hand-removal of newly discovered plants will decrease the probability that this plant will spread in the north basin and protect the ecology of this sensitive area.

Action Steps:

1. The KLA works with Kari Hagenow (Nature Conservancy Door Peninsula Land Steward and Door County Invasive Species Team Coordinator 920.743.8695 ext. 306) to coordinate the annual monitoring and volunteer-based hand-removal of EWM within the north basin of Kangaroo Lake.

Management Action: Investigate feasibility of implementing diver-assisted suction harvesting (DASH) system to control dominant colony of EWM in north basin of Kangaroo Lake.

Timeframe: Initiate in 2018

Facilitator: KLA Board of Directors

Description: As is discussed in the previous management action, the EWM population within the north basin of Kangaroo Lake is largely concentrated in a 1.0-acre colony adjacent to the causeway (Maps 10 and 11). The EWM within this colony is dense and was delineated with density ratings of *highly dominant* in 2016 and *dominant* in 2017. The KLA currently works with Kari Hagenow with the Nature Conservancy to monitor and manually hand-remove EWM within the north basin each year. However, it is believed the size and density of the EWM colony adjacent to the causeway would require effort beyond volunteer manual hand-removal to successfully control.

At the planning meetings, it was discussed that given the colony's size and location near the causeway's culverts where water movement is higher, an herbicide application would likely not be successful at controlling this colony. However, this colony may be a successful candidate for control using the Diver Assisted Suction Harvesting (DASH) system.

The DASH system has been found to be effective at removing these smaller, dense colonies of EWM. During this process, a scuba diver manually extracts the invasive plants (including the roots) and then feeds the removed plants into a vacuum tube that transports the plants to a bin or bag on a boat. They do not simply vacuum the area to remove the plants as that would result in the removal of sediment and non-target native plants which would be considered suction dredging (requires elaborate permitting). A mechanical harvesting permit from the WDNR is needed (fee of $30 per acre) to use the DASH system.

The DASH system is said to be more efficient than manual removal alone as the diver does not have to go to the surface to deliver the pulled plants to someone on a boat. The DASH system also is theorized to cause less fragmentation, as the plants are immediately transported to the surface using the vacuum technology. However, the costs of conducting hand-harvesting with one of these firms is more expensive than just hiring trained divers and/or snorkelers.

The cost of implementing DASH on Kangaroo Lake may be lower given the proximity of the colony to the causeway. Rather than taking time to transfer removed EWM plants to a boat and then to a land-based vehicle for disposal, it may be possible to directly transfer the removed EWM plants to a vehicle parked on the causeway. If possible, this reduced transfer time would be a cost savings for the DASH effort.

During the planning meetings, the KLA Planning Committee indicated that they would like to investigate the feasibility of utilizing professional DASH harvesting on the north basin of Kangaroo Lake to remove the 1.0-acre colony of dominant EWM. The KLA will want to reach out to firms which conduct DASH harvesting (contacts listed below) to determine if this type of harvesting would be feasible in the north basin and what it would cost. If DASH is a feasible option, the KLA will reach out to the Town of Baileys Harbor to see if they would be willing to partner and offer financial assistance in this endeavor.

Companies that offer DASH Services in Wisconsin

Many Waters, LLC
Barb Gajewski
skih2o@hotmail.com

Ecowaterways
Patricia Dalman
pdalman@ecowaterway.com

Lakefront Restoration and Diving
Tyler Bowe
tsblakefrontrestorationanddiving@yahoo.com

Aquatic Plant Management, LLC
Andrew McFerrin

andrew@aquaticplantmanagement.com

Diver Assisted Suction Harvesting, LLC
Al Pahnke
diveral@sbcglobal.net
jefflong@new.rr.com

Action Steps:

1. KLA contacts firms which offer DASH services to determine if this type of harvesting is applicable and obtain cost estimates. The KLA should inquire about transferring removed EWM directly to vehicle on the causeway as a cost-savings measure.
2. Depending on feasibility and cost, KLA determine if they would like to move forward with harvesting of colony in north basin.
3. If the KLA elects to move forward with DASH in the north basin, retain qualified professional to map EWM prior to and following harvesting to determine efficacy and develop future strategy.
4. The KLA will reach out to the Town of Baileys Harbor for cost-sharing assistance on a potential DASH project.

Management Action: Investigate implementing annual, volunteer-based monitoring of Kangaroo Lake's zebra mussel population following established WDNR/UW-Extension protocols.

Timeframe: Initiate 2018

Facilitator: KLA Board of Directors

Description: The non-native, invasive zebra mussel was discovered in Kangaroo Lake in 2008. As is discussed within the Aquatic Invasive Species in Kangaroo Lake Section (Section 3.5), zebra mussels have been shown to alter lake water quality and ecosystem function in addition to becoming a recreational nuisance. Unfortunately, there is currently no method for eradicating zebra mussels from a lake once they become established. However, the KLA should focus on educating lake users on how to prevent the spread of zebra mussels from Kangaroo Lake to other waterbodies.

While the KLA understands that eradication of zebra mussels from Kangaroo Lake is not possible, they would like to investigate initiating a monitoring program to track zebra mussel abundance over time. There have been anecdotal reports from lake users that the population has been increasing and the KLA would like to determine if these reports are valid. Monitoring zebra mussel abundance over time will also provide resource managers with information on how the population is changing and if any changes in water quality could be correlated with changes in zebra mussel abundance.

The UW-Extension's publication Aquatic Invasive Species Monitoring Manual – Citizens Lake Monitoring Network (2014) includes a chapter on how volunteers can monitor established zebra mussel populations in their lake. This monitoring method involves deploying substrate samplers in areas of the lake where zebra mussels have been found. The substrate samplers are made of four square plates ranging from 12 to 6 inches in size and are spaced apart in a pyramid shape with the smallest plate at the top and the largest plate at the bottom. Two samplers are suspended mid-depth in the water at each sampling location. Both samplers are deployed in the lake from May through September. One sampler is analyzed once per month over the growing season while the other remains in the water for the entire season and is removed and analyzed in September.

The samplers are analyzed by counting the number of zebra mussels that have attached to the plates of the sampler to obtain an estimate of density. A subsample of the zebra mussels is also measured for length. The data are reported on a recording sheet provided by the UW-Extension and the KLA will report these data to the UW-Extension each year. A detailed description of this monitoring methodology, data analysis, and reporting can be found in the UW-Extension publication mentioned previously.

Action Steps:

1. KLA holds discussions on whether they would like to pursue monitoring of the zebra mussel population in Kangaroo Lake.
2. If the KLA elects to move forward with zebra mussel monitoring, they need to recruit volunteers to complete the annual monitoring.
3. Volunteer monitors should contact Paul Skawinski (715.346.4853), the statewide CLMN coordinator, to obtain zebra mussel substrate samplers, other necessary equipment, and training.
4. Volunteers conduct annual monitoring and report results to WDNR on annual basis.
5. KLA recruits new volunteer(s) as needed and assures proper training for monitoring is provided.

<u>Management Action:</u> Initiate aquatic invasive species rapid response plan upon discovery of new infestation.

Timeframe: Initiate upon invasive species discovery

Facilitator: KLA Board of Directors

Description: In the event that a new aquatic invasive species such as curly-leaf pondweed is located by Kangaroo Lake users, the areas should be marked with a small buoy or GPS and the KLA should contact resource managers (Nature Conservancy, WDNR) immediately. The areas marked would serve as focus areas for professional ecologists and those areas would be surveyed by professionals during the plant’s peak growth phase. The results of this initial survey would then be used to develop control strategies. Curly-leaf pondweed populations are found in nearby Lake Michigan and Clark Lake. The

KLA should educate their membership at their annual meetings on how to identify this invasive plant so that they can recognize potential occurrences while recreating on Kangaroo Lake.

Action Steps:

1. KLA Board of Directors contact The Nature Conservancy or WDNR upon discovery of new aquatic invasive species in Kangaroo Lake.

Management Goal 3: Protect and Enhance Native Aquatic Plant Communities in Kangaroo Lake

Management Action: Protect and enhance the hardstem bulrush (*Schoenoplectus acutus*) population in the south basin of Kangaroo Lake.

Timeframe: Continuation of current effort

Facilitator: Paul Mahlberg, Sherrill Eichler, and the KLA Board of Directors

Description: As is presented in the Aquatic Plant Section (Section 3.4), anecdotal reports from long-term residents indicate that the south basin of Kangaroo Lake historically supported a larger population of hardstem bulrush. It is estimated that there was potentially up to 175 acres of hardstem bulrush in the south basin in the early to mid-20th century. However, since the mid-20th century the hardstem population has been in decline with approximately 13 acres remaining in 2017, representing a 93% reduction in acreage from historical levels.

The cause of the hardstem bulrush decline within the south basin over the second half of the 20th century is not known, but it may be due to a combination of factors including the alteration of the lake's natural water levels, shoreland development, and increased watercraft traffic. Recognizing the importance hardstem bulrush communities provide to the lake in terms of habitat and sediment/shoreland stabilization, the KLA has already undertaken a number of efforts to protect what remains of the hardstem bulrush population and also restore areas of hardstem bulrush that were lost.

These efforts include the implementation of a mandatory slow-no-wake zone in the southern area of the lake and a voluntary 500-foot slow-no-wake from the shoreline areas elsewhere around the lake and from the island. In addition, the KLA has also undertaken projects to reintroduce hardstem bulrush to areas where it once occurred historically. Most recently, the KLA was awarded a WDNR small scale planning grant in 2014 to aid in funding a project aimed at planting seedling and cuttings of hardstem bulrush plants from 2014-2017 in various locations around the lake and determining what site-specific conditions are present that result in successful restoration.

Their study found that hardstem bulrush rhizomes (cuttings) had successful establishment when planting occurred in May to mid-June in near-shore areas of water of approximately one inch of water or less with a substrate of marl, sand, or gravel (Mahlberg and Eichler 2016). The KLA would like to continue their investigations into the establishment of hardstem bulrush plants in the south basin of Kangaroo Lake.

To continue this hardstem bulrush reestablishment project, the KLA will investigate creating an online website or database which lists current lake riparians who are participating in the program and to provide information for property owners who may be interested. Participants can also provide monitoring data about their plantings which will provide information on whether or not the plantings are expanding and the success/failure of long-term reestablishment. As is discussed further in this section, the KLA will continue to educate KLA property owners on the importance of the hardstem bulrush population and how to protect it. In addition, the subsequent management action discusses future professional monitoring of the hardstem bulrush population in the south basin.

Action Steps:

1. Paul Mahlberg works with KLA Board of Directors to develop website or database to track participants and status of planted hardstem bulrush populations.
2. KLA utilizes information gathered from ongoing monitoring of planted hardstem bulrush populations to determine optimal conditions for reestablishment.

Management Action: Conduct periodic, professional monitoring of the emergent and floating-leaf aquatic plant communities within the south basin of Kangaroo Lake.

Timeframe: Initiate in 2025

Facilitator: KLA Board of Directors

Description: In addition to completing whole-lake point-intercept surveys on the south basin every five years, it is recommended that an emergent and floating-leaf aquatic plant community mapping survey be completed in the south basin once every 10 years. Like in 2016, the aim of this survey would be to accurately map areas of emergent (e.g. hardstem bulrush) and floating-leaf (e.g. white water lily) plant populations. Given the decline in the hardstem bulrush population in particular within the south basin, this survey would provide further insight into the dynamics of the hardstem bulrush population and identify areas that may need additional protection.

Action Steps:

1. Retain qualified professional to complete emergent and floating-leaf aquatic plant community survey on Kangaroo Lake's south basin in 2026 and once every 10 years thereafter.

2. Work with qualified professional to develop protection/restoration strategies if warranted.
3. Update management plan to reflect changes in emergent/floating leaf aquatic plant management/monitoring needs and those of the lake ecosystem.

Management Goal 4: Assure and Enhance the Communication and Outreach of the Kangaroo Lake Association with Lake Stakeholders

Management Action: Promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Kangaroo Lake.

Timeframe: Continuation of current effort

Facilitator: KLA Board of Directors

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. The KLA will continue its effort to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the KLA publishes three hardcopy newsletter issues per year. These newsletters provide members with association-related information including current projects and updates, meeting times, and educational topics. In addition, the KLA also maintains a website (www.kangaroolake.org) which provides lake users with information about the KLA and current and past projects, facts and figures about Kangaroo Lake, lake-related news, boating information, meeting times and other events, and a host of lake-related links.

In the 2016 stakeholder survey, 97% of respondents indicated that the KLA has kept them *fairly* or *highly* informed regarding issues with Kangaroo Lake and its management and indicates that the KLA's current methods of outreach to lake users are highly effective. In an effort to reach even more Kangaroo Lake users, the KLA planning committee expressed interest in creating a page on the social media platform Facebook. The creation of a KLA Facebook page would serve as an additional avenue for the distribution of information pertaining to Kangaroo Lake. A Facebook page would allow the KLA to provide its members and non-members alike with real-time information.

Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newsletter, website, future Facebook page, or distributed as separate educational materials. The KLA has historically invited lake-related speakers to discuss lake topics at their annual meetings and they intend to continue to do so in the future in an effort to educate their membership on responsible lake stewardship. The KLA should also reach out to professionals from the Nature Conservancy (Door County), WDNR, UW-Extension, Door County Soil and Water Conservation Department, etc. to obtain educational pieces for their newsletter or to invite guest speakers to the annual meeting. The KLA may also provide new members with an informational pamphlet on Kangaroo Lake on aquatic invasive species prevention and responsible boating practices. The KLA will also reach out to owners of rental properties on the lake in an effort to educate renters on responsible boating practices.

Example Educational Topics

- Aquatic invasive species identification and prevention
- Boating regulations and responsible use on a shallow lake
- Current science on Eurasian watermilfoil management in Wisconsin, including herbicide treatments, dynamics of populations over time, and the importance of continued monitoring (Michelle Nault, WDNR Water Resources Management Specialist as possible guest speaker)
- Shoreline restoration and protection
- Importance of maintain coarse woody habitat (CWH) and current efforts being undertaken to improve CWH on Kangaroo Lake
- Effect lawn fertilizers/herbicides have on the lake
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community including hardstem bulrush populations
- Respect to and maintaining a safe distance from wildlife within the lake
- Water quality monitoring updates from Kangaroo Lake
- Actions to reduce likelihood of swimmer’s itch
- Fishing rules and regulations
- Catch-and-release fishing
- Septic system maintenance

Action Steps:

1. KLA continues to provide Kangaroo Lake-related information through the association’s newsletter, website, and meetings.
2. KLA Board of Directors will investigate the creation of a KLA Facebook page.

<u>Management Action:</u> Enhance the KLA's involvement with other entities that manage aspects of Kangaroo Lake.

Timeframe: Continuation of current effort

Facilitator: KLA Board of Directors

Description: The waters of Wisconsin belong to everyone and, therefore, this goal of protecting and enhancing these shared resources is also held by other agencies and entities. It is important that the KLA actively engage with all management entities to enhance the association's understanding of the common management goals and to participate in the development of these goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. While not an inclusive list, the primary management units regarding Kangaroo Lake are the WDNR (fisheries, AIS, and lake management personnel), The Nature Conservancy, the Town of Baileys Harbor, the Town of Jacksonport, and the Door County Soil and Water Conservation Department. Each entity is specifically addressed in the table on the next page.

Action Steps:

1. See the following table guidelines on the next page.

Partner	Contact	Role	Contact Frequency	Contact Basis
Town of Baileys Harbor	Donald Sitte - Town Chairman yn3water@live.com 920.421.0481	The majority of Kangaroo Lake falls within the Town of Baileys Harbor	Once per year or more as needed. May check website for updates (www.townofbaileysharbor.com)	Town staff may be contacted regarding ordinance reviews or questions and for information on community events.
Town of Jacksonport	Randy Halstead halsteadfarms@aol.com 920.559.0646	Part of Kangaroo Lake falls within the Town of Jacksonport	Once per year or more as needed. May check website for updates (www.jacksonport.org)	Town staff may be contacted regarding ordinance reviews or questions and for information on community events.
The Nature Conservancy	Kari Hagenow khagenow@tnc.org 920.743.8695	Door Peninsula Land Steward	Kari Hagenow is currently serving as the Vice-President for the KLA, a member of the KLA Planning Committee, and takes an active role in AIS monitoring and control; therefore, contact with her will be frequent.	Kari may be contacted for questions relating to general lake ecology, AIS identification and management, shoreland restoration, and many other lake-related topics as needed.
Door County Soil and Water Conservation	Erin Hanson - Department Head swcd@co.door.wi.us 920-746.2214	Oversees conservation for land and water projects in Door County	As needed.	Can provide assistance with the preparation of conservation and construction plans for landowners to address conservation and environmental needs of their land and land use. Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Mary Gansberg - Lakes Coordinator mary.gansberg@wisconsin.gov 920.662.5489	Oversees management plans, grants, Citizen Lake Monitoring Network, and all lake activities	Once per year or as needed.	Keep updated on lake management activities.
	Scott Hansen - Fisheries Biologist scott.hansen@wisconsin.gov 920.746.2864	Manages the fishery for Kangaroo Lake	Once per year or as needed.	Scheduled surveys, survey results, coarse woody habitat implementation, volunteer opportunities for improving the fishery.
	Paul Skawinski - Citizens Lake Monitoring Network Contact - Statewide paul.skawinski@uwsp.edu 715.346.4853	Provides training and assistance on CLMN monitoring, methods, and data entry.	Once per year or as needed.	Arrange for training of new volunteers as needed.
Wisconsin Lakes	General Staff 800.542.5253	Facilitates education, networking, an assistance on all matters involving Wisconsin lakes	As needed. May check website often for updates (www.wiscosinlakes.org)	KLA members may attend Wisconsin Lakes' annual conference to keep up-to-date on lake issues. Wisconsin Lakes reps ca assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Goal 5: Enhance the Fishery of Kangaroo Lake

Management Action:	Develop a Kangaroo Lake Fisheries Committee to work with WDNR fisheries managers to enhance the fishery of Kangaroo Lake.
Timeframe:	Continuation of current effort.
Facilitator:	KLA Board of Directors
Description:	While respondents to the 2016 stakeholder survey listed fishing as a relatively low priority activity for owning property on Kangaroo Lake behind relaxing/entertaining, nature viewing, canoeing/kayaking, swimming, and motor boating, the fishery of Kangaroo Lake is still a concern to the KLA. During the planning meetings, the Planning Committee expressed concerns regarding current fisheries management and steps they could take to enhance the lake's fishery. Many discussion points were raised including changes to harvest regulations, walleye stocking, shift of the fish community from walleye-dominated to panfish-dominated, spawning habitat enhancement, and the effect of migratory birds (e.g. cormorants) on the fishery. Understanding the limitations and stresses on the Kangaroo Lake ecosystem is the first step in developing a realistic solution to angler concerns. From there, realistic goals and actions may be developed. Part of this process involves the education of Kangaroo Lake property owners on the fishery by distributing information to lake residents through the association's newsletter, website, etc. Residents need to understand the importance of conserving aquatic habitat (e.g. bulrush colonies and coarse woody habitat). The KLA is already taking an active role to enhance fish habitat in Kangaroo Lake with the addition of coarse woody habitat through the WDNR Fish Sticks Program. Over the past four years including 2018, the KLA has placed 101 trees (35-55 feet in length) along the shore in the south basin of the lake and has plans to continue coarse woody habitat improvement in the future if funding can be obtained. The KLA is actively trying to recruit new property owners that would be willing to have these trees placed along their property. As is discussed within the Shoreland Condition Section (Section 3.3), one of the most important functions and benefits coarse woody habitat provides enhanced habitat for fish. In addition, coarse woody habitat provides shoreland erosion control, reduces sediment resuspension, and provides habitat for other aquatic life such as macroinvertebrates. In addition to improving coarse woody habitat, the KLA would like to investigate if any other habitat enhancements can be made to improve the lake's fishery. To accomplish this, the KLA will appoint a Fisheries Committee which will be tasked with working with WDNR fisheries biologists to enhance the lake's fishery. Kangaroo

Lake is currently overseen by WDNR fisheries biologist Scott Hansen. The Fisheries Committee will contact Scott Hansen annually or as needed to gather information on the current management of Kangaroo Lake's fishery, survey studies that are occurring on the lake, and how the KLA can further work to enhance the fishery. The Fisheries Committee can also create educational pieces discussing Kangaroo Lake's fishery for the association's newsletter, website, etc. Scott can also be invited to speak about the lake's fishery at the KLA's annual meeting.

Action Steps:

1. See description above.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Kangaroo 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 once in spring and three times during the summer. In addition to the samples collected by KLA members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall, and winter (Table 6.0-1). 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).

Table 6.0-1. Water quality parameters collected from Kangaroo Lake in 2016.

	Spring		June	July		August	Fall		Winter	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**S**	**B**	**S**	**B**
Ammonia Nitrogen	■	■	●	■	■	●	■	■	■	■
Calcium	■	■								
Chlorophyll-a	■		♦	■♦		♦	■			
Color	■	■		■	■					
Dissolved Phosphorus	■	■					■	■	■	■
Hardness	■	■								
Laboratory Conductivity	■	■		■	■					
Laboratory pH	■	■		■	■					
Magnesium	■	■								
Nitrate-Nitrite Nitrogen	■	■	●	■	■	●	■	■	■	■
Secchi Depth (feet)	■		♦	■♦		♦	■			
Total Alkalinity	■	■		■	■					
Total Kjeldahl Nitrogen	■	■	●	■	■	●				
Total Phosphorus	■♦	■	♦	■♦	■	♦	■	■	■	■
Total Suspended Solids	■	■								
Turbidity	■	■								

♦ *Indicates samples collected as part of the Citizen Lakes Monitoring Network*
● *Indicates samples collected by KLA volunteers*
■ *Indicates samples collected by Onterra*
S = Sub-surface; B = Near-Bottom

Watershed Analysis

The watershed analysis began with an accurate delineation of Kangaroo 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

An early-season aquatic invasive species survey was completed on Kangaroo Lake on June 17 and 24, 2017. The primary objective of this meander-based survey was to locate and map occurrences of curly-leaf pondweed and pale-yellow iris which both have the highest probability of being located at this time of year. Visual, meander-based surveys to map Eurasian watermilfoil in Kangaroo Lake were completed in late-summer on September 19, 2016 and September 27, 2017.

Comprehensive surveys of aquatic macrophytes were conducted on Kangaroo Lake to characterize the existing communities within the lake and include inventories of emergent, submersed, and floating-leaved aquatic plants populations. 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 the north and south basins of Kangaroo Lake. A point spacing of 45 meters was used resulting in 401 sampling locations in the north basin, and a point spacing of 80 meters was used resulting in 610 sampling locations in the south basin. The point-intercept surveys were completed on August 11 and 12, 2016 in the south basin and on August 25, 2016 in the north basin.

As part of the aquatic plant community assessment in Kangaroo Lake, the emergent and floating-leaf aquatic plant communities were mapped in both basins. These communities were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake. The emergent and floating-leaf aquatic plant community mapping surveys were completed on August 15, 2016 in the south basin and on August 26, 2016 in the north basin.

Representatives of all plant species located during the aquatic plant surveys were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium.

7.0 LITERATURE CITED

Asplund, T.R. and C.M. Cook. 1997. Effects of motor boats on submerged aquatic macrophytes. Lake and Reserv. Manage. 13(1): 1 – 12.

Bajer, P.G. and P.W. Sorensen. 2015. Effects of common carp on phosphorus concentrations, water clarity, and vegetation density: a whole system experiment in a thermally stratified lake. Hydrobiologia. Vol. 746. 30 –311.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. London, England.

Canter, L.W., D.I. Nelson, and J.W. Everett. 1994. Public Perception of Water Quality Risks – Influencing Factors and Enhancement Opportunities. Journal of Environmental Systems. 22(2).

Carpenter, S.R., Kitchell, J.F., and J.R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity. BioScience, Vol. 35 (10) pp. 634-639.

Carlson, R.E. 1977 A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Dinius, S.H. 2007. Public Perceptions in Water Quality Evaluation. Journal of the American Water Resource Association. 17(1): 116-121.

Elias, J.E. and M.W. Meyer. 2003. Comparisons of Undeveloped and Developed Shorelands, Northern Wisconsin, and Recommendations of Restoration. Wetlands 23(4):800-816. 2003.

Fischer J.R. and R.M. Krogman. 2013. Influences of native and non-native benthivorous fishes on aquatic ecosystem degradation. Hydrobiologia. Vol. 711. 187–199.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Garn, H.S. 2002. Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Two Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigations Report 02-4130.

Garrison, P., Jennings, M., Mikulyuk, A., Lyons, J., Rasmussen, P., Hauxwell, J., Wong, D., Brandt, J. and G. Hatzenbeler. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. Pub-SS-1044.

Graczyk, D.J., Hunt, R.J., Greb, S.R., Buchwald, C.A. and J.T. Krohelski. 2003. Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999-2001. USGS Water-Resources Investigations Report 03-4144.

Gettys, L.A., W.T. Haller, & M. Bellaud (eds). 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp. Available at http://www.aquatics.org/bmp.htm.

Hanchin, P.A., Willis, D.W. and T.R. St. Stauver. 2003. Influence of introduced spawning habitat on yellow perch reproduction, Lake Madison South Dakota. Journal of Freshwater Ecology 18.

Jennings, M. J., E. E. Emmons, G. R. Hatzenbeler, C. Edwards and M. A. Bozek. 2003. Is littoral habitat affected by residential development and landuse in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3):272-279.

Karatayev, A.Y., L.E. Burlakova, and D.K. Padilla. 1997. The effects of *Dreissena polymorpha* (Palla) invasion on aquatic communities in eastern Europe. Journal of Shellfish Research 16: 187-203.

Lathrop, R.D., and R.A. Lillie. 1980. Thermal Stratification of Wisconsin Lakes. Wisconsin Academy of Sciences, Arts and Letters. Vol. 68.

Lin Y. and C.H. Wu. 2013. Response of bottom sediment stability after carp removal in a small lake. Ann. Limnol. – Int. J. Lim. Vol. 49. 157–168.

Lindsay, A., Gillum, S., and M. Meyer 2002. Influence of lakeshore development on breeding bird communities in a mixed northern forest. Biological Conservation 107. (2002) 1-11.

Lutze, Kay. 2015. 2015 Wisconsin Act 55 and Shoreland Zoning. State of Wisconsin Department of Natural Resources

MacIsaac, H.J. 1996. Potential abiotic and biotic impacts of zebra mussels on the inland waters of North America. American Zoologist 36:287-299.

Netherland, M.D. 2009. Chapter 11, “Chemical Control of Aquatic Weeds.” Pp. 65-77 in *Biology and Control of Aquatic Plants: A Best Management Handbook*, L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp

Newbrey, M.G., Bozek, M.A., Jennings, M.J. and J.A. Cook. 2005. Branching complexity and morphological characteristics of coarse woody structure as lacustrine fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 62: 2110-2123.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Panuska, J.C., and J.C. Kreider. 2003. Wisconsin Lake Modeling Suite Program Documentation and User’s Manual Version 3.3. WDNR Publication PUBL-WR-363-94.

Radomski P. and T.J. Goeman. 2001. Consequences of Human Lakeshore Development on Emergent and Floating-leaf Vegetation Abundance. North American Journal of Fisheries Management. 21:46–61.

Reed, J. 2001. Influence of Shoreline Development on Nest Site Selection by Largemouth Bass and Black Crappie. North American Lake Management Conference Poster. Madison, WI.

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Vol. 1, pp. 60-69 Oxford: Elsevier.

Scheuerell M.D. and D.E. Schindler. 2004. Changes in the Spatial Distribution of Fishes in Lakes Along a Residential Development Gradient. Ecosystems (2004) 7: 98–106.

Shaw, B.H. and N. Nimphius. 1985. Acid Rain in Wisconsin: Understanding Measurements in Acid Rain Research (#2). UW-Extension, Madison. 4 pp.

Smith D.G., A.M. Cragg, and G.F. Croker.1991. Water Clarity Criteria for Bathing Waters Based on User Perception. Journal of Environmental Management.33(3): 285-299.

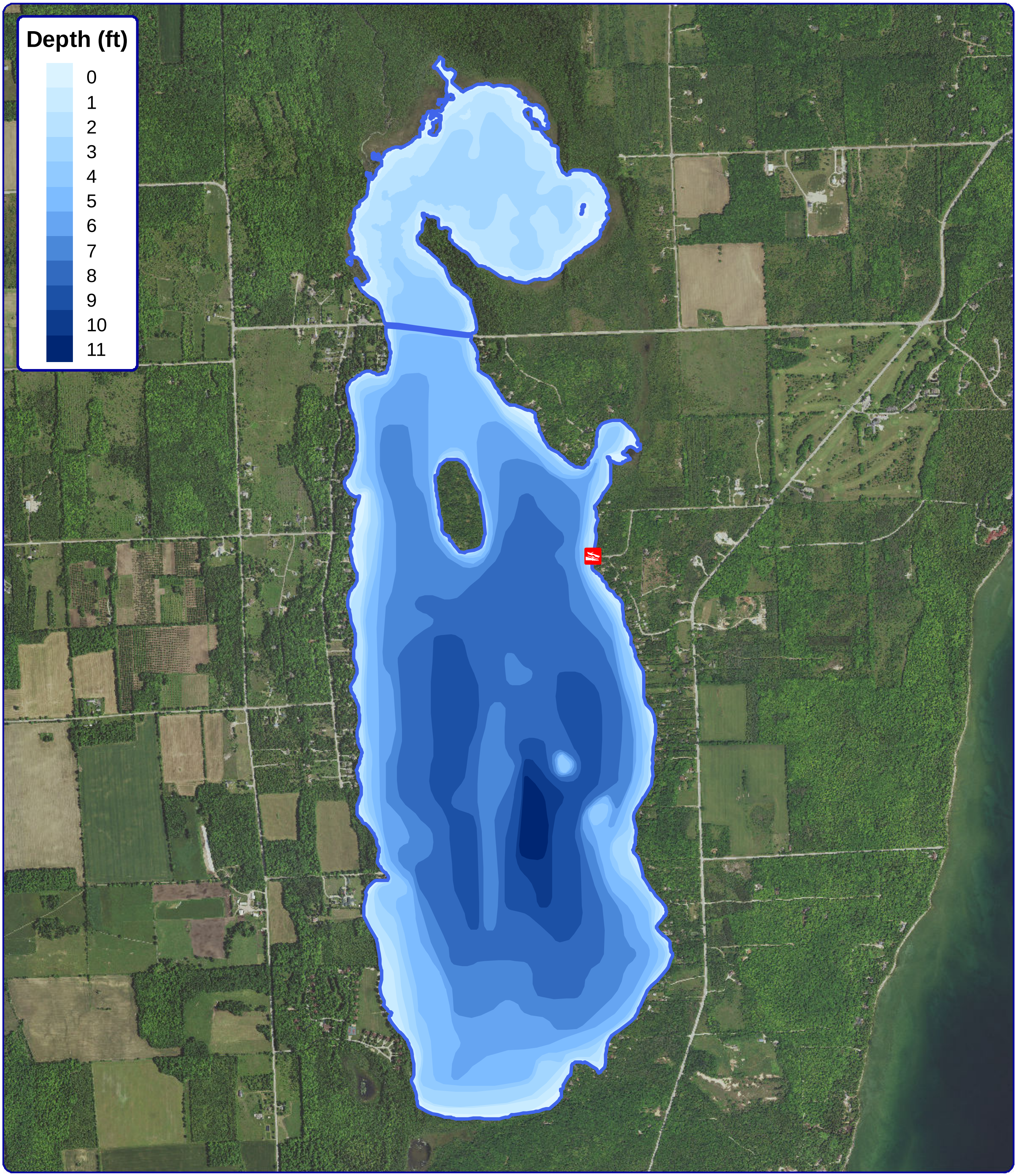
United States Environmental Protection Agency. 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R-09-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Weber, M.J., M.J. Hennen, and M.L. Brown. 2011. Simulated population responses of common carp to commercial exploitation. North American Journal of Fisheries Management. Vol. 31. 269–279.

Wisconsin Department of Natural Resources – Bureau of Science Services. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. PUB-SS-1044.

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2011. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed March 2011.

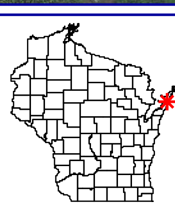
Wisconsin Department of Natural Resources (WDNR). 2013. Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM). Bureau of Water Quality Program Guidance.



N
W
E
S
1,800
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP 2015
Bathymetry: Onterra 2016
Map Date: May 2, 2017
Filename: Map1_Kangaroo_Location.mxd


Project Location in Wisconsin

Legend

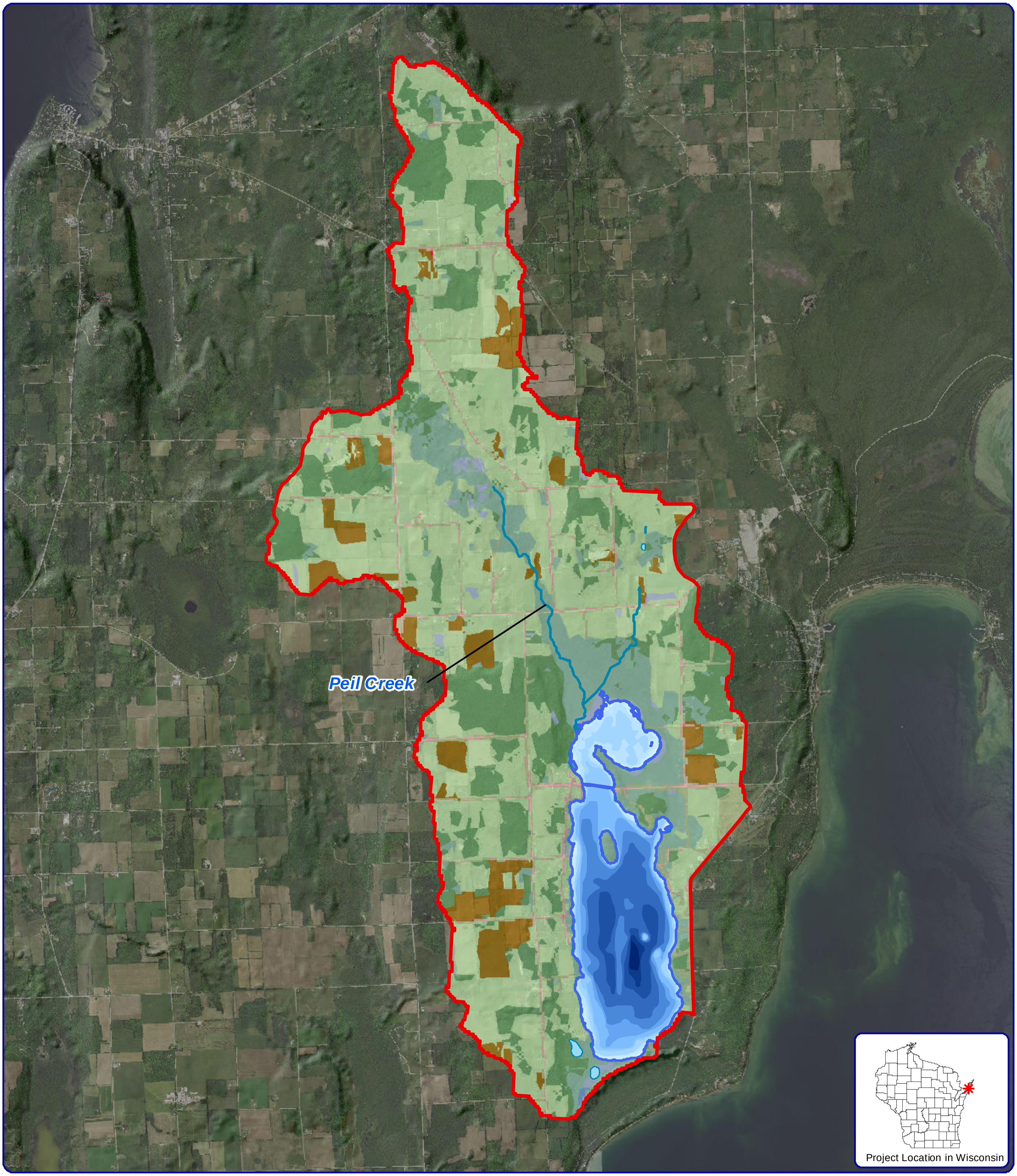
Kangaroo Lake ~1,156 acres
WDNR Definition

Public Access

Map 1

Kangaroo Lake
Door County, Wisconsin

Project Location & Lake Boundaries



N
W E
S

5,400

Feet

Onterra LLC
Lake Management Planning

815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Land Cover: NLCD, 2011
Orthophotography: NAIP, 2015
Hydro: WDNR
Map Date: January 6, 2017
Filename: Map2_Kangaroo_WS.mxd

Legend

Land Cover Types

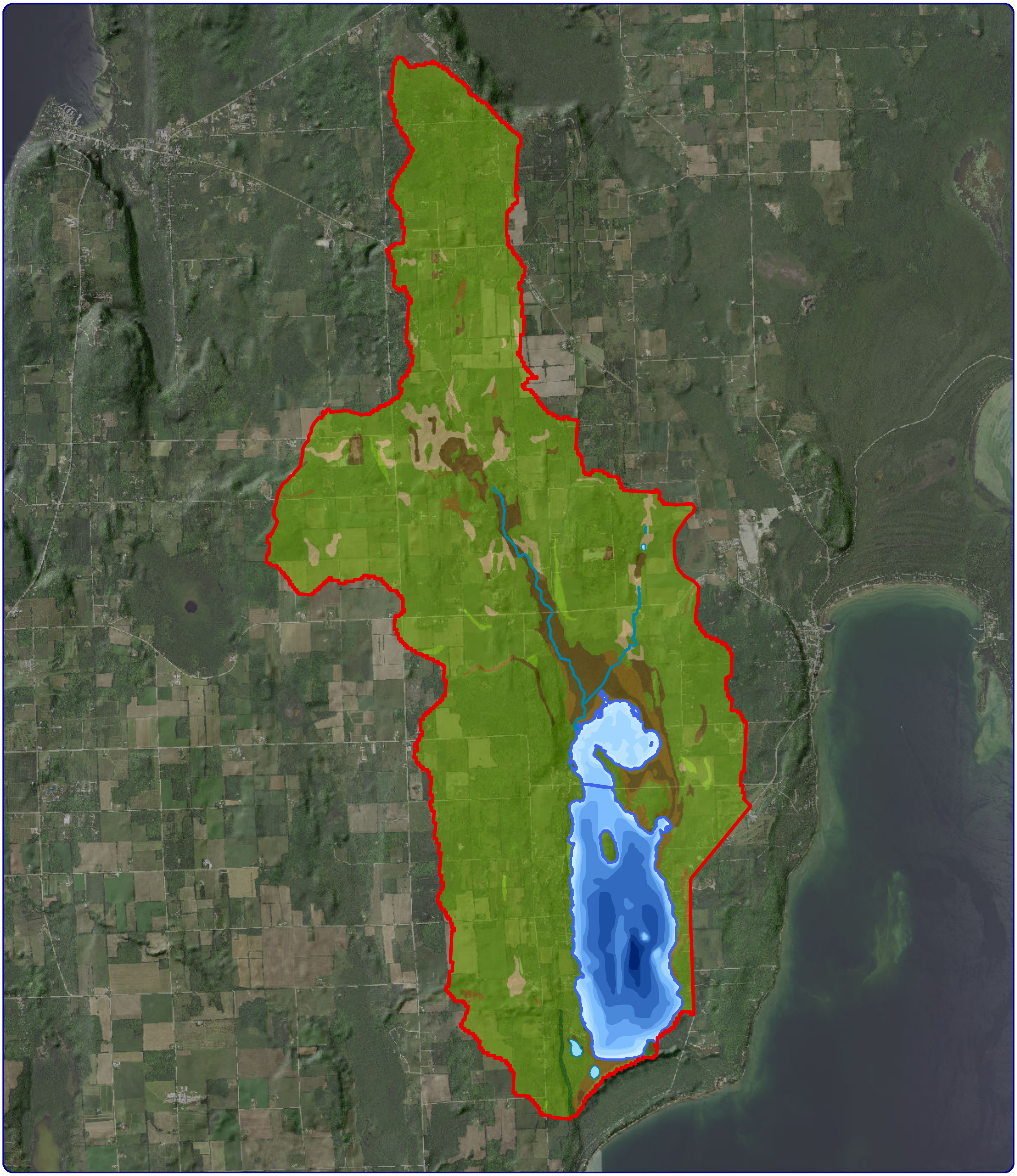
- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Medium Density Urban
- River/Stream
- Kangaroo Lake Watershed Boundary

Map 2

Kangaroo Lake

Door County, Wisconsin

Watershed Boundaries & Land Cover Types



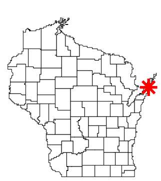
N
W E
S

5,400

Feet

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Land Cover: NLCD, 2011
Orthophotography: NAIP, 2015
Hydro: WDNR
Map Date: January 6, 2017
Filename: Map2_Kangaroo_WS.mxd



Project Location in Wisconsin

Legend

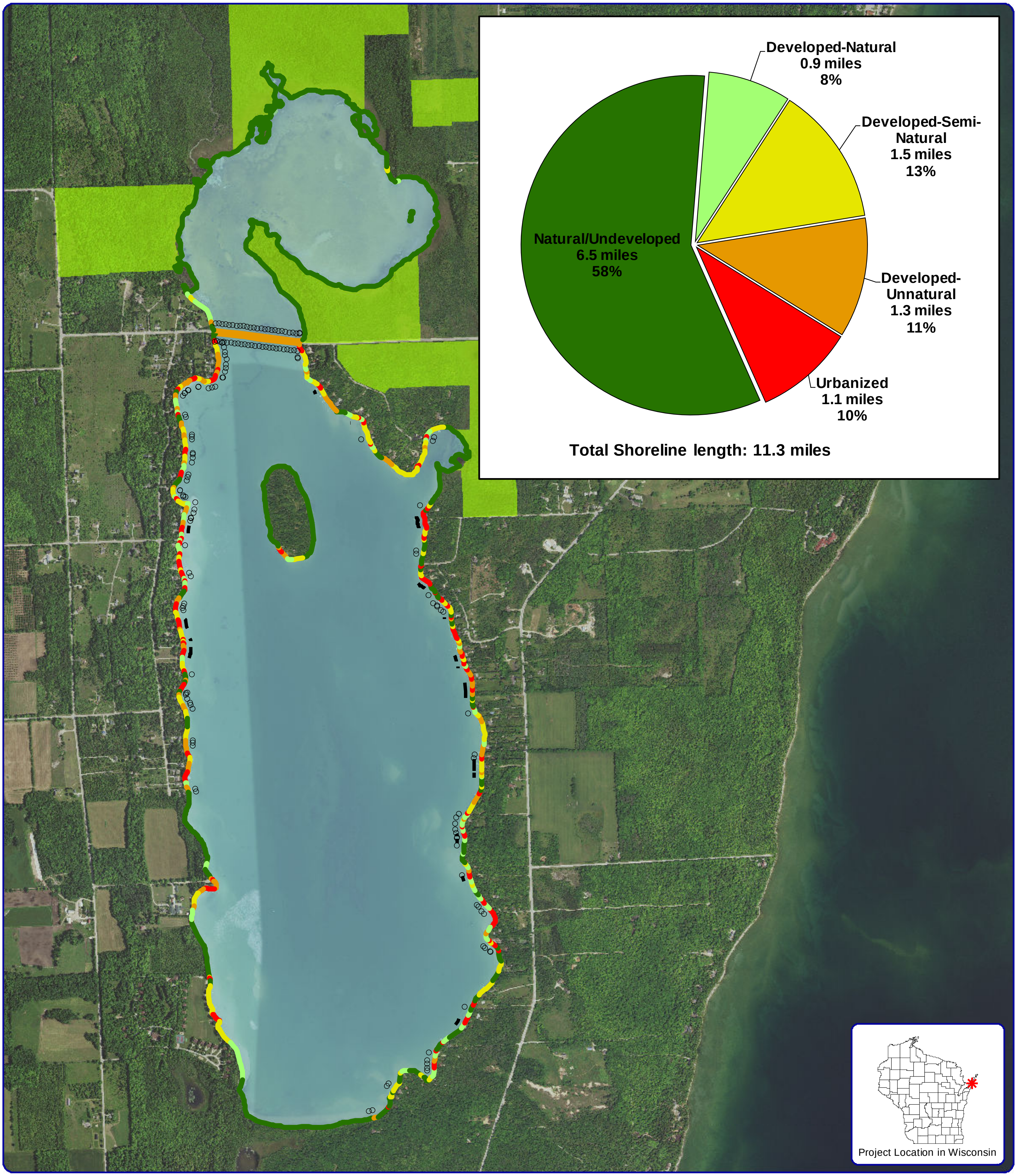
- Very Poorly Drained
- Poorly Drained
- Somewhat Poorly Drained
- Moderately Well Drained
- Well Drained
- Excessively Drained

Map 3

Kangaroo Lake

Door County, Wisconsin

Watershed Soil Drainage Classes



N W E S

1,800

Feet

Legend

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

Seawall
- Masonry/Wood/Metal
- Rip-Rap

WDNR Managed Land

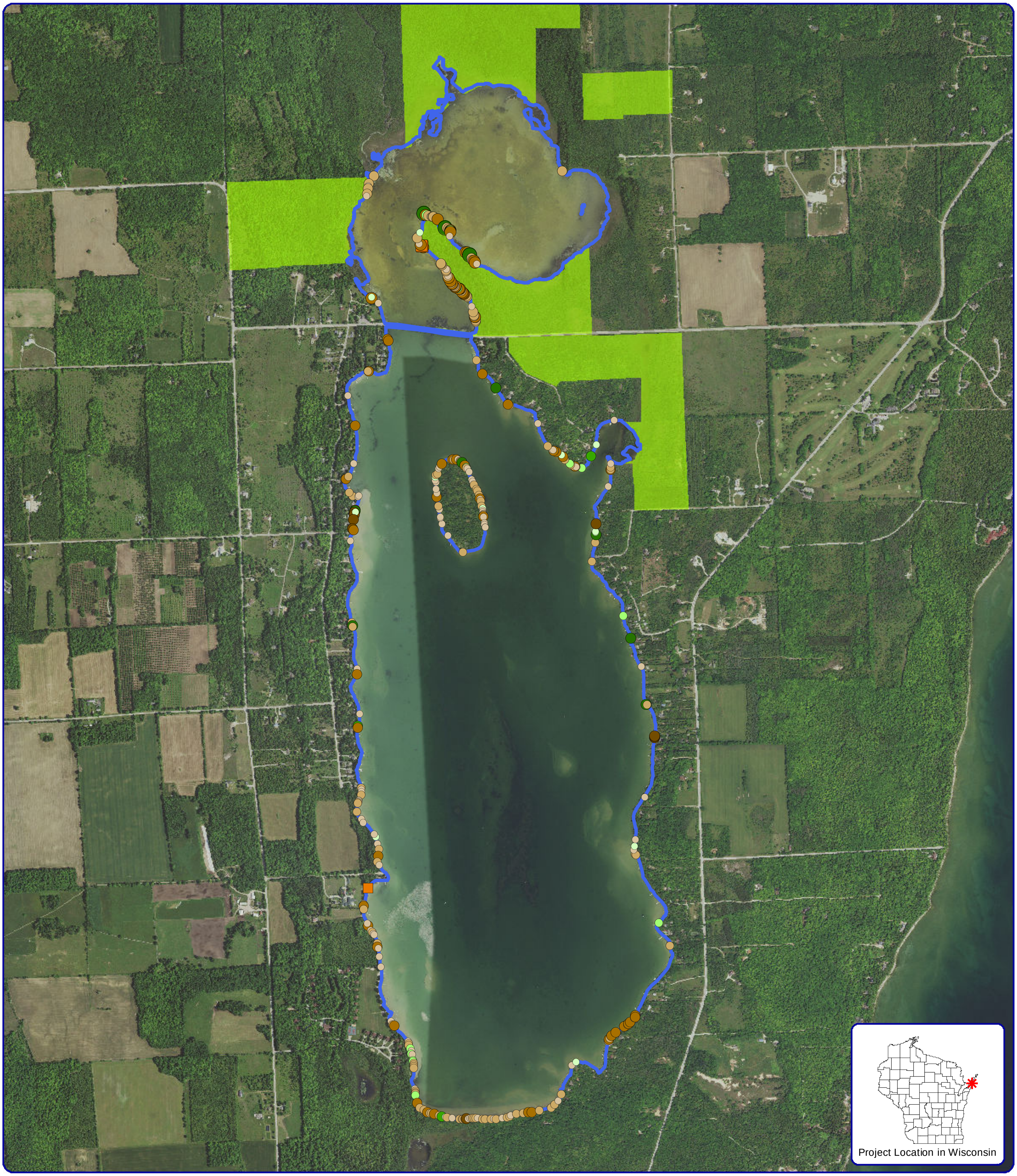
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Orthophotograph: NAIP, 2015
Map Date: December 9, 2016
Filename: Map4_Kangaroo_SCA_2016.mxd

Map 4

Kangaroo Lake
Door County, Wisconsin

2016 Shoreline Condition



N
W E
S
1,800
Feet

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy

State-Owned Land

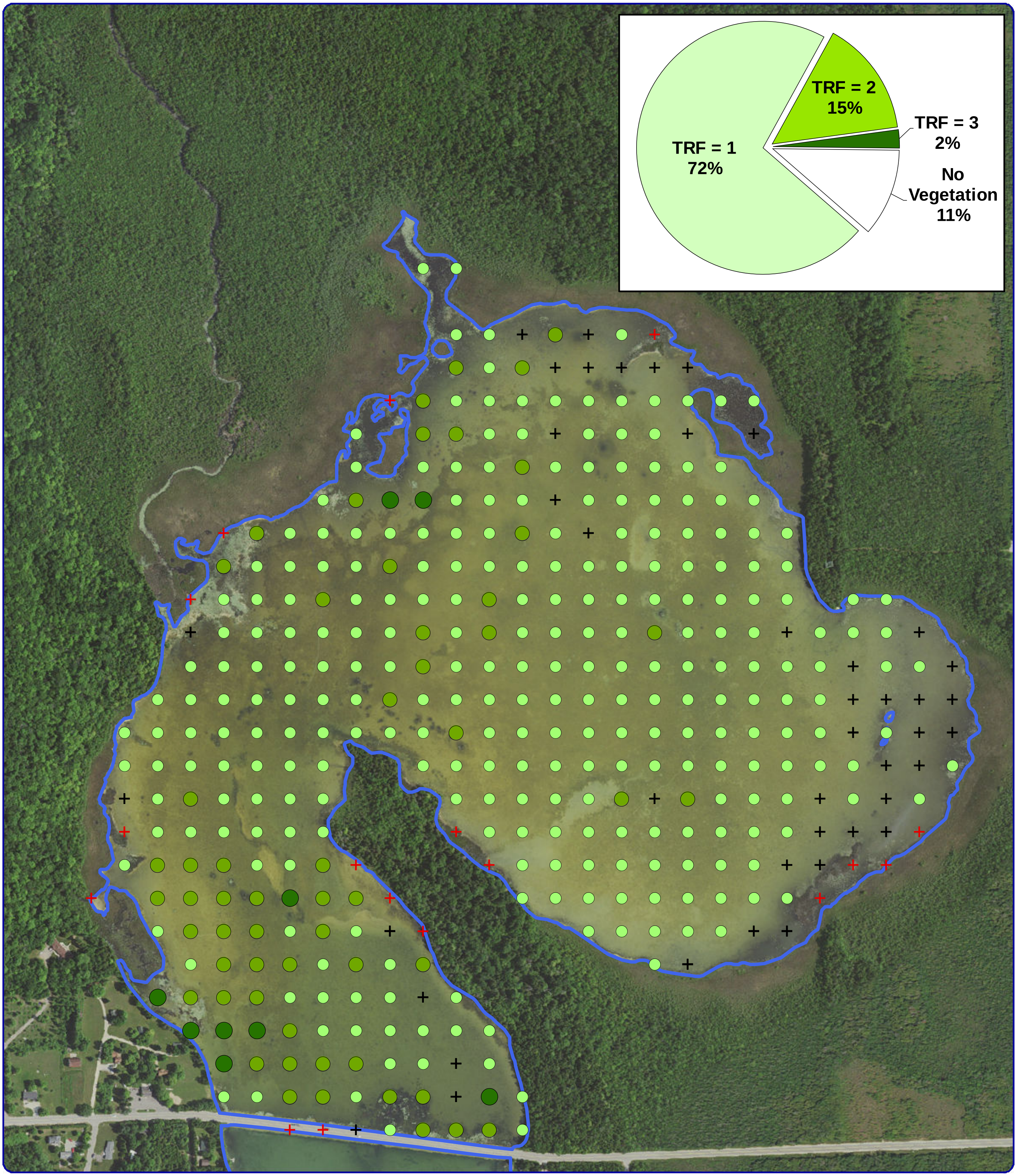
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Orthophotograph: NAIP, 2015
Map Date: December 9, 2016
Filename: Map5_Kangaroo_CWH_2016.mxd

Map 5

Kangaroo Lake
Door County, Wisconsin

2016 Coarse Woody Habitat

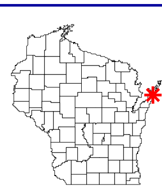


N
W E
S

560
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Map Date: November 29, 2016
Filename: Map6_Kangaroo_North_TRF.mxd

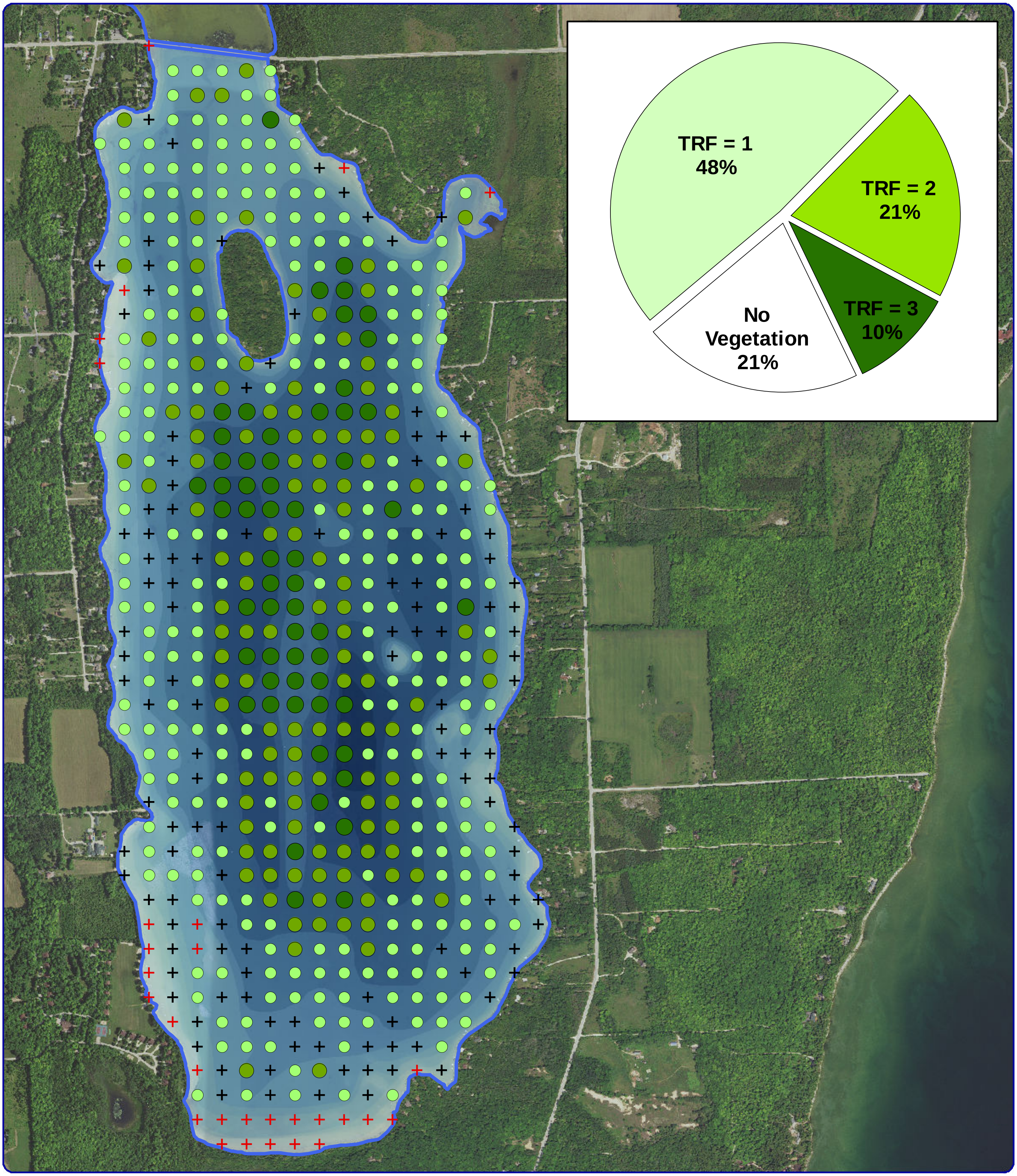


Project Location in Wisconsin

Legend

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

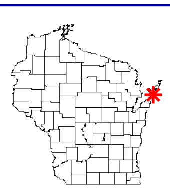
Map 6
Kangaroo Lake - North
Door County, Wisconsin
2016 PI Survey: Aquatic Plant Distribution



N
W E
S
1,300
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

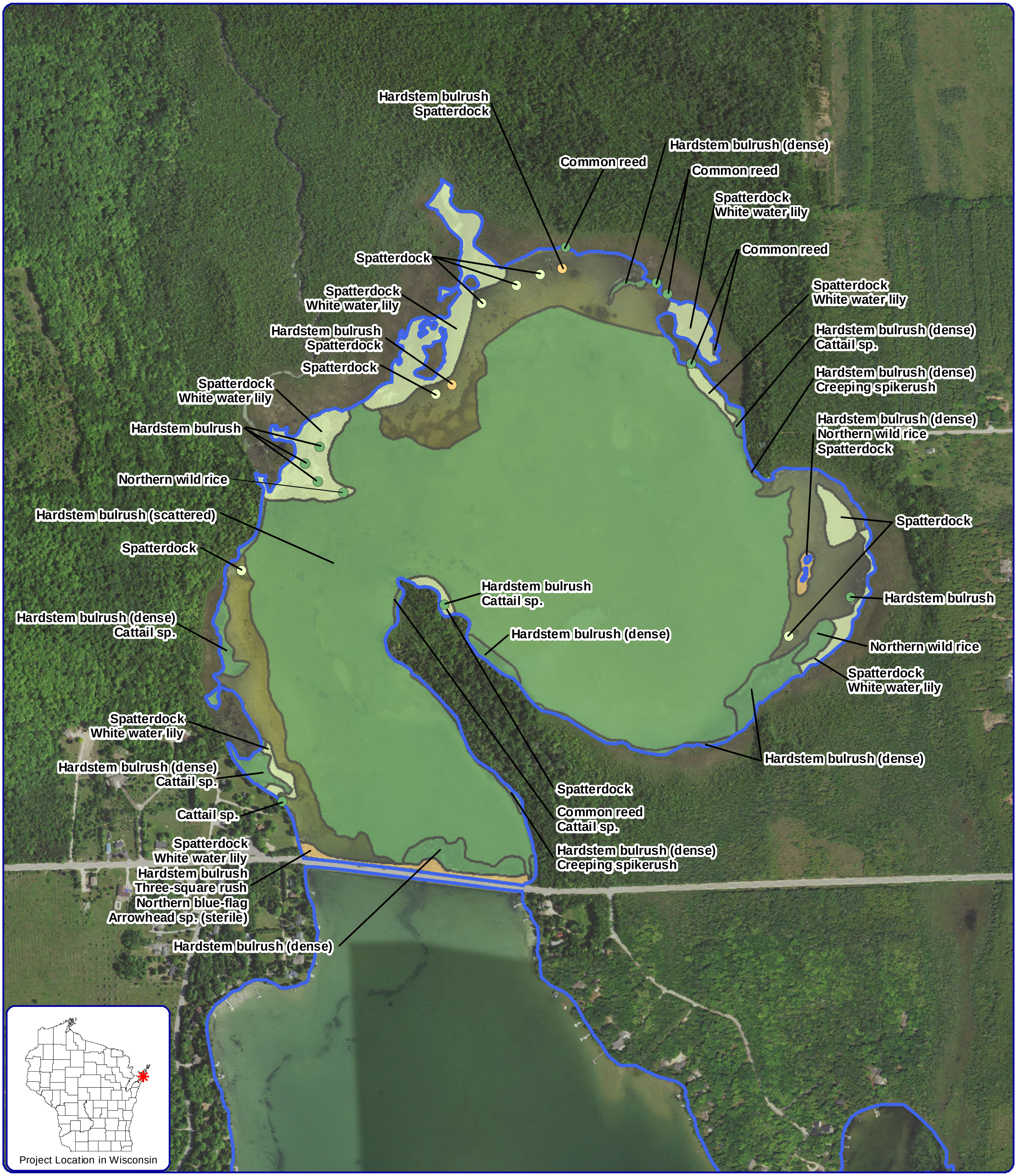
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Map Date: November 29, 2016
Filename: Map7_Kangaroo_South_TRF.mxd


Project Location in Wisconsin

Legend

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

Map 7
Kangaroo Lake - South
Door County, Wisconsin
2016 PI Survey:
Aquatic Plant Distribution



N
W E
S
625
Feet

Legend

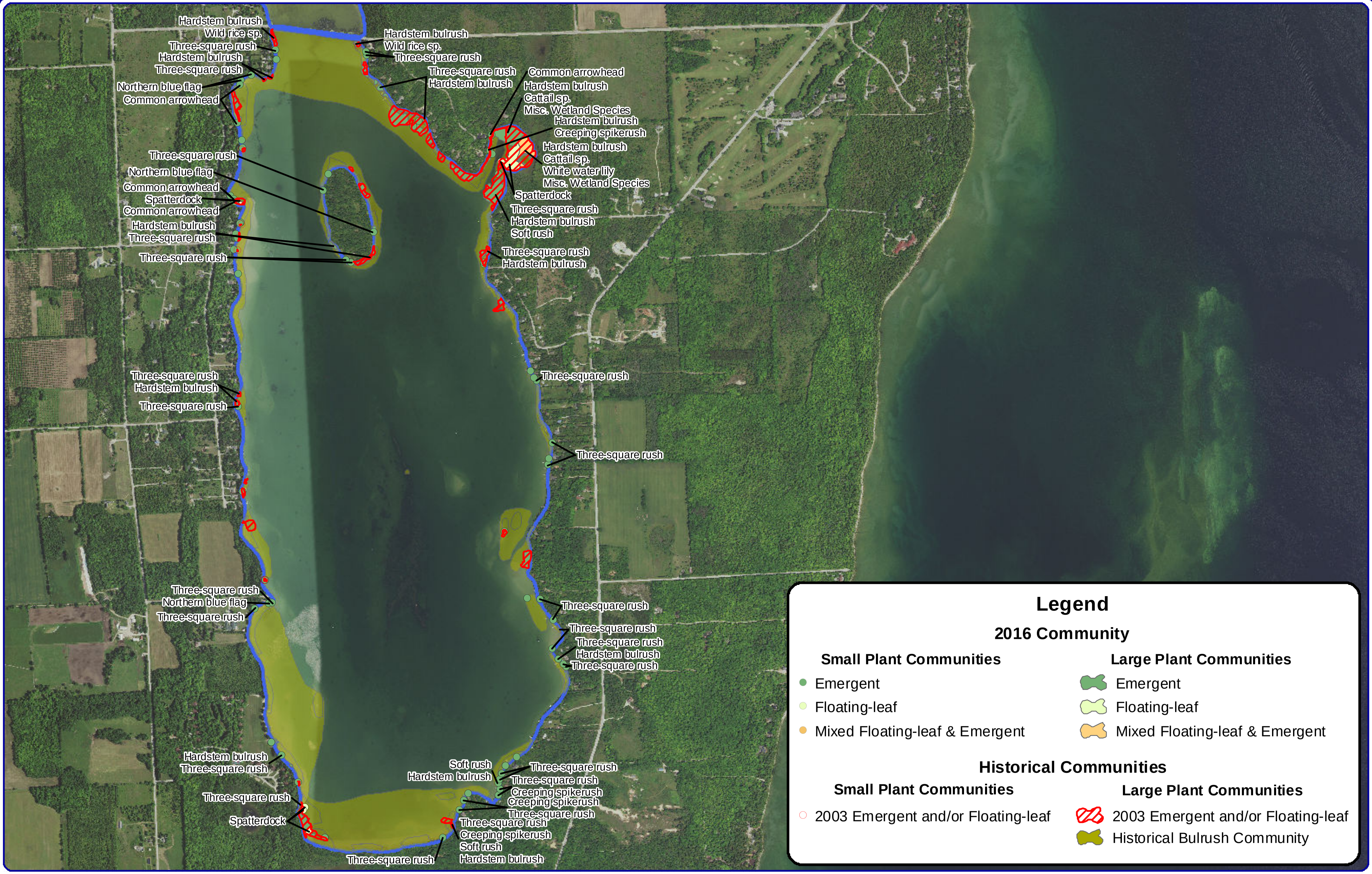
Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, 2016
Map Date: November 2, 2016
Filename:Map8_Kangaroo_North_Comm.mxd

Map 8
Kangaroo Lake - North
Door County, Wisconsin
Emergent & Floating-leaf Plant Communities

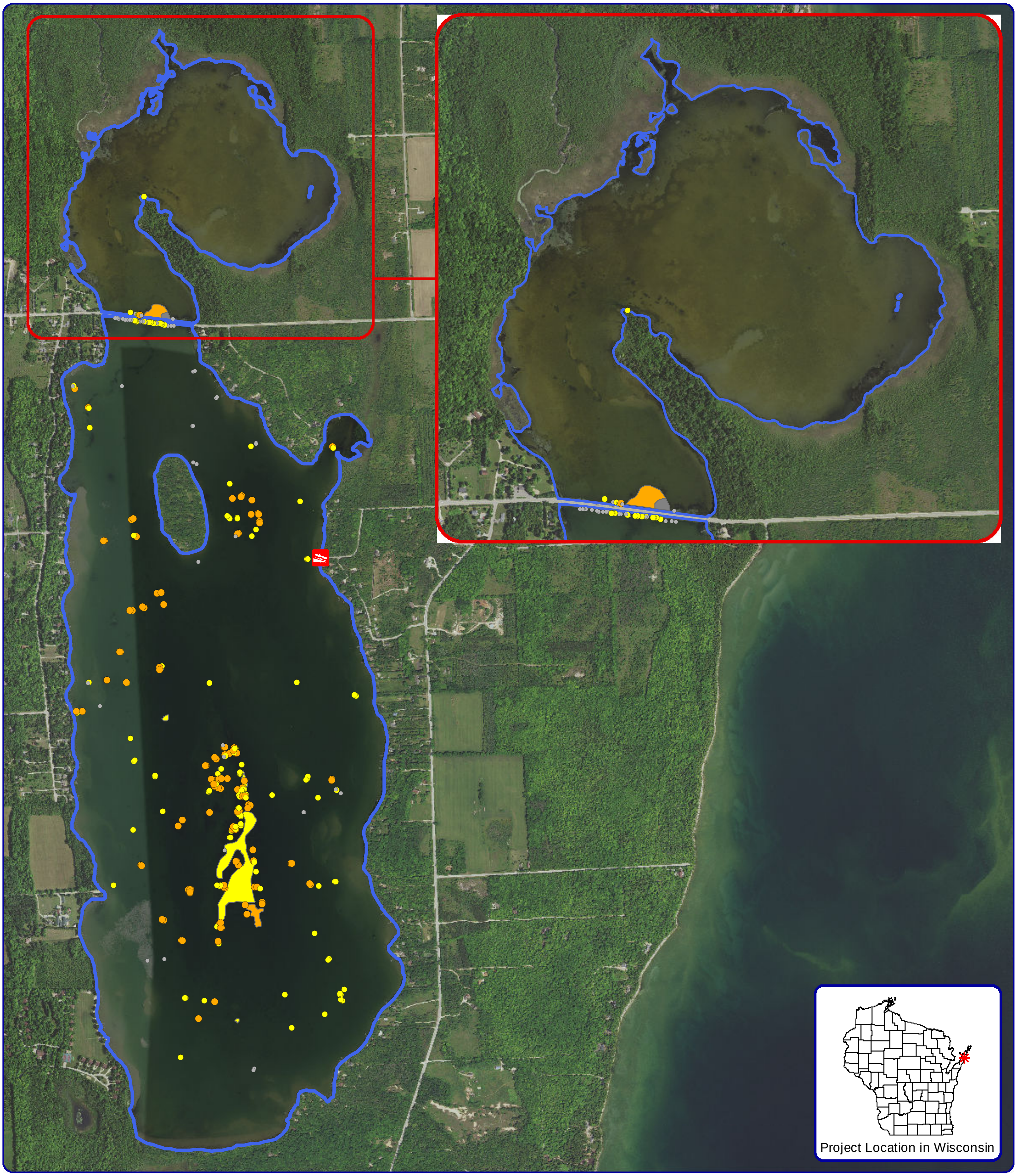


Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
YYYY Aquatic Plants: KLA
2003 Aquatic Plants: NES
2016 Aquatic Plants: Onterra
Map Date: May 18, 2017
Filename: Map9_Kangaroo_South_Comm.mxd

Map 9
Kangaroo Lake - South
Door County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities



N
W E
S

1,800
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP 2015
Bathymetry: Onterra 2016
Map Date: May 2, 2017
Filename: Map10_Kangaroo_EWM_Sept16.mxd

Legend

Eurasian watermilfoil

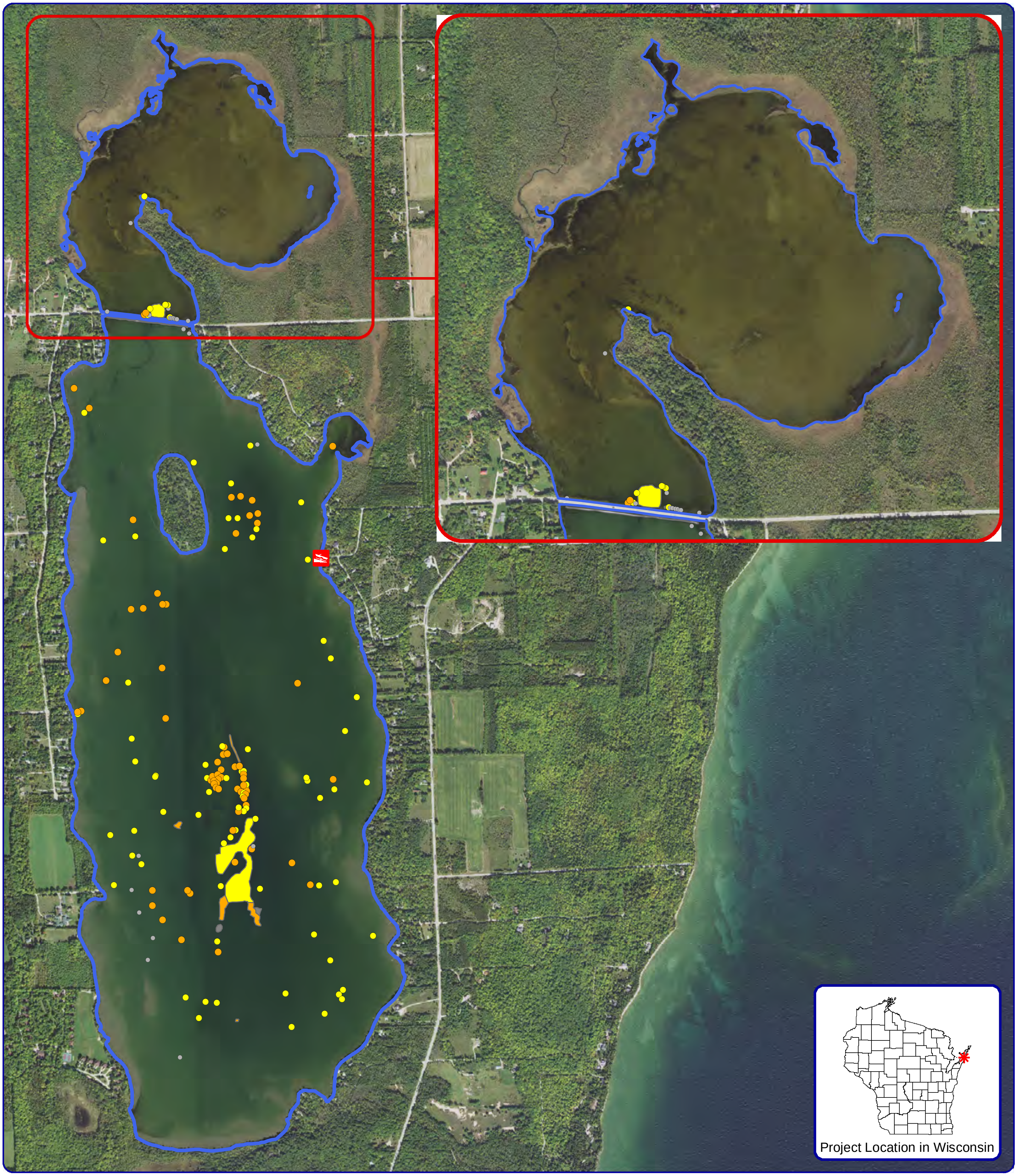
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Public Access

Map 10

Kangaroo Lake

Door County, Wisconsin

2016 EWM Locations



N
W E
S
1,800
Feet

Legend

Eurasian watermilfoil

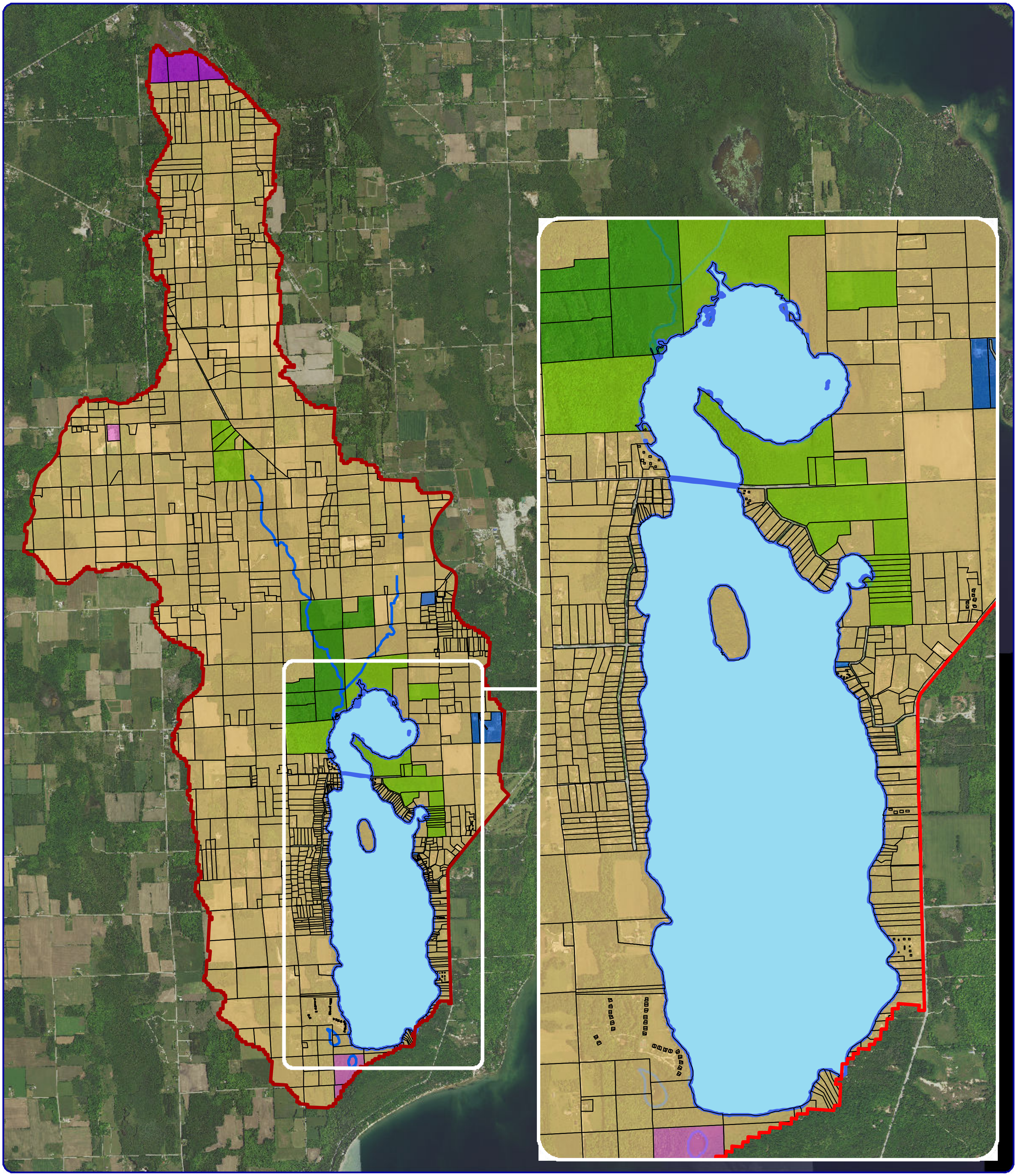
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Public Access

Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP 2017
Bathymetry: Onterra 2016
Map Date: May 2, 2017
Filename: Map11_Kangaroo_EWM_Sept17.mxd

Map 11
Kangaroo Lake
Door County, Wisconsin

2017 EWM Locations



N
W E
S

5,400

Feet

Land Ownership

- Privately Owned
- Town of Baileys Harbor
- Village of Ephraim
- Door County
- The Nature Conservancy
- Door County Land Trust
- Kangaroo Lake Watershed Boundary

Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Hydro: WDNR
Parcels: V3 Statewide Parcel Initiative; Wisconsin SCO and Land Information Program
Orthophotography: NAIP 2015
Watershed Boundaries: Onterra 2016
Map Date: November 7, 2017
Filename: Kangaroo_WS_LandOwnership.mxd

Map 12

Kangaroo Lake

Door County, Wisconsin

Watershed Land Ownership