Kentuck Lake

Forest & Vilas Counties, Wisconsin

Comprehensive Management Plan

October 2015

Sponsored by:

Kentuck Lake Protection & Rehabilitation District

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Lake Management Planning

Kentuck Lake

Vilas and Forest Counties, Wisconsin

Comprehensive Management Plan

October 2015

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1.0 INTRODUCTION

Kentuck Lake, Forest and Vilas Counties, is a 1,008-acre spring lake with a maximum depth of 40 feet and a mean depth of 13 feet (Map 1). This eutrophic lake has a surficial watershed that encompasses approximately 2,724 acres, yielding a watershed to lake area ratio of 2:1. Kentuck Lake is within the Brule River Drainage Basin and is drained via Kentuck Creek, a class II trout stream. During surveys in 2011 and 2013, 41 native aquatic plant species were located, of which coontail (*Ceratophyllum demersum*) was the most abundant. The non-native, invasive aquatic plants curly-leaf pondweed (*Potamogeton crispus*) and Eurasian water milfoil (*Myriophyllum spicatum*) were first documented in Kentuck Lake in 1999 and 2011, respectively.

Field Survey Notes

The lake is productive with an abundant submersed macrophyte community. Water clarity is low with higher amounts of free-floating algae present. Large colonies of hardstem bulrush (Schoenoplectus acutus), particularly in the northern portion of the lake are present in shallower areas.

Photograph 1.0-1 Kentuck Lake, Vilas County

Lake at a Glance - Kentuck Lake

Morphology	
Acreage	1,008
Maximum Depth (ft)	40
Mean Depth (ft)	13
Shoreline Complexity	2.0
Vegetation	
Early-Season AIS Survey Date	July 3, 2013
Comprehensive Survey Date	July 18, 19, & 20, 2011 (WDNR)
Number of Native Species	41
Threatened/Special Concern Species	0
Exotic Plant Species	Curly-leaf pondweed; Eurasian water milfoil
Simpson's Diversity	0.81
Average Conservatism	6.1
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.6
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	2:1

The Kentuck Lake Protection and Rehabilitation District (KLPRD) was formed in 1985 to plan for the long-term management of Kentuck Lake. Since its inception, the district has undergone two projects aimed at enhancing and protecting the quality of the lake: a shoreline and watershed management survey in 1999 and an aquatic plant management plan in 2007.

The discovery of Eurasian water milfoil in Kentuck Lake was the driving factor in moving forward with the development of a lake management plan. However, district members also had concerns regarding the lake's water quality, specifically the occurrence of periodic algae blooms. Beyond the issue of controlling Eurasian water milfoil in Kentuck Lake, the KLPRD was interested in creating a lake management plan in order to ensure the preservation of Kentuck Lake for future generations. They want to assure that they are working to preserve Kentuck Lake as an ecosystem, not just as a recreational resource. Overall, the KLPRD recognized the value of gaining a better understanding of the Kentuck Lake ecosystem and its current condition. In the end, the information obtained from these studies will help guide future KLPRD plans and programs.

This report discusses the stakeholder, water quality, watershed, shoreline, and aquatic plant studies that were conducted in Kentuck Lake in 2013/2014. Also included is the Implementation Plan, which includes goals and actions specific to Kentuck Lake's current and future management that were developed by both members of the Kentuck Lake Planning Committee and Onterra ecologists.

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

Kick-off Meeting

On June 8, 2013, a project kick-off meeting was held at the Phelps High School to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Kentuck Lake Protection & Rehabilitation board members. The approximately 10 attendees observed a presentation given by Brenton Butterfield, an aquatic ecologist with Onterra. Mr. Butterfields'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 April 8, 2014, Onterra ecologists Brenton Butterfield and Tim Hoyman met with members of the Kentuck Lake Planning Committee. In advance of this meeting, a draft copy of the Results and Discussion Sections were provided to attendees. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including the aquatic plant inventories, water quality analyses, and watershed modeling were presented and discussed. Information regarding moving forward with AIS monitoring and control program was also discussed.

Planning Committee Meeting II

On May 1, 2014, Onterra ecologists Brenton Butterfield and Tim Hoyman again met with members of the Kentuck Lake Planning Committee to begin developing management goals and actions for the Kentuck Lake Protection and Rehabilitation District's Comprehensive Lake Management Plan. The lake's water quality, invasive species, and district volunteerism were some of the major topics discussed.

Project Wrap-up Meeting

Scheduled for the spring of 2016.

Management Plan Review and Adoption Process

As mentioned, Onterra ecologists met with the Kentuck Lake Planning Committee in May of 2014 and developed the framework for the Implementation Plan. The first draft of the Implementation Plan was created and approved by the Kentuck Lake Planning Committee. In addition, by the Kentuck Lake Protection and Rehabilitation District Board of Directors also indicated their approval of the draft Implementation Plan by providing a resolution for the Wisconsin Department of Natural Resources Lake Protection Grant being applied for in February of 2015.

Stakeholder Survey

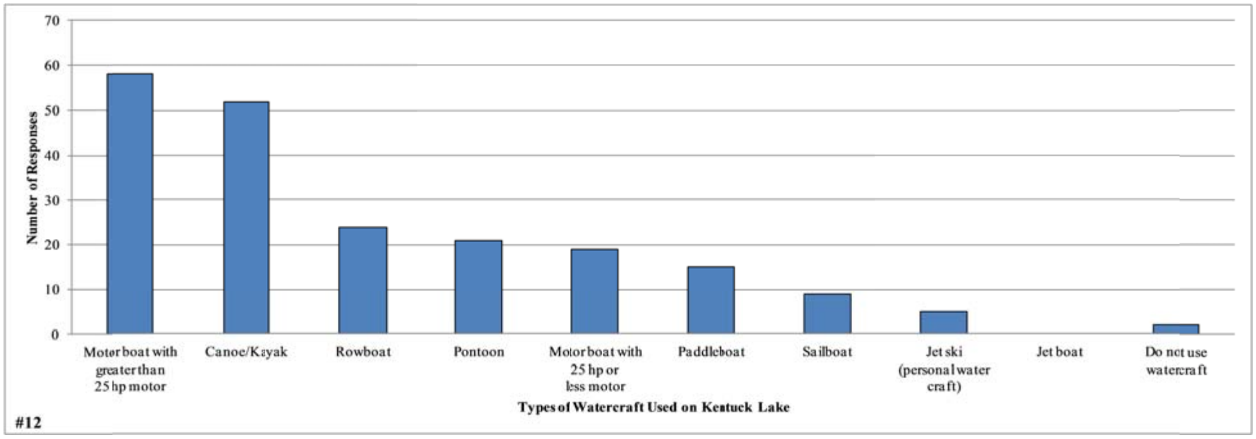
In October 2013, a seven-page, 30-question survey was mailed to 149 riparian property owners in the Kentuck Lake watershed. Of the 149 surveys sent, 90 (60.4%) were returned and those results were entered into a spreadsheet by members of the Kentuck Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Kentuck Lake. The majority of stakeholders (45%) visit on weekends throughout the year, while 32% are year-round residents, and 12% live on the lake during the summer months only. Sixty percent of stakeholders have owned their property for over 15 years with 41% of them owning their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a larger motor boat or canoe/kayak, or a combination of these two vessels on Kentuck Lake (Question 12). Rowboats, pontoons and smaller motor boats were also popular choices. Boating traffic was listed as having a negative impact on Kentuck Lake but was low on the list of concerns (Question 20). As seen on Question 13, fishing is the top recreational activities on the lake. Fish stocking and spear fishing were concerns that were discussed throughout the survey and excessive fishing pressure was listed as one of the top factors potentially impacting Kentuck Lake in a negative manner (Question 21). A further explanation of the fishing concerns will be discussed in the Fisheries Data Integration section.

A concern of stakeholders noted throughout the stakeholder survey (see Question 20 and survey comments – Appendix B) was water quality and algae blooms within Kentuck Lake. These topics are touched upon in the Water Quality and Aquatic Plants sections as well as within the Implementation Plan.

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



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

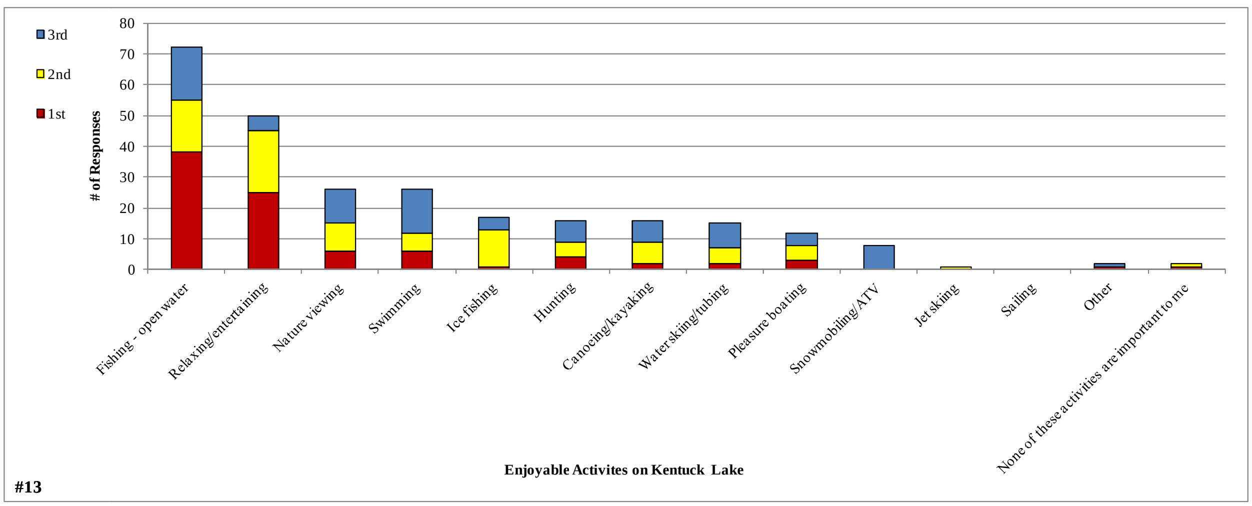
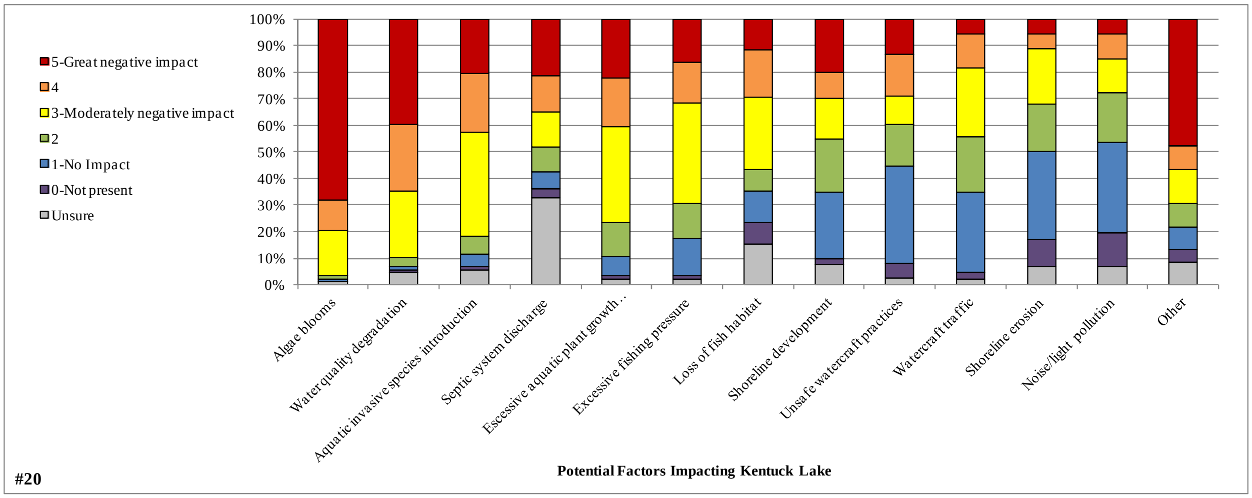


Figure 2.0-1. Select survey responses from the Kentuck Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 20: To what level do you believe these factors may be negatively impacting Kentuck Lake?



Question 21: Please rank your top three concerns regarding Kentuck Lake.

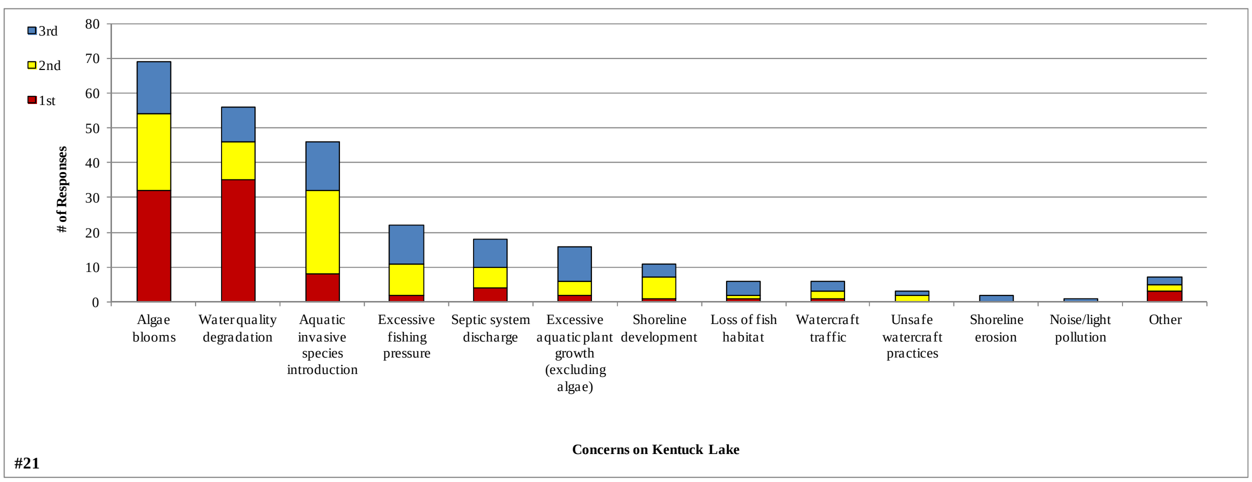


Figure 2.0-2. Select survey responses from the Kentuck Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Kentuck 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 Kentuck 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 (vascular plants). Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

Chlorophyll-*a* is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epiliminion 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.

Internal Nutrient Loading

In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled. The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. months 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 2013) 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 Kentuck 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, and 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.

Following this classification scheme, Kentuck Lake is classified as a deep (stratified), lowland drainage lake (Class 5) (Figure 3.1-1). However, because Kentuck Lake does not possess a tributary inlet and only an outlet, it is technically classified as a spring lake. Though for this analysis, any lake possessing an inlet and/or outlet is classified as a drainage lake.

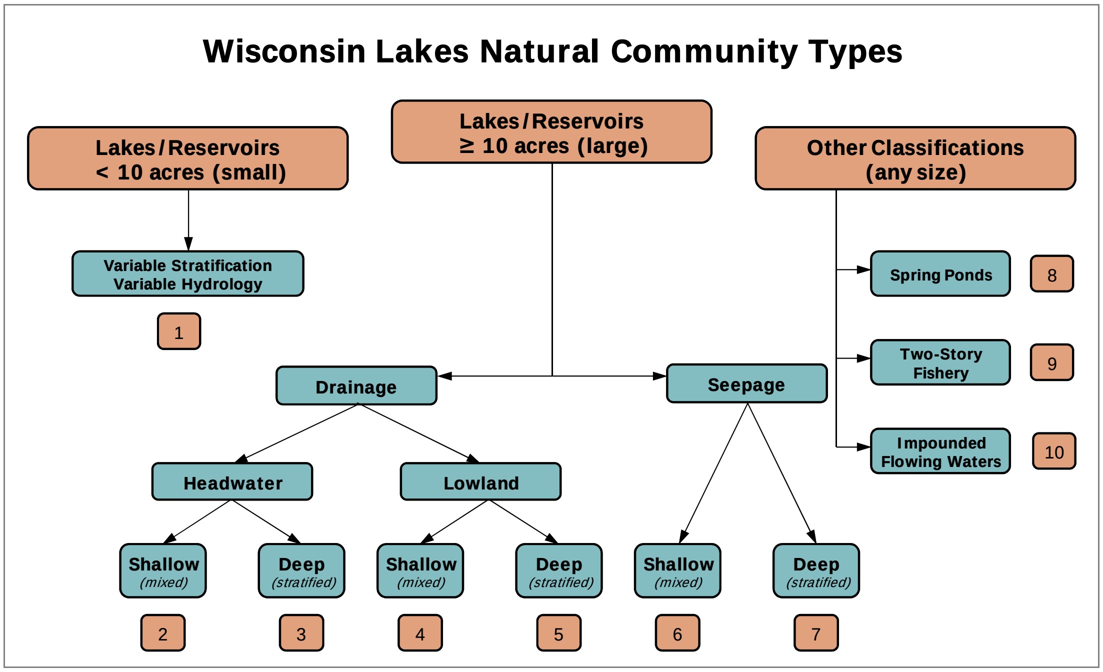


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013. Kentuck Lake is classified as a deep lowland drainage lake (Class 5).

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. Pigeon Lake is within the Southeastern Wisconsin Till Plains ecoregion.

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.

Kentuck Lake water quality data is presented along with comparable data from similar lakes throughout the state and ecoregion in Figures 3.1-3 - 3.1-5.

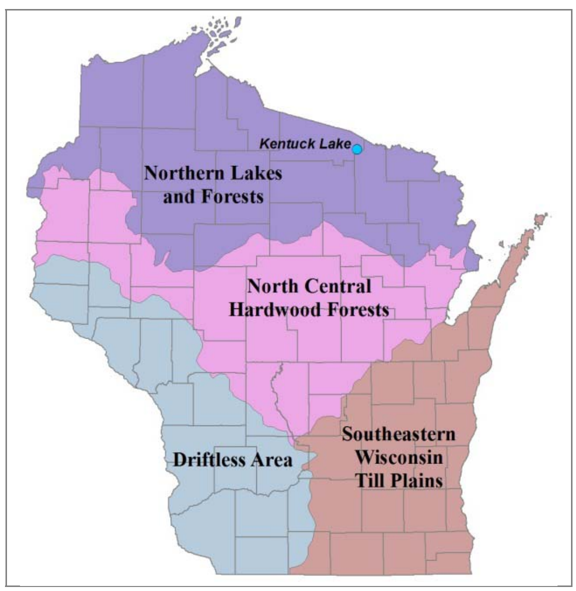


Figure 3.1-2. Location of Kentuck Lake within the ecoregions of Wisconsin. After Nichols 1999.

Please note that the data in these graphs represent samples taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Kentuck Lake Water Quality Analysis

Kentuck Lake Long-term Trends

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year-to-year based upon environmental conditions such as precipitation or lack thereof, and b) differences in observation and perception of water quality can differ greatly from person-to-person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, as whether the lake health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, one can determine what the status of the lake is by comparison.

Volunteers have collected annual water quality data in Kentuck Lake since 1986 and continue to collect data through the Citizens Lake Monitoring Network (CLMN). Through this program, volunteers are trained to collect water quality data on their lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website. In addition, the water quality in Kentuck Lake has been monitored through the WDNR's long-term trends baseline monitoring program where annual water quality data have been collected in since 1988.

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. The data gathered by both Kentuck Lake volunteers and the WDNR since the 1980s have built a robust dataset that will yield valuable information on Kentuck Lake's water quality over this time period.

Near-surface total phosphorus data are available annually from Kentuck Lake from 1988 to 2014 (Figure 3.1-3). As illustrated, growing season near-surface total phosphorus concentrations were sporadic from 1988 to 1991, with average values ranging from 78 µg/L in 1988 to 32 µg/L in 1989 over this period. From 1992-1998 near-surface total phosphorus concentrations were relatively stable, averaging 29 µg/L and straddling the *good-fair* threshold for deep lowland drainage lakes. While the average near-surface total phosphorus concentration increased to 43 µg/L in 1999, this average was based on only two samples collected in mid-summer when phosphorus concentrations have shown to be higher in Kentuck Lake. And again from 2000-2010 average annual growing season near-surface total phosphorus concentrations fluctuated little and averaged 23 µg/L, slightly less than concentrations from 1992-1998.

However, near-surface total phosphorus concentrations increased markedly in 2011, increasing to a growing season average value of 64 µg/L, similar to what was measured in the late 1980s and early 1990s. In 2012, the average near-surface total phosphorus concentration fell to 32 µg/L but still higher than average values from 2000-2010. And in 2013, similar to what was observed in 2011, near-surface total phosphorus concentrations increased to an average value of 46 µg/L. In 2014, concentrations were similar to the weighted average, with a value of 29.5 µg/L. The likely reasons for the increase in phosphorus concentrations observed in early in the dataset and more recently in 2011 and 2013 will be discussed later in this section.

Because ecoregional and state median values were determined from summer data, average annual summer near-surface total phosphorus concentrations from Kentuck Lake are also displayed in Figure 3.1-3. The weighted average summer near-surface total phosphorus concentration for all data available (1988-2014) is approximately 31 µg/L, and falls right on the *good-fair* threshold for deep lowland drainage lakes in Wisconsin. This value also falls above the median values for other deep lowland drainage lakes in the state as well as other lakes within the NLF Ecoregion. However, summer near-surface total phosphorus concentrations from 2000-2010, prior to the increases observed in 2011-2013, were more comparable to other lakes throughout the ecoregion and the state.

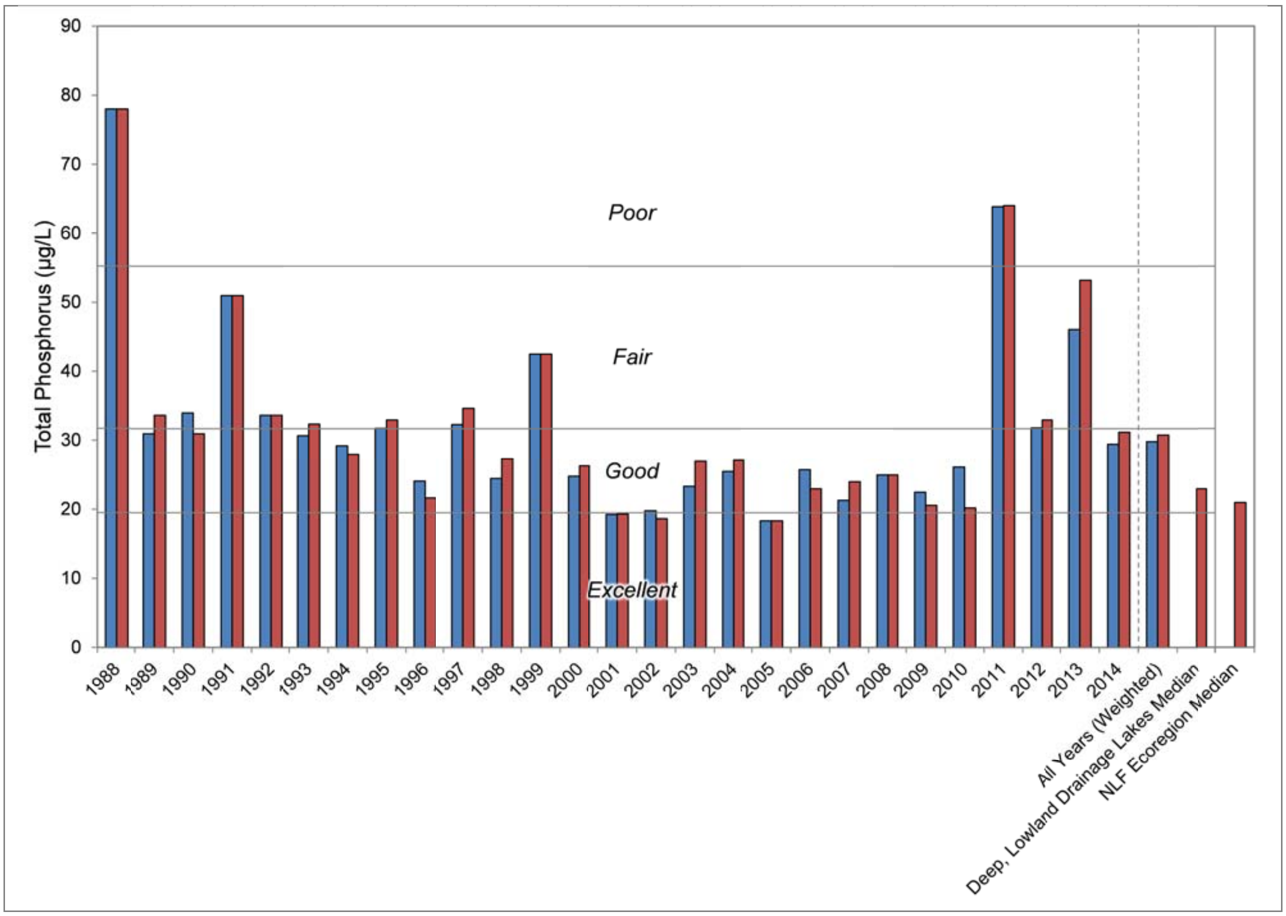


Figure 3.1-3. Kentuck Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, lowland drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, in the majority of Wisconsin lakes is usually positively correlated with total phosphorus concentrations. As will be discussed, mid-summer nitrogen to phosphorus ratios indicate that Kentuck Lake is phosphorus-limited, indicating phosphorus largely controls the amount of algae within the lake. While phosphorus limits the amount of algae growth, other factors also affect the amount of algae produced within the lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton which feed on algae all also influence algal abundance. Chlorophyll-*a* data from Kentuck Lake are available over the same time period as total phosphorus, 1988-2014 (Figure 3.1-4). And as expected, average growing season annual chlorophyll-*a* concentrations mirror the average near-surface total phosphorus concentrations.

Chlorophyll-*a* concentrations were sporadic from 1988-1992, with average values ranging from 86 µg/L in 1988 to 10.3 µg/L in 1990. Average chlorophyll-*a* concentrations from 1993-1999 were relatively stable, averaging approximately 14 µg/L and falling into the *fair* category for deep lowland drainage lakes. From 2000-2010, chlorophyll-*a* concentrations were also relatively constant and fell even lower, averaging approximately 9 µg/L and falling within the *good* category for deep lowland drainage lakes. Then, in response to increased total phosphorus concentrations, chlorophyll-*a* concentrations increased dramatically in 2011 to an annual average of 72 µg/L, six times higher than the average in 2010 and falling well into the *poor* category for deep lowland drainage lakes. Chlorophyll-*a* concentrations decreased in 2012 to an average of 18 µg/L (*fair* category), but increased again in 2013 to an average of 43 µg/L (*poor* category). In 2014, chlorophyll-*a* concentrations were similar to the weighted average value, falling within the *fair* category.

Like with total phosphorus, summer chlorophyll-*a* data are also displayed in Figure 3.1-4. The weighted average for all summer data available from 1988-2014 falls within the *fair* category for deep lowland drainage lakes, and exceeds the median values for deep lowland drainage lakes throughout the state and for other lakes within the NLF Ecoregion. However, the weighted average chlorophyll-*a* concentration during the more stable period from 1993 to 2010 falls right on the *good-fair* threshold for deep lowland drainage lakes.

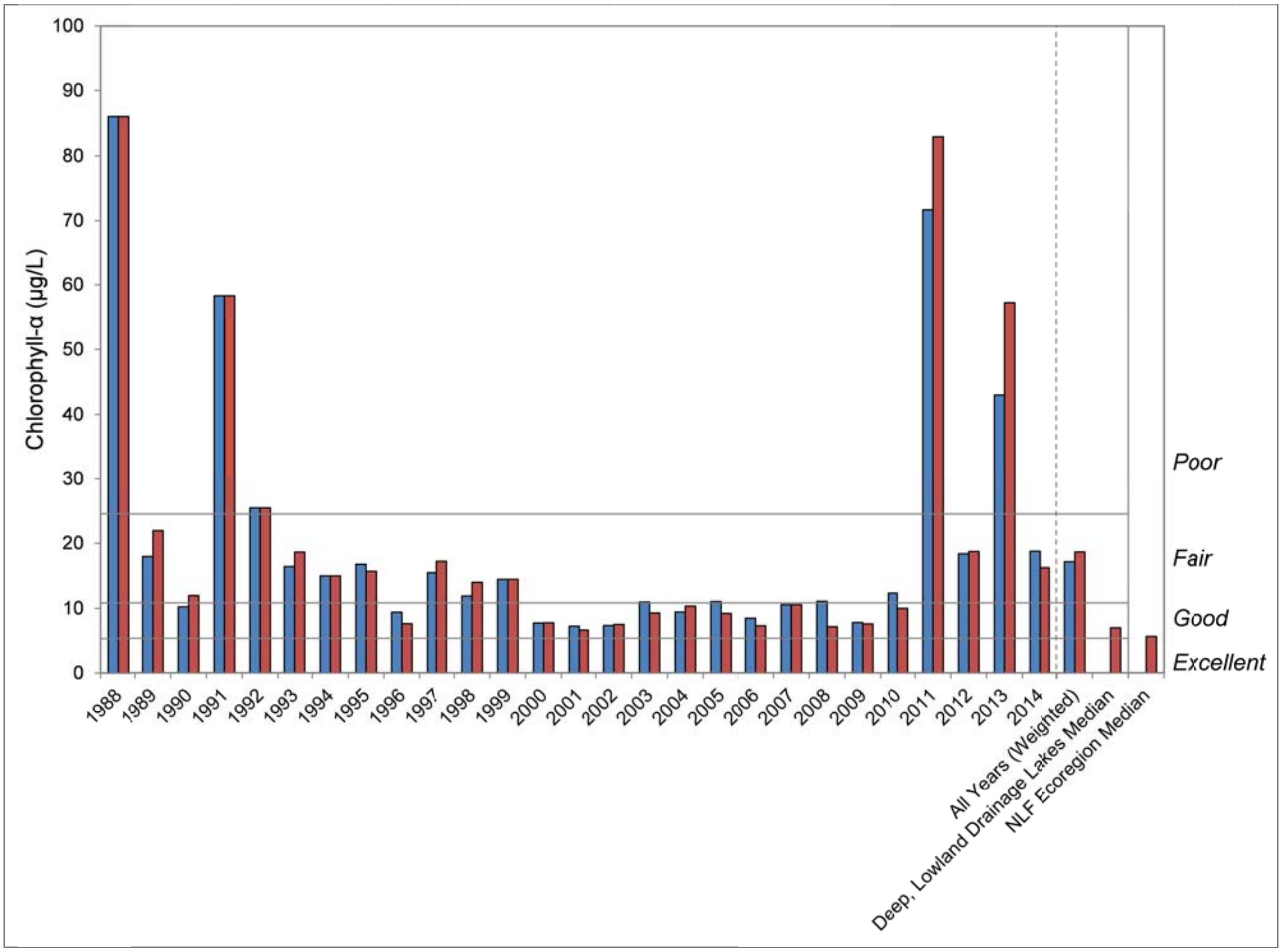


Figure 3.1-4. Kentuck Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep, lowland drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

While total phosphorus controls the amount of algae within the lake, the amount of algae within the lake controls the lake's water clarity. Average Secchi disk transparency values are available for Kentuck Lake from 1986 to 2014 (Figure 3.1-5). As illustrated, the Secchi disk transparency values over this time period are more variable than total phosphorus and chlorophyll-*a* values. Average Secchi disk transparency was very low when measurements began in 1986, indicating high levels of algae. Following 1986, there was an increasing trend in water clarity until 1996 with some years falling into the *excellent* category for deep lowland drainage lakes. From 1997 to 1999 water clarity declined into the *fair* category, then increased again from 2000 to 2003. From 2004 to 2010, water clarity was relatively stable, straddling the *good-excellent* threshold. With the increased algae levels in 2011 and 2013, average water clarity declined four to five feet. Average annual summer Secchi disk transparency data are also displayed in Figure 3.1-5. The weighted average for all data available from 1986-2014 falls within the *good* category, and is only slightly below the median values for other deep lowland drainage lakes within the state and other lakes within the NLF Ecoregion.

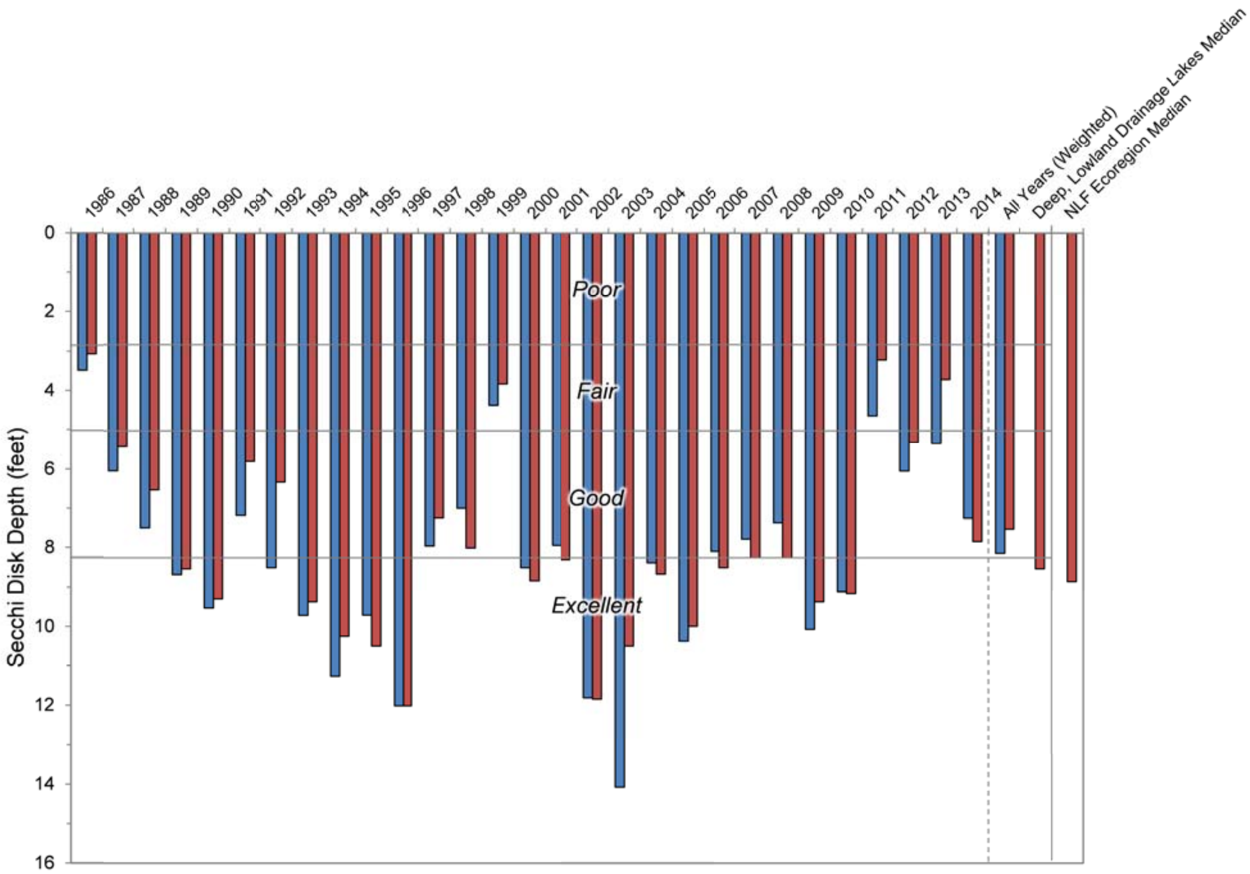


Figure 3.1-5. Kentuck Lake average annual Secchi disk transparency and median Secchi disk transparency for state-wide deep, lowland drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Potential Sources of Kentuck Lake Intermittent Phosphorus Loading

The water quality data that have been collected annually on Kentuck Lake since the late 1980s indicate that there are no apparent trends (positive or negative) occurring over this time period. However, the data do show that Kentuck Lake periodically experiences years with elevated near-surface total phosphorus concentrations and consequent increased levels of algae and lower water clarity. Within the data that are available, these years of poorer water quality have occurred in 1988, 1991, and most recently in 2011 and 2013. This indicates that Kentuck Lake is intermittently receiving higher than normal loads of phosphorus during those years.

Generally speaking, there are several possible sources that could cause the elevated phosphorus levels observed in Kentuck Lake. In instances where there is high variability of total phosphorus concentrations between years, like on Kentuck Lake, managers first look to the lake's surficial watershed to determine if there are any point or non-point sources of phosphorus discharging to the lake. Point sources include sources of phosphorus that originate from a single location, and may include a drainage ditch from an agricultural field or a discharge pipe from a sewerage treatment plant. Non-point sources include sources of phosphorus that originate over a larger, widespread area, and may include phosphorus originating from large agricultural or urban areas. In general, point sources are easier to control than non-point sources of phosphorus.

As is discussed in the Watershed Assessment Section, Kentuck Lake's watershed is mainly comprised of natural land cover types (forest) and there are no apparent point sources of phosphorus entering the lake (Map 2). While there is a small amount of row crop agriculture within the watershed, modeling indicates this is not contributing a significant amount of phosphorus to the lake. The natural land cover types within Kentuck Lake's watershed export minimal amounts of phosphorus and modeling indicates that the watershed's land cover composition and size does not account for the levels of phosphorus observed in the lake, especially during years like 2011 and 2013 where total phosphorus concentrations were highly elevated. It is not believed that the high levels of phosphorus observed in some years are being delivered directly from sources within Kentuck Lake's surficial watershed.

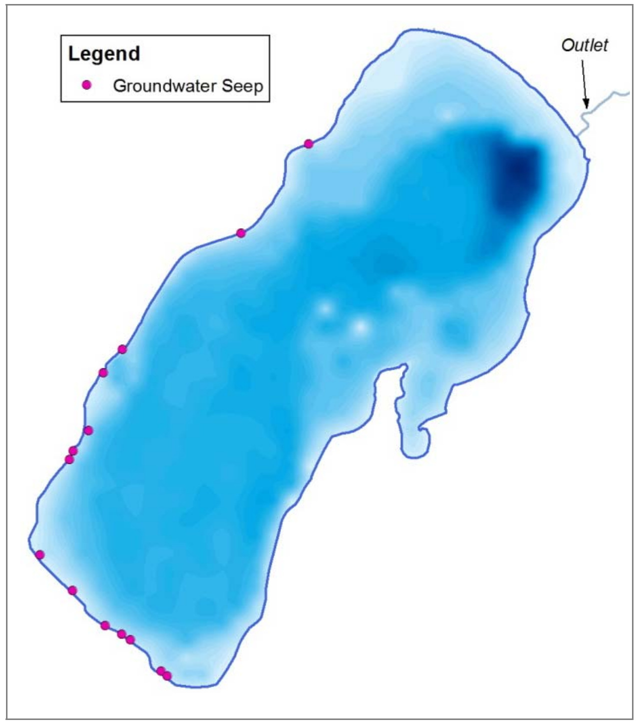


Figure 3.1-6. Kentuck Lake visible groundwater seepage areas. Data provided KLPRD volunteer and verified by Onterra ecologists.

Another potential source that could cause increases in total phosphorus, particularly in mid-summer as is observed in Kentuck Lake, is the presence of a curly-leaf pondweed population. As is discussed further in the Aquatic Plant Section, curly-leaf pondweed is present in Kentuck Lake. Unlike many of our native aquatic plants, curly-leaf pondweed begins growing immediately after ice-out and reaches its peak growth in mid- to late-June and then naturally senesces (dies back) in early summer. In lakes with large curly-leaf pondweed populations, the natural senescence and subsequent decay of plant material can release large amounts of phosphorus into the lake as it decays. However, Kentuck Lake was found to have a very small population of curly-leaf pondweed, the amount of which would not account for the increases in phosphorus observed.

Septic systems within the lake's watershed, a type of point source, can leach phosphorus which can make its way into a lake. Using the septic output estimator in Wisconsin Lakes Modeling Suite (WiLMS), an estimate of phosphorus loading attributed to septic leakage was calculated based on the results received from the Kentuck Lake stakeholder survey. Using the number of riparians per type of residence (year-round, seasonal, etc.) and assuming each residence has two people and that the septic system is functioning properly, the model indicated that Kentuck Lake receives approximately 14 pounds of phosphorus annually from septic tank outputs, or 1.7% of its annual phosphorus budget. While this is only an estimate, this amount of phosphorus does not account for the total phosphorus concentrations observed in 2011 and 2013. In addition, this estimate does not include the flow of groundwater into and out of Kentuck Lake. Those septic sources located in areas where groundwater flow is moving out of Kentuck Lake would not have any impact on the lake in terms of phosphorus loading.

In the winter of 2013, Kentuck Lake residents expressed concerns regarding areas of open water near shore in along the southern and western shore of the lake. Fearing that these ice-free areas were created by septic systems leaching into the lake, GPS coordinates of these locations were provided to Onterra (Figure 3.1-6). On April 3, 2014, Onterra ecologists visited Kentuck Lake to investigate these areas and to also collect plankton samples as some residents reported algae growing under the ice. During this visit, each of these areas of open water near shore were inspected. These locations occurred along areas of the shoreline that were both developed and undeveloped. At each location, the water appeared very clear and there were no significant amounts of free-floating or benthic algae observed that would indicate significant septic leaching (Photo 3.1-1). At the northwestern-most groundwater seep location, iron flocs were observed right at the groundwater-surface water interface (Photo 3.1-1). These iron flocs naturally occur when anoxic groundwater containing ferrous iron meets oxygenated water and ferric iron forms a visible precipitate (Kato et al. 2013). The orange-colored flocculent iron is a natural occurrence, and not an indicator of leaching septic systems.

Given the locations of these areas around the lake, it is believed these are groundwater seepage areas, or springs, where groundwater has reached the surface and is entering the lake and were not created by leaching septic systems. Given the location of the lake's outlet on the northeast side, the location of these groundwater seeps indicates a directional flow of groundwater from the southwest to the northeast. Regarding septic systems around Kentuck Lake, it does not appear that they are significant contributor of phosphorus to the lake at this time.

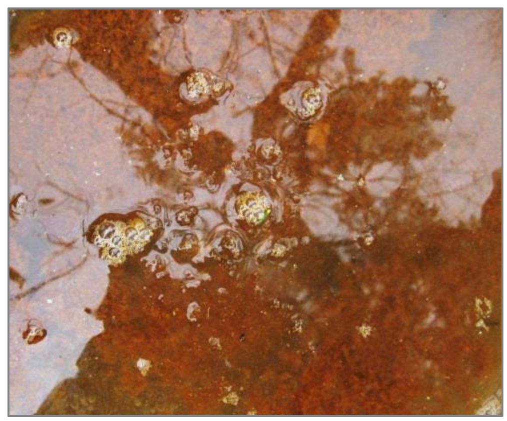



Photo 3.1-1. Groundwater seep on the southern shore of Kentuck Lake (left) and iron floc created by anoxic groundwater encountering oxygenated surface water at a groundwater seep on the northwest shore of Kentuck Lake (right). Photos taken on April 3, 2014.

The most likely explanation for the intermittent years of elevated phosphorus levels in Kentuck Lake is internal phosphorus recycling, or internal phosphorus loading from bottom sediments. Lakes that experience stratification, or form a distinct cooler, dense layer of water near the bottom (hypolimnion) and a warmer, less dense layer at the surface (epilimnion) may experience internal phosphorous loading. During stratification, due to differences in water temperature and thus density, the hypolimnion becomes isolated and does not mix with the oxygen-rich epilimnion. Without oxygen input from the atmosphere or plants, decomposition of organic material within the hypolimnion utilizes the remaining dissolved oxygen and the hypolimnion becomes anoxic, or devoid of oxygen. When the hypolimnion experiences anoxia, phosphorus bound within the sediment is released into the hypolimnetic waters.

If the lake remains stratified, the phosphorus released into the hypolimnion does not mix into the epilimnion until fall during turnover. At this time, the metabolism of organisms within the lake, including algae, has slowed, and the release of phosphorus from the hypolimnion into the epilimnion in fall may have little to no impact on the lake's productivity. Lakes that remain stratified over the course of summer and experience only two turnover events, one in spring and fall, are termed *dimictic* lakes. However, in some lakes that are relatively shallow or have larger surface area, stratification can be broken multiple times throughout the summer and phosphorus that was released into the anoxic hypolimnion from bottom sediments is mixed up into the epilimnion. Because this occurs during summer, this phosphorus fuels actively growing algae and can create noxious algae blooms. Lakes that tend to break stratification and mix multiple times during the summer are termed *polymictic* lakes. While both dimictic and polymictic lakes experience internal phosphorus loading, the impact it has on the lake's water quality and productivity depends on the timing of phosphorus delivery from the hypolimnion to the epilimnion.

To determine if a lake is dimictic or polymictic, the Osgood Index, which utilizes the relationship between the lake's surface area and average depth, is used (Osgood 1988). Lakes with an Osgood Index value of greater than 9 are generally dimictic, while lakes with Index Values of less than 4 are polymictic. Kentuck Lake has an Osgood Index of approximately 1.9, indicating that its polymictic. However, as is discussed below, temperature and dissolved oxygen profiles collected from Kentuck Lake have never captured a turnover (mixing) event at the lake's deep hole in summer. This area of the lake may be small and deep enough where it does not mix during the summer, but the area within the rest of the lake is relatively shallow and likely mixes intermittently throughout the summer.

In polymictic lakes, the frequent delivery of phosphorus from the hypolimnion to the epilimnion generally results in near-surface total phosphorus concentrations increasing over the course of the summer (Robertson et al. 2012). Figure 3.1-7 illustrates each individual near-surface total phosphorus data collected from Kentuck Lake from 1988 to 2014 and shows that concentrations increase throughout the summer in every year. While the magnitude of increase was much greater in 1988, 1989, 1991, 2011, and 2013, the same representative pattern of increasing phosphorus concentrations occurs over the summer. This pattern is an indicator that internal phosphorus loading from bottom sediments is likely occurring in Kentuck Lake.

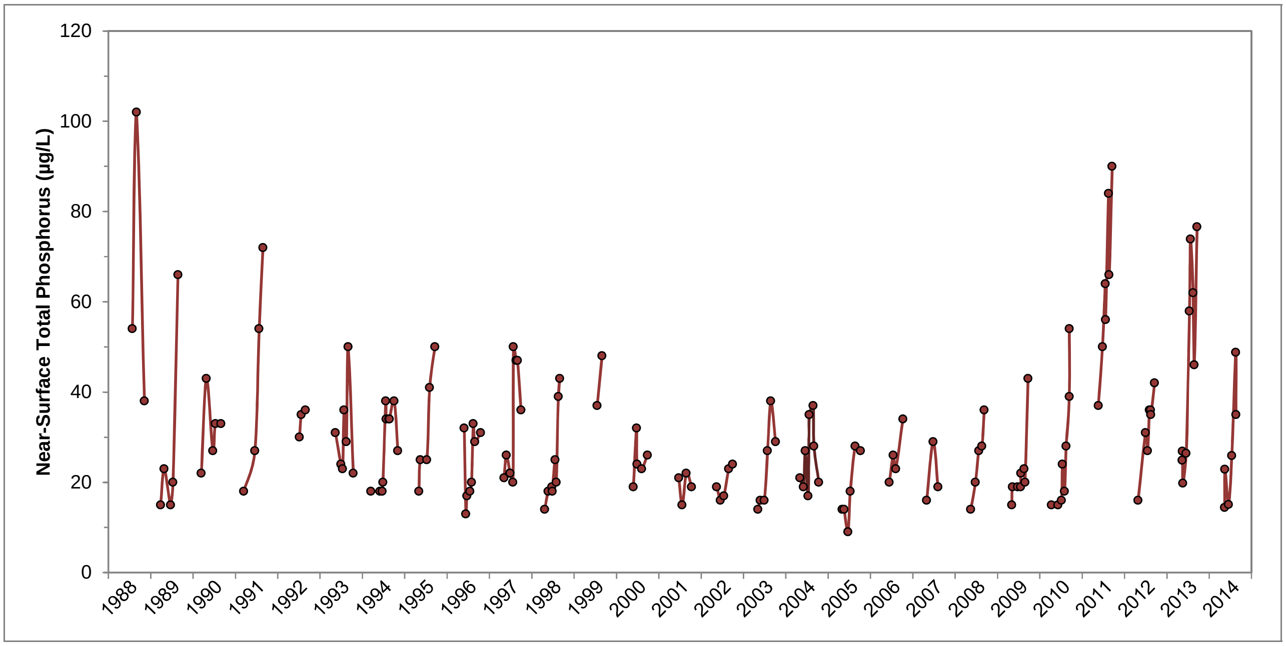


Figure 3.1-7. Kentuck Lake near-surface total phosphorus concentrations from 1988 – 2014.

Another indicator that internal phosphorus loading is occurring in Kentuck Lake is the concentration of total phosphorus within the hypolimnion. While no hypolimnetic total phosphorus concentrations were measured in 2013 or 2014, historical data indicates that summer hypolimnetic total phosphorus concentrations average 325 µg/L, while some measurements have exceeded 1,000 µg/L. As discussed in the primer section, hypolimnetic total phosphorus concentrations which exceed 200 µg/L generally indicate that phosphorus concentrations from bottom sediments may impact a lake's water quality.

While internal phosphorus loading is likely occurring to some degree every year in Kentuck Lake, the data indicate that the magnitude of increase in some years, like 2011 and 2013, is substantial. Using total phosphorus concentrations from Kentuck Lake measured in 2013 during spring and fall turnover events when phosphorus concentrations are relatively uniform throughout the water column, it was estimated that approximately 360 pounds of phosphorus had been released into the lake from bottom sediments over the course of the summer. To determine what factors led to these years with higher-than-average phosphorus, historical dissolved oxygen and temperature profiles were examined.

The historical dissolved oxygen and temperature profiles collected from Kentuck Lake's deep hole indicate that the lake does not likely mix down to the maximum depth of 40 feet during the summer. However, as the epilimnion gets deeper and erodes the hypolimnion over the course of the summer, this likely transfers phosphorus from the hypolimnion into the epilimnion. In a typical year, like 2012, the epilimnion initially extends to a depth of 25 – 30 feet, resulting in a hypolimnion that encompasses the bottom 10 to 15 feet of water (Figure 3.1-8). Using bathymetric data for the lake, in a typical year, approximately 25 acres of bottom sediments are exposed to anoxic conditions and are releasing phosphorus. Because this is a relatively small area and a relatively small volume of water when compared to the rest of the lake, when

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phosphorus is delivered from the hypolimnion to the epilimnion there is little or no detectable impact to the lake's water quality.

However, in years where near-surface total phosphorus concentrations were elevated (2011 and 2013), dissolved oxygen and temperature profiles indicate that the lake had stratified much shallower. In July 2011, the epilimnion extended to a depth of around 15 feet, and anoxic conditions were present from 15 feet and below. When anoxic conditions were present at depths of 15 feet and less, greater than 500 acres of bottom sediments in Kentuck Lake were exposed to anoxic conditions and likely releasing phosphorus. In shallower areas of the lake, wind events likely mixed the larger amounts of hypolimnetic phosphorus into the epilimnion where it was now available to fuel algae blooms. In addition, the epilimnion grew deeper over the course of the summer, eroding the hypolimnion, and likely caused mixing of hypolimnetic phosphorus into the epilimnion. Dissolved oxygen and temperature profiles indicated a similar phenomenon in 2013, with a shallower-than-typical epilimnion and a larger hypolimnion (Figure 3.1-8). While dissolved oxygen and temperature profiles are not available from the late 1980s and early 1990s, this is likely what likely caused the elevated total phosphorus concentrations measured in those years as well.

Weather patterns mainly drive the differences in the depth of stratification observed between typical years on Kentuck Lake and years where phosphorus concentrations were highly elevated. Periods of hot, calm weather rapidly heat the surface water of the lake (epilimnion) and increase the density gradient between the epilimnion and the hypolimnion. Without wind, the epilimnion forms shallower as there is no wind energy mixing the epilimnion and the heat deeper into the water. It is believed that a period of hot, calm weather in spring or early summer of 2011 and 2013 caused Kentuck Lake to stratify shallower, creating a larger area of anoxia, and thus, increasing the amount of phosphorus released into the lake from bottoms sediments. The years with elevated phosphorus concentrations appear to be dependent on where the lake stratifies early in the summer, which is mainly driven by weather.

The studies conducted on Kentuck Lake in 2013 were baseline studies, and with these data and historical data that are available, it appears that internal nutrient loading is the main source of increasing phosphorus concentrations observed over the course of the summer, while the magnitude of increase is dependent on the lake's initial thermal stratification driven by weather. While two of the three most recent years saw elevated levels of total phosphorus and algae, this is not necessarily an indication of a trend of declining water quality into the future. As discussed, these levels of phosphorus and algae were measured early in the dataset in the late 1980s and early 1990s, and appears to be an intermittent phenomenon. While there are other sources, such as groundwater, that could be contributing phosphorus to the lake, it does not appear likely at this time. However, groundwater is naturally a source of phosphorus for some lakes in the northern region, and the nutrient content of Kentuck Lake's groundwater may reveal if it is a significant contributor of phosphorus.

As is discussed in detail within the Implementation Plan Section, the KLPRD, with Onterra's assistance, initiated a three-year (2014-2016) in-depth analysis of Kentuck Lake's water quality to gain a better understanding of its thermal behavior and presumed internal phosphorus recycling. The first year of the project included temperature and dissolved oxygen monitoring at various locations and depths throughout the lake, while the final two years will include additional parameters such as nutrients and chlorophyll-*a*. The next section discusses the results of the 2014 temperature/dissolved oxygen monitoring from 2014.

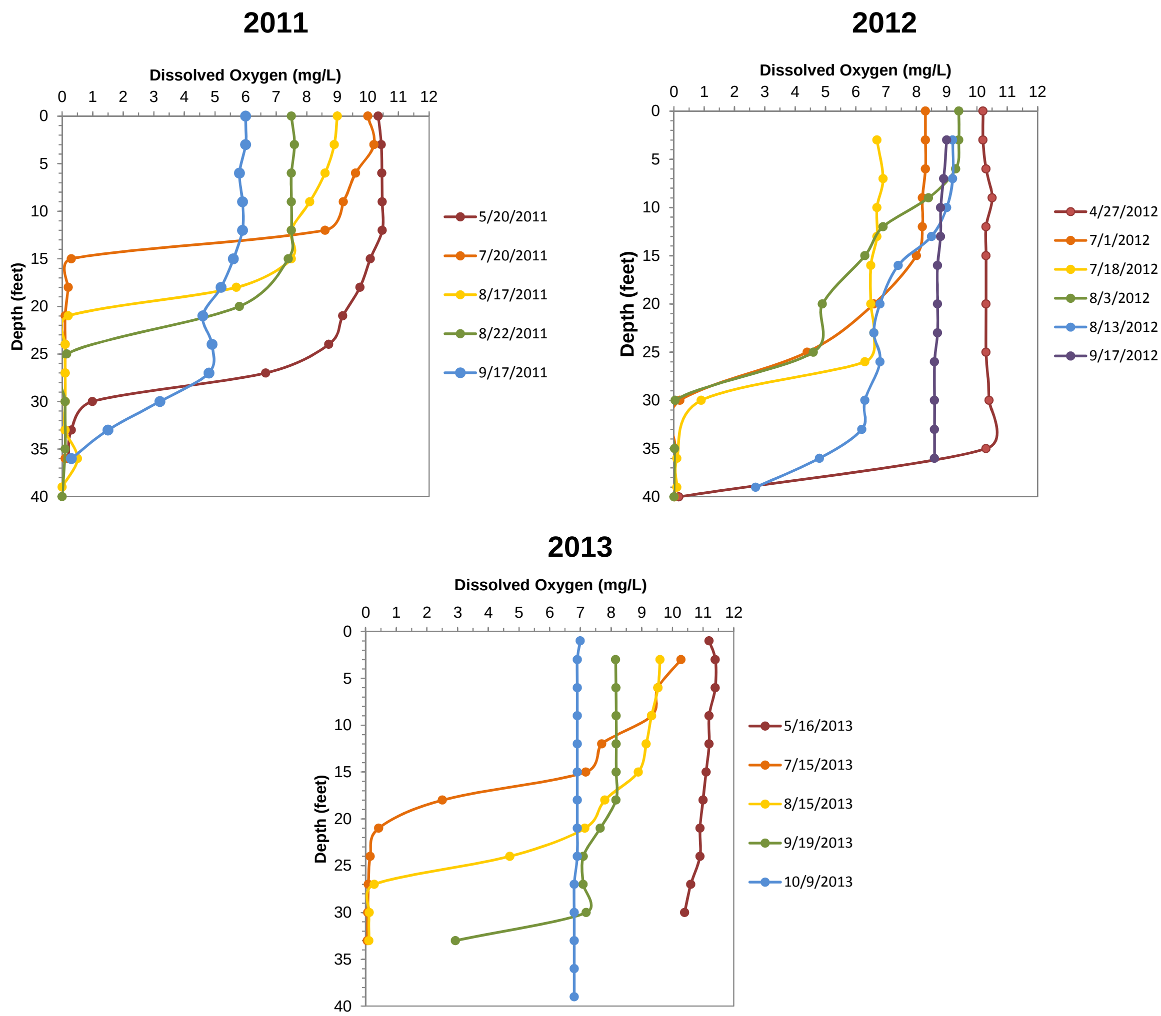


Figure 3.1-8. Dissolved oxygen profiles from Kentuck Lake in 2011, 2012, and 2013.

Kentuck Lake 2014 Temperature/Dissolved Oxygen Monitoring Results

As mentioned, as part of a three-year study of Kentuck Lake's water quality, KLPRD volunteers collected temperature and dissolved oxygen profiles from seven locations throughout the lake biweekly (every other week) from late-May through early-October of 2014 (Map 10). In addition to the biweekly sampling, the volunteers also periodically sampled during or immediately after storm events, or weather events that generated high winds to create whitecap conditions on the lake.

Figure 3.1-9 displays temperature and dissolved oxygen isopleths generated from the data collected by the KLPRD volunteers at Kentuck Lake's deep hole (Site 1). As illustrated, the lake was stratified in late-May and through most of June with a defined epilimnion, metalimnion, and hypolimnion. In June, dissolved oxygen was present down to a depth of approximately 27 feet, indicating that Kentuck Lake's early-season stratification aligned with what has been observed in most years, and the lake did not form a shallower epilimnion as was observed in 2011 and 2013.

Data collected at the other six locations showed a similar pattern, and the isopleths of these data can be found in Appendix C.

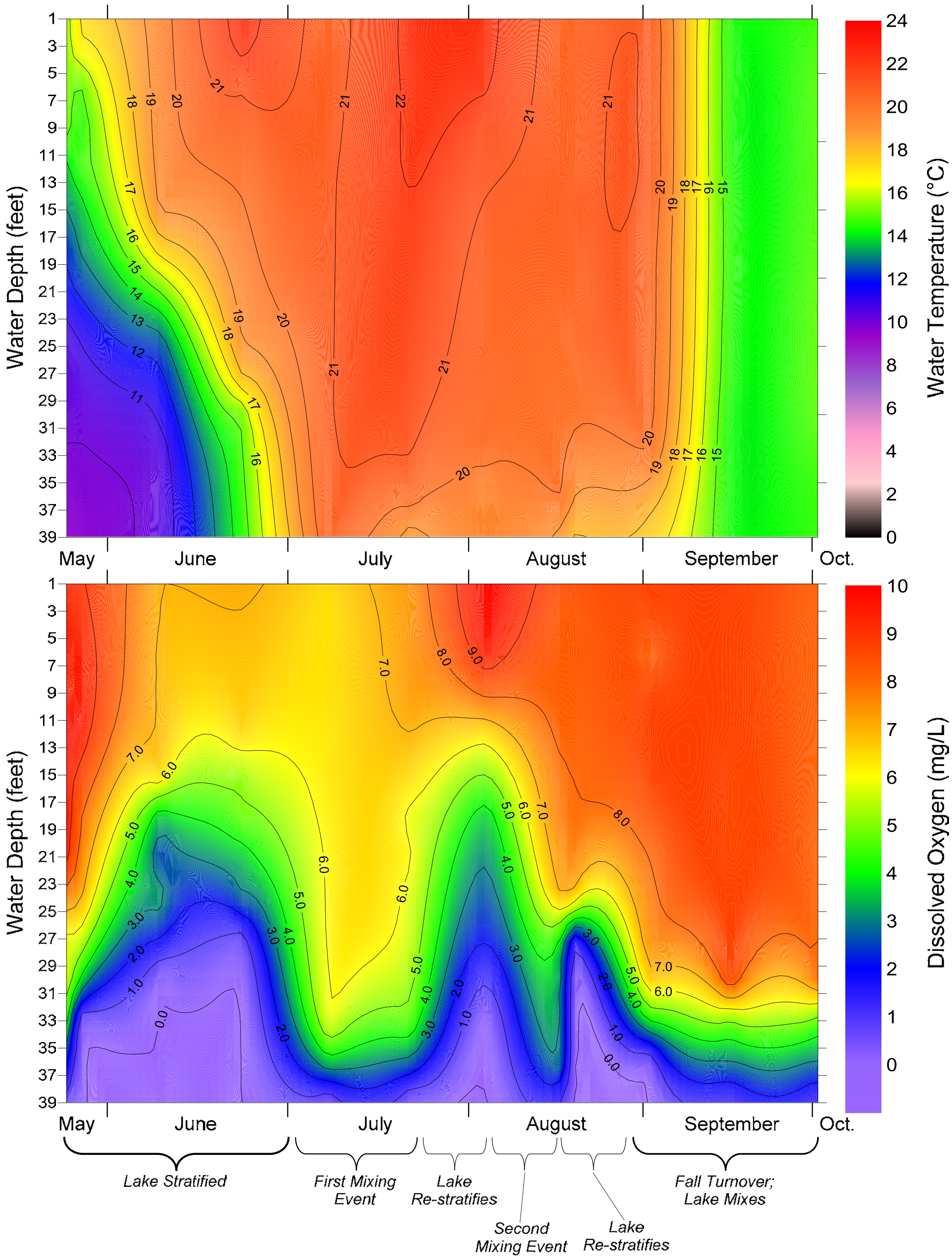


Figure 3.1-9. Kentuck Lake 2014 temperature (top) and dissolved oxygen (bottom). Isopleths created using data collected biweekly from KLPRD volunteers at Kentuck Lake's deep hole (Site 1 on Map 10).

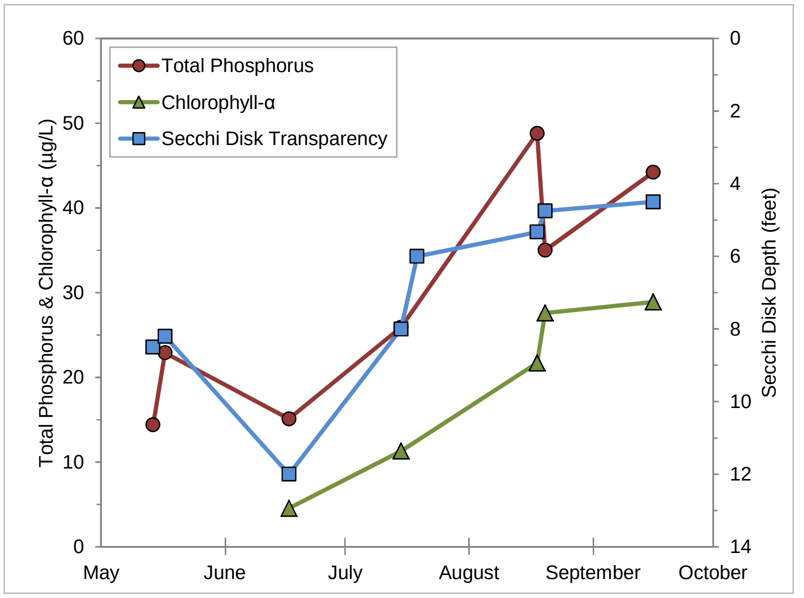


Figure 3.1-10. Kentuck Lake near-surface total phosphorus, chlorophyll-α, and Secchi disk transparency. Data collected by KLPRD CLMN and WDNR Long-Term Trends Monitoring Programs.

However, sometime between the sampling periods of June 25 and July 9, the lake broke stratification and water circulated (mixed) completely from the surface to the bottom of the deep hole as indicated by the uniform temperature throughout the water column. Coinciding with this mixing event, near-surface total phosphorus also increased from 15.1 µg/L in mid-June to 25.9 µg/L, representing a delivery of phosphorus from the hypolimnion of approximately 397 pounds (3.1-10). With this increase in phosphorus within the surface waters of the lake, algae levels also increased with chlorophyll-*a* levels increasing from 4.6 µg/L in mid-June to 11.3 µg/L in mid-July. With the increase in algae, Secchi disk transparency declined from 12.0 feet in mid-June to 6.0 in mid-July.

Following the early-July mixing event, Kentuck Lake became stratified again forming an anoxic hypolimnion; however, while the dissolved oxygen gradient across depths was apparent, the thermal gradient was weak with near-surface and near-bottom temperatures differing by only 1-2°C. In mid-August, there was another mixing event; however, the data did not capture a complete mixing from the surface to maximum depth of the lake as was observed in earlier in the summer. While it is possible that another complete mixing from the surface to the maximum depth of the lake occurred between two sampling periods, it is believed the mid-August mixing event was an incomplete mixing – the epilimnion and only the upper portion of the hypolimnion mixed. Regardless, this event caused a substantial increase in near-surface total phosphorus concentrations, increasing to an average of 41.9 µg/L in August, which equates to approximately another 817 lbs of phosphorus being delivered to the epilimnion. As expected, algal levels also increased significantly following this event.

Even though the period of stratification prior to the July mixing event was longer than the period of stratification following this event and prior to the mid-August mixing event, the August mixing event delivered approximately 420 more pounds of phosphorus to the epilimnion than the mixing event in July. This difference is believed to be due to the difference in water temperature within the hypolimnion during periods of stratification. Phosphorus release from bottom sediments increases with temperature (Søndergaard et al. 1999; Wilhelm and Adrian 2008). Because of the complete mixing event in July, when the lake re-stratified the hypolimnion was now warmer by an average of 9°C (17°F) warmer. The warmer hypolimnetic temperatures likely facilitated an increased release rate of phosphorus from the sediment into the hypolimnion, and upon mixing in mid-August, the hypolimnetic phosphorus delivered to the surface waters of Kentuck Lake.

While Kentuck Lake has a maximum depth of 40 feet, most of the lake is relatively shallow with a mean depth of 13 feet. It's relatively shallow depth, large surface area, and southwest to northeast orientation all contribute to its susceptibility to periodic mixing during the growing season. In the early summer of 2014, Kentuck Lake was strongly stratified, or there was large difference in temperature (and density) between the epilimnion and the hypolimnion. In order to break this stratification, the epilimnion either needs to be cooled and brought to a similar density as the hypolimnion below, or there needs to be a sufficient amount of energy (turbulence) in the lake to physically mix these layers together.

Weather data from May-September 2014 were obtained from a monitoring station in nearby Phelps, WI (Figure 3.1-11). The time period for which the first and complete mixing event occurred is highlighted in purple. Both the daily high ambient air temperature data and the surface water temperature data collected by KLPRD volunteers indicate that there was not a significant period of cooler weather prior to the first mixing event that would have cooled the epilimnion and made the lake more prone to mixing. However, daily wind data indicate that south-southwest winds persisted from June 26 through July 1, and wind speed increased each day within this period to some of the highest speeds recorded over this five-month period. Maximum wind gusts ranged from 9 mph on June 26 to 31 mph on July 1. It is believed that the complete mixing event observed occurred within this timeframe.

Given Kentuck Lake's orientation, its *maximum fetch length* falls on a line oriented from southwest to northeast. Maximum fetch length is defined as the largest unbroken stretch of open water across the lake (Wetzel 2001). Wind blowing across the lake over the direction of the maximum fetch length has the capacity to impart the greatest amount of wind energy on the lake's surface. It is believed the sustained south-southwest winds over the period from June 26 to July 1 imparted enough energy to break the lake's stratification and completely mix the entire water column. Predominantly south-southwest winds through most of the rest of July prevented the lake from re-stratifying until late-July/early-August. While not as clearly defined, the mid-August partial mixing event is believed to have also been driven by wind.

The 2014 KLPRD volunteer temperature and dissolved oxygen monitoring has revealed that what was originally theorized is occurring in Kentuck Lake – the lake periodically breaks stratification and mixes during the summer, or is polymictic. During these mixing events, phosphorus that was released from the sediment into the anoxic hypolimnion is delivered to surface waters where it is available to algae. In addition, the data indicate that following the first mixing event in early summer, the temperature of the hypolimnion increases significantly. Because phosphorus release from anoxic sediments increases with temperature, there is likely more phosphorus being released under these warmer conditions. Consequently, phosphorus delivery to the epilimnion during subsequent mixing events is likely more sever.

This periodic mixing of the lake and concurrent phosphorus delivery from bottom sediments explains why phosphorus concentrations increase throughout the growing season in Kentuck Lake. While the biweekly phosphorus concentration monitoring planned to occur in 2015 and 2016 will provide more accurate information on the phosphorus dynamics in Kentuck Lake, the 2014 data indicate that an estimated 1,100 pounds of phosphorus were delivered from bottom sediments over the course of the growing season. As is discussed in the Watershed Section, this internal phosphorus loading accounts for the majority of Kentuck Lake's phosphorus budget and dwarfs estimated external phosphorus loads from the lake's watershed

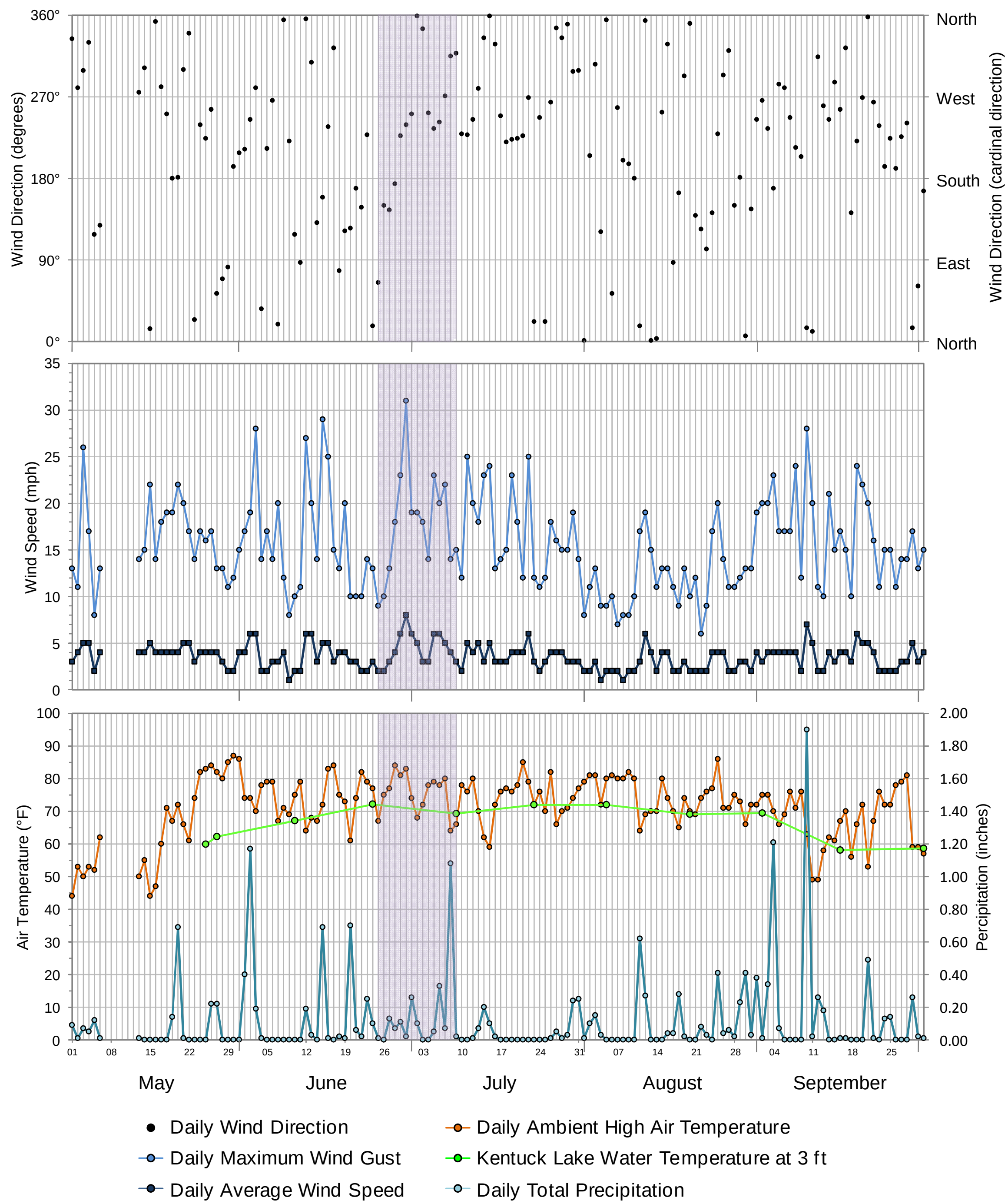


Figure 3.1-11. May – September 2014 wind, temperature, and precipitation data from Phelps, WI. Weather data obtained from www.weatherunderground.com. Kentuck Lake surface water temperatures collected by KLPRD volunteers.

Limiting Plant Nutrient of Kentuck Lake

Using mid-summer nitrogen and phosphorus concentrations from Kentuck Lake, a nitrogen:phosphorus ratio of 22:1 was calculated. This finding indicates that Kentuck Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Kentuck Lake Trophic State

Figure 3.1-12 contains the Trophic State Index (TSI) values for Kentuck Lake. The TSI values calculated with summer month Secchi disk, chlorophyll-*a*, and total phosphorus values range from mesotrophic to hypereutrophic. In general, the best values to use in judging a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors such as dissolved organic compounds. Based upon the weighted average TSI values for total phosphorus and chlorophyll-*a*, it can be concluded that Kentuck Lake is in a eutrophic state. However, the lake has the capacity in some years, like 2011 and 2013, to reach hypereutrophic levels.

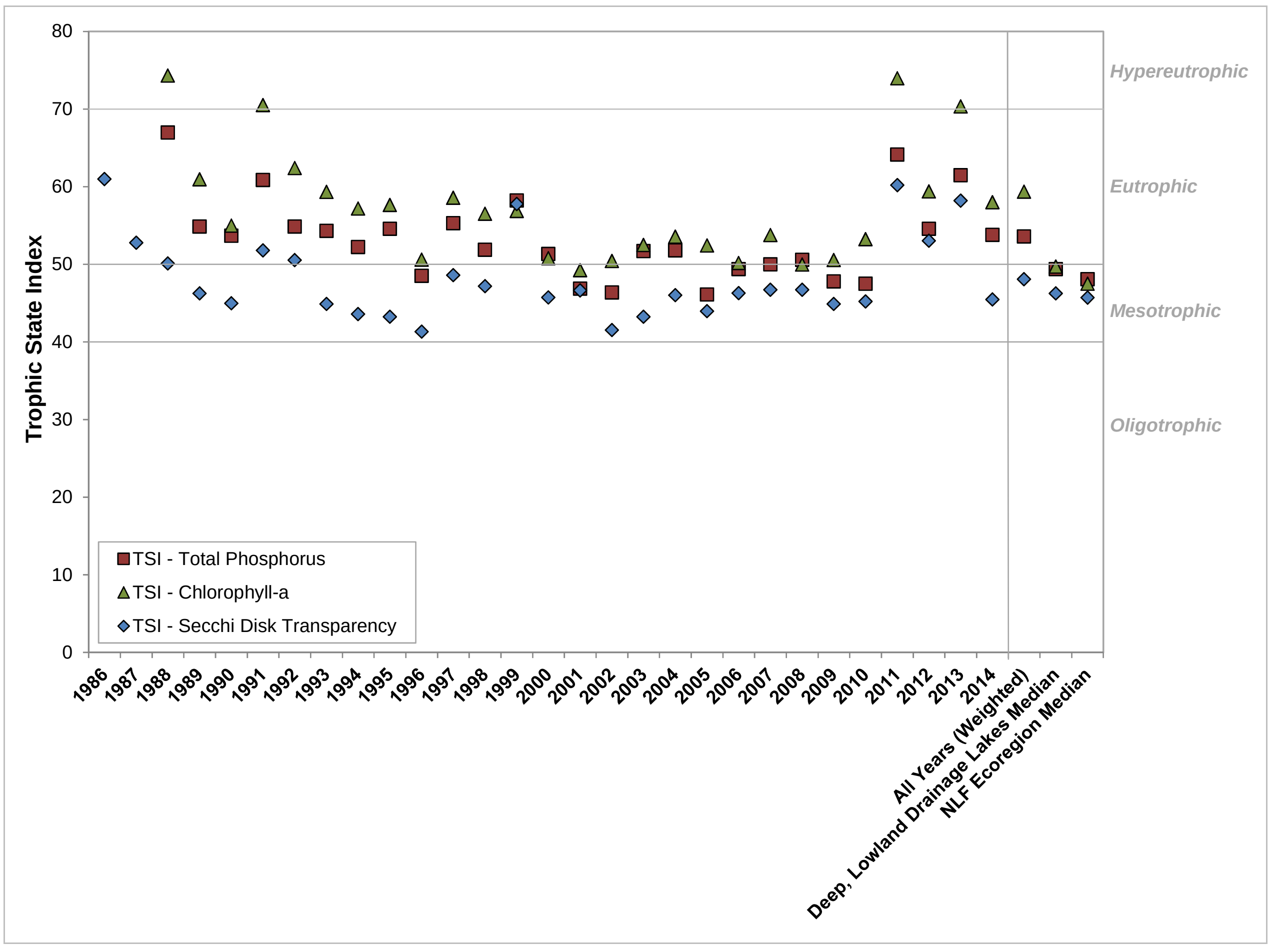


Figure 3.1-12. Kentuck Lake, state-wide deep, lowland drainage lakes, and Northern Lakes and Forests (NLF) ecoregional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Additional Water Quality Data Collected at Kentuck Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Kentuck Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Kentuck Lake was found to be slightly alkaline with a value of 7.6, and falls within the normal range for Wisconsin Lakes.

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 Kentuck Lake was measured at 34.2 (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 mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Kentuck Lake's pH of 7.6 falls inside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Kentuck Lake was found to be 6.7 mg/L, falling well below the optimal range for zebra mussels.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu).

Based upon this analysis, Kentuck Lake was considered borderline suitable for mussel establishment. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not record the presence of larval zebra mussels. Because Kentuck Lake is one of the WDNR's Long-Term Trends Monitoring lakes, WDNR staff annually collect and analyze samples for larval zebra mussels and spiny water fleas.

Spiny water fleas, like zebra mussels, were introduced to the Great Lakes and have since invaded some inland waters of Wisconsin. Nearby Butternut, Stormy, Star, and Trout Lakes have confirmed populations of spiny water fleas. They feed on and can greatly reduce zooplankton within a lake, an important food source for many fish. In addition, their spine can cause them to get stuck within the digestive tracks of fish. They spread between waterbodies by attaching to fishing lines, anchor ropes, fishing nets, live wells, bait buckets, and bilge water. Recreationalists should check their fishing and boating equipment for spiny water fleas upon leaving a waterbody to prevent their spread, as once they are introduced and established, there is no current method to control them.

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 deposition 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.

Kentuck Lake's watershed was delineated using a combination of United States Geological Survey (USGS) topographic maps and watershed delineation modeling developed by the Department of Agricultural and Biological Engineering at Purdue University. Using these tools, Kentuck Lake's watershed was originally believed to encompass approximately 7,715 acres, which included nearby Spectacle Lake's watershed. However, after inspecting aerial photos and site visits by Onterra ecologist to the wetland along the northern shore, an unnamed stream was located which flowed through the wetland and into Kentuck Creek. This finding led Onterra ecologists to believe that water flowing from Spectacle Lake into the wetland was not flowing into Kentuck Lake.

Light Detection and Ranging (LIDAR) data, which is high-resolution land elevation data, were obtained from Vilas County for the wetland area in question. These data confirmed that water flowing from Spectacle Lake and two unnamed tributaries from the north into the wetland does not flow into Kentuck Lake. A large ridge is present along the north shore that has been formed over time from wind, waves, and ice creates a barrier between the wetland and the lake. The trail that goes through the Kentuck Lake State Natural Area is on top of this ridge. However, a small portion of this wetland on its southwest side is within Kentuck Lake's watershed and drains to the lake underneath a small wooden boardwalk along the trail. Using the Vilas County LIDAR data, Kentuck Lake's watershed was reduced in size to approximately 2,765 acres (Figure 3.2-1 and Map 2).

The land cover within Kentuck Lake's watershed is comprised of forests (58%), the lake's surface (37%), wetlands (5%), and pasture/grass (<1%) (Figure 3.2-2). Overall, Kentuck Lake's watershed is in excellent condition being mainly comprised of natural land cover types with minimal human development. These land cover types (e.g. forests and wetlands), in general, export the least amount of phosphorus to a lake and are beneficial for maintaining good water quality.

Kentuck Lake's watershed area relative to the lake surface area yields a small watershed to lake area ratio of 2:1. This means that there are approximately two acres of land draining to every one acre of Kentuck Lake. As discussed previously, in watersheds with smaller watershed to lake area ratios, the types of land cover draining to the lake play a significant role in influencing the lake's water quality. WiLMS estimated that the water residence time, or time it takes for the water in Kentuck Lake to completely replace itself is approximately five years and four months.

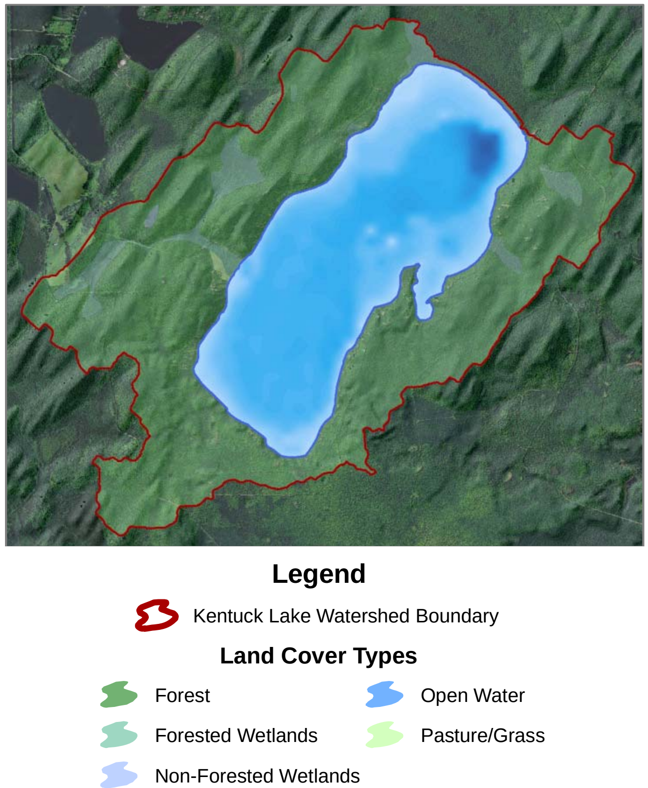


Figure 3.2-1. Kentuck Lake watershed boundary and land cover types. Final watershed boundaries were determined using Vilas County LIDAR data.

Using WiLMS, the acreages of land cover types within Kentuck Lake's watershed were used to determine the annual potential phosphorus load to the lake. This modeling indicated that Kentuck Lake potentially receives an estimated 428 pounds of phosphorus from its watershed on an annual basis (Figure 3.2-3). Atmospheric deposition of phosphorus directly onto the lake surface itself and forested areas within the watershed account for the largest external sources of phosphorus to the lake. Septic systems within the lake's watershed can leach phosphorus which can make its way into a lake.

Using the septic output estimator in WiLMS, an estimate of phosphorus loading attributed to septic leakage was calculated based on the results received from the Kentuck Lake stakeholder survey (Appendix B). Using the number of riparians per type of residence (year-round, seasonal, etc.) and assuming each residence has two people and that the septic system is functioning properly, the model indicated that Kentuck Lake receives approximately 14 pounds of phosphorus annually from septic tank outputs. While this is only an estimate, this is a small amount relative to the other external sources of phosphorus entering the lake.

The model also predicts the average in-lake growing season mean phosphorus concentration based upon the estimated annual total phosphorus load. The natural lake model in WiLMS estimated the growing season mean total phosphorus concentration to be approximately 17.0 μg/L, around 13 μg/L lower than the measured growing season mean total phosphorus concentration of approximately 30 μg/L. The discrepancy between the predicted and measured phosphorus concentrations is an indication that sources of phosphorus are entering the lake that were not accounted for in the model.

As discussed within the Water Quality Section, it is believed this unaccounted source of phosphorus is largely a result of internal phosphorus loading from bottom sediments as a result of periodic mixing events over the course of the growing season. The watershed modeling predicted that Kentuck Lake has a water residence time of approximately 5.4 years, indicating that phosphorus has likely accumulated within the sediment over time as it is not being flushed downstream. In essence, Kentuck Lake is acting as a settling basin for incoming nutrients. While phosphorus is likely being released from bottom sediments annually as evidenced by mainly moderate increases in total phosphorus concentrations throughout the growing season, the magnitude of increase observed in 2011 and 2013 was likely due to weather-related factors and resulting differences in stratification between these years as previously discussed.

In order to achieve the actual in-lake growing season mean total phosphorus concentration of around 30 μg/L an additional 1,100 lbs of phosphorus (total 1,528 lbs) need to be loaded to Kentuck Lake on an annual basis. This means that approximately 72% of Kentuck Lake's annual phosphorus load originates from internal sources, while the remaining 28% is delivered from the external sources within the watershed (Figure 3.2-2).

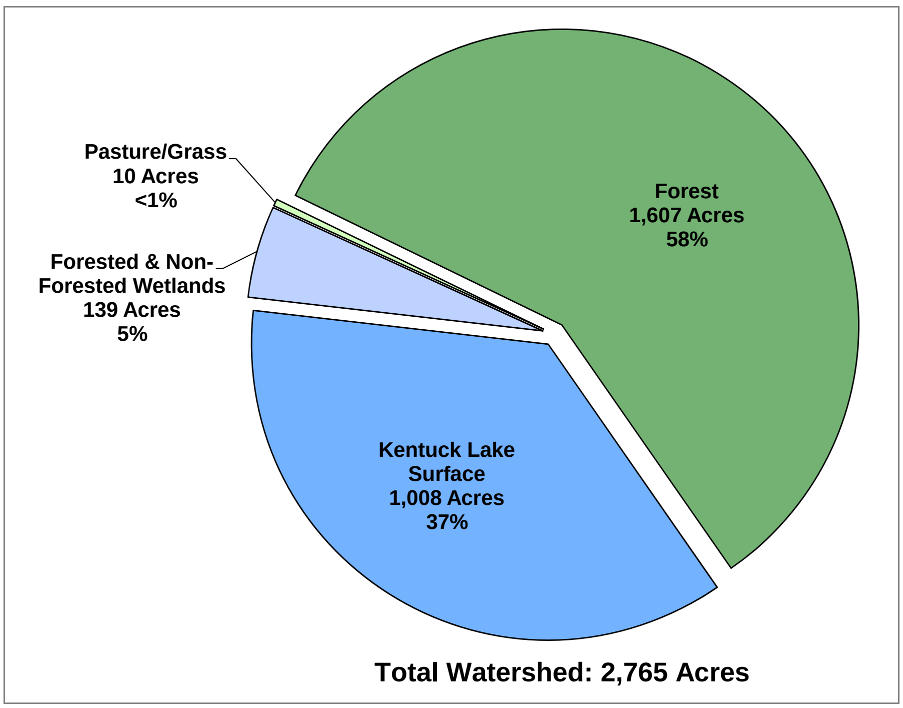


Figure 3.2-2. Kentuck Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

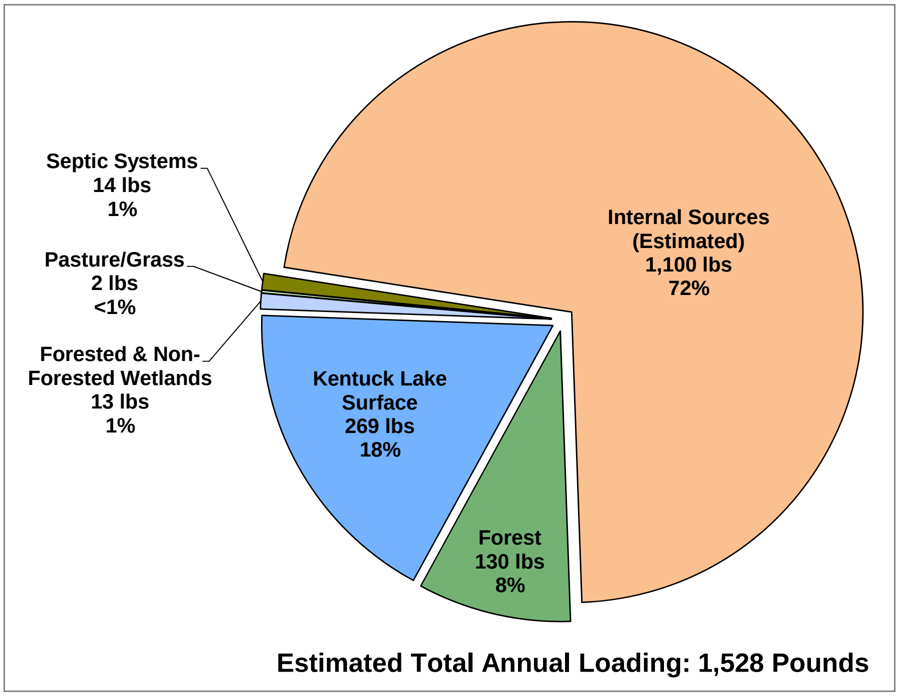


Figure 3.2-3. Kentuck Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates and 1988-2014 water quality data.

3.3 Shoreland Condition Assessment

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 reduce 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 where they can watch 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 along the shoreland zone such as rip rap or seawalls comprised of masonry, steel, or wood completely remove natural habitat for most animals, and prevent some animals such as amphibians from migrating from the water onto shore. In addition, these developments may also create habitat for snails, which can become problematic in lakes that experience problems with swimmers itch. 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 more strict shoreland ordinances. Passed in February of 2010, a revised 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 of their own. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013. These policy regulations require each county address ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- 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 the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. No permit is required for removal of vegetation that meets any of the above criteria. 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 entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- 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. New 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 no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: New 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, dependent on the county.

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county's regulations/zoning department.

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, including Kentuck Lake, 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. Ground-water 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.

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 in 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*".

The results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect and restore lakes. This will become increasingly important as development pressure on lakes continue to steadily 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 3.3-1. 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.

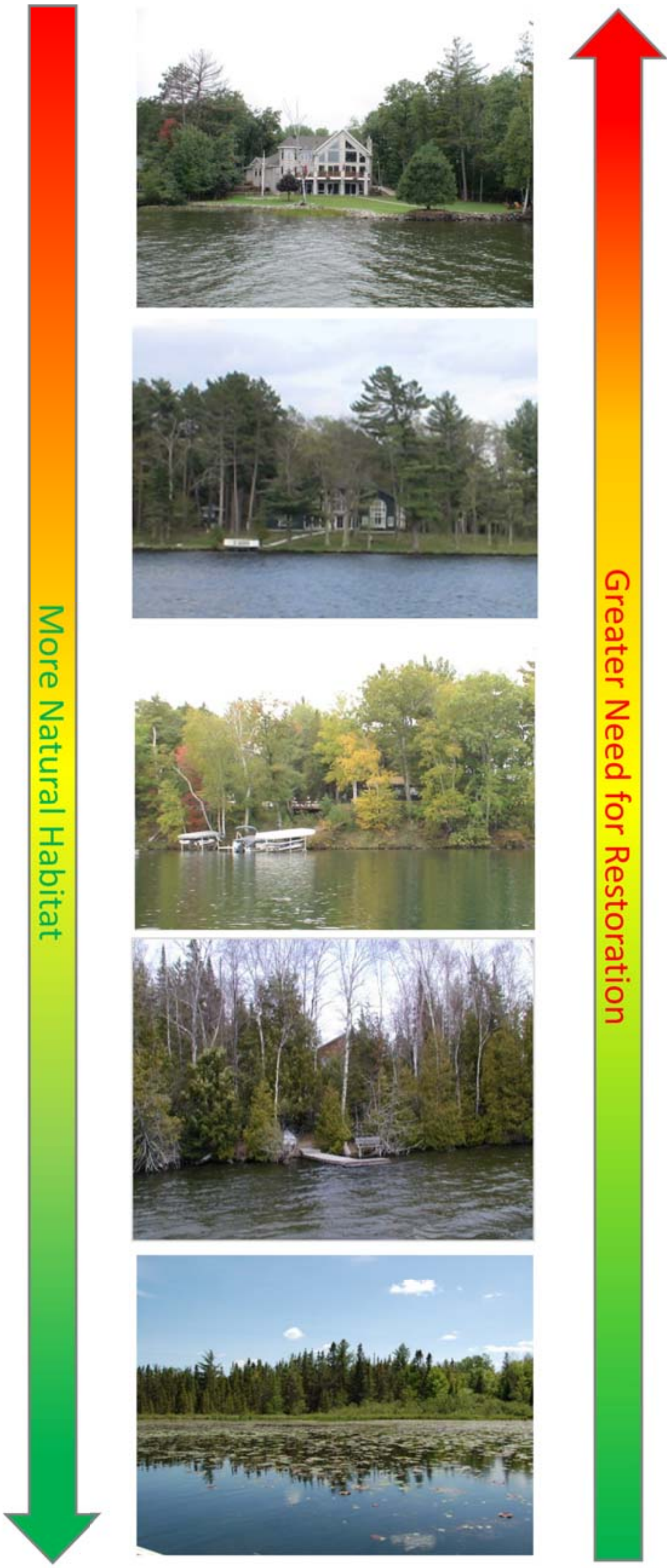
- An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be 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.

Kentuck Lake Shoreland Zone Condition

Shoreland Development

Kentuck 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, from “Urbanized”, meaning the shoreland zone is completely disturbed by human influence, to “Natural/Undeveloped”, meaning the shoreland has been left in its original state.



Urbanized: This type of 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.

On Kentuck Lake, the development stage of the entire shoreland was surveyed during the fall of 2013 using a GPS unit. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

Kentuck Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.3 miles (53%) of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.5 miles (9%) of urbanized and developed–unnatural shoreland were observed. If restoration of the Kentuck Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

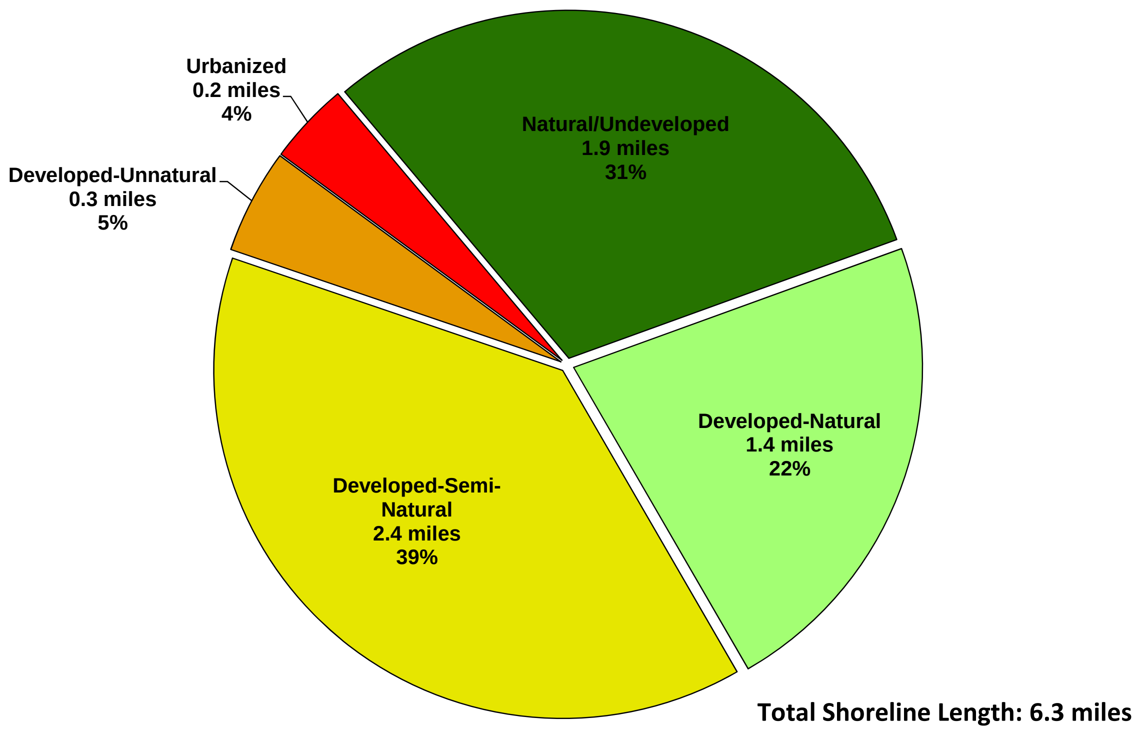


Figure 3.3-2. Kentuck Lake shoreland categories and total lengths. Based upon a Fall 2013 survey. Locations of these categorized shorelands can be found on Map 3.

Approximately 1.26 miles of the Kentuck Lake shoreline is federally owned of which 0.86 miles along the northern shore was designated as a State Natural Area in 2007 (Fig 3.3-3). This 291 acre area has a unique topography created over time by wind and wave action that provides habitat for a wide variety of plant and animal species, many of which are relatively rare.

An extensive shoreline study was completed in 1999 that provides a thorough assessment of the shores of Kentuck Lake at that time (Gillum). The study looked at parcels of land around the lake broken up by individual landowners (public or private) and provides a detailed description of the characteristics of the shoreland buffer zones as well as shoreline and near shore - shallow

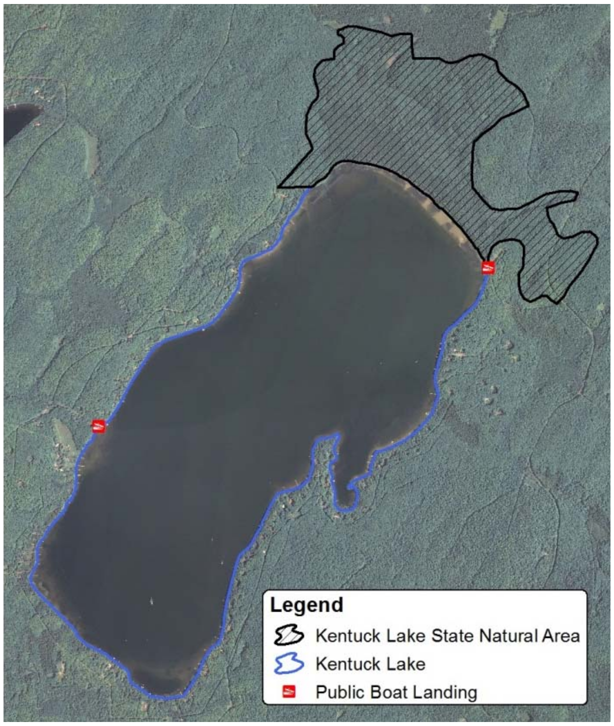


Figure 3.3-3. Location of Kentuck Lake State Natural Area.

water locations. The survey methods differ between the survey conducted in 1999 and the one done in 2013, however some aspects may be compared between the studies. The 1999 study found approximately 1,159 feet (or 3.6%) of shoreline containing rip-rap or a seawall. In the survey conducted by Onterra in 2013, approximately 667 feet of shoreline was identified as containing a seawall composed of rip-rap or masonry work, showing a decrease of about 42% since 1999 (Map 3). Approximately 70% of the shoreland footage was classified as having some degree of development in 1999 with about 30% being described as undeveloped (Gillum), which is similar to the percentages of developed/undeveloped shoreland classified in the 2013 study (Fig 3.3-2).

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, 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

Kentuck Lake was also surveyed in 2013 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 three size categories (2-8 inches diameter, >8 inches diameter, or cluster) 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, 43 total pieces of coarse woody habitat were observed along 6.3 miles of shoreline, which gives Kentuck Lake a coarse woody habitat to shoreline mile ratio of 7:1. Locations of coarse woody habitat are displayed on Map 4.

Coarse woody debris was documented in the 1999 survey of Kentuck Lake (Gillum). In the study, the relative amount of downed logs and large braches at each parcel was described within the 35 foot shoreland zone, the shoreline, and in shallow water (Table 3.3-1). These data are not directly comparable to the 2013 survey due to differences in survey methodology. In 2013, only the coarse woody habitat that stretched from the shoreline into the water was considered. The data collected in 1999 indicated that at least some coarse woody habitat was present in approximately 73% of the shallow water sites and 84% of the shoreline locations within the parcels studied.

Table 3.3-1. Summary of coarse woody debris from Gillum 1999 study.

	None		Little		Moderate		Much	
Lakeshore Area	#	%	#	%	#	%	#	%
Buffer Zone	17	12.98	33	25.19	31	23.66	50	38.17
Shoreline	21	16.03	45	34.35	33	25.19	32	24.43
Shallow Water*	35	26.72	65	49.62	20	15.27	9	6.90

** 9 parcels (1.53%) not noted on field sheet*

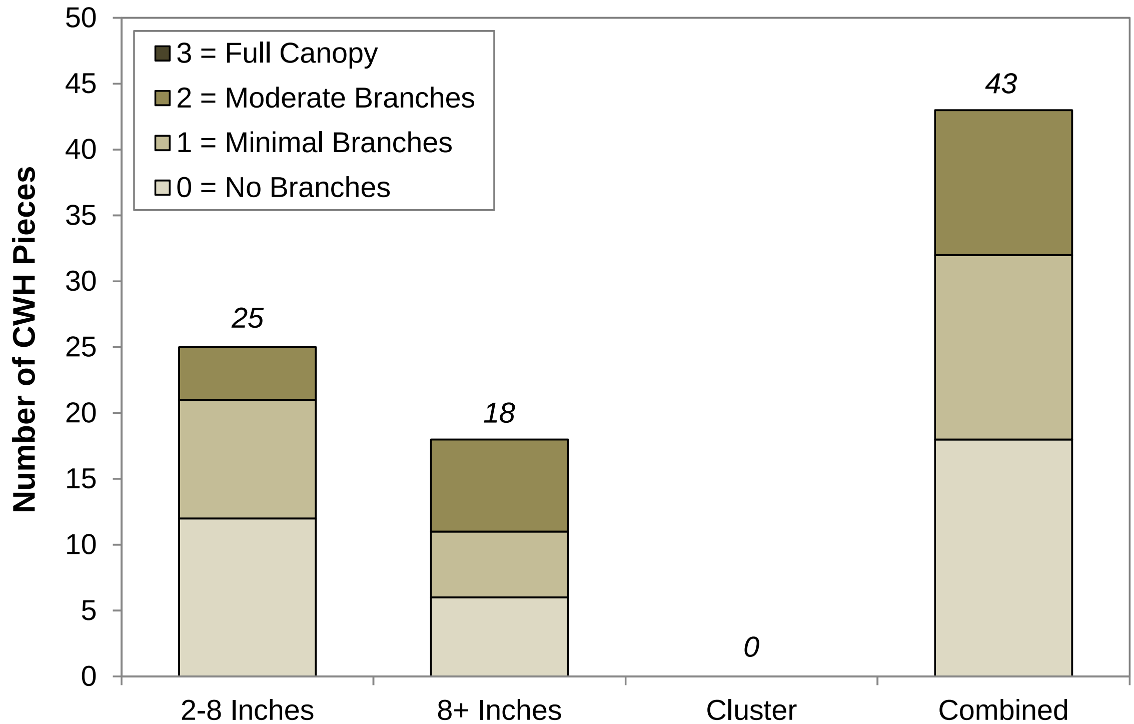


Figure 3.3-4. Kentuck Lake 2013 coarse woody habitat survey results. Based upon a Fall 2013 survey. Locations of Kentuck Lake coarse woody habitat can be found on Map 4.

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.

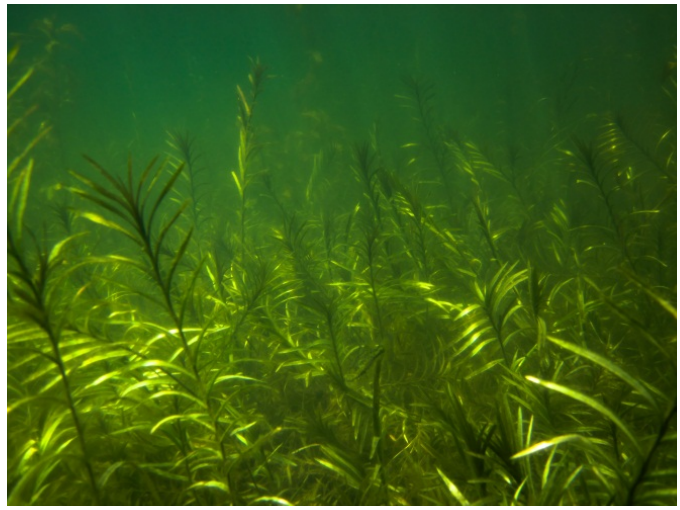


Photo 3.4-1. Native aquatic plant community. Fern pondweed (*Potamogeton robbinsii*).

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife (Photo 2.1-1). 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 water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

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

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

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

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

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 water-milfoil 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

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

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

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

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

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

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

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.

2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • 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 fishkills 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 water-milfoil 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 water-milfoil 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 water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

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

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Kentuck Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. The point-intercept method as described by the Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was used to complete the whole-lake point-intercept surveys on Kentuck Lake. Based upon guidance from the WDNR, a point spacing (resolution) of 86 meters was used resulting in 543 sample locations.

At each point-intercept location within the littoral zone, information regarding the depth, substrate type (muck, sand, or rock), and the plant species sampled along with their relative abundance (Figure 3.4-1) on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 13 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 13 feet. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways.

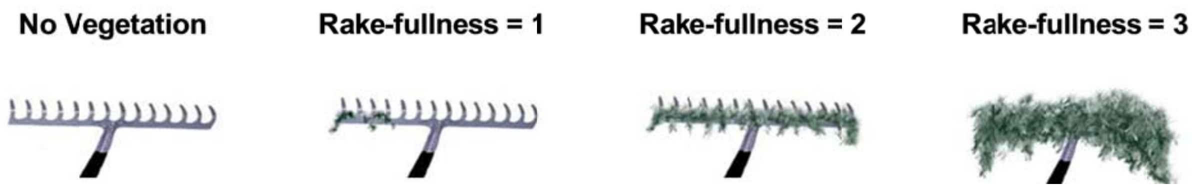


Figure 3.4-1. Aquatic plant rake fullness ratings. Adapted from Hauxwell et al (2010).

Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset are compared to Kentuck Lake. Comparisons are displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

A box plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreland. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreland complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreland complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

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

Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

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

Community Mapping

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

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). Eurasian water-milfoil 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 water-milfoil 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 water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

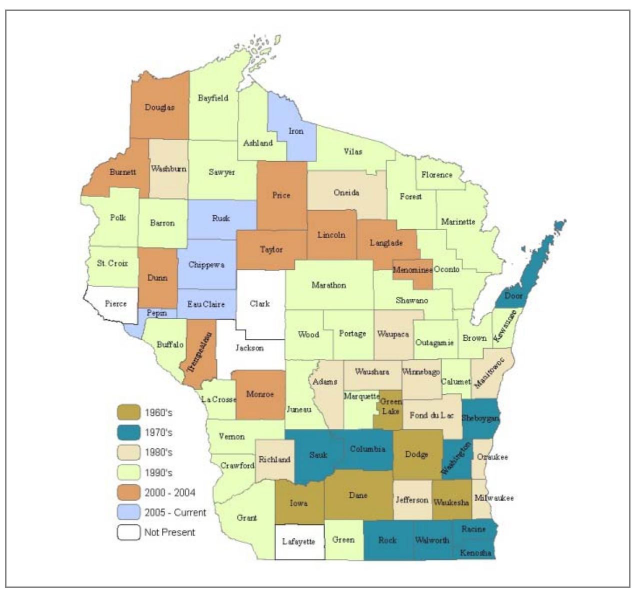


Figure 3.4-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

As mentioned earlier, numerous aquatic plant surveys were completed as a part of this project. On July 3, 2013, an Early-Season Aquatic Invasive Species (AIS) survey was completed on Kentuck Lake. While the intent of this survey is to locate any potential non-native species within the lake, it's primarily focused on locating any occurrences of curly-leaf pondweed. During this meander-based survey of the *littoral zone*, Onterra ecologists located a number of single occurrences of curly-leaf pondweed occurrences widely scattered throughout shallower areas of the lake. Because of this plant's importance, the occurrence of curly-leaf pondweed in Kentuck Lake and recommended actions to control this invasive plant is discussed in the following Non-Native Plant Section.

Littoral Zone is the area of a lake where sunlight is able to penetrate down to the sediment and support aquatic plant growth.

The whole-lake aquatic plant point-intercept survey was conducted by members of the WDNR on July 18, 19, and 20, 2011, while the emergent and floating-leaf aquatic plant community mapping survey was conducted by Onterra on August 14, 2013. During these surveys, 43 species of aquatic plants were located in Kentuck Lake, two of which are considered to be non-native, invasive species: curly-leaf pondweed and Eurasian water milfoil (Table 3.4-1). As mentioned, these non-native aquatic plants are discussed in detail in the Non-Native Plant Section.

Despite having lower-than-average water clarity in Kentuck Lake in 2011, aquatic plants were found growing to a maximum depth of 24 feet during the WDNR's point-intercept survey, indicating the majority of Kentuck Lake is comprised of littoral area. Of the 518 point-intercept sampling locations that fell at or below the maximum depth of plant growth, approximately 57% contained aquatic vegetation. Figure 3.4-3 displays the distribution of aquatic vegetation in Kentuck Lake as determined from the 2011 point-intercept survey and illustrates the majority of the lake supports aquatic plant growth. In addition, total rake fullness ratings indicate that aquatic plant biomass is relatively low, with the majority (61%) of point-intercept locations containing aquatic vegetation having a total rake fullness rating of 1.

Table 3.4-1. Aquatic plant species located in Kentuck Lake during a WDNR 2011 point-intercept survey and an Onterra 2013 community mapping survey.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2011 (WDNR)	2013 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5		I
	Carex lacustris	Lake sedge	6		I
	Dulichium arundinaceum	Three-way sedge	9		I
	Eleocharis palustris	Creeping spikerush	6	X	I
	Equisetum fluviatile	Water horsetail	7	I	I
	Sagittaria latifolia	Common arrowhead	3		I
	Sagittaria spp. *(sterile)*	Arrowhead spp. (sterile)	N/A		I
	Schoenoplectus acutus	Hardstem bulrush	5	X	I
	Schoenoplectus pungens	Three-square rush	5	X	
	Schoenoplectus subterminalis	Water bulrush	9	X	
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Sparganium spp.	Bur-reed species	N/A	X	
	Typha spp.	Cattail spp.	1	I	I
FL	*Nuphar variegata*	Spatterdock	6	I	
	Nymphaea odorata	White water lily	6	I	I
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9		I
	Sparganium fluctuans	Floating-leaf bur-reed	10		I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	
	Chara spp.	Muskgrasses	7	X	
	Elodea canadensis	Common waterweed	3	X	
	Elodea nuttallii	Slender waterweed	7	X	
	Heteranthera dubia	Water stargrass	6	X	
	Isoetes spp.	Quillwort species	N/A	X	
	Myriophyllum sibiricum	Northern water milfoil	7	X	
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	I
	Myriophyllum tenellum	Dwarf water milfoil	10	X	
	Najas flexilis	Slender naiad	6	X	
	Nitella spp.	Stoneworts	7	X	
	Potamogeton amplifolius	Large-leaf pondweed	7	X	
	Potamogeton crispus	Curly-leaf pondweed	Exotic		I
	Potamogeton gramineus	Variable pondweed	7	X	
	Potamogeton illinoensis	Illinois pondweed	6	X	
	Potamogeton praelongus	White-stem pondweed	8	X	
	Potamogeton pusillus	Small pondweed	7	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	
	Potamogeton robbinsii	Fern pondweed	8	I	
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	
	Sagittaria sp. *(rosette)*	Arrowhead rosette	N/A	X	
	Vallisneria americana	Wild celery	6	X	
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	
	Juncus pelocarpus	Brown-fruited rush	8	X	
	Sagittaria cuneata	Arum-leaved arrowhead	7	I	
FF	*Lemna turionifera*	Turion duckweed	2	X	

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

As discussed, during the 2011 whole-lake point-intercept survey, information regarding substrate type was also collected at point-intercept locations within littoral areas. These data indicate that 55% of the sampling locations where the sediment type was able to be determined contained soft sediments, 37% contained sand, and 8% contained rock (Figure 3.4-4). 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. In Kentuck Lake, areas of sand are located in shallower, near-shore areas, while areas of softer sediments were located in areas of deeper water.

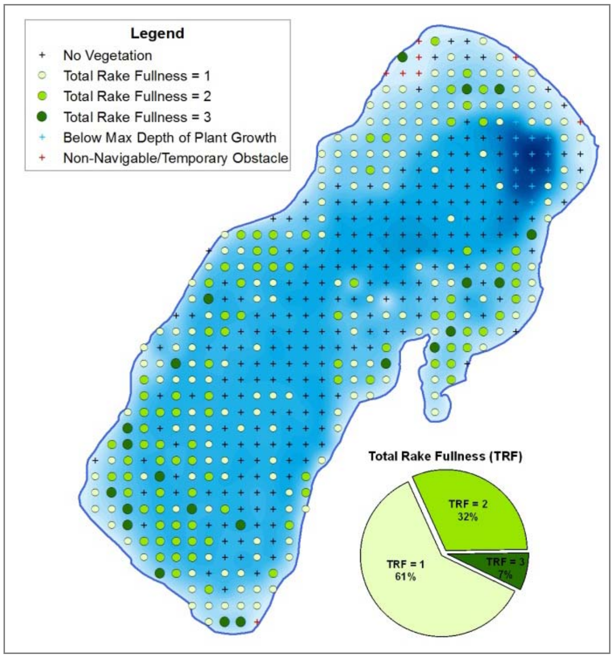


Figure 3.4-3. Kentuck Lake distribution of aquatic vegetation. Created using data from WDNR 2011 point-intercept survey.

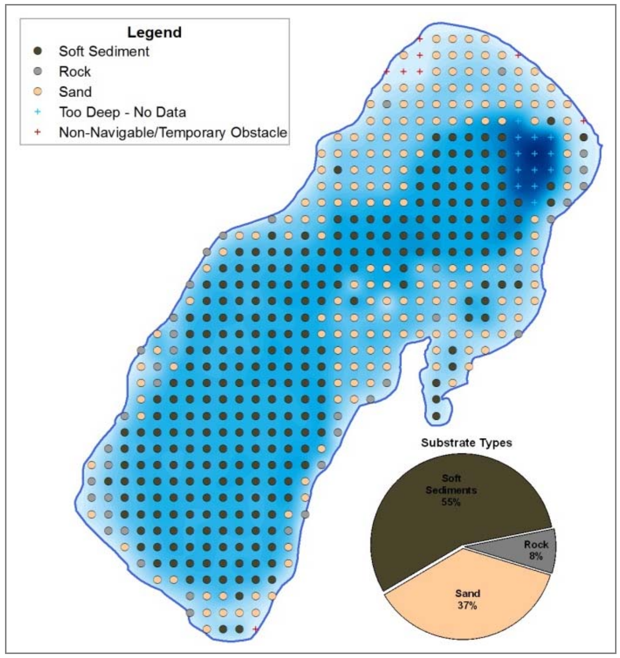


Figure 3.4-4. Kentuck Lake distribution of substrate types. Created using data from WDNR 2011 point-intercept survey.

Of the 35 aquatic plant species located during 2011 point-intercept survey on Kentuck Lake, 29 were physically encountered on the rake during the whole-lake point-intercept survey. The remaining 6 species were located incidentally. Of the 29 species encountered on the rake, coontail, common waterweed, slender naiad, and small pondweed were the four-most frequently encountered (Figure 3.4-5). Coontail, with a littoral occurrence of approximately 46%, is arguably the most common aquatic plant in Wisconsin. Free-floating beneath the water, coontail lacks true roots and obtains all of its nutrients directly from the water. It can be found growing along the bottom or tangled amongst rooted aquatic plants. Because of its ability to obtain nutrients directly from the water and tolerate low-light conditions, coontail is often one of the most dominant plants in eutrophic systems like Kentuck Lake. Its stiff and dense foliage provides excellent structural habitat for aquatic organisms. In 2011, coontail was most abundant between 7 and 16 feet of water in Kentuck Lake.

With a littoral occurrence of 16%, common waterweed was the second-most frequently encountered aquatic plant in Kentuck Lake in 2011 (Figure 3.4-5). As its name indicates, common waterweed like coontail can be found in waterbodies across North America. And like coontail, common waterweed is often one of the more dominant aquatic plants in high-nutrient lakes as it is able to tolerate low-light conditions and obtain nutrients from the water. In 2011, common waterweed was most abundant between 6 and 9 feet of water.

Slender naiad, the third-most frequently encountered plant species in Kentuck Lake with a littoral occurrence of 7.3% (Figure 3.4-5), is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 1997). Being an annual, slender naiad produces numerous seeds every year, and its small, condensed network of leaves provide excellent habitat for aquatic organisms. In Kentuck Lake, slender naiad was most abundant between 4 and 6 feet of water over areas with sandy substrates.

The fourth-most frequently encountered aquatic plant in Kentuck Lake in 2011 was small pondweed, with a littoral occurrence of 7.0% (Figure 3.4-5). Small pondweed is the most common of the several narrow-leaf pondweed species found in Wisconsin. This plant possesses long stems that contain narrow, linear-shaped leaves. Often growing in dense beds, small pondweed creates a dense network of structural habitat for aquatic wildlife.

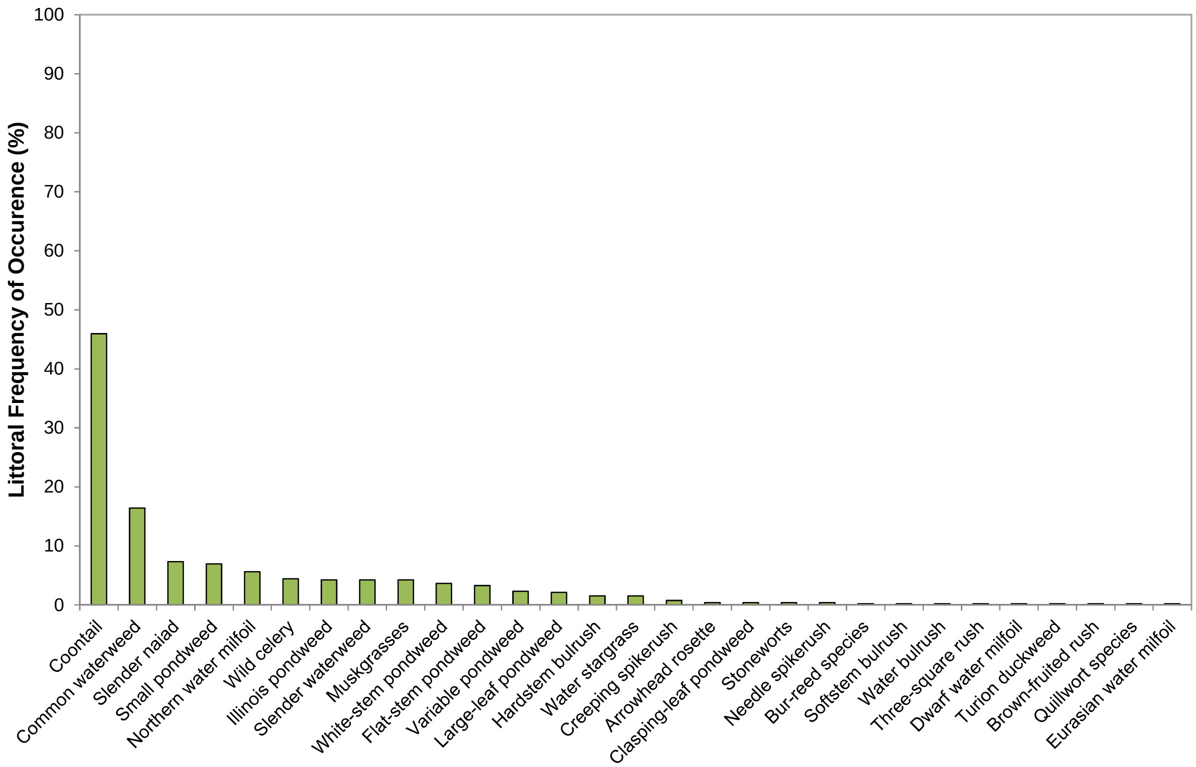


Figure 3.4-5. Kentuck Lake 2011 littoral frequency of occurrence of aquatic plant species. Created using data from WDNR 2011 point-intercept survey. Exotic species indicated with red.

As discussed in the primer section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the native aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The 28 native aquatic plant species encountered on the rake during the 2011 point-intercept survey and their conservatism values were used to calculate the FQI of Kentuck Lake's aquatic plant community (equation shown below).

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

Figure 3.4-6 compares the 2011 FQI components of Kentuck Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion and lakes throughout Wisconsin. As illustrated, Kentuck Lake's native species richness (28) exceeds the upper quartile values for other lakes within the ecoregion and the state. However, Kentuck Lake's average conservatism value (6.1) falls below the median value of 6.7 for the ecoregion and is slightly above the state-wide median value of 6.0. This indicates that Kentuck Lake contains fewer sensitive species (species with higher C-values) than the majority of other lakes in the NLFL Ecoregion, and its plant community's composition is more comparable to lakes state-wide. Many of these sensitive species found in northern Wisconsin cannot tolerate lower-light conditions, or become out-competed by species more suited to eutrophic systems. While Kentuck Lake contains fewer sensitive aquatic plant species, its high species richness results in a high FQI value of 32.7, which exceeds the upper quartile values for both lakes in the ecoregion and the state.

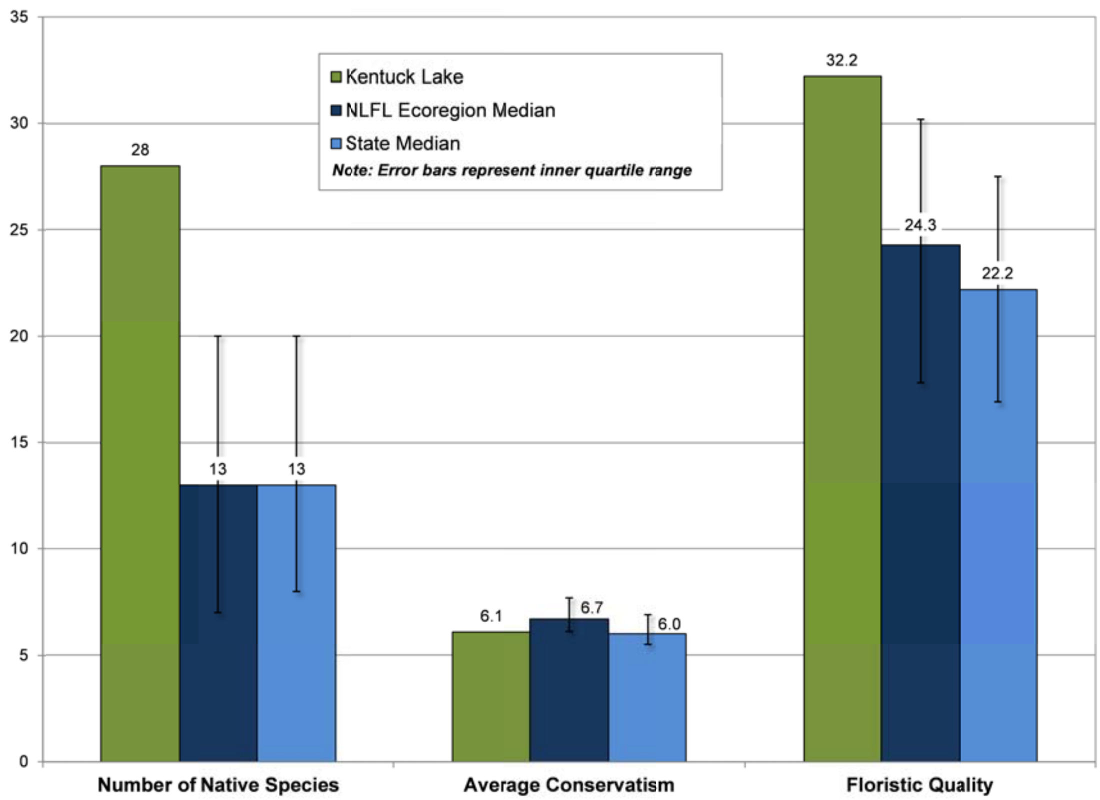


Figure 3.4-6. Kentuck Lake Floristic Quality Assessment. Created using data from WDNR 2011 point-intercept survey.

As explained earlier, 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 Kentuck Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However,

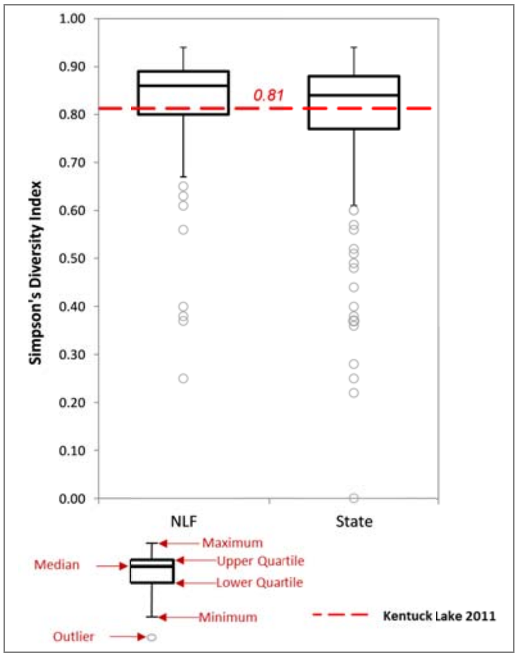


Figure 3.4-7. Kentuck Lake Simpson's Diversity Index. Created using data from WDNR 2011 point-intercept survey.

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 Kentuck Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 3.4-7). Using the data collected from the 2011 point-intercept survey, Kentuck Lake's aquatic plant community was shown to have low species diversity with a Simpson's diversity value of 0.81, indicating a relatively uneven distribution of species within the community. This value falls below the median values for both lakes in the ecoregion and lakes throughout the state. In other words, if two individual aquatic plants were randomly sampled from Kentuck Lake in 2011, there would be an 81% probability that they would be different species.

As previously discussed, the previously displayed littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at approximately 46% of the littoral sampling locations in Kentuck Lake in 2011, its relative frequency of occurrence was 39%. Explained another way, if 100 plants were randomly sampled from Kentuck Lake, 39 of them would be coontail. Figure 3.4-8 displays the relative occurrence of aquatic plant species from Kentuck Lake in 2011. Over 50% of the plant community is dominated by just two plant species, coontail and common waterweed. This dominance by a few species is why the community's diversity is so low. The eutrophic conditions in Kentuck Lake likely give coontail and common waterweed a competitive advantage over other aquatic plant species.

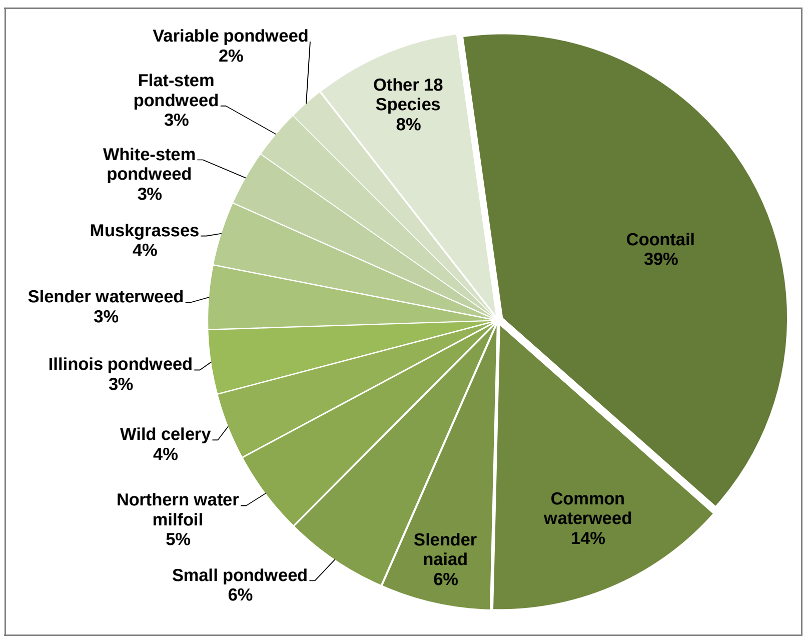


Figure 3.4-8. Kentuck Lake 2011 relative frequency of occurrence of aquatic plant species. Created using data from WDNR 2011 point-intercept survey.

The 2013 aquatic plant community mapping survey revealed that Kentuck contains approximately 60.6 acres of emergent and floating-leaf aquatic plant communities (Table 3.4-2, Map 6). Thirteen emergent and floating-leaf aquatic plant species were located in the lake in 2013 (Table 3.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. In addition, they stabilize bottom sediments and reduce sediment resuspension and shoreline erosion.

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Kentuck Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. A stakeholder survey of Kentuck Lake stakeholders indicates that motorboats with a 25 horsepower or greater motor are the most prevalent watercraft on the lake (Appendix B, Question #12).

Table 3.4-2. Acres of emergent and floating-leaf aquatic plant communities on Kentuck Lake. Created using data from 2013 aquatic plant community mapping survey.

Plant Community	2013 Acres
Emergent	54.8
Floating-Leaf	5.6
Mixed Emergent & Floating-Leaf	0.2
Total	**60.6**

Non-Native Aquatic Plants in Kentuck Lake

Eurasian water milfoil

Eurasian water milfoil (*Myriophyllum spicatum*; EWM) was first documented in Kentuck Lake in 2011, and during the WDNR's 2011 point-intercept survey, it had very low littoral occurrence of 0.2% (Figure 3.4-5). In the summer of 2012, Onterra was contracted by the KLPRD to conduct an EWM Peak-Biomass Survey to locate and map areas of EWM. Coordinates relating to EWM locations were provided to Onterra by members of the KLPRD to aid in the August 2012 survey. During this survey, approximately 13.4 acres of colonized EWM were located in near shore along the eastern and southeastern portions of the lake (Map 6). Areas comprised of single plants and clumps of plants were also located in other areas around the lake. Following discussions between Onterra and the KLPRD, an 18.6-acre treatment was proposed for 2013 targeting these colonized areas of EWM.

Understanding concentration-exposure times are important considerations for implementing successful control strategies utilizing 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 a joint research project between the WDNR, U.S. Army Engineer Research and Development Center (USAERDC), and private consultants. Based on their preliminary findings, lake managers have adopted two main treatment strategies: 1) whole-lake treatments, and 2) spot treatments.

Whole-lake treatments are those where the herbicide is applied to specific sites, but the goal of the strategy is for the herbicide to reach a target concentration when it equally distributes throughout the entire volume of the lake (or lake basin, or within the epilimnion of the lake or lake basin). The application rate of whole-lake treatments is dictated by the volume of water in which the herbicide will reach equilibrium with. Because exposure time is so much greater, effective herbicide concentrations for whole-lake treatments are significantly less than required for spot treatments. Whole-lake treatments are typically conducted when the target plant is spread throughout much of the lake or basin.

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 effects outside of that area. Ongoing research indicates that herbicide quickly dissipates and dilutes from spot treatments, especially small spot treatments (less than five acres). In order for mortality of the target plants to occur, the short exposure time (often hours) needs to be offset by the plants being exposed to a high herbicide concentration. Like terrestrial herbicide applications, spot treatments are used by lake managers to strategically target a specific colony of a target plant. However, obtaining effective herbicide concentration and exposure times has proven difficult in many instances. In these cases, the treatment results in seasonal control such that the target plants are greatly injured by the treatment, but fully rebounds by the end of the summer. Because EWM was not widespread in Kentuck Lake, a spot treatment strategy was proposed for 2013.

With Onterra's assistance, the KLRPD successfully applied for a WDNR AIS Early Detection and Response Grant to cover the costs of the 2013 treatment and associated monitoring. In addition, the grant would cover the treatment and monitoring costs for 2014. Granular 2,4-D, which is typically used in spot-treatment scenarios, was chosen for site C-13. 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. 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. These two factors led to the use of liquid 2,4-D being applied on sites A-13 and B-13. It was theorized that the close spatial relationship of these two sites would also aid in obtaining sufficient herbicide concentrations and exposure times to cause EWM control.

Herbicide concentration monitoring within and around the treatment areas following the treatment indicated that a higher 2,4-D concentration was achieved within the liquid 2,4-D application sites compared to the granular 2,4-D site. As discussed, the granular treatment site was conducted in an area of the lake that was more exposed, while the liquid treatment areas were more protected that had more barriers (shorelines) that kept the herbicide from migrating out of this area.

Post-treatment EWM evaluation indicated that the 2013 treatments were highly successfully at reducing EWM. No EWM could be located within treatment sites A-13 or B-13 following the treatment, while only a few single EWM plants were located in site C-13 (Map 7). Quantitative evaluation of the treatment via sub-sample point-intercept survey (104 locations) indicated the frequency of EWM declined by a statistically valid 88.5% following the treatment (Chi-square $\alpha = 0.05$) (Figure 3.4-9).

Along with assessing the 2013 treatment areas, Onterra conducted another meander-based Late-Summer EWM Peak-Biomass Survey in August of 2013. Again, members of the KLRPD provided coordinates regarding areas where they had located EWM. As displayed on Map 7, numerous EWM occurrences were located in Kentuck Lake during the August 2013 survey. Although more wide-spread than was thought to have existed, the EWM population within Kentuck Lake was found to be extremely sparse and of low density. Only two small colonies of *Highly Scattered* and *Scattered* EWM were located, totaling less than a third of an acre.

As discussed, conducting an effective herbicide control project on small sites can be extremely challenging and the results can be unpredictable. Conducting herbicide control strategies on individual plants or even small colonies will not prove effective unless grouped into a much larger treatment site where sufficient herbicide concentrations and exposure times are more likely to be achieved. The EWM population within Kentuck Lake is currently at too low of a level for herbicide control methods to be effective, and no treatment was proposed for 2014.

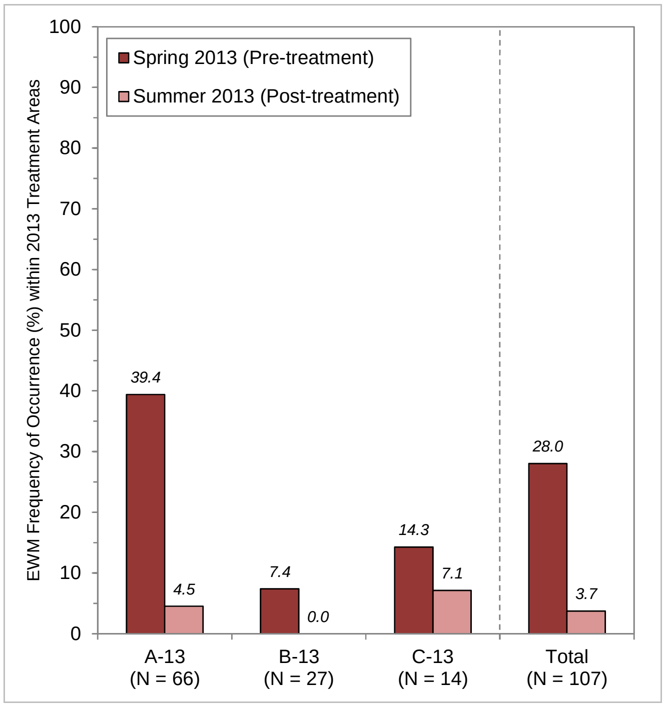


Figure 3.4-9. Quantitative 2013 EWM treatment monitoring results. Pre- and post-treatment EWM occurrence was statistically different (Chi-square α = 0.05) in site A-13 and when data were combined from all treatment areas. Created using data collected from 104 sampling locations within 2013 treatment areas.

On August 26, 2014, Onterra ecologists conducted the Late-Summer EWM Peak-Biomass Survey on Kentuck Lake. During the survey, the majority of the EWM observed was comprised of widely distributed *single or few plants*, *clumps of plants*, and *small plant colonies*, with the highest concentrations occurring along the southern and northern shores (Map 8). An area of slightly denser EWM delineated as *highly scattered* was located in the southeastern portion of the lake within the 2013 treatment area C-13, indicating EWM is beginning to rebound within this area. Additionally, two small areas of *highly scattered* EWM were located along the north shore, a small *scattered* area was located along the southern shore, and a 0.03-acre area of *surface matted* EWM was located along the west shore.

As discussed within the Implementation Plan Section, the threshold or “trigger” for initiating an EWM herbicide spot treatment on Kentuck Lake is if a colonized area of EWM of at least three acres and has a density rating of *dominant* or greater is located. Because no areas of EWM within Kentuck Lake met these criteria in 2014, no herbicide control strategy targeting EWM is proposed for 2015.

Curly-leaf pondweed

Curly-leaf pondweed (*Potamogeton crispus*; CLP) was first documented in Kentuck Lake in 1999. However, according to KLPRD members, it was not observed again in the lake again until July of 2012. During the early summer of 2012, the KLPRD observed a few CLP occurrences within the lake, but there was not an accurate understanding of where in the lake the CLP existed. During Onterra's 2012 survey, a few floating CLP fragments were observed, but no rooted plants could be located.

An Early-Season AIS (ESAIS) survey was planned to occur in late-June of 2013 to coincide with the peak growth stage of CLP. However, scheduling conflicts due to weather conditions pushed the survey back to July 3, 2013. During this whole-lake meander-based survey, a small number of CLP *single or few plants* and *clumps of plants* were observed during this survey (Map 8). The current CLP population within Kentuck Lake is not forming dense colonies that are negatively impacting the ecology nor the recreational use of the lake, and no herbicide control strategy was proposed for 2014. Particularly in northern Wisconsin, not all established CLP populations become problematic to the lake ecosystem. However, continued monitoring will be essential so actions can be taken quickly if the population expands and becomes problematic.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Kentuck Lake. The goal of this section is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, angling regulations, etc) that were brought forth by the KLPRD stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2014 & GLIFWC 2013A and 2013B).

Kentuck Lake Fishery

Kentuck Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on Kentuck Lake (Question #13). Approximately 33% of these same respondents believed that the quality of fishing on the lake was either *good* or *excellent*, approximately 41% believed it to be *fair*, and 26% believed it to be *poor* or *very poor* (Question #11); and approximately 88% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Question #12).

Table 3.5-1 shows the popular game fish that are present in the system. 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 Kentuck Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

Table 3.5-1. Gamefish present in Kentuck Lake with corresponding biological information. (Becker 1983).

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
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)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of coarse 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

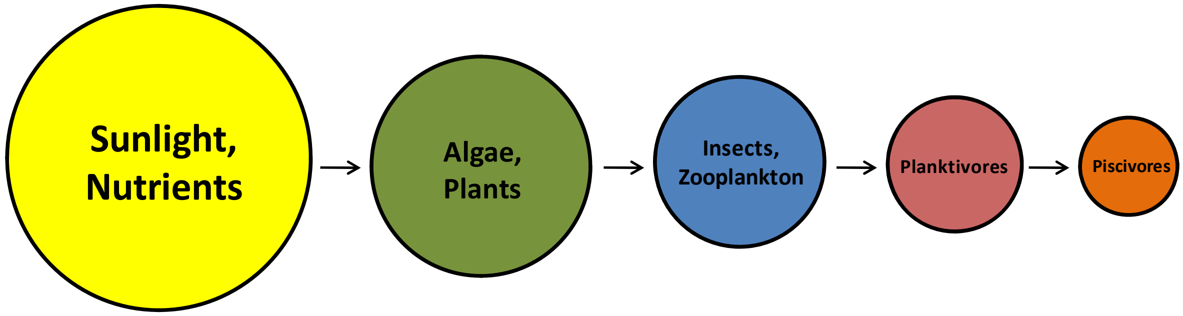


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Kentuck Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Kentuck Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

Because Kentuck Lake is located within ceded territory (discussed further below), special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Kentuck Lake. In 2013-2014, the daily bag limit was adjusted to two walleye per day. There is currently no minimum length limit for walleye, but only one fish over 14” is allowed.

For bass species, a catch and release season exists from the first Saturday in May through the third Friday in June. After the third Saturday in June the minimum length limit is 18” and a daily bag limit is limited to one fish. Kentuck Lake is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 40” to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and five pike may be kept in a single day. Statewide regulations apply for all other fish species.

Kentuck Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-1). Kentuck Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a “total allowable catch” is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake’s known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the “safe harvest level”. Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

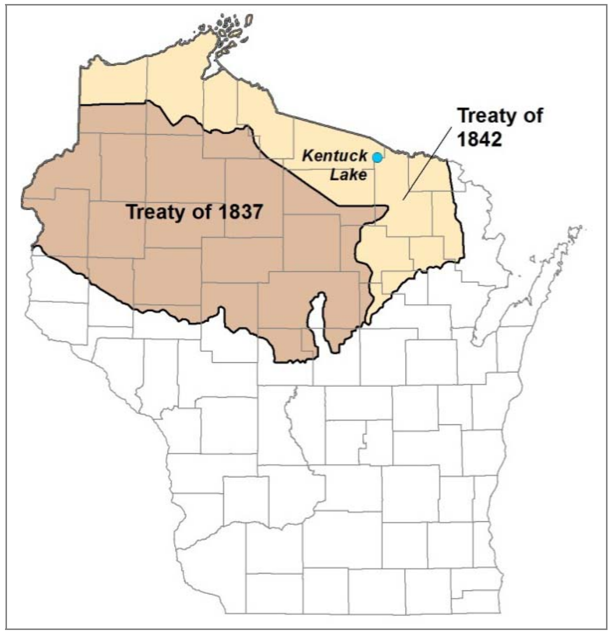


Figure 3.5-2. Location of Kentuck Lake within the Native American Ceded Territory (GLIFWC 2013A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2013B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 3.5-3. One common misconception is that the spear harvest targets the large spawning females. Figure 3.5-3 shows that 6.5% of the total walleye harvest (5,517 fish) from 1989 to 2013 was comprised of female fish. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2013B). This regulation limits the harvest of the larger, spawning female walleye.

Beginning in 1988, there were a series of walleye year class failures, the reasons for which are still unknown. In 1997, GLIFWC and the tribes presented a walleye recovery plan for Kentuck Lake to the WDNR. Following two years of discussion, this plan was implemented and included stocking of walleye fingerlings and a voluntary suspension of spearing from 1998-2000. In addition, stricter regulations for anglers were also put in place.

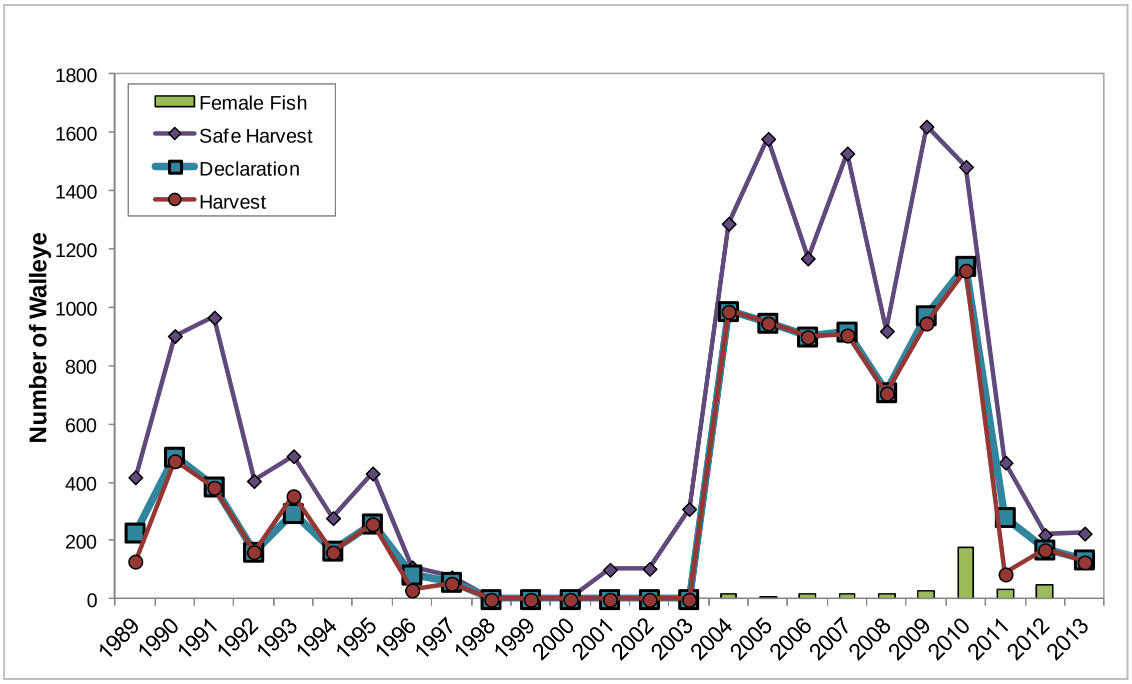


Figure 3.5-3. Kentuck Lake walleye spear harvest data. Annual total walleye harvest and female walleye harvest are displayed since 1989 from WDNR records (T. Cichosz, personal communication).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1989. Since 1989, approximately 1.3 muskellunge per year have been harvested during the open water spear fishery. In 2009 and 2010, seven and ten fish were harvested from the lake while in most years the harvest is considerably less.

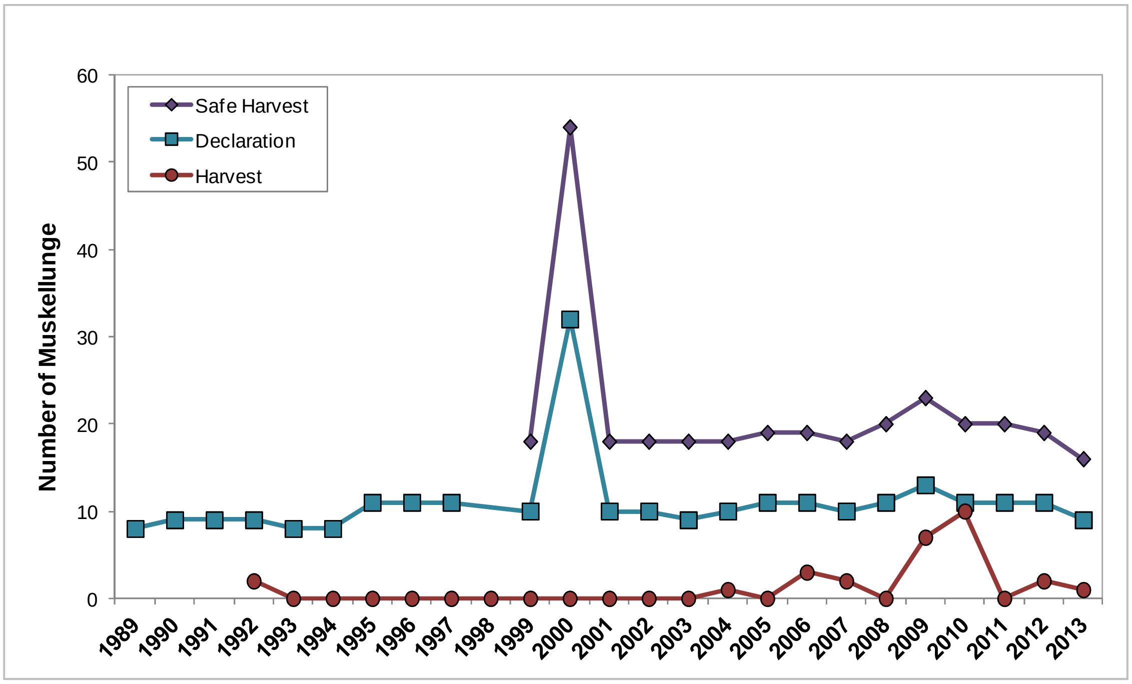


Figure 3.5-4. Kentuck Lake muskellunge spear harvest data. Annual total muskellunge harvest is displayed since 1989 from WDNR records (T. Cichosz, personal communication).

Kentuck Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by the WDNR in 2011, 55% of the substrate sampled in the littoral zone on Kentuck Lake was soft sediments, 37% was sand, and 8% was rock. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

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

Kentuck Lake Angling Regulations and Management

Because Kentuck Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Kentuck Lake. In 2014-2015, the daily bag limit has been set at two fish. Walleye of any length may be harvested, however only one fish can be over 14” in length.

Kentuck Lake is in the northern management zone for large and smallmouth bass as well as muskellunge and northern pike. Table 3.5-2 displays the 2014-2015 regulations for species that may be found in the lake. Please note that this table is intended to be for reference purposes only; anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-2. WDNR fishing regulations for the Kentuck Lake, 2014-2015.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth bass	May 3, 2014 – March 1, 2015	The minimum length limit is 18" and the daily bag limit is 1.
Smallmouth bass	May 3, 2014 to June 20, 2014	Fish may not be harvested (catch and release only)
	June 21, 2014 to March 1, 2015	The minimum length limit is 18" and the daily bag limit is 1.
Muskellunge and hybrids	May 24, 2014 to November 30, 2014	The minimum length limit is 40" and the daily bag limit is 1.
Northern pike	May 3, 2014 to March 1, 2015	No minimum length limit and the daily bag limit is 5.
Walleye, sauger, and hybrids	May 3, 2014 to March 1, 2015	No minimum length limit, but only 1 fish over 14” is allowed and the daily bag limit is 2 fish.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

Kentuck Lake has historically been managed by the WDNR as a bass and panfish fishery as the system is favorable to these species. In the 1970’s, a WDNR survey turned up several small walleyes, and the adult population was found to be quite large in the 1980’s, with some natural recruitment documented during this time. They walleye populations declined drastically during the 1990’s, spurring concern from anglers, residents, and GLIFWC. With coordination from the WDNR, tribes began stocking walleye in 1999 and 2000. Walleye densities increased in the late 1990’s into the early 2000’s, with as many as 13.5 adult fish being estimated per acre in 2001. A 2005 walleye management plan was assembled by WDNR and GLIFWC staff and aimed to identify issues with the fishery and provide a course of action to be followed. As a result of this plan, tribes will continue to stock walleye (roughly 35 fingerlings per acre projected for 2014) and restrictions placed on harvest (described above).

Currently, the lake is believed to have no natural recruitment of walleye occurring, with declining populations of bass, crappies and perch as well. Bluegill are experiencing some decent year class success however there is little carry-over to adulthood with this species. In 2011, a strange die-off of bluegill was observed in the lake during late fall just prior to ice formation. It is believed by WDNR fisheries biologists that a virus may be cause for this die-off. Several specimens were collected and tested for abnormalities, though no evidence of a virus or other illness was uncovered. Should another fish kill of this nature occur, WDNR fisheries biologist Steve Gilbert hopes to take additional samples of the fish and have them tested in an effort to understand the cause. Kentuck Lake residents and other anglers are advised to keep an eye out for suspicious events such as this, and contact WDNR staff should something be observed.

In 2014, several reoccurring surveys are planned for Kentuck Lake. GLIFWC will conduct a walleye population estimate, while also tagging muskellunge. WDNR staff will complete a fall electrofishing survey, which is aimed at assessing the survival of young walleye that were either stocked or born the previous spring. In 2015, the WDNR has a comprehensive survey planned for Kentuck Lake, which will include a muskellunge population estimate (completed with coordination of GLIFWC's 2014 survey), panfish netting, a creel survey as well as a complete fishery assessment.

4.0 SUMMARY AND CONCLUSIONS

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

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

The three objectives were fulfilled during the project and have led to a good understanding of the Kentuck Lake ecosystem, the people who care about the lake, and what needs to be completed to protect and enhance it.

Through the studies conducted on Kentuck Lake, it is clear that the lake is naturally productive and overall the ecosystem is in a healthy condition. As discussed in the Water Quality Section, the majority of years for which historical water quality data are available, the water quality of Kentuck Lake is comparable to other deep, lowland drainage lakes throughout Wisconsin. While Kentuck Lake's watershed is relatively small when compared to the size of the lake and is comprised of land cover types that export minimal amounts of phosphorus, Kentuck Lake's morphology (large surface area and shallow average depth) lends it to experience internal phosphorus loading from bottom sediments annually. This internal phosphorus loading creates a more productive lake than would be expected from external watershed phosphorus loading alone.

Although internal phosphorus loading likely occurs annually to some extent in Kentuck Lake, historical data indicates that in 1988, 1991, 2011, and 2013 the magnitude of phosphorus increase, and consequently algae production, was significantly greater and led to hypereutrophic conditions. As discussed, it is believed that differences in early-season thermal stratification in those years led to the higher phosphorus concentrations. A three-year expanded water quality study to gain a better understanding of Kentuck Lake's thermal behavior and its relationship to internal phosphorus loading is proposed within the following Implementation Plan Section.

A lake's water quality is largely a reflection of its drainage basin, or watershed. Spring lakes, like Kentuck Lake, generally have a small surficial watershed when compared to the size of the lake. Kentuck Lake's watershed encompasses approximately 2,765 acres and results in a small watershed to lake area ratio of 2:1. The relatively small size in combination with a watershed that is mainly comprised of intact forests results in minimal amounts of nutrients and sediments being delivered to the lake. In addition, the majority (53%) of Kentuck Lake's shoreland zone is undeveloped or minimally developed. In regards to protecting Kentuck Lake, conserving the existing natural shoreline and restoring areas of developed shoreline may be one of the best options at this time.

As discussed, a lake's aquatic plant community is defined by and an indicator of the lake's water quality. Kentuck Lake's native aquatic plant community was of comparable quality to other lakes throughout Wisconsin buy of slightly lower quality when compared to other lakes in the Northern Lakes and Forests Ecoregion. The eutrophic conditions of Kentuck Lake favor species like coontail and common waterweed which can tolerate low-light conditions. The dominance of Kentuck Lake's aquatic plant community by coontail and common waterweed creates relatively low species diversity. However, while species diversity may be low, the number of native species present is relatively high, but most are present in relatively low abundance. The native aquatic plant community in Kentuck Lake should be protected, as the benefits include the presence of diverse fish habitat, improving water quality, and providing competition against non-native, invasive plants like Eurasian water milfoil and curly-leaf pondweed.

The 2013 Eurasian water milfoil herbicide treatment proved to be very successful at reducing the densest, colonized areas within the lake. The 2014 Late-Summer Eurasian water milfoil Peak-Biomass Survey indicated that the population remains mainly comprised of single plants and clumps of plants widely distributed throughout shallow areas around the lake, and no treatment is proposed to occur in 2015. Eradication of Eurasian water milfoil and curly-leaf pondweed is certainly difficult, if not an impossible task with what is currently known about aquatic invasive species management. A combination of volunteer- and professional-based monitoring of these populations will be essential in maintaining small populations that exert little if any ecological and recreational impairment on the lake. A Eurasian water milfoil and curly-leaf pondweed monitoring strategy for Kentuck Lake is discussed within the Implementation Plan.

Through the process of this lake management planning effort, the KLPRD has learned much about their lake, both in terms of its positive and negative attributes. Overall, the lake is healthy, but there are certain aspects which require attention. It is now the KLPRD's responsibility to maximize the positive attributes while minimizing the negative attributes as much as possible. The Implementation Plan that follows this section stems from discussions between Onterra ecologists and the KLPRD Planning Committee on which action items the district may implement to properly maintain and care for this resource.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Kentuck Lake Planning Committee and ecologist/planners from Onterra. It represents the path the KLPRD 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 Kentuck 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. 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.

Volunteer Involvement in Implementation of Kentuck Lake Management Plan

The Kentuck Lake Management Plan relies heavily on the involvement of volunteers from the Kentuck Lake Protection and Rehabilitation District. During the development of the plan, it was apparent that a core group of less than ten people were completing the vast majority of work managing Kentuck Lake. This core group cannot solely be responsible for the implementation of the management plan spelled out below, more people need to step-up and be involved. A specific management action to increase volunteerism is included under Goal 4.

Management Goal 1: Control Existing and Prevent Further Introductions of Non-Native, Invasive Species to Kentuck Lake

Management Action: Coordinate annual monitoring of Kentuck Lake's Eurasian water milfoil (EWM) and curly-leaf pondweed (CLP) populations and other potential non-native species.

Timeframe: Initiate 2015

Facilitator: KLPRD Board of Commissioners

Description: In lakes without invasive species, early detection of new introductions commonly leads to successful control, and in cases of very small infestations, possibly even eradication. Even in lakes with invasive species already present, monitoring their populations over time is essential for effective management.

In addition to the surveys focused on locating and mapping aquatic invasive species as part of the lake management planning project, monitoring of EWM and CLP has been conducted by KLPRD volunteers. It is the goal of the KLPRD to continue volunteer-based invasive species monitoring on an annual basis and report the findings to resource managers. Their data will yield an understanding of changes in the EWM and CLP populations through time, and indicate if a threshold for initiation of a particular control strategy has been reached.

To maximize volunteer efforts and ensure accurate data collection and transfer of information between volunteers and resource managers, a three-year invasive species monitoring project on Kentuck Lake is proposed that would include professional training of volunteers and a combination of volunteer- and professional-based invasive species monitoring. It is the goal of this three-year project to establish an ongoing volunteer-based invasive species monitoring program on Kentuck Lake, where volunteers collect data regarding invasive species and report their findings to resources managers. Because there was funding still available within the 2013-2014 WDNR Aquatic Invasive Species (AIS) Early Detection and Response (EDR) Grant to cover the costs of professional monitoring of EWM in 2014, AIS monitoring costs for 2015 and 2016 will be included within the WDNR Lake Protection Grant being sought in February 2015 (discussed under Management Goal 2).

In the first year of the project (2015), professional surveys would be conducted to map and locate occurrences of both CLP and EWM in Kentuck Lake. During the Early-Season AIS Survey, a June survey focused on locating curly-leaf pondweed while at its peak growth and EWM while it is higher in the water column than most emerging native plants, KLPRD volunteers would join the professional ecologists during the survey and receive training on survey methodology including invasive species identification and how to use a GPS to accurately map and categorize findings. In July of 2015, KLPRD volunteers would survey the lake and mark locations of Eurasian water milfoil. Following their survey, they would send their GPS and data to professional ecologists. Professional ecologists would use the volunteer data in a late-summer EWM Peak-Biomass Survey and refine the areas of EWM located by the volunteers.

If the CLP population in Kentuck Lake remains at low levels, KLPRD volunteers would be responsible for locating and mapping areas of CLP in June of 2016 and report their findings to professional ecologists. As in 2015, KLPRD volunteers would also locate and map areas of EWM in July and then send their GPS and data to professional ecologists. Because the EWM population is more widespread in Kentuck Lake and has shown it has the capacity to create large, monotypic stands, a professional-based Late-Summer EWM Peak-Biomass Survey would be conducted in 2016 to refine the volunteer data. At the end of each year, electronic maps would be created displaying areas of CLP and EWM. In addition, their GPS would be updated with the most current information regarding CLP and EWM locations for their use during their surveys.

Action Steps:

1. KLPRD, with professional assistance, applies for a WDNR Lake Protection Grant to aid in funding a two-year invasive species training and monitoring project from 2015-2016.
2. KLPRD volunteers join professional ecologists during 2015 Early-

Season AIS Survey to gain training in AIS survey and mapping methodologies. Areas of CLP will be mapped by professional ecologists during this survey in 2015.

3. KLPRD volunteers locate and map areas of EWM in July of 2015 and 2016 and send data to professional ecologists. Using the KLPRD volunteers' data, professional ecologists conduct Late-Summer EWM Peak-Biomass Surveys in 2015 and 2016. KLPRD volunteers map and locate areas of CLP in June of 2016 and report findings to professional ecologists.

Management Action: Enact Eurasian water milfoil and/or curly-leaf pondweed control strategy.

Timeframe: As AIS infestation dictates

Facilitator: KLPRD Board of Commissioners

Funding Source: AIS Established Population Control Grant

Description: As discussed in the Aquatic Plant Section, aquatic invasive plants become problematic when they form dense monotypic stands which begin to affect the lake's ecology, recreation, and aesthetics. Following the successful control of large, colonized areas of EWM in 2013, the populations of both EWM and CLP are mainly comprised of single plants widely scattered throughout shallower areas of the lake and are not impressing significant negative impacts on Kentuck Lake. However, continued monitoring will be essential to determine if and when future control strategies will need to be initiated for both or one of these species in Kentuck Lake.

As discussed in the previous management action, professional surveys for both CLP and EWM will be conducted in 2014 and the KLPRD will be seeking funds to initiate a three-year invasive species monitoring program from 2015-2017 that incorporates both volunteer- and professional-based surveys. While the previous management action outlines methodologies for invasive species monitoring and reporting in Kentuck Lake, a threshold or 'trigger' for initiating potential control strategies.

At this time, management of EWM and CLP populations in Kentuck Lake is not conducted to eradicate either of these species, as this is impossible given the current management tools available. The objective is to maintain low levels of these plants so that they exert minimal pressure on the lake's ecosystem. The thresholds for initiating control strategies for EWM and CLP in Kentuck Lake are as follows:

EWM

As discussed, a combination of both volunteer-based and professional EWM monitoring will occur on Kentuck Lake from 2014-2017. If over this time period the professional ecologists conducting the EWM monitoring believe that the EWM population has grown to levels where it is beginning to impact the lake's ecology and/or interfere with recreational activities on the lake, a EWM control strategy for the following spring would be developed. The trigger level would be areas of approximately three acres or greater with the majority of that area being at a dominant or greater EWM density. However, the shape (round versus long and narrow) and location (secluded versus deep, open, or flowing water) would also be considered in the strategy development. Because the 2,4-D spot treatments in 2013 were successful, this strategy would likely be utilized in the future to control colonized areas of EWM. And like in 2013, if an herbicide treatment strategy is implemented, quantitative monitoring using WDNR protocols and qualitative monitoring using observations at individual treatment sties would be implemented.

If the KLPRD elects not to utilize professional ecologists for invasive species monitoring following the three-year invasive species monitoring project, KLPRD volunteers would be responsible for mapping EWM and relaying those data to resource managers. Professional monitoring of EWM will occur on Kentuck Lake under one of two scenarios: 1) the KLPRD believes that the amount of EWM located warrants control action, or 2) a period of five years has passed from the previous professional survey.

CLP

As discussed, CLP has been present in Kentuck Lake for over 20 years, and since its introduction, has not posed a threat to Kentuck Lake's ecology or recreation. However, continued monitoring will be essential to initiate control strategies quickly if the population increases. Because the CLP population in Kentuck Lake is currently at very low levels, professional monitoring of CLP is only scheduled to take place in 2014 under the current WDNR-EDR Grant. Starting in 2015, KLPRD monitoring will be the responsibility of KLPRD volunteers. Starting in 2015, professional monitoring of CLP will occur on Kentuck Lake under one of two scenarios: 1) the KLPRD believes that the amount of CLP located warrants control action (i.e. colonized areas of CLP with a density of *dominant* or greater) or, 2) a period of five years has passed from the previous professional survey. As with EWM, if the professional ecologists feel that the CLP population has reached levels that are beginning to impact the lake's ecology or interfere with recreation, potential control strategies will need to be discussed and developed with the KLPRD.

Action Steps:

1. See description above.

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Kentuck Lake public access locations.

Timeframe: Continuation of current effort

Facilitator: KLPRD Board of Commissioners

Funding Source: Clean Boats Clean Waters Grant

Description: Currently the KLPRD monitors the two public boat landings using a combination of paid inspectors and KLPRD volunteers that have received training provided by the Clean Boats Clean Waters program. Kentuck Lake is an extremely popular destination for recreationalists and anglers, making it vulnerable to new infestations of exotic species as well as invasive species already present being transported from Kentuck Lake. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access points, but also to prevent the infestation of other waterways with invasive species that originated in Kentuck Lake. The goal would be to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of their spread.

Action Steps:

1. See description above.

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

Timeframe: Initiate upon invasive species discovery

Facilitator: Planning Committee with professional help as needed

Description: While Kentuck Lake already contains populations of the invasive plants Eurasian water milfoil and curly-leaf pondweed, nearby lakes harbor aquatic invasive species not yet present in Kentuck Lake. These include the spiny water flea located in nearby Butternut, Stormy, Star, and Trout Lakes, and the zebra mussel, located in Lake Metonga. While Kentuck Lake is not believed to be highly susceptible to zebra mussel establishment, spiny water fleas will likely be able to establish a population if introduced into the lake. The WDNR currently collects and analyzes samples annually from Kentuck Lake for zebra mussels and spiny water fleas, but lake users should also familiarize themselves with these species in the event they encounter them within the lake.

If lake users do encountered either of these species on Kentuck Lake, it should be reported to resource managers immediately. While there is currently no method of eradication or control for either of these species, identification of an early infestation can aid in preventing these species from spreading from the lake.

Action Steps:

1. See description above.

Management Goal 2: Enhance Kentuck Lake's Water Quality Conditions

Management Action: Continue monitoring of Kentuck Lake's water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: KLPRD Board of Commissioners

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. Early discovery of negative trends may lead to the reason as of 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 KLPRD have collected water quality data annually on Kentuck Lake since 1986. The KLPRD realizes the importance of continuing this effort, which will supply them with valuable data about their lake. Moving forward, it is the responsibility of KLPRD Board of Commissioners to coordinate new water quality sampling volunteers as needed. When a change in the collection volunteer occurs, Sandra Wickman 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. The KLPRD Board of Commissioners recruits new water quality sampling volunteer(s) as needed.
2. New volunteer(s) contact Sandra Wickman (715.365.8951) as needed.
3. Volunteer(s) reports results to WDNR and KLPRD members during annual meetings.

Management Action: Initiate a three-year focused water quality assessment to investigate Kentuck Lake's thermal behavior and its influence on internal phosphorus recycling.

Timeframe: Initiated in 2014

Facilitator: KLPRD Board of Commissioners

Funding Source: Lake Management Protection Grant

Description: During the Kentuck Lake Management Planning Project, historical and current water quality data were analyzed and indicated that significant internal phosphorus loading is likely occurring. Additionally, data collected by KLPRD volunteers in 2014 indicated that Kentuck Lake has the capacity to break stratification and completely mix from top to bottom during the summer. These mixing events likely transfer phosphorus from the hypolimnion to surface waters where it fuels algae growth. While the data indicate that internal phosphorus loading likely occurs annually in the lake, it is believed the years where hypereutrophic conditions were present (2011 and 2013) were dictated by the lakes initial thermal stratification in spring. The scope of work described outlines a three-year project and study design (2014-2016) that will allow for a more detailed understanding of the dynamics of Kentuck Lake's thermal stratification and total phosphorus concentrations over the course of the growing season.

2014

The first year of the project (2014) included KLRPD volunteers collecting only dissolved oxygen and temperature profiles at seven locations distributed across the deepest areas of the lake using a probe provided by Onterra (Map 10). Volunteers collected dissolved oxygen and temperature profiles biweekly (every other week) on the same day each week (give or take one day) starting in late-May and continuing through early-October, when the deep hole displayed uniform dissolved oxygen and temperature from the surface to the bottom (turnover). In addition to sampling biweekly over the course of the growing season, the volunteers also attempted to record profiles during or immediately after storm events that generated whitecap conditions on the lake.

As discussed within the Water Quality Section, the results of their data collection indicated that Kentuck Lake has the capacity to mix, or turnover periodically during the growing season. In 2014, these mixing events were believed to be driven by high winds blowing across the maximum fetch of the lake. Total phosphorus data collected in 2014 also indicated that increases in epilimnetic phosphorus are associated with these mixing events, as hypolimnetic phosphorus released from anoxic bottom sediments is mixed into the epilimnion. These data indicate that internal phosphorus loading is likely the largest source of Kentuck Lake's phosphorus budget.

2015-2016

In project years two and three (2015 and 2016), in addition to collecting dissolved oxygen/temperature profiles, the KLPRD volunteers would also collect water chemistry parameters. Emerging research is indicating that under nitrogen-limiting conditions, ferrous iron generated under anoxic conditions may be a significant factor contributing to nitrogen-fixing cyanobacteria blooms that have been documented in lakes with high chlorophyll-*a* to phosphorus ratios (Cory McDonald WDNR, personal comm.; Molot et al. 2014). In addition to total phosphorus and chlorophyll-*a* concentrations, this study would also quantify iron concentrations and relative abundance of phytoplankton taxa, and would be the first study in Wisconsin to attempt to quantify the relationship between ferrous iron and cyanobacteria blooms. Analysis of sediment cores would also provide information on any potential changes in the lake's water quality over the past 200 years as well as the release rate of phosphorus under anoxic conditions.

In-lake water quality monitoring would include sample collection by KLPRD volunteers every other week at five locations throughout the lake starting immediately after ice-out (April) through October in 2015 and 2016. In addition, Onterra would collect samples from two locations through the ice in late-winter once in February of 2016 and 2017. Growing season (April-October) monitoring parameters include: total phosphorus, dissolved phosphorus, nitrate-nitrite nitrogen, ammonia nitrogen, chlorophyll-*a*, and total iron. Samples would also be collected for phytoplankton taxa analysis.

Total phosphorus would be measured from near-surface and near-bottom at all 5 sampling locations (Map 11). Dissolved phosphorus, nitrite-nitrate nitrogen, ammonia nitrogen, total iron, and phytoplankton samples would be collected at two locations (sites 1 and 5) from near-surface, just below the oxycline, and near-bottom. Chlorophyll-*a* would be collected from sites 1 and 5 from near-surface only. Winter samples would include near-surface and near-bottom total phosphorus from sites 1 and 5. Temperature and dissolved oxygen profiles would be collected from each sampling location visited during each sampling event. Phytoplankton taxa analysis would be conducted by Jim Kreitlow, while the remaining parameters would be analyzed by the Wisconsin State Lab of Hygiene. WDNR Science Services would cover the analysis costs of the inorganic nutrients and iron samples.

Shallow groundwater would be assessed to determine the areas of groundwater inflow/outflow as well as the quality of the groundwater entering Kentuck Lake. Mini-piezometers would be utilized at 500-foot intervals around the lake for a total of 67 locations (Map 12). At every location, groundwater temperature and conductivity as well as static head level relative to the surface of the lake would be measured once the well was purged. A colorimeter would be used to determine if relatively high or low levels of phosphorus exist. Actual phosphorus samples would be collected from half of the groundwater monitoring locations, determined by presence of inflow as well as higher phosphorus readings from the colorimeter.

Four sediment cores would be collected from the lake in 2015. Top and bottom sections of two cores would be analyzed to discover how Kentuck Lake's water quality has changed over the past 200 years, and the two others would undergo analysis for nutrient release rates.

A combination of volunteer and professional AIS monitoring would occur in 2015 and 2016. KLPRD volunteers would join Onterra ecologists in 2015 where they would learn how to systematically search for and map AIS. Volunteers would conduct the Early-Season AIS survey in 2016. Onterra ecologists would conduct late-summer surveys in 2015 and 2016 aimed at mapping EWM.

The two-year water quality study would provide an improved understanding of the relationship between the lake's thermal behavior, nutrients, and algal abundance. Depending on the proposed study's results, applicable management actions that could lead to improvements in Kentuck Lake's water quality would be discussed with the KLPRD. If the study reveals that no applicable management actions exist, the KLPRD would still gain detailed knowledge of the lake's water quality dynamics. Through this study, managers may be able to predict which years are going to see higher levels of phosphorus and algae. This water quality study also has implications beyond Kentuck Lake, and would be the first to study the relationship between ferrous iron and cyanobacteria. Improving understanding of this relationship has significance for similar lakes with higher-than-expected productivity.

Action Steps:

1. KLPRD Board of Commissioners recruit volunteer(s) to collect/record water quality data on a biweekly basis over the course of the growing season from 2014-2016.
2. Consultant solidifies study design with assistance from WDNR and other agencies as applicable.
3. Create preliminary project cost estimate.

2. KLPRD to apply for a WDNR Lake Protection Grant for February 2015 grant cycle to aid in funding for costs of 2015 and 2016 analyses.

<u>Management Action:</u> Restore highly developed shoreland areas on Kentuck Lake.

Timeframe: Initiate in 2017

Facilitator: KLPRD Board of Commissioners

Funding Source: Healthy Lakes Project Grant

Description: As discussed in the Shoreland Condition Section, the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. In 2013, the shoreland assessment survey indicated that 0.8 miles, or 9% of Kentuck Lake's 6.3 mile shoreline, consists of Urbanized or Developed-Unnatural areas.

Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Vilas/Forest County staff devoted to these types of projects give private property owners the funds and informational resources to restore quality shoreland habitat to their lakeside residence.

Map 3 indicates the locations of Urbanized and Developed-Unnatural shorelands on Kentuck Lake. These shorelands should be prioritized for restoration. A Board of Commissioners appointee will work with appropriate entities such as the Forest County Land Conservation Department and the Vilas County Land and Water Conservation Department to research grant programs, shoreland restoration techniques, and other pertinent information that will help the KLPRD restore areas of Kentuck Lake's shorelands. 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 Board of Commissioners appointee will oversee/plan demonstration tours, as well as be a point-of-contact, for Kentuck Lake property owners who require more information on this topic.

Action Steps:

1. KLPRD Board of Commissioners recruits shoreland restoration appointee.
2. Facilitator receives proper shoreland restoration training through the UW-Extension (Patrick Goggin - 715.365.8943, patrick.goggin@ces.uwex.edu).
3. Appointee coordinates demonstration site tour (annual event or as needed) and serves as a person of contact for shoreland restoration questions. Appointee puts interested parties in contact with Forest County Land Conservation Department or Vilas County Land and Water Conservation Department officials.
4. Property owners interested in conducting shoreland restorations complete a cost-share application and submit it to the Forest County Land Conservation Department of Vilas County Lane and Water

Conservation Department.

5. Conservation specialists with Forest or Vilas County works with property owners to determine site eligibility, design plants, etc.

Management Goal 3: Increase Navigation Safety on Kentuck Lake

Management Action: Place waterway markers (regulatory danger buoys) in Kentuck Lake to indicate areas that are hazardous to vessel operation.

Timeframe: Initiate 2014

Facilitator: KLPRD Board of Commissioners

Description: Kentuck Lake is visited by numerous lake users that recreate on the lake in different ways. Like many lakes, Kentuck Lake contains areas that present navigation hazards to lake users. While it is the responsibility of lakes users to familiarize themselves with the waterbody and employ safe boating practices, the KLPRD annually places four regulatory danger buoys in the eastern portion of the lake which warn lake users of the large rocks present in the area (Map 13). However, the KLPRD would like to improve navigation safety further by placing an additional four regulatory danger buoys marking navigation hazards in Kentuck Lake (Map 13).

Three of these additional buoys would be placed in the eastern portion of the lake, one marking an area of submerged rocks that are near the surface, while the other two would mark an area of submerged rocks around an already marked emersed rock and shore (Map 11). The fourth buoy would be placed on the western side of the lake marking an old fish crib that is close to the surface.

These four additional buoys would be placed in the lake in the spring following ice-out and removed in the fall prior to ice-on. The initial installation of these danger buoys involves the following requirements (WDNR PUB-LE-317 2008):

- The submittal of a Waterway Marker Application and Permit with local government approval
- WDNR review and approval of the permit application
- Buoys must be installed by individuals with the proper authorization from the municipality having jurisdictions over the waters involved
- The buoys must be of the proper type:
    - Cylindrical in shape.
    - A minimum diameter of seven inches.
    - The "danger" buoy will be white with an orange diamond. Any information (i.e. "rocks") will be printed on this buoy in black.
    -

Action Steps:

1. The KLPRD submits a Waterway Marker Permit Application (form 8700-58) to the WDNR (http://dnr.wi.gov/topic/boat/ordinances.html).
2. Following approval by the WDNR, the KLPRD will purchase five buoys that meet the previously discussed size, shape, and color regulations for “danger” buoys.
3. Individuals with proper authorization will place the buoys in the lake following ice-out and will remove the buoys prior to ice-on annually.

Management Goal 4: Assure and Enhance the Communication and Outreach of the Kentuck Lake Protection & Rehabilitation District with Lake Stakeholders

Management Action: The KLPRD will support an Education and Communication Committee to promote stakeholder involvement, inform stakeholders and various lake issues, as well as the quality of life on Kentuck Lake.

Timeframe: Develop in 2015

Facilitator: KLPRD Board of Commissioners to form Education and Communication Committee

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. An Education and Communication Committee will be created to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the KLPRD regularly publishes and distributes a biannual newsletter and maintains a district website that provides district-related information including current district projects and updates, meeting times, volunteer opportunities, and educational topics. Both of these mediums are an excellent source for communication and education to both association and non-association members.

While 85% of respondents indicated that the KLPRD keeps them either *fairly well informed* or *highly informed* regarding issues with Kentuck Lake and its management (Appendix B, Question #28), the KLPRD would like to increase its capacity to reach out to and educate district and non-district members regarding Kentuck Lake and its preservation. In addition to creating a biannual newsletter, a variety of educational efforts will be initiated by the Education and Communication Committee. These may include educational materials such as a tri-fold brochure containing information about the KLPRD (projects, finances, etc.) as well as facts about Kentuck Lake and steps lake residents can take to maintain and enhance the quality of the lake, as well as quality of life for those who live and recreate on it. The Education and Communication Committee can also organize workshops and speakers surrounding lake-related topics.

Education of lake stakeholders on all matters is important. During the second planning meeting with KLPRD Planning Committee members, the list below of educational topics was developed. These topics can be included within the association's newsletter and/or website or distributed as separate educational materials. In addition, the KLPRD can invite professionals who work within these topics to come and speak at the district's annual meeting or hold workshops if available.

Example Educational Topics

- Shoreline restoration and protection
- Boating regulations and safety
- Light pollution
- Lake user/neighbor etiquette
- Riparian property management
- Septic system maintenance
- Information pertaining to Native American spear harvests in Kentuck Lake
- Importance of maintaining coarse woody habitat
- Aquatic invasive species (AIS) prevention and updates for AIS in Kentuck Lake
- Water quality monitoring updates from Kentuck Lake
- Importance of naturally fluctuating water levels for lake ecology

Action Steps:

1. The KLPRD Board of Commissioners recruits volunteers to form Education and Communication Committee.
2. The KLPRD Board of Commissioners will identify a base level of financial support for educational activities to be undertaken by the Education and Communication Committee on an annual basis.

Management Action: Develop an updated district website.

Timeframe: Initiate in 2015

Facilitator: Education and Communication Committee

Description: While the KLPRD currently has a website (www.kldistrict.com), the individual who created and maintained the website passed away, and the KLPRD can no longer gain access to control or update the material on this website. Because this is an effective communication tool, it is important that the district maintain a website that can provide up-to-date information. The website will be constructed in an easy-to-use format to ensure stakeholders of all levels of computer literacy will have access to the information posted.

In addition to the website, the KLPRD will able to create a district email (i.e. klprd-president@klprd.org) that can be used to quickly disseminate important information to district members such as the presence of a blue-green algae bloom.

Action Steps:

1. Education and Communication Committee gathers appropriate information relating to website development.

<u>Management Action:</u> Increase volunteerism within the KLPRD.

Timeframe: Begin summer of 2015

Facilitator: KLPRD Board of Commissioners to recruit volunteer coordinator

Description: Even though lake districts consist of individuals who are passionate about the lake they reside upon, it is often difficult to recruit volunteers to complete the tasks that are necessary to protect that lake. Many lake district members are elderly and retired, often making labor intensive volunteer jobs are difficult to perform. Other residents may only visit the lake several times during the year, often on weekends to "get away" from the pressures of the work-week back home. Some have cut back on volunteering because of recent economic downturns or concerns over the time commitment involved with various volunteer tasks, while others may simply have not been asked to lend their services.

Those that have volunteered in the past and have had a poor experience may be hesitant to volunteer again. Without good management, volunteers may become underutilized. Some may have been turned off by an impersonal, tense or cold atmosphere. Volunteers want to feel good about themselves for helping out, so every effort must be made by volunteer managers to see to it that the volunteer crews enjoy their tasks and their co-volunteers.

The KLPRD is proud of their active role in preserving and enhancing Kentuck Lake for all stakeholders; however, they are in constant need of volunteers to continue this high level of commitment. An excellent way to show gratification to those who volunteer and to showcase the work that volunteers do for the KLPRD and Kentuck Lake is to highlight an outstanding volunteer within each newsletter and/or on the district's website. As a result of this lake management planning project, the district is now in need of additional help to increase the level of protection the KLPRD wishes to provide for the lake. In order to retain volunteer help and recruit more volunteers for these tasks, the KLPRD will undertake a volunteer recruitment strategy as outlined below. While volunteer recruitment for a lake district may be difficult, the following tips will be helpful in the KLRPD's efforts to solicit help for lake-related efforts.

Action Steps:

1. KLPRD Board of Commissioners appoints a volunteer coordinator.

This should be a friendly, outgoing person who is able to engage people they may know or not know. The volunteer coordinator's duties are to recruit, train, supervise and recognize volunteers. Building and maintaining a volunteer database with names, contact information, tasks, hours completed, etc. will be necessary.

2. Coordinator will initially recruit volunteers through personal means, not via telephone, email or newsletter notification. Engaging a person in a friendly atmosphere through a personal invitation is more likely to result in a successful recruitment than through an impersonal email.
3. Coordinator will have duties outlined prior to recruiting volunteers. A volunteer's time should not be wasted! Work descriptions, timeframes and other specifics should be known by each worker prior to their shift.
4. Coordinator will be flexible in allowing volunteers to contribute towards project designs and implementation. Recruiting new leaders through delegating tasks will empower volunteers and give them reason to continue volunteering.
5. The board of directors will continue to recognize volunteers through incentives and appreciation. Snacks, beverages, public acknowledgement and other means of expressing appreciation are encouraged.

Management Goal 5: Enhance the Fishery of Kentuck Lake

Management Action: The KLPRD will work with fisheries managers to enhance the fishery of Kentuck Lake.

Timeframe: Ongoing

Facilitator: KLPRD Board of Commissioners

Description: The results of the stakeholder survey indicate that fishing is a highly popular recreational activity on Kentuck Lake. Open-water fishing was ranked 1st on a list of reasons property owners reside on Kentuck Lake (Appendix B, Question #13). Approximately 86% of survey respondents indicated they have fished on Kentuck Lake (Question #8), and 36% of these same respondents have done so for longer than 25 years (Question #7).

However, the KLPRD have concerns over the fishery. Approximately 41% of survey respondents indicate the quality of fishing is only fair on the lake (Question #10), and 77% indicated that the quality of fishing has become either somewhat or much worse since they began fishing (Question #11).

Understanding the limitations and stresses on the Kentuck 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 educating Kentuck Lake property owners on the fishery. Specifically, information within this document may be summarized and presented to residents through the Educational Initiative described in Management Goal 4. Residents must have an understanding of fishing pressure on Kentuck Lake and how important intact and diverse habitats (plant-filled bays, rocky areas, coarse woody habitat, etc.) are to the fishery.

Kentuck Lake is currently overseen by WDNR fisheries biologist Steve Gilbert as well as Mark Luehring of GLIFWC (contact information below). In order to keep informed of survey studies and fisheries management (e.g. stocking) that are occurring on Kentuck Lake, a volunteer from the KLPRD should contact Mr. Gilbert and Mark Luehring at least once per year (perhaps during the winter months when field work is not occurring) for a brief summary of activities each agencies activities. Additionally, the KLPRD may discuss options for improving the fishery in Kentuck Lake, which may include changes in angling regulations and habitat enhancements.

Agency	Contact Person	Role	Contact Frequency
WDNR	Steve Gilbert (715.358.9229)	Fisheries Biologist – Vilas County	Once per year, or more as needed.
GLIFWC	Mark Luehring (715.682.6619 ext. 2133)	Inland Fisheries Biologist	Once per year, or more as needed.

During the Kentuck Lake 2013 Coarse Woody Habitat Survey, many pieces of coarse woody habitat were located along the shorelines of the lake (Map 4). Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation, shore-fishing, or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition and Fisheries Data Integration Section discuss the benefits of coarse woody habitat in detail.

The KLPRD may elect to work with Steve Gilbert of the WDNR and Mark Luehring of GLIFWC to improve coarse woody habitat along the shoreland areas of Kentuck Lake through strategic tree-drops or other means. Please note that WDNR permits and approval would be required for this action to be taken.

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 Kentuck 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 KLPRD members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, winter, and fall. Although KLPRD members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

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

	Spring		**June**	**July**	**August**	**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**S**	**S**	**S**	**B**	**S**	**B**
Total Phosphorus	■♦	■	♦	♦	♦	■	■	■	■
Dissolved Phosphorus	■	■						■	■
Chlorophyll-*a*	■		♦	♦	♦	■			
Total Kjeldahl Nitrogen	■	■	●	●	●	■		■	■
Nitrate-Nitrite Nitrogen	■	■	●	●	●	■		■	■
Ammonia Nitrogen	■	■	●	●	●	■		■	■
Laboratory Conductivity	■	■							
Laboratory pH	■	■							
Total Alkalinity	■	■							
Total Suspended Solids	■	■				■	■	■	■
Calcium	■								

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Kentuck Lake during an early summer 2014 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Kentuck Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. Members of the WDNR utilized the point-intercept method as described in the WDNR 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) to complete this study on July 18-20, 2011. A point spacing of 86 meters was used resulting in approximately 543 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Kentuck Lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake. Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium.

2013 EWM Treatment Monitoring

The methodology used to monitor the 2013 EWM herbicide treatments is included within the Non-Native Aquatic Plant Section.

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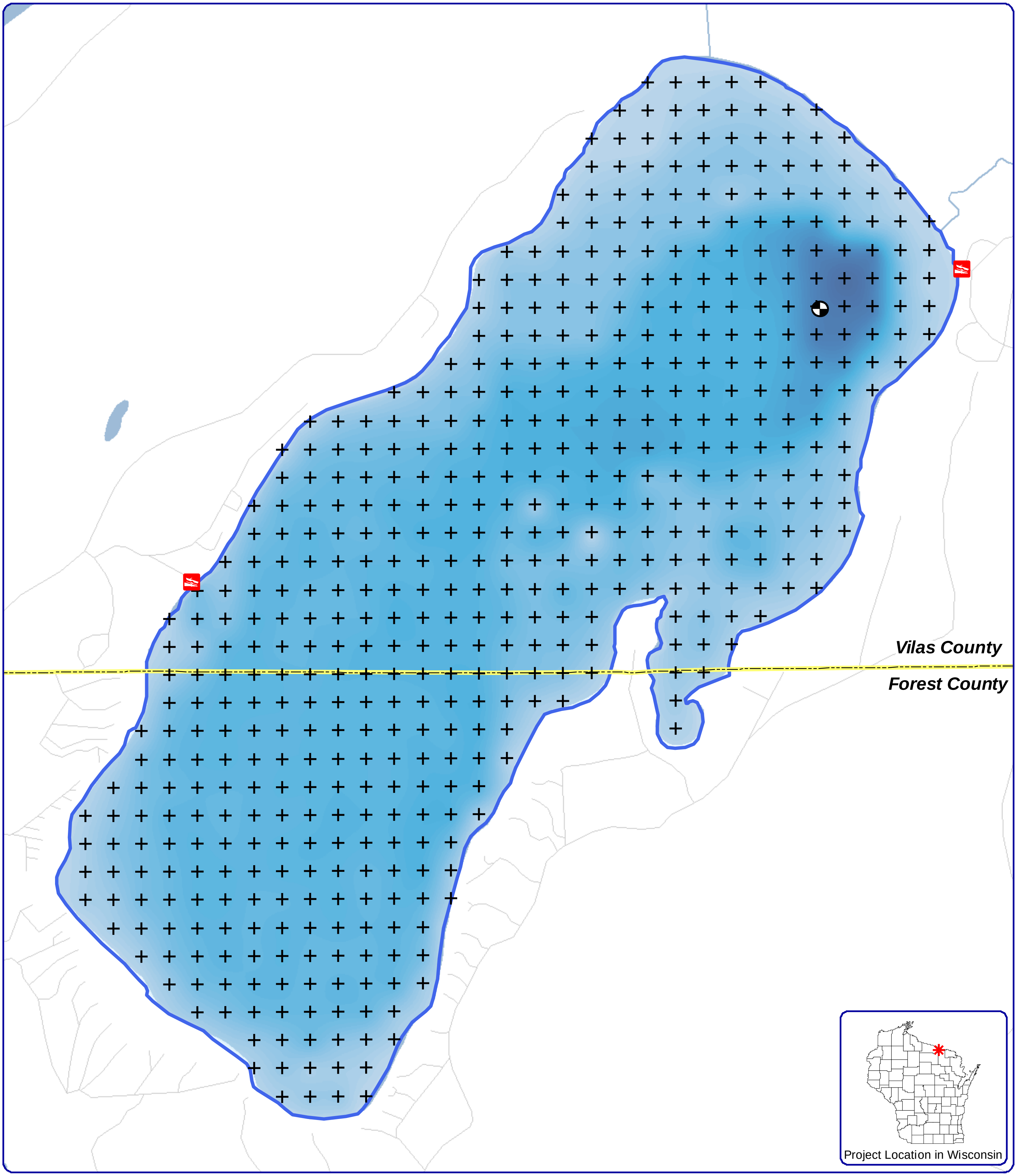


N W E S

1,250
Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: March 26, 2014
Filename: Map1_Kentuck_Location.mxd

Legend

Kentuck Lake ~957 acres
WDNR Definition

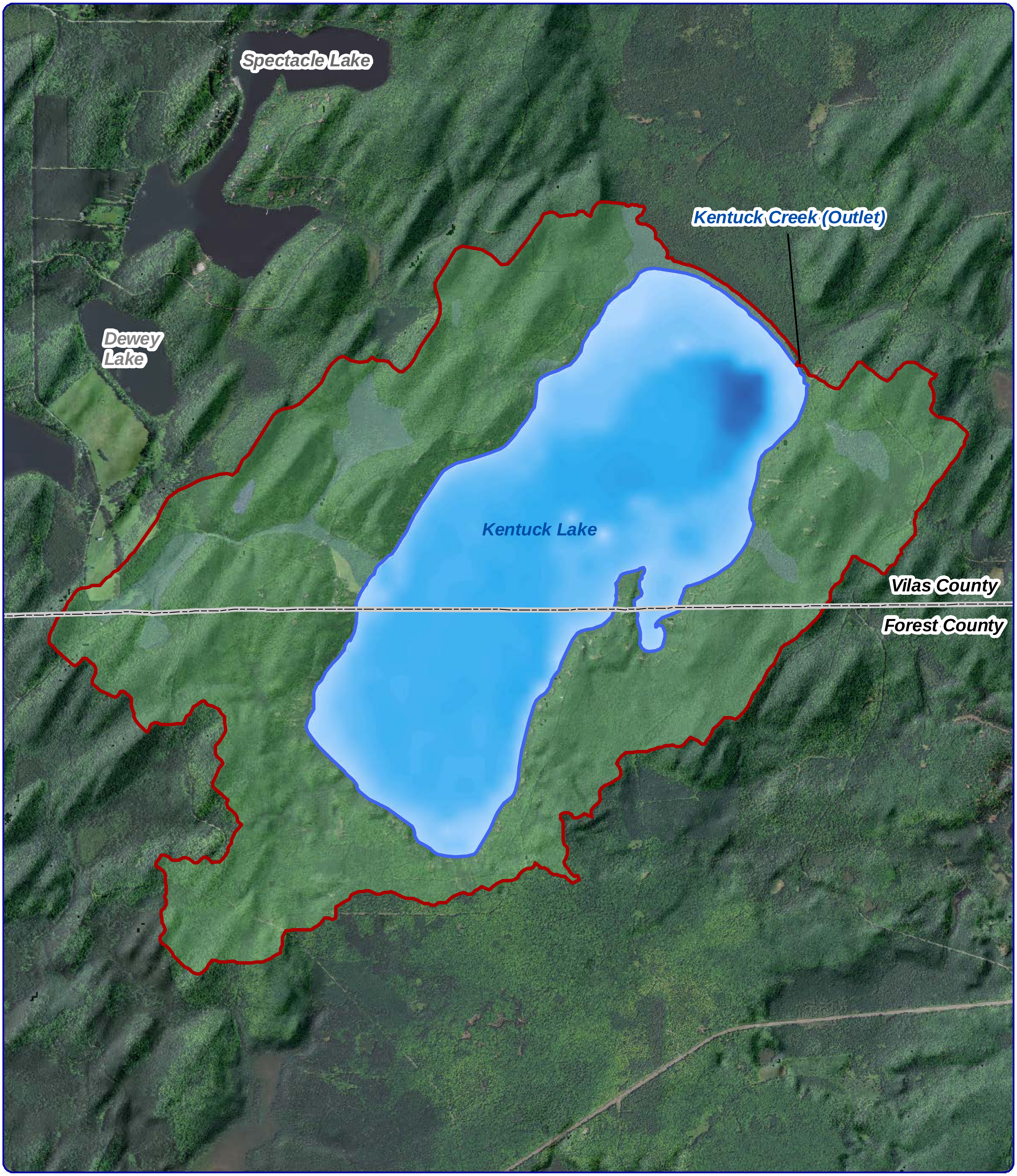
Point-Intercept Survey Location
86-meter spacing, 543 total points

Water Quality Sampling Location

Public Access

Map 1
Kentuck Lake
Forest & Vilas Counties, Wisconsin

Project Location & Lake Boundaries

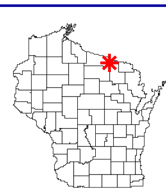


N
W E
S

2,400
Feet

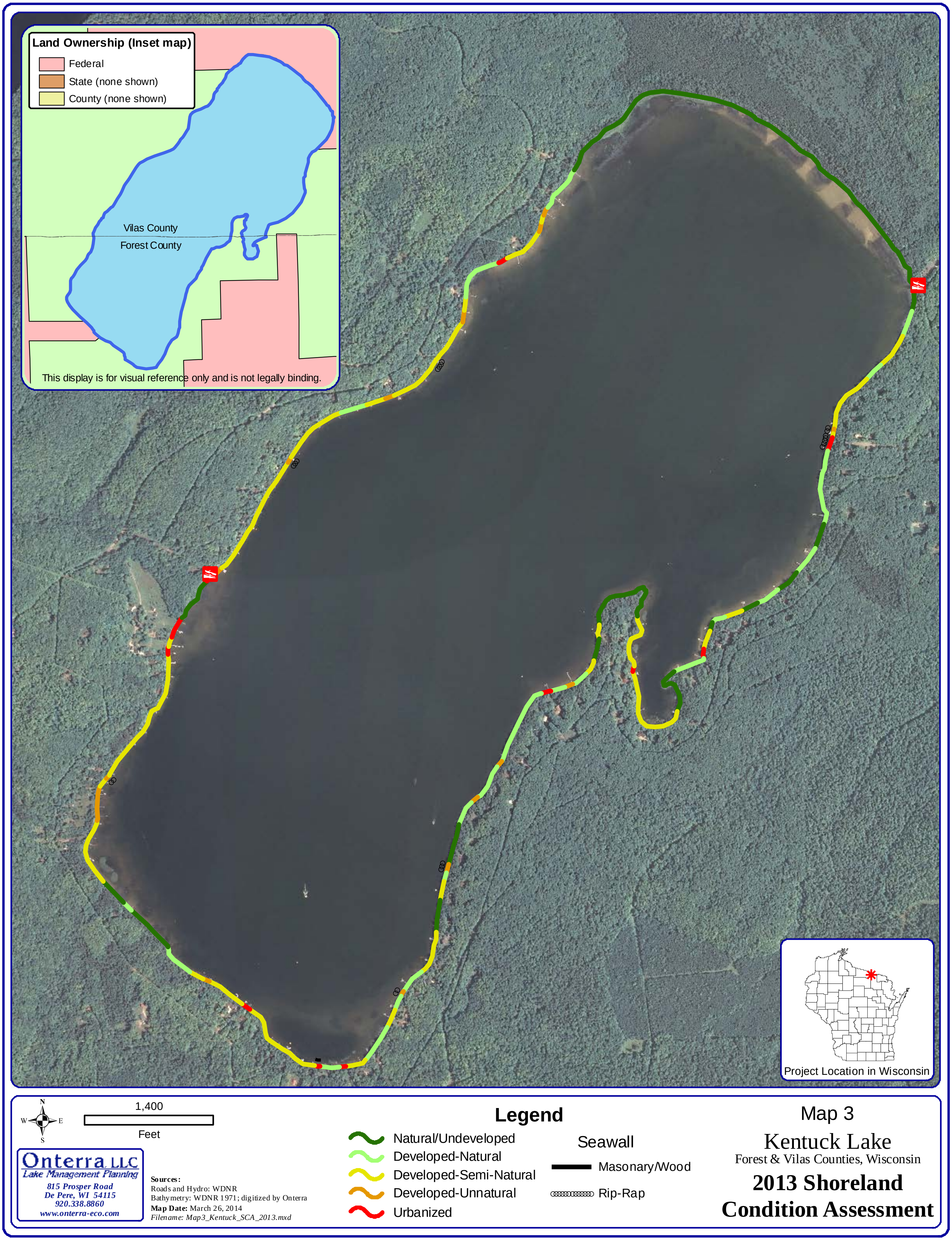
Onterra LLC
Lake Management Planning
135 South Broadway Suite C
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

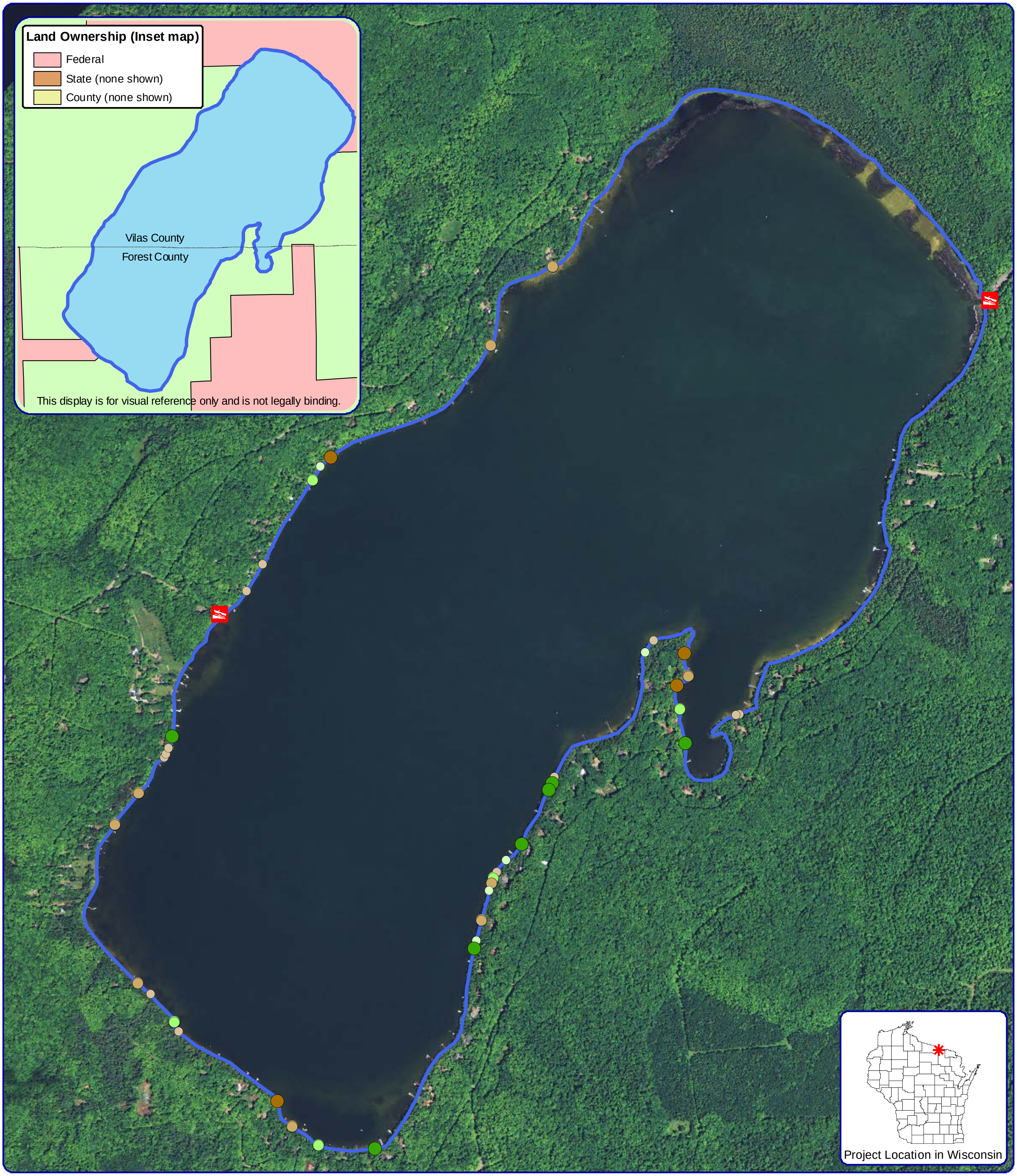
Sources:
Hydro: WDNR
Land Cover: NLCD, 2006
Bathymetry: Onterra, 2014
Orthophotgraphy: NAIP, 2013
Map Date: September 9, 2015
Filename: Map2_Kentuck_WS.mxd


Project Location in Wisconsin

Legend
Kentuck Lake Watershed Boundary
Land Cover Types
Forest
Open Water
Forested Wetlands
Pasture/Grass
Non-Forested Wetlands

Map 2
Kentuck Lake
Forest & Vilas Counties, Wisconsin
Watershed Boundaries & Land Cover Types


Land Ownership (Inset map)
Federal
State (none shown)
County (none shown)
Vilas County
Forest County
This display is for visual reference only and is not legally binding.
Project Location in Wisconsin
N
W
E
S
1,400
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: March 26, 2014
Filename: Map3_Kentuck_SCA_2013.mxd
Legend
Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized
Seawall
Masonary/Wood
Rip-Rap
Map 3
Kentuck Lake
Forest & Vilas Counties, Wisconsin
2013 Shoreland
Condition Assessment



N
W E
S

1,250
Feet

Onterra LLC
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De Pere, WI 54115
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Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: March 26, 2014
Filename: Map4_Kentuck_CWH_2013.mxd

Legend

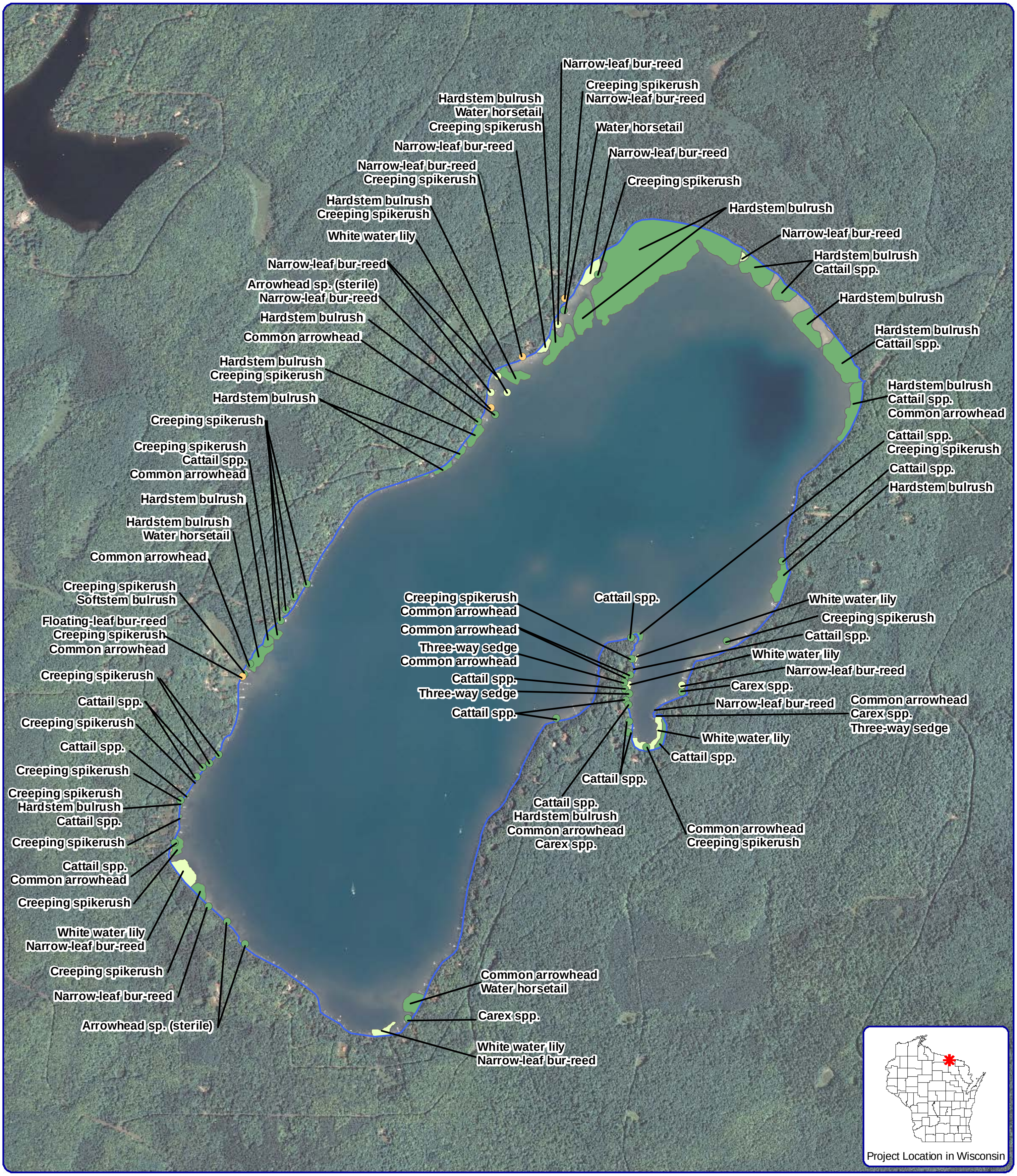
2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches (none)
Minimal Branches	Minimal Branches	Minimal Branches (none)
Moderate Branches	Moderate Branches	Moderate Branches (none)
Full Canopy (none)	Full Canopy (none)	Full Canopy (none)

Map 4

Kentuck Lake

Forest & Vilas Counties, Wisconsin

2013 Coarse Woody Habitat



Legend

Large Plant Community
- Emergent
- Floating-Leaf
- Mixed Emergent & Floating-Leaf

Small Plant Community
- Emergent
- Floating-Leaf
- Mixed Emergent & Floating-Leaf

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Sources:
Orthophotography: NAIP, 2010
Aquatic Plants: Onterra, 2013
Map Date: March 28, 2014
Filename: Map5_Kentuck_Comm_2013.mxd

Map 5

Kentuck Lake

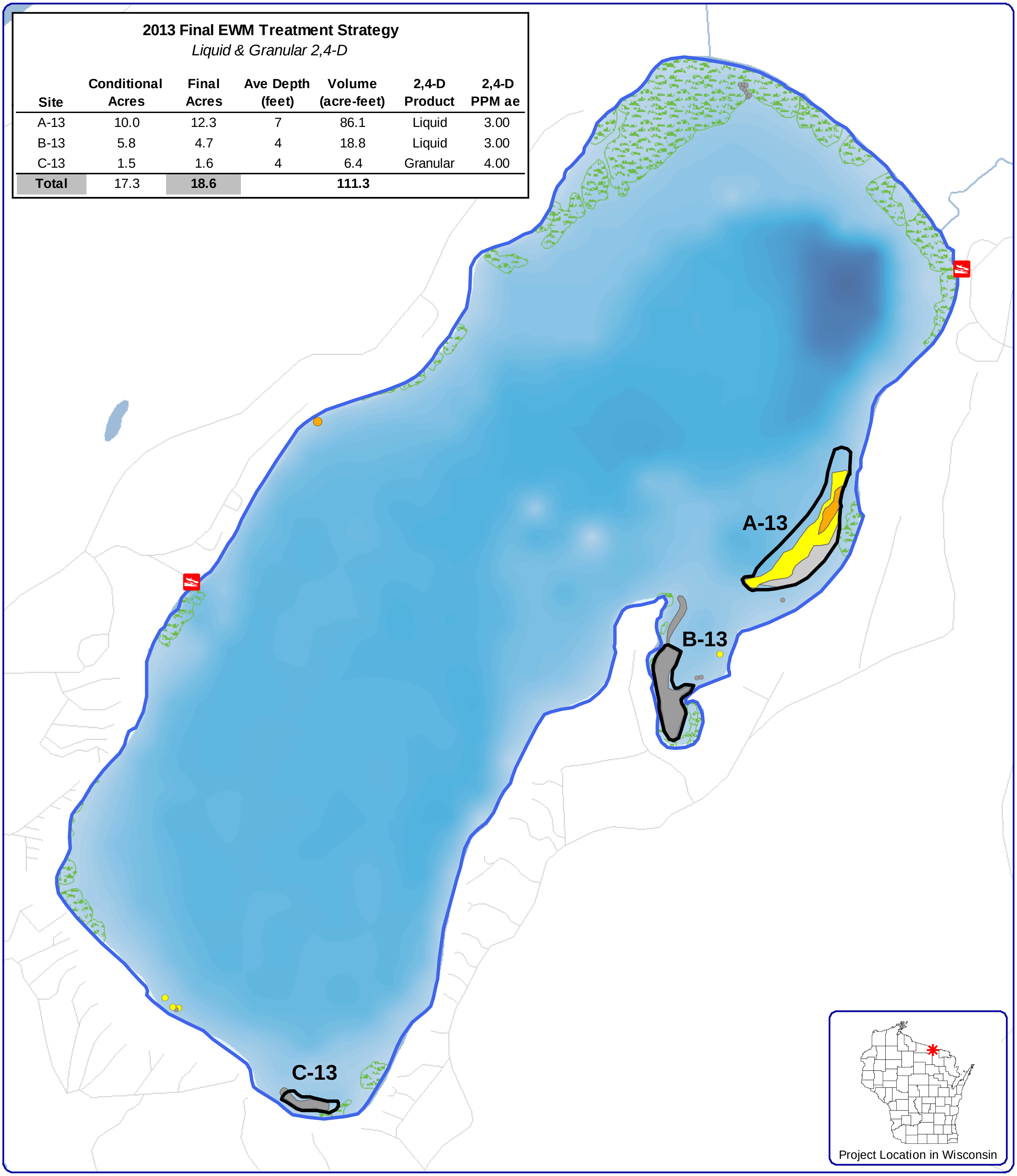
Forest & Vilas Counties, Wisconsin

Emergent & Floating-Leaf Aquatic Plant Communities

2013 Final EWM Treatment Strategy

Liquid & Granular 2,4-D

Site	Conditional Acres	Final Acres	Ave Depth (feet)	Volume (acre-feet)	2,4-D Product	2,4-D PPM ae
A-13	10.0	12.3	7	86.1	Liquid	3.00
B-13	5.8	4.7	4	18.8	Liquid	3.00
C-13	1.5	1.6	4	6.4	Granular	4.00
Total	17.3	**18.6**		**111.3**		



Legend

Eurasian water milfoil (August 2012)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2013 Final EWM Treatment Area
- Emergent and/or Floating-Leaf Community
- Public Access

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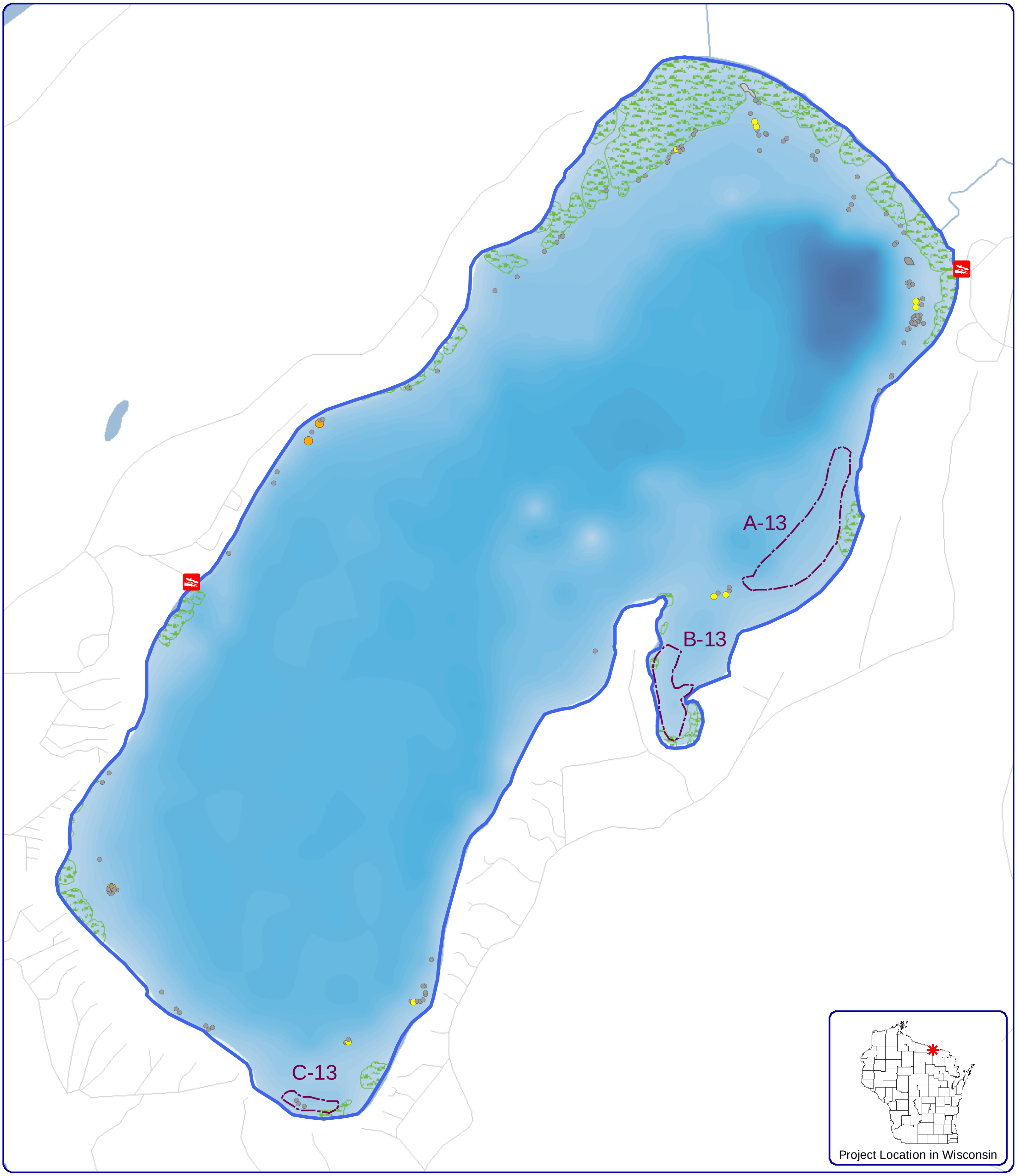
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: March 26, 2014
Filename: Map6_Kentuck_EWM_T2013.mxd

Map 6

Kentuck Lake

Forest & Vilas Counties, Wisconsin

2012 EWM Locations & 2013 Final Treatment Areas



N
W E
S

1,300
Feet

Legend

Eurasian water milfoil (August 2013)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- 2013 Final EWM Treatment Area
- Emergent and/or Floating-Leaf Community
- Public Access

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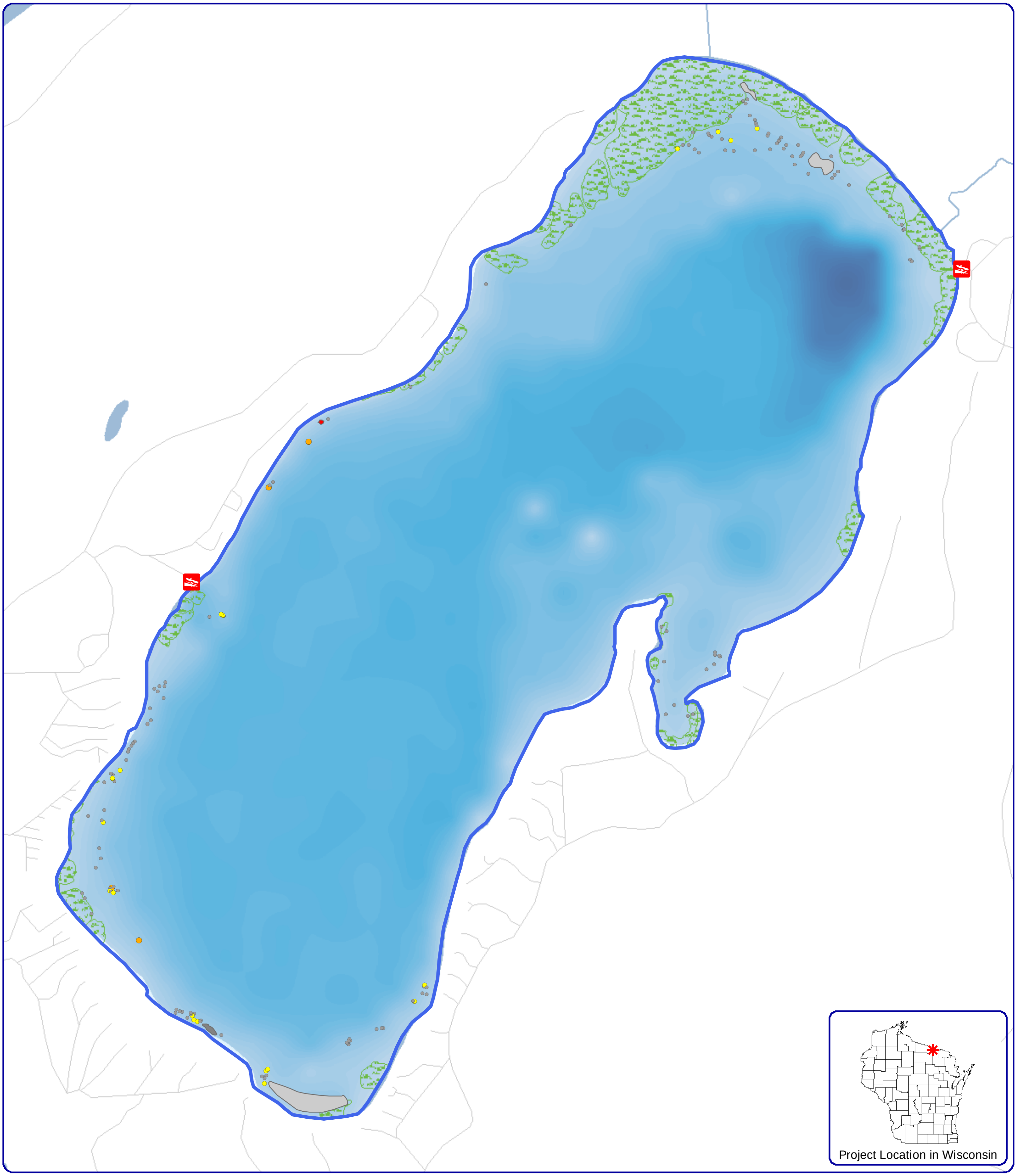
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: March 26, 2014
Filename: Map7_Kentuck_EWMPB_August13.mxd

Map 7

Kentuck Lake

Forest & Vilas Counties, Wisconsin

2013 EWM Locations



Legend

Eurasian water milfoil (August 2014)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Emergent and/or Floating-Leaf Community
- Public Access

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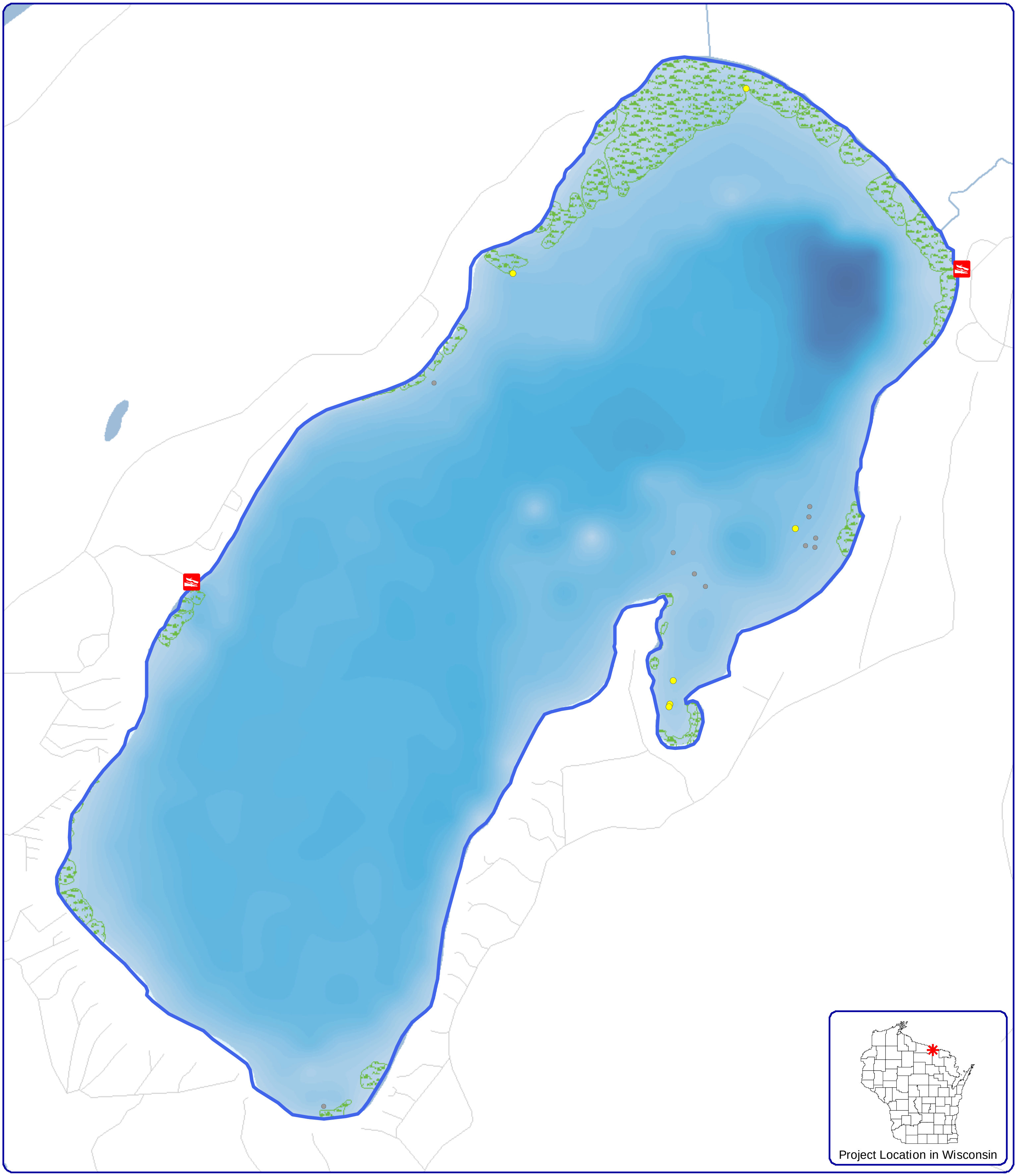
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: September 23, 2014
Filename: Map8_Kentuck_EWMPB_August14.mxd

Map 8

Kentuck Lake

Forest & Vilas Counties, Wisconsin

2014 EWM Locations



Legend

Curly-leaf pondweed (July 3, 2013)

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

Map 9

Kentuck Lake

Forest & Vilas Counties, Wisconsin

2013 CLP Locations

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Lake Management Planning
815 Prosper Road
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920.338.8860
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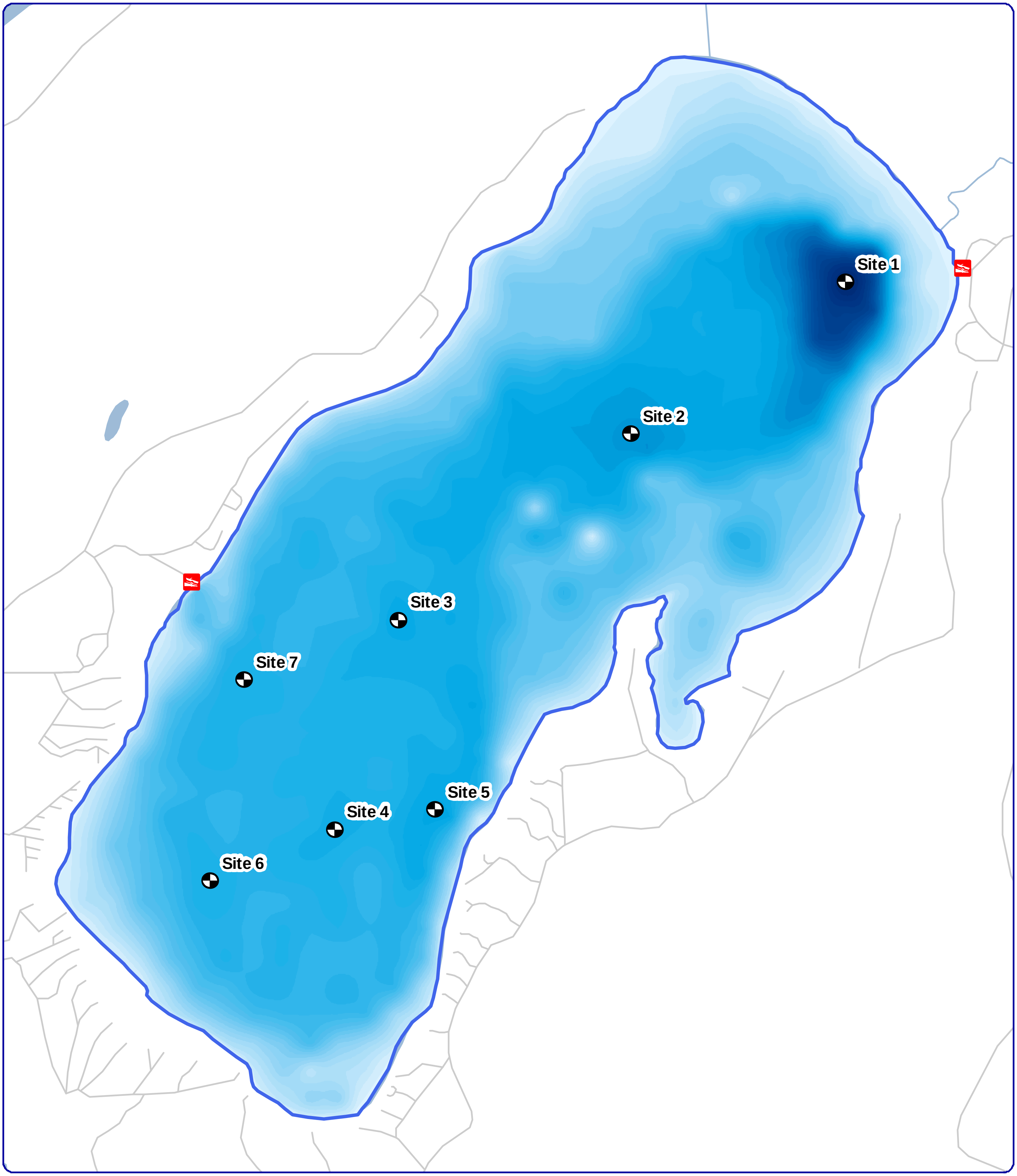
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra
Map Date: March 26, 2014
Filename: Map9_Kentuck_CLPPB_July13.mxd

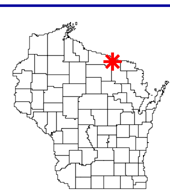


N
W E
S

1,200
Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 2011; digitized by Onterra
Map Date: April 18, 2014
Filename: Map10_Kentuck_2014_WQ_Locations.mxd



Project Location in Wisconsin

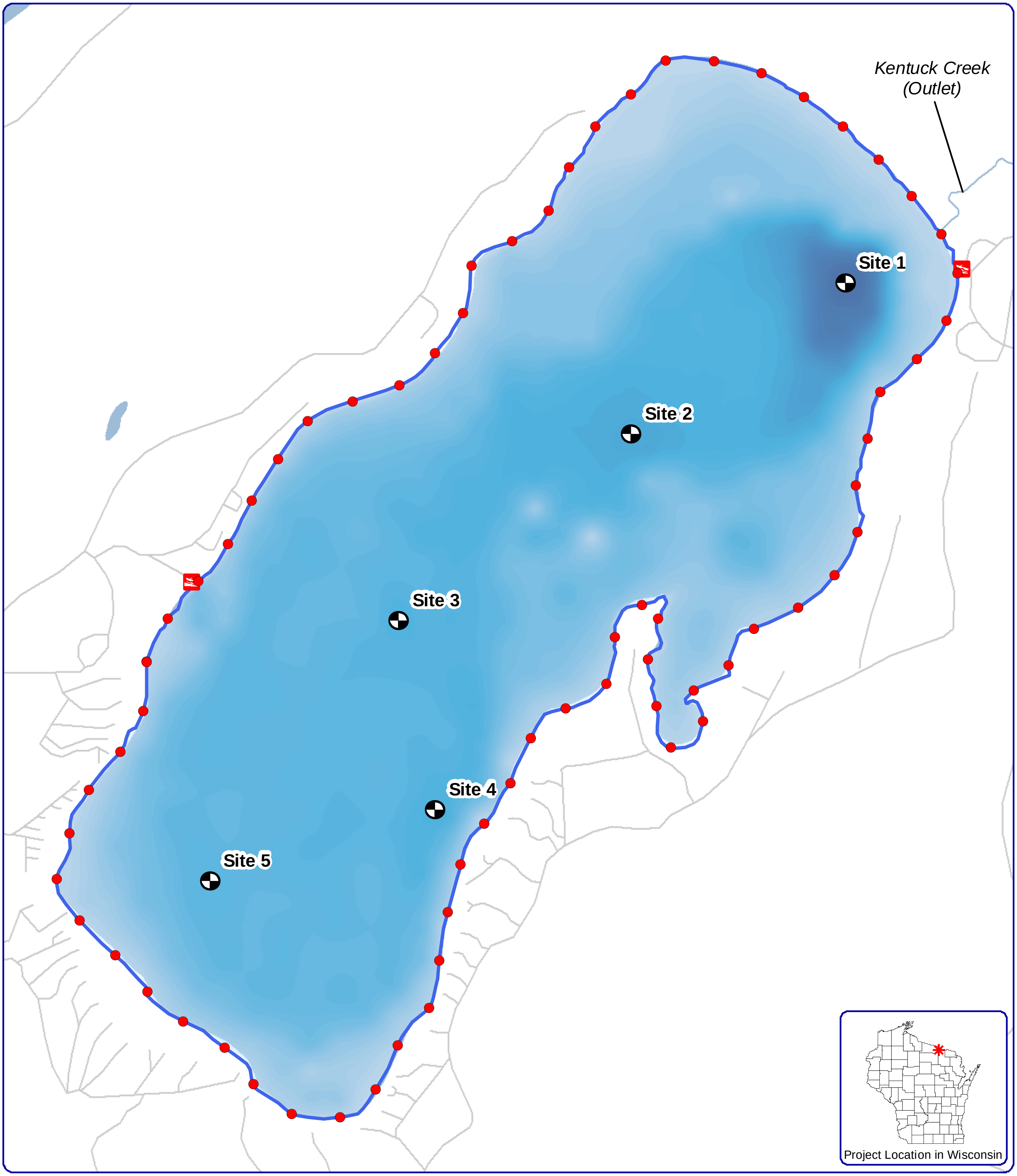
Legend

Water Quality Sampling Location

Public Access

Map 10
Kentuck Lake
Forest & Vilas Counties, Wisconsin

2014 Dissolved Oxygen & Temperature Profile Sampling Locations



N
W E
S

1,200
Feet

Legend

Kentuck Lake ~1,008 acres

Public Access

Mini-Piezometer Sampling Location
500-foot spacing, 67 total locations

In-Lake Water Quality
Sampling Location

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920.338.8860
www.onterra-eco.com

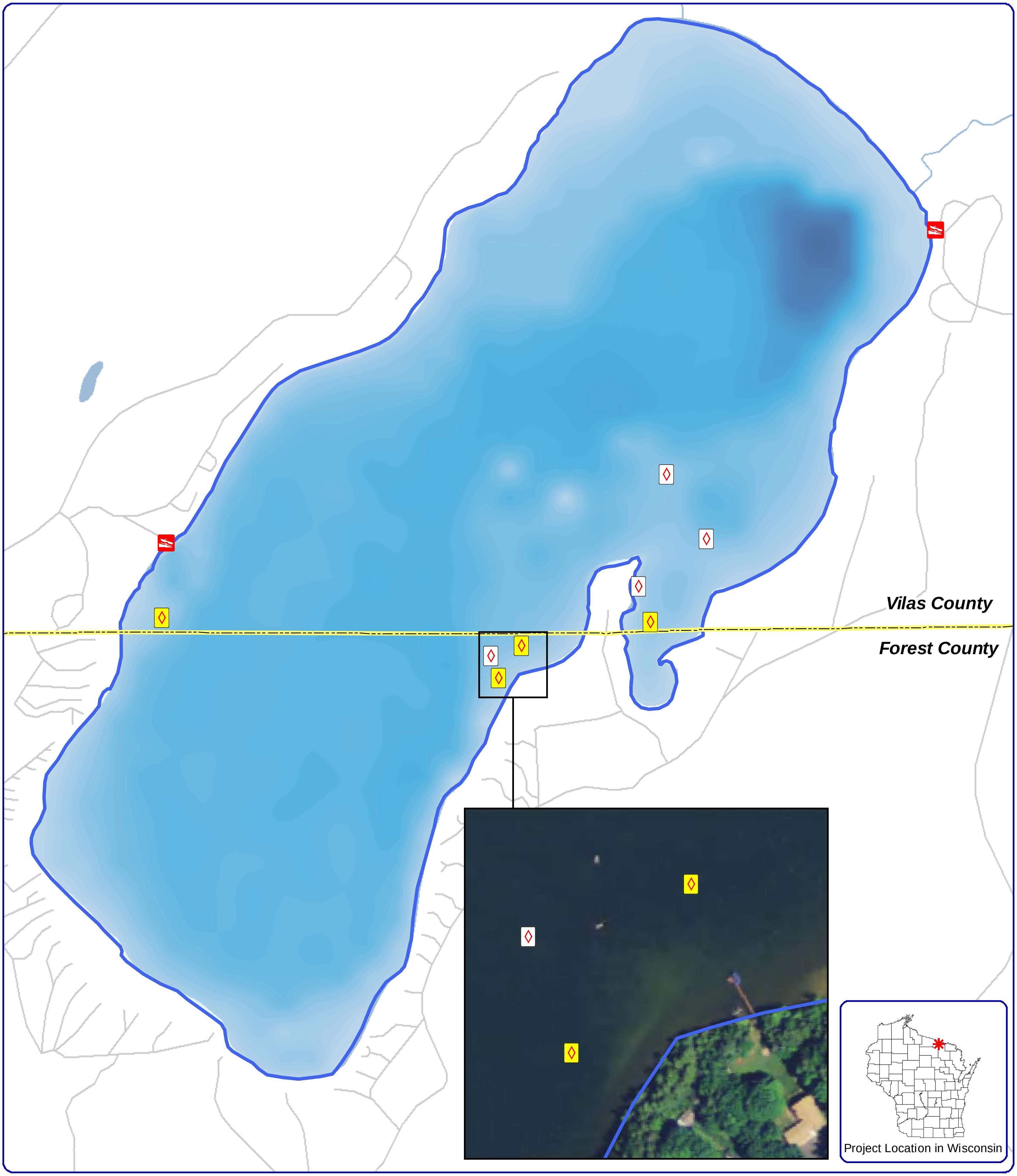
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 2011; digitized by Onterra
Map Date: January 20, 2015
Filename: Map11_Kentuck_2015-2016_WQ_Locations.mxd

Map 11

Kentuck Lake

Forest & Vilas Counties, Wisconsin

In-Lake & Groundwater Sampling Locations



Legend

- Kentuck Lake ~957 acres *WDNR Definition*
- Public Access
- Existing Regulatory Danger Buoy Location
- Proposed Additional Regulatory Danger Buoy Location

Map 12

Kentuck Lake

Forest & Vilas Counties, Wisconsin

Proposed Regulatory Danger Buoy Placement Locations

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920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR 1971; digitized by Onterra

Map Date: October 31, 2014

Filename: Map12_Kentuck_NavHazards.mxd