# Three Lakes Chain

**Oneida County, Wisconsin**

# Phases I – IV Comprehensive Management Plan

**April 2016**

Sponsored by:

**Three Lakes Waterfront Association**

Wisconsin Department of Natural Resources
Grant Program

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Onterra LLC
Lake Management Planning

# Three Lakes Chain
Oneida County, Wisconsin
# Comprehensive Management Plan
April 2016

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Funded by: Three Lakes Waterfront Association
Wisconsin Dept. of Natural Resources Lakes Grant Program

## Acknowledgements

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

### Three Lakes Chain of Lakes Planning Committee

The Planning Committee was comprised of 2-5 riparian property owners from the following lakes:

| | | |
|---|---|---|
| Virgin Lake | Whitefish Lake | The Thoroughfare |
| Big Lake | Dog Lake | Crystal (Mud) Lake |
| Deer Lake | Big Stone Lake | Laurel Lake |
| Big Fork Lake | Fourmile Lake | Maple Lake |
| Moccasin Lake | Spirit Lake | |

#### Organization

| | |
|---|---|
| Town of Three Lakes | Wisconsin Valley Improvement Company |

#### Wisconsin Dept. of Natural Resources

| | |
|---|---|
| Tim Plude | Kevin Gauthier |
| Carol Warden | John Kubisiak |

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Individual lake reports are drafted as separate attachments to the chain-wide document.

# 1.0 INTRODUCTION

The Three Lakes Chain of Lakes is a 6,900+ acre flowage residing in north-eastern Oneida County, WI (Map 1). The chain drains north as the Eagle River over the Burnt Rollways Dam into the lower Eagle River Chain of Lakes, Vilas County. The date of the original dam construction is unknown, though in 1893 Nine Mile Creek Improvement Company was authorized to build this dam. The Wisconsin Valley Improvement Company (WVIC) acquired the structure in 1907. After this dam was washed out in 1909, it was replaced with the current concrete structure that holds wooden slide gates. A federal license specifies that water levels be kept between 1,625.71 and 1,622.96 ft NGVD (National Geodetic Vertical Datum).

Since its inception, the Three Lakes Waterfront Association (TLWA), along with its long-time partner, the Town of Three Lakes, has worked to prevent introduction and establishment of aquatic invasive species within the chain of lakes. The groups have approached this sometimes overwhelming task through diligent volunteer monitoring of the chain's littoral zone (Adopt-A-Shoreline) and an annual educational initiative that includes direct contact with lake stakeholders through multiple avenues, such as conducting annual meetings with educational speakers, staffing informational booths and manning the chain's many landings with Clean Boats / Clean Waters watercraft inspectors. The association also educates stakeholders through more passive activities, like direct mailings, newsletters and signage at boat landings.

Along with preventing aquatic invasive species establishment within the chain, it has been the long-term objective of the TLWA to create comprehensive management plans for the 21 lakes and two connecting waterways (the Thoroughfare and Townline Creek) within the Three Lakes Chain over a span of five to ten years. This project began with studies on Long Lake due to the discovery of Eurasian water milfoil and subsequent need for immediate attention. Beginning with discussions in 2009/2010, a phased approach was developed to address each lake within the chain, starting from the top of the chain (south) and working downstream towards Long Lake and the Eagle River above the Burnt Rollways Dam (Map 1). Developing management plans for small clusters of lakes within the chain allow for financial savings to be realized in overall project costs while creating a manageable process that allows for sufficient attention to be applied to each lake's needs. This is opposed to completing all plans simultaneously, which would facilitate great cost savings, but only produce generic plans for each lake and the chain as a whole. Financial assistance was obtained through the Wisconsin Department of Natural Resources' Lake Management Grant Program for each phase of the project.

The Three Lakes Chain is a highly sought after location amongst recreationists. In addition to the 14 public boat landings on the chain, there is access to the eight boat landings on the Lower Eagle River Chain by traveling over the Burnt Rollways Dam using the tracked boat-lift system. These public use opportunities most likely contributed to two small areas on the chain (Virgin Lake and Long Lake/Eagle River channel) becoming populated with Eurasian water milfoil. Throughout the project, Onterra staff continued to monitor these known infestations as well as sweeping new areas for signs of invasive species. During this time, the TLWA and Town of Three Lakes worked to educate stakeholders about Eurasian water milfoil and other aquatic invasive species. Through various efforts including the Clean Boats / Clean Waters program, TLWA volunteers have helped to reduce the risk of invasive species transfer as well as facilitate education on this important matter.

# 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.

## *Project Planning Process*

**Kick-off Meeting**

On July 23, 2011, Tim Hoyman met with members of the TLWA for a dual -purpose meeting. First, an update was provided on activities associated with the Long Lake Management Plan and Eagle River Channel Eurasian water milfoil control and monitoring project. Then, the management planning project for the Phase I and Phase II lakes was discussed in detail. At that point in time, field studies had been completed for the Phase I lakes and activities regarding the Phase II lakes were underway. All project components were discussed and reported upon as available. Following the presentation, Mr. Hoyman answered many questions on general lake ecology as well as how the chain-wide management planning process would be conducted.

**Planning Committee Meetings**

Planning meetings were conducted periodically through the chain-wide study, and focused upon the lakes involved with each current phase. In 2012, Tim Hoyman and Dan Cibulka met with a planning committee consisting of stakeholders from Phase I and Phase II lakes. Onterra staff met with Phase III representatives in 2013 and Phase IV representatives in July of 2014. During these meetings, Mr. Hoyman and Mr. Cibulka went over the study results from lakes represented. All project components, including water quality analyses, watershed studies, aquatic plant surveys and stakeholder survey information were discussed in detail. Many questions were answered by Mr. Hoyman and Mr. Cibulka pertaining to issues such as aquatic invasive species, nutrient concentrations within the lakes, dissolved oxygen levels and navigation/safety.

Within Phase I and II of the project, a meeting was held to brainstorm on the initial Implementation Plan. On August 23, Tim Hoyman and Dan Cibulka met again the Phase I and II lakes Planning Committee. During this meeting, the committee and Onterra staff discussed management goals the TLWA would implement for protecting and preserving the Three Lakes Chain of Lakes, and what steps would need to occur to reach these goals. The Implementation Plan (see Implementation Plan section) is largely the result of these conversations. Within each following phase, the lake representatives were asked to look over the Implementation Plan and if any revisions or additions were required a second meeting would be held. Following these meetings, the Implementation Plan was reviewed and modified appropriately.

**Management Plan Review and Adoption Process**

Prior to the first Planning Committee Meeting of each phase, the Results Section of this document (Section 3.0) as well as the individual lake sections were sent to all planning committee members for their review and preparation for the meeting. Following discussions at the second Planning Committee Meeting, Onterra staff drafted this report's Implementation Plan and sent it to TLWA board members for review. Their comments were integrated to the plan, and a first official draft was sent to the WDNR for a review in December of 2012. The WDNR approved of the Phase I and II plan in September of 2013 and Phase III in February of 2014. A draft containing updates from Phase IV of the project was sent to the WVIC in November of 2014 and the WDNR in March of 2015 for review. The report was reviewed and returned to Onterra, and revisions occurred before a second draft was produced in March of 2016.

## *Stakeholder Survey*

As a part of phase of Phase II of this project, a stakeholder survey was distributed to TLWA members and non-member riparian property owners. This survey was designed by Onterra staff and the TLWA planning committee in September of 2011. The draft survey was sent to a WDNR social scientist for review that same month. During October 2011, the eight-page, 32-question survey was mailed to 1,694 riparian property owners in the Three Lakes Chain of Lakes watershed. Thirty-seven percent of the surveys were returned. 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. Following review of the survey data by Onterra and TLWA board members, Onterra staff assisted Jerry Schiedt of the TLWA in preparing a presentation of the survey results. Mr. Schiedt delivered this presentation to TLWA members at their July 2012 annual meeting.

Because of a relatively low response rate (37%), the results may not statistically represent the opinions of the stakeholder population. The results may however represent stakeholders holding the strongest opinions, thereby identifying issues and concerns of the larger population. Survey results will be shared within this report; however, caution was used in interpreting their results due to the low level of participation. Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Three Lakes Chain of Lakes. Thirty-seven percent of stakeholders are year-round residents, while 32% live on the chain seasonally and 23% visit on weekends throughout the year (Appendix B – Question #2). Fifty-nine percent of stakeholders have owned their property for over 15 years, and 35% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use a canoe or kayak on the chain (Question #9). Motorboats of various sizes, pontoon boats, and rowboats were also popular choices on this question. On an intense recreational system such as Three Lakes Chain of Lakes, the importance of responsible boating activities is increased. The need for boating responsibly increases during increased traffic on the lake. As seen on Question #10, several of the top recreational activities on the lake involve boat use. Three Lakes Chain stakeholders overwhelmingly indicated that watercraft use (jet skiing, water skiing/tubing and motor boating) has increased since they obtained their property (Question #11). Furthermore, boat traffic was ranked as the highest factor negatively impacting the Three Lakes Chain, and was ranked as the second top concern regarding the Chain of Lakes as well (Question #20 and #21). Comments were recorded regarding this issue on the Three Lakes Chain – both supporting the use of watercraft and criticizing the use of watercraft (Appendix B – Written Comments).

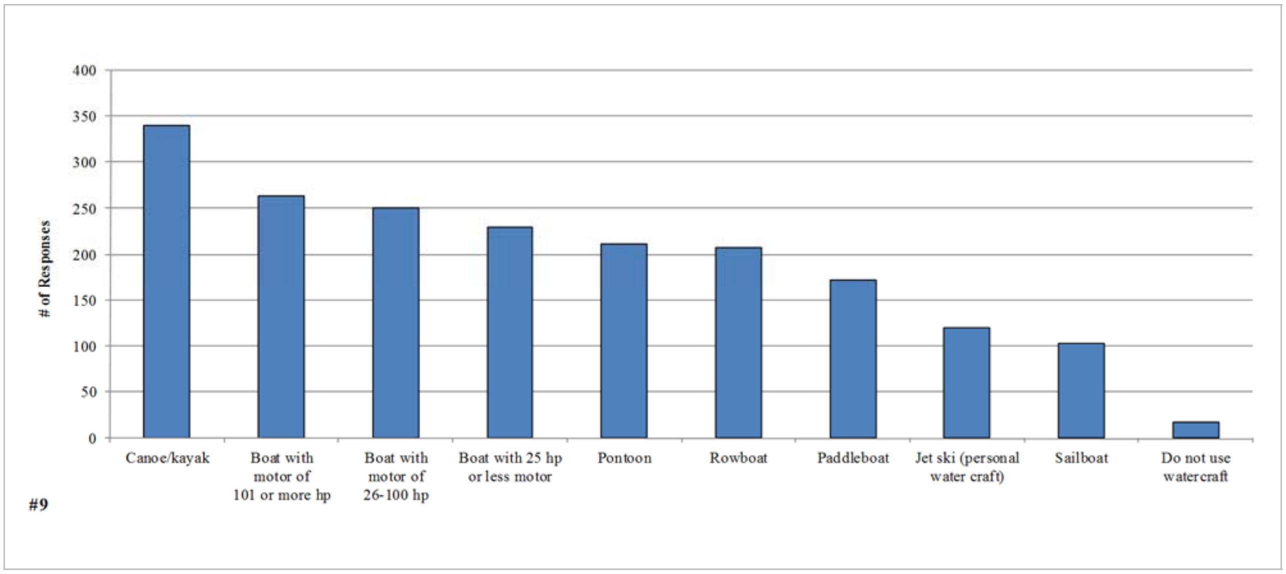
To gather information about opinions on watercraft speed and use on the chain, the TLWA, with assistance from Onterra staff and approval from social scientists at the WDNR, developed two questions on the stakeholder survey regarding the matter. The majority of survey respondents indicated that the number of slow-no-wake areas on the chain are "just right" (Question #12). 75% of all respondents indicated that they support the Wisconsin boating regulation prohibiting boaters from operating their boats at speeds greater than slow-no-wake 100 feet from shore and/or structures (Questions #13).

This regulation is known as Wisconsin Act 31, and was enacted in 2010. This act was set into place because of the disturbance to the lake that can result from boating at high speeds in this zone. Specifically, shoreline erosion, disruption of lake bottom sediments and nutrients, and destruction of aquatic organism habitats may occur. Safety for swimmers, slow-moving watercraft and other recreationalists was also considered into Act 31. Legislators writing this regulation realized there may be times when local authorities may wish to enact their own ordinances, either in addition to this regulation or in opposition to opt out of Act 31.

The Town of Three Lakes created a committee (Three Lakes Act 31 Advisory Committee) to examine this regulation and offer a recommendation to the Three Lakes Board of Supervisors on the applicability of Act 31 to the Three Lakes Chain of Lakes. The Committee offered a recommendation in favor of opting out of Act 31, and ultimately in 2010/2011 the Town of Three Lakes decided to opt out of the Act as well. Thus, the 100-foot rule does not apply to any waterbodies within the Town of Three Lakes (on the Three Lakes Chain or otherwise). The Committee's overall recommendation included suggestions for areas to be slow-no-wake zones, policing and enforcement options, and areas designated as quiet sport (canoe/kayak) zones, caution zones, or shallow water areas. A report detailing the Committee's consideration of Act 31 and their recommendations can be found in Appendix C.

Several concerns noted throughout the stakeholder survey include watercraft issues as described above and within the written comments portion of Appendix B, concern over aquatic invasive species detection and control, and Native American spear harvesting of walleye on the Three Lakes Chain. Spearing regulations and harvest data is summarized with the Fisheries Data Integration Section and aquatic invasive species information is detailed within the Aquatic Plants Section. Discussion regarding watercraft use on the Three Lakes Chain of Lakes is described completely within Appendix C, and is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

*Question #9: What types of watercraft do you currently use on the lake?*




*Question #10: Please rank up to three activities that are important reasons for owning your property on or near the lake.*

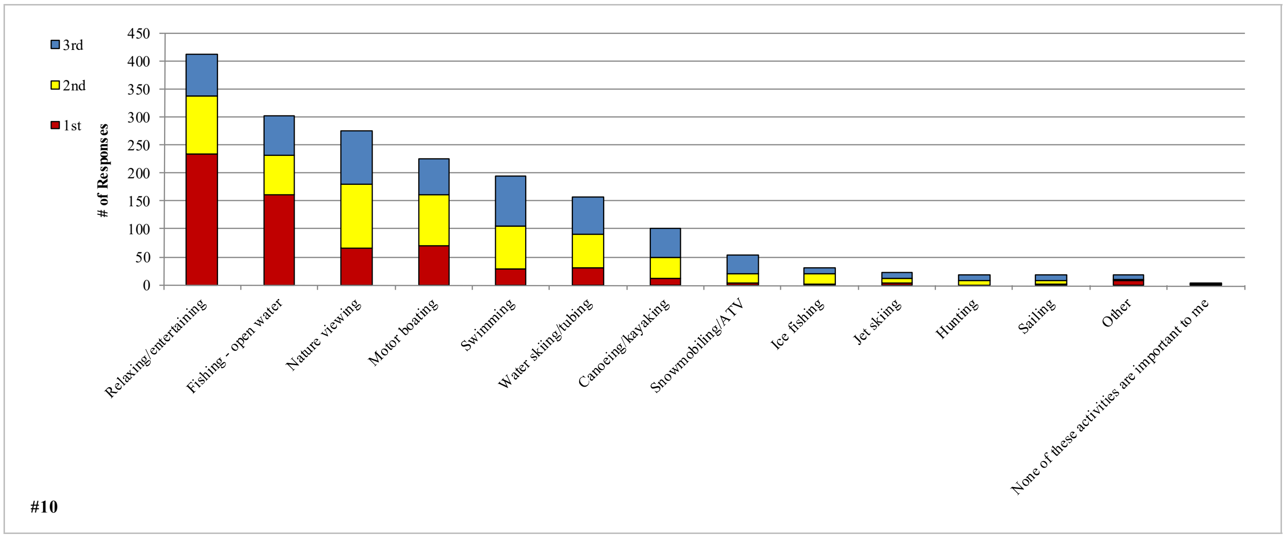
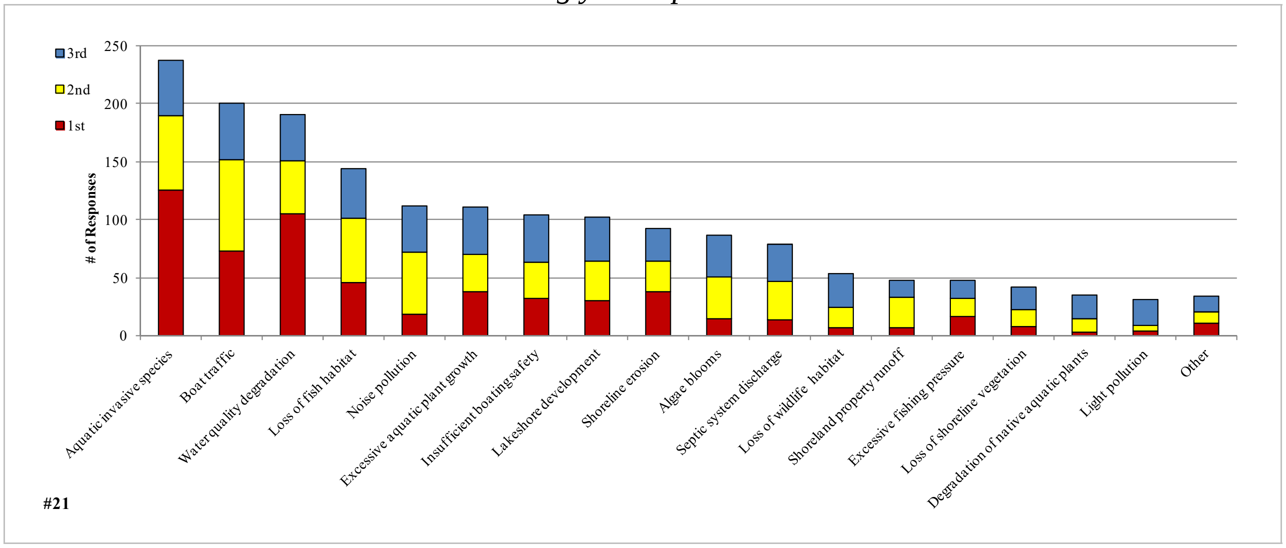
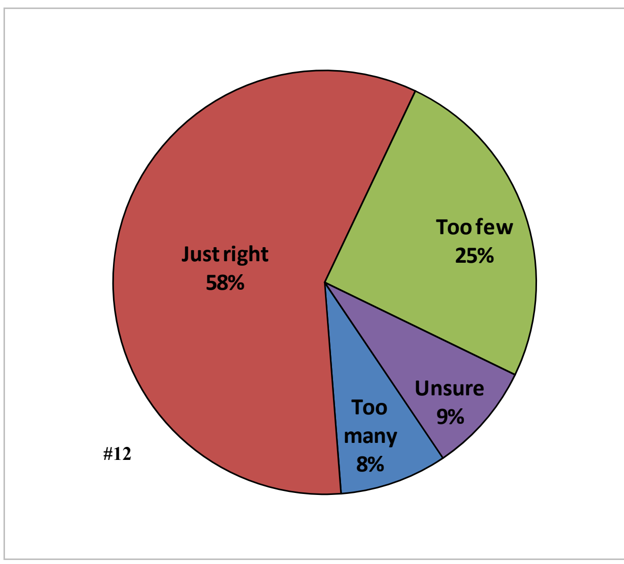



**Figure 2.0-1. Select survey responses from the Three Lakes Chain Stakeholder Survey.** Additional questions and response charts may be found in Appendix B.

*Question #21: Please rank your top three concerns regarding Three Lakes Chain of Lakes, with 1 being your top concern.*




*Question #12: What is your opinion of the number of slow-no-wake areas on the entire Three Lakes Chain?*




*Question #13: Do you support or oppose the Wisconsin boating regulation prohibiting boaters from operating their boats at speeds greater than slow-no-wake 100 feet from shore and/or structures?*

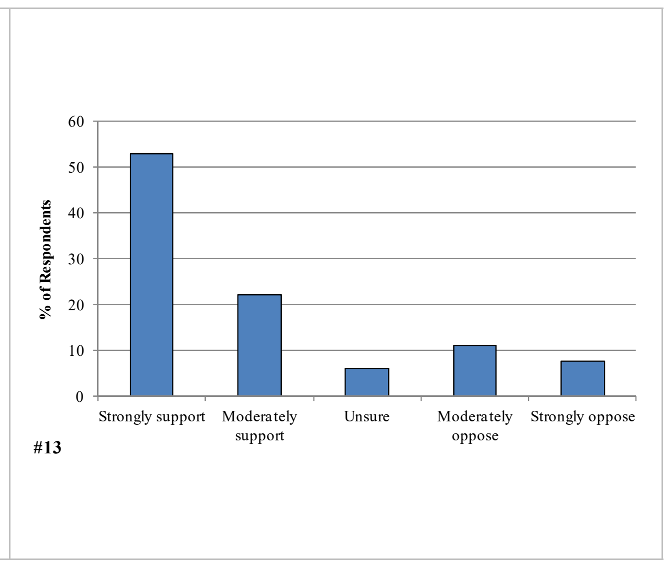



**Figure 2.0-2. Select survey responses from the Three Lakes Chain Stakeholder Survey, continued.** Additional questions and response charts may be found in Appendix B.

## *Three Lakes Chain of Lakes Stakeholder AIS*

As with most Wisconsin lakes, there is great concern with Three Lakes Chain of Lakes stakeholders over the threat of aquatic invasive species. The Town of Three Lakes and TLWA have put forth much effort in educating area stakeholders and Three Lakes Chain visitors about the threat that invasive plants pose. Approximately 99% of stakeholder survey respondents indicated that they have heard of aquatic invasive species (Appendix B, Question #16). About 78% indicated they believe aquatic invasive species are present in their lake (Question #17). When asked what aquatic invasive species were present in their lake, survey respondents selected Eurasian water milfoil, rusty crayfish, Chinese mystery snail, *Heterosporosis*, and purple loosestrife as top choices. Table 2.0-1 lists the confirmed aquatic invasive species in each of the Three Lakes Chain lakes.

96% of survey respondents indicated that they are either somewhat or very concerned about the spread of invasive species to their lake (Question #19), and this topic was ranked first on a list of concerns stakeholders have regarding their lake (Question #21). Invasive species management can be a costly, time consuming and complicated task. Control strategies often become dependent on the stage of infestation, environmental factors of the ecosystem, and budget constraints of the managing entities. When it comes to managing plant species, Three Lakes Chain stakeholders favor an integrated control using several methodologies most (Question #24).

While no reasonable and efficient control strategy exists for several of the species on Table 2.0-1 (banded and Chinese mystery snails and rusty crayfish), several effective methods have been utilized for control of Eurasian water milfoil and purple loosestrife. For the Three Lakes Chain of Lakes in which aquatic invasive plants are present, the history and management strategy for each is discussed further within that lake's Aquatic Plant Section and Implementation Plan.

**Table 2.0-1. Aquatic Invasive Species located on the Three Lakes Chain.** Information obtained from WDNR internet databases (Invasive Species – How Wisconsin Is Doing - www.dnr.wi.gov/lakes/invasives/Default.aspx & Surface water data viewer - http://dnr.wi.gov/org/water/data_viewer.htm).

| Lake | AIS and Year Confirmed |
|---|---|
| Big Lake | Chinese Mystery Snail (2011), Rusty Crayfish (2002), Purple Loosestrife (2010) |
| Big Fork Lake | Chinese Mystery Snail (2007), Pale yellow iris (2012) |
| Big Stone Lake | Banded Mystery Snail (2007), Chinese Mystery Snail (2007), Purple Loosestrife (2011), Rusty Crayfish (2002), |
| Crystal (Mud) Lake | Rusty Crayfish (2002) |
| Deer Lake | Chinese Mystery Snail (2007), Rusty Crayfish (2002) |
| Dog Lake | Rusty Crayfish (2002) |
| Fourmile Lake | Rusty Crayfish (2002), Pale yellow iris (2012) |
| Island Lake | Rusty Crayfish (Unknown) |
| Laurel Lake | Chinese Mystery Snail (2011), Purple Loosestrife (2011), Rusty Crayfish (2002) |
| Little Fork Lake | Chinese Mystery Snail (2007), Rusty Crayfish (2002) |
| Long Lake | Eurasian water milfoil (Eagle River channel - 2006), Hybrid cattail (2009), Purple Loosestrife (2009), Rusty Crayfish (1964) |
| Maple Lake | Banded Mystery Snail (2007), Chinese Mystery Snail (2007) |
| Medicine Lake | Chinese Mystery Snail (2007) |
| Moccasin Lake | Pink water lily (2014) |
| Planting Ground Lake | Chinese Mystery Snail (2007), Rusty Crayfish (Unknown) |
| Range Line Lake | Banded Mystery Snail (2007), Chinese Mystery Snail (2007), Rusty Crayfish (2002) |
| Spirit Lake | Pale yellow iris (2013) |
| The Thoroughfare | Chinese Mystery Snail (2005) |
| Townline Lake | Chinese Mystery Snail (2005), Rusty Crayfish (2002) |
| Whitefish Lake | Rusty Crayfish (1957) |
| Virgin Lake | Eurasian water milfoil (2010) |

# 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 Three Lakes Chain of Lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix D). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Three Lakes Chain of Lakes' water quality analysis:

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

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

## Trophic State

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

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

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

## Limiting Nutrient

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

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

## Temperature and Dissolved Oxygen Profiles

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

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

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 processes that occur within a lake. Internal nutrient loading is an excellent example that is described below.

## Internal Nutrient Loading

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

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

**Non-Candidate Lakes**

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. 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 the Three Lakes Chain will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

**Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.

**Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.

Headwater drainage lakes have a watershed of less than 4 square miles.

Lowland drainage lakes have a watershed of greater than 4 square miles.

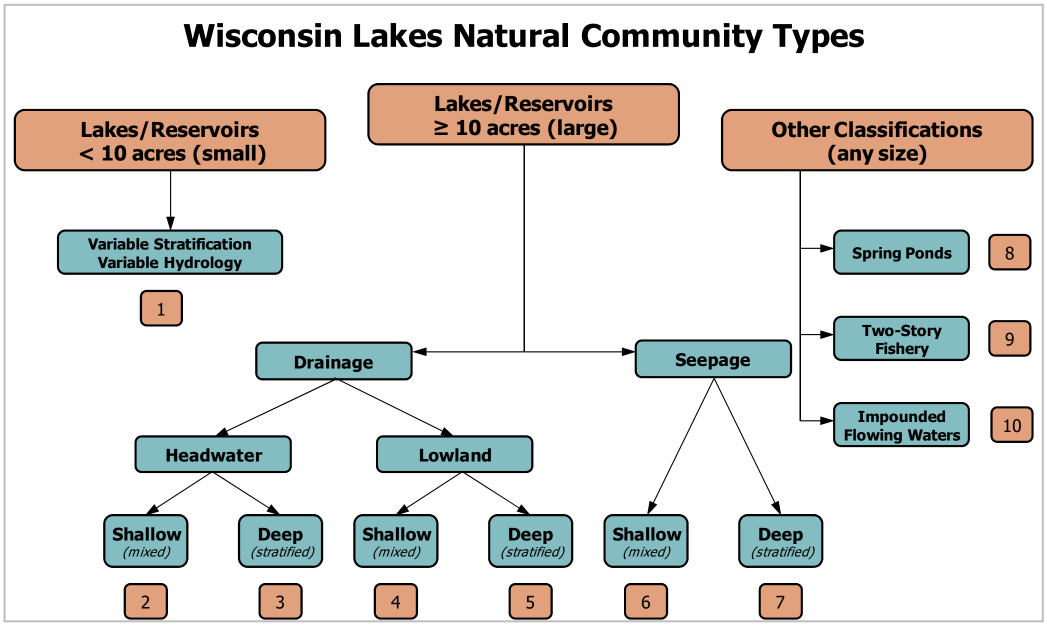



**Figure 3.1-1. Wisconsin Lake Natural Community classifications.** Adapted from WDNR 2013.

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

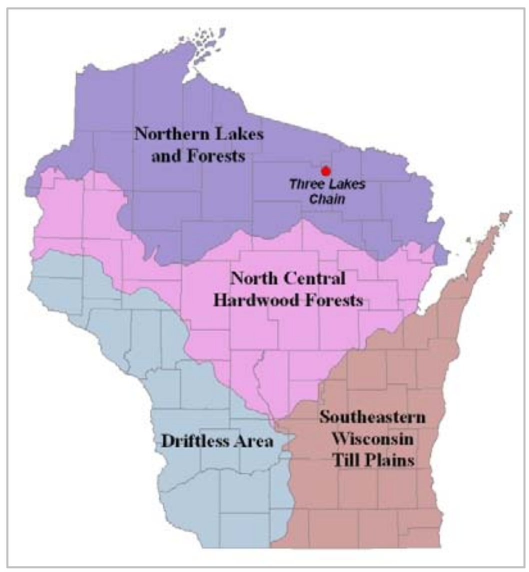



**Figure 3.1-2. Location of Three Lakes Chain within the ecoregions of Wisconsin.** After Nichols 1999.

The Wisconsin 2014 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake averages, historic, current, and average data from Three Lakes Chain of Lakes are displayed in Figures 3.1-3 - 3.1-6. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

## *Three Lakes Chain of Lakes Water Quality Analysis*

### Three Lakes Chain of Lakes Nutrient Content and Clarity

The amount of historical water quality data existing on the Three Lakes Chain varies by lake. Several lakes have volunteers that are actively monitoring their lake through the WDNR's Citizens Lake Monitoring Network (CLMN), collecting nutrient samples or Secchi disk clarity data several times each summer. Many lakes do not have active CLMN volunteers and because of this, there are no historic data to compare against the data that were collected as a part of this project. The importance of consistent, reliable data cannot be stressed enough; just as a person continuously monitors their weight or other health parameters, the water quality of a lake should be monitored in order to understand the system better and make sounder management decisions.

Onterra staff collected water quality samples and monitored Secchi disk clarity on each Three Lakes Chain lake during the course of this project. Monitoring occurred during the spring, summer, fall and following winter of each project phase (Phase I lakes sampled in 2010/2011, Phase II lakes sampled in 2011/2012, etc.). Long Lake completed a management plan in 2009, so data obtained through that process are displayed in the figures below. As a part of the current management project consisting of the entire Three Lakes Chain, Long Lake will be sampled again in 2017. Please note on the following figures that comparisons are best made across lakes of similar classification (shallow, lowland drainage lakes in light blue, deep, lowland drainage lakes in dark blue, etc.). Unless otherwise indicated, parameters represent samples collected from the sub-surface of each lake.

Total phosphorus values ranged between 9.7 and 32 μg/L (Figure 3.1-3). However, Crystal (Mud) Lake's average summer concentration averaged 72 μg/L in 2011. This value is exceptionally high, exceeding the value for other shallow, lowland drainage lakes across the state and region. All other lakes are near or even below the median value for their respective lake class (shallow or deep lowland drainage lakes) for this parameter. These levels are normal and healthy for Wisconsin Lakes.

Average summer chlorophyll-*a* concentrations vary little within the Three Lakes Chain of Lakes (Figure 3.1-4). Several lakes include average summer concentrations that lie only slightly above the median value for their respective lake class (Big, Laurel and Fourmile), while most lie below this benchmark value. Regardless, all lakes display average chlorophyll-*a* values that are healthy for their ecosystem. As with aquatic macrophytes (aquatic plants), light penetration into the water column is necessary for algae to grow. As discussed further below, algae growth may be limited to a certain extent in the Three Lakes Chain due to the naturally stained water.

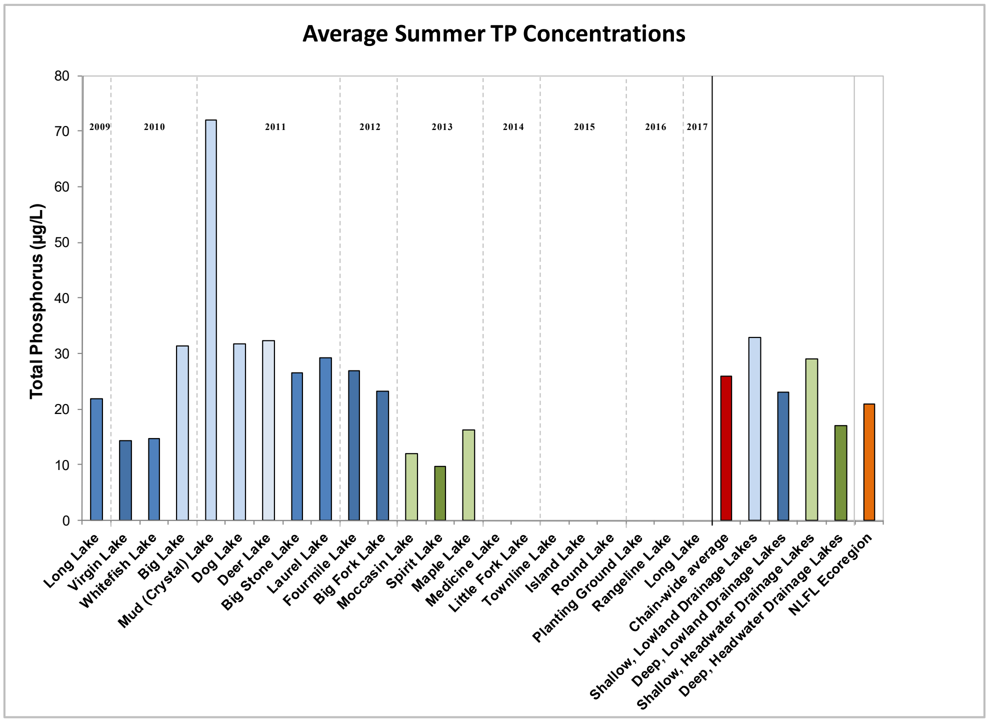



**Figure 3.1-3. Three Lakes Chain and comparable lakes total phosphorus concentrations.** Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests Lakes ecoregion median.

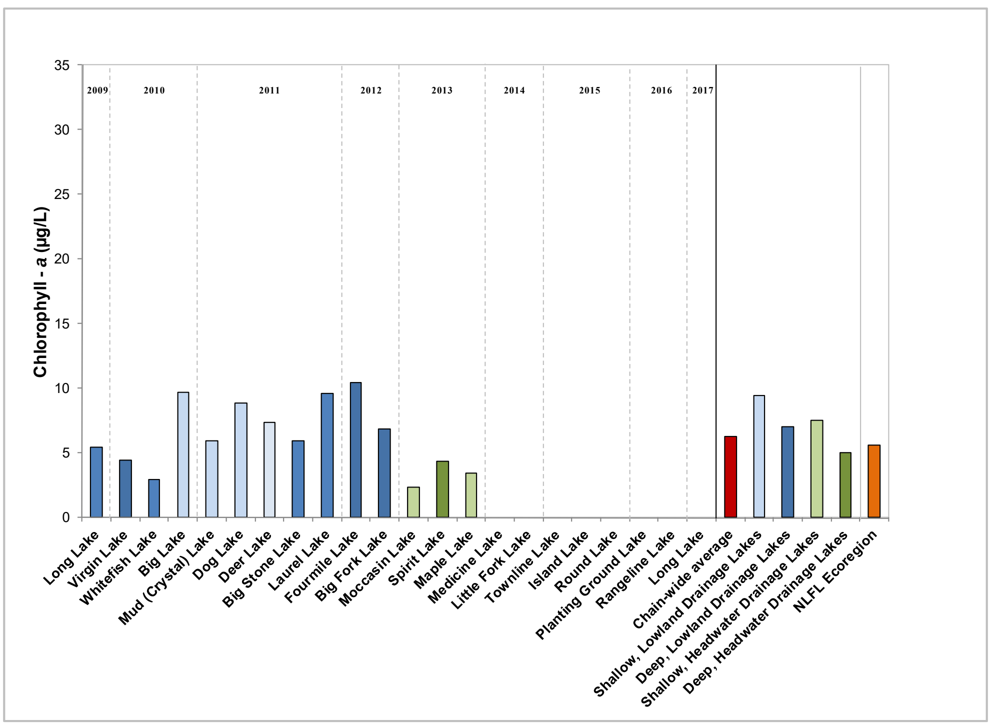



**Figure 3.1-4. Three Lakes Chain and comparable lakes chlorophyll-*a* concentrations.** Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests Lakes ecoregion median.

Average summer Secchi disk clarity ranged from 1.5 feet to 12.5 feet deep in the Three Lakes Chain lakes (Figure 3.1-5). In the two lakes at the upper reaches of the chain (Virgin and Whitefish Lakes) and in Spirit Lake, Secchi disk depth was the greatest, lying above the value for similar class lakes statewide. Several lakes displayed average Secchi depths between one and four feet of depth. While the water in these lakes can be said to have very low clarity, the reason is not because of excessive algae, as established above. Systems with large watersheds (discussed further in the Watershed Section) drain many acres of forested lands and wetlands. When water drains these tracts of land into a lake, naturally occurring organic acids accumulate and stain the lake water a dark brown color. This is the cause of the Three Lakes Chain's "root beer" color. Furthermore, it is this factor that is limiting light penetration into the waters of the lakes which in turn limits algal production as well as the depth of aquatic plant growth (see the Aquatic Plant Section).

Beginning in 2012, a parameter called "true color" was added to the water quality sampling regime for the Three Lakes Chain project. True color is a measurement of the dissolved organic materials in water, and is measured in Platinum-cobalt units (Pt-co units, or PCU). Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color. This helps to explain the stained colors of the Three Lakes Chain, as this parameter indicates the higher level of dissolved organics acids that are naturally found in the lakes here. For example, in Fourmile and Big Fork Lakes, two lakes with relatively larger (>14,000 acres) watersheds, color exceeded 70 PCU. In the Phase IV lakes (Moccasin, Spirit and Maple) the watershed sizes are all less than 1,400 acres. True color was measured at less than 35 PCU in each of these lakes in 2013.

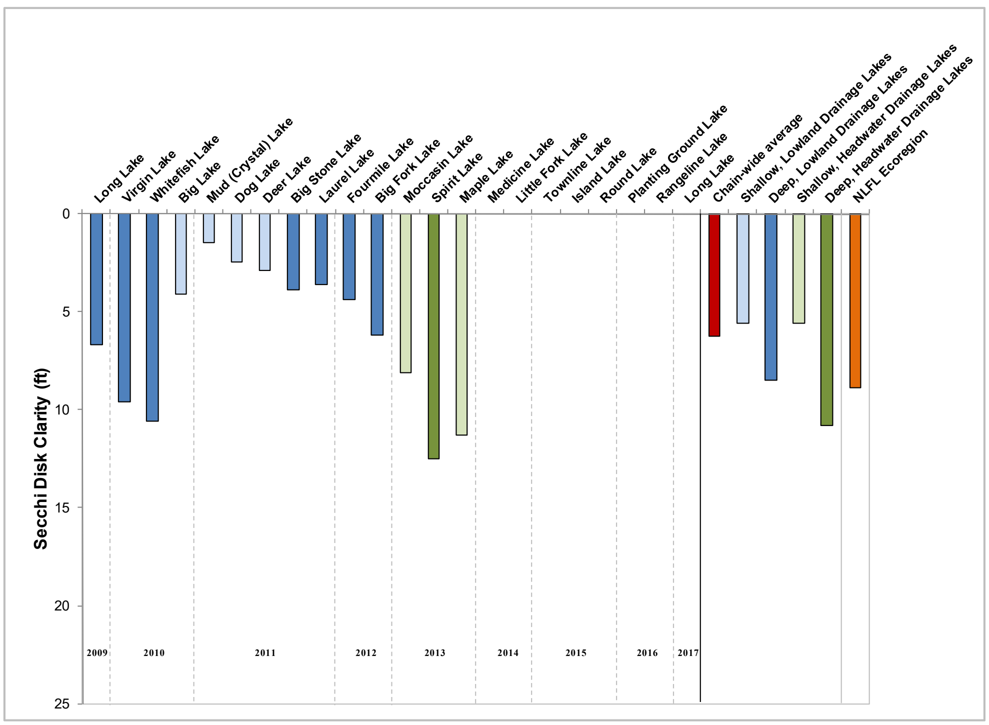



**Figure 3.1-5. Three Lakes Chain and comparable lakes Secchi disk clarity values.** Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests Lakes ecoregion median.

## Limiting Plant Nutrient of Three Lakes Chain of Lakes

Using average nitrogen and phosphorus concentrations from all lakes included in the Three Lakes Chain of Lakes study, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.1-1). In all lakes, the ratio weighed heavily in favor of nitrogen, rather than phosphorus. This finding indicates that all of the lakes of the Three Lakes Chain of Lakes are 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 lakes.

**Table 3.1-1. Three Lakes Chain nitrogen and phosphorus values and N:P ratios.** Ratios calculated from sub-surface samples taken in summer from each lake.

| Project Phase | Lake Name | Avg. Summer Nitrogen (µg/L) | Avg. Summer Phosphorus (µg/L) | N:P Ratio |
|---|---|---|---|---|
| Long Lake - 2009 | Long Lake | 665 | 21.8 | 31:1 |
| Phase I - 2010 | Virgin Lake | 543 | 14.3 | 38:1 |
| | Whitefish Lake | 520 | 14.7 | 35:1 |
| | Big Lake | 953 | 31.4 | 30:1 |
| Phase II - 2011 | Crystal (Mud) Lake | 1160 | 72.0 | 16:1 |
| | Dog Lake | 950 | 31.7 | 30:1 |
| | Deer Lake | 860 | 32.3 | 27:1 |
| | Big Stone Lake | 710 | 26.5 | 27:1 |
| | Laurel Lake | 1010 | 29.3 | 34:1 |
| Phase III - 2012 | Big Fork Lake | 590 | 27.0 | 20:1 |
| | Fourmile Lake | 480 | 23.3 | 23:1 |
| Phase IV - 2013 | Moccasin Lake | 344 | 12.0 | 25:1 |
| | Spirit Lake | 513 | 9.7 | 58:1 |
| | Maple Lake | 510 | 16.2 | 47:1 |
| Phase V - 2014 | Little Fork Lake | | | |
| | Medicine Lake | | | |
| Phase VI - 2015 | Island Lake | | | |
| | Round Lake | | | |
| | Townline Creek | | | |
| | Townline Lake | | | |
| Phase VII - 2016 | Rangeline Lake | | | |
| | Planting Ground Lake | | | |
| Phase VIII - 2017 | Long Lake | | | |

## Three Lakes Chain of Lakes Trophic State

Figure 3.1-6 contain the Trophic State Index (TSI) values for Three Lakes Chain of Lakes. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to lower eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; particularly with the Three Lake Chain's stained water which impacts Secchi disk clarity much. Many of the lakes within the chain fall within the range of eutrophic – characterized higher phosphorus and chlorophyll-*a* content. Several lakes, such as Virgin, Whitefish, Moccasin, Spirit and Maple rank within the mesotrophic category. This is not surprising, seeing that these lakes are at the very top of the Three Lakes Chain or otherwise have small watersheds and thus are not influenced by the other lakes (further discussion of this topic takes place in the Watershed Section).

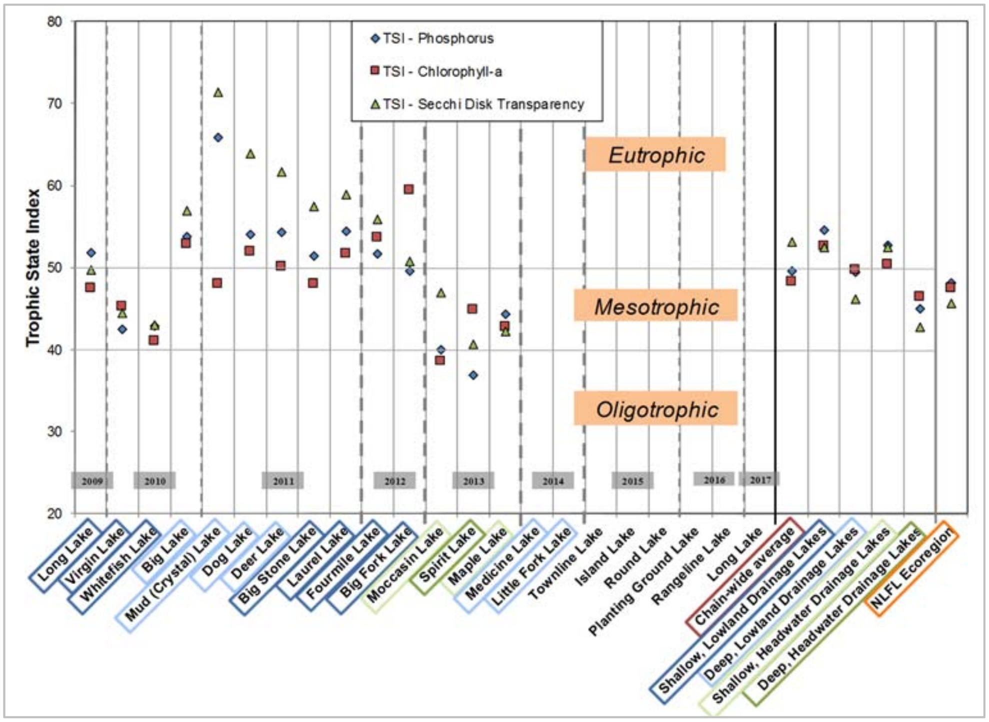



**Figure 3.1-6. Three Lakes Chain and comparable lakes Trophic State Index values.** Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests Lakes ecoregion median.

## Additional Water Quality Data Collected on the Three Lakes Chain of Lakes

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 the Three Lakes Chain of lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14.0 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7.0 has equal amounts of hydrogen ions and hydroxide ions ($OH^-$), and is considered to be neutral. Water with a pH of less than 7.0 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7.0 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The variability in pH between lakes is most likely attributable to a number of environmental factors, with the chief determiner being geology near the lake and within its surface and underground watersheds. On a smaller scale within a lake or between similar lakes, photosynthesis by plants can impact pH because the process uses dissolved carbon dioxide, which acts as a carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. Within the Three Lakes Chain, there is little variability between lakes, as is to be expected on a string of connected waterbodies (Figure 3.1-7). The values seen within the chain lakes are near neutral and are normal for Wisconsin lakes.

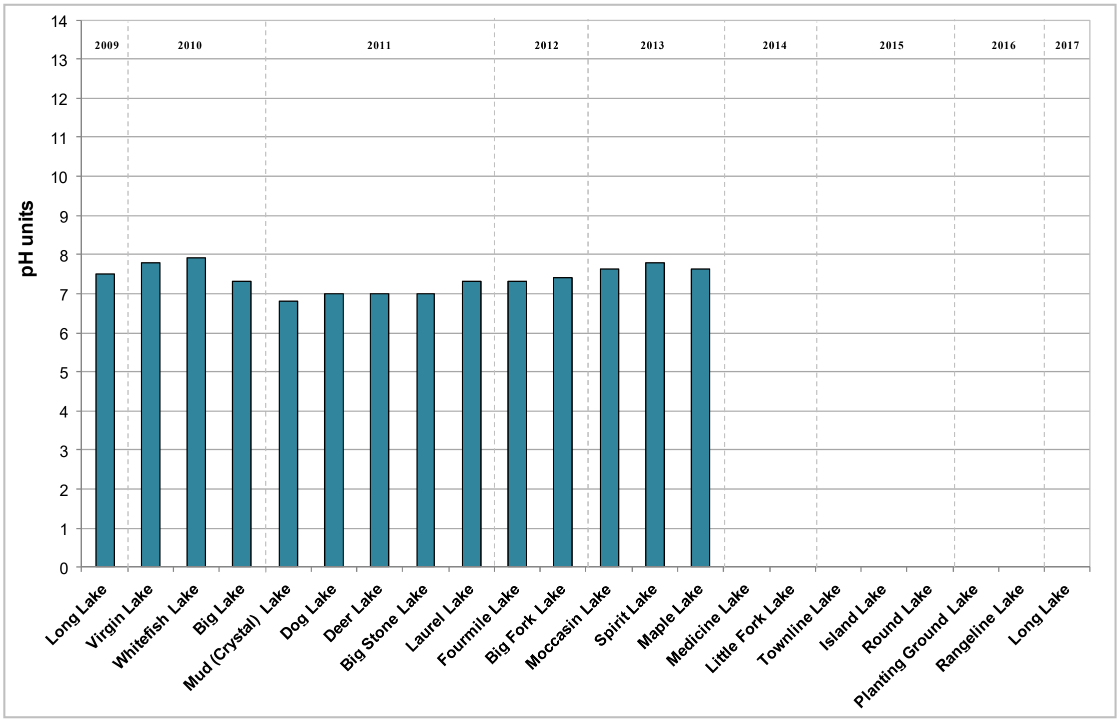



**Figure 3.1-7. Three Lakes Chain pH values.** Data collected from summer month surface samples.

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 it contains. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. Alkalinity is variable between the Three Lakes Chain of Lakes, but still within expected ranges for northern Wisconsin lakes (Figure 3.1-8). Alkalinity determines the sensitivity of a lake to acid rain. Values between 2.0 and 10.0 mg/L as $CaCO_3$ are considered to be moderately sensitive to acid rain, while lakes with values of 10.0 to 25.0 mg/L as $CaCO_3$ are considered to have low sensitivity, and lakes above 25.0 mg/L as $CaCO_3$ are non-sensitive.

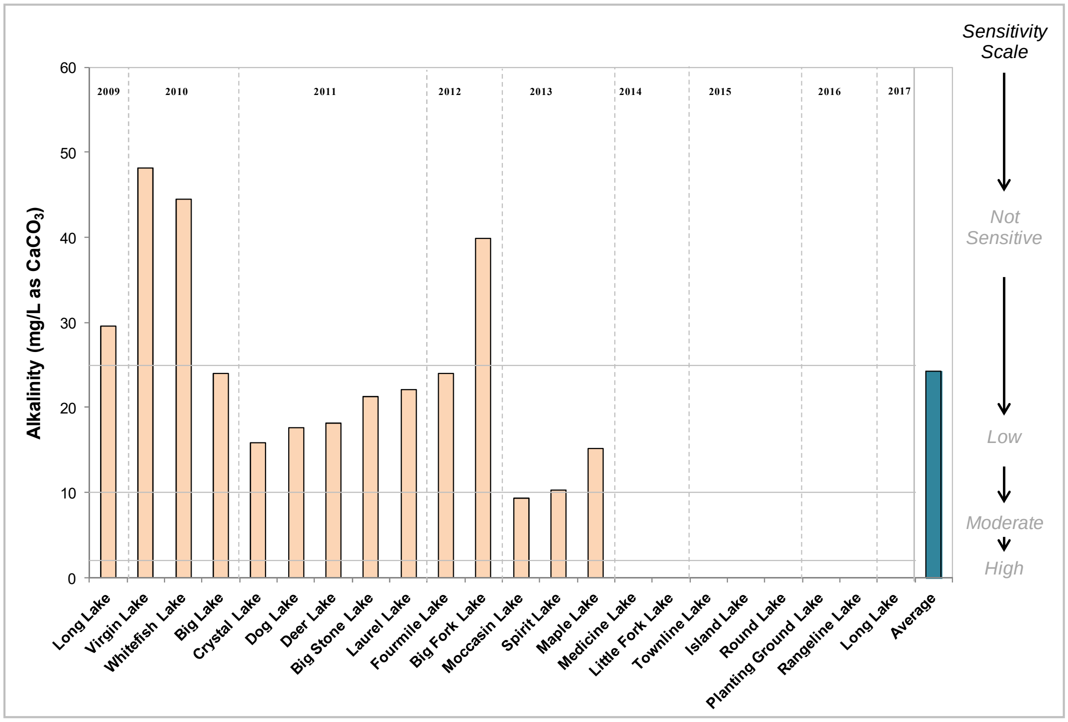



**Figure 3.1-8. Three Lakes Chain alkalinity values and acid rain sensitivity ranges.** Data collected from summer surface samples.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, calcium concentration has been used to determine what lakes can support zebra mussel populations if they are introduced. These studies, conducted by researchers at the University of Wisconsin-Madison, have led to a suitability model called Smart Prevention (Vander Zanden and Olden 2008). 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).

Nearly all the lakes within the Three Lakes Chain are suitable for zebra mussel establishment based upon pH; Crystal (Mud) Lake (pH=6.8) falls slightly outside of this range. However, as indicated on Figure 3.1-9, the calcium concentrations within the chain lakes are at the very low end for zebra mussel suitability. Virgin Lake, with calcium concentrations of 12.0 mg/L, is on the Low/Very Low Susceptibility borderline. Overall, these data indicate calcium levels may be a limiting factor in allowing the lakes within the Three Lakes Chain of Lakes to support zebra mussels, should they be introduced.

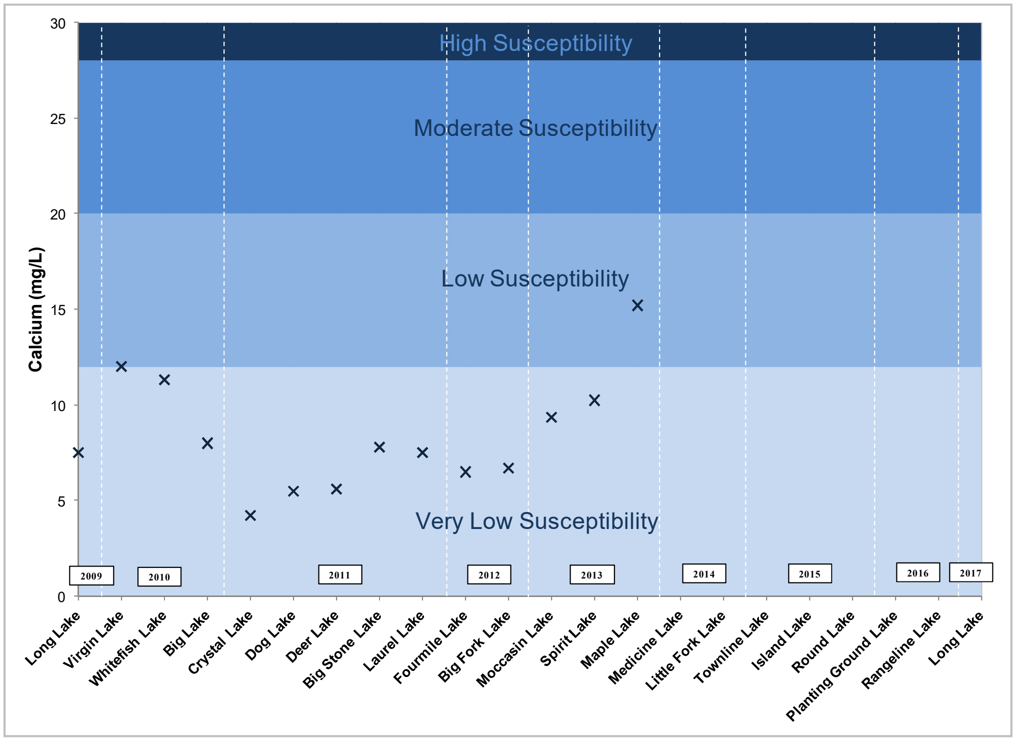



**Figure 3.1-9. Three Lakes Chain zebra mussel susceptibility analysis, based upon calcium concentration.** Created from lake surface calcium values. Calcium susceptibility range adapted from Whittier et al. 2008.

## 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.

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 (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. 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 affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS – Panuska, 2003). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. 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.

As discussed above, the size of the watershed in relation to the size of the lake can have a considerable impact on the lake's water quality. There is an incredibly large amount of land draining through the Three Lakes Chain lakes (Figure 3.2-1 and Map 2). However headwater lakes do exist (Maple, Spirit and Maple) that have significantly smaller watersheds than their lowland drainage neighbors. Approximately 72,196 acres of land drains to the Three Lakes Chain lakes, the majority (55% or 39,426 acres) of which is classified as wetland (Figure 3.2-2). Forested lands account for the second largest land cover type in the watershed (29% or 20,804 acres) while the surface of the Three Lakes Chain lakes is the third largest cover type at 10% (6,956 acres). Pasture/grass (4%) and row crops (2%) are found within the watershed to a lesser extent, while insignificant amounts of rural residential and urban areas exist as well.

*Watershed and phosphorus load modeling is scheduled to be completed with Phase VIII of this project. Once completed, modeling results will be discussed here. Watershed modeling data will be produced in Appendix E.*

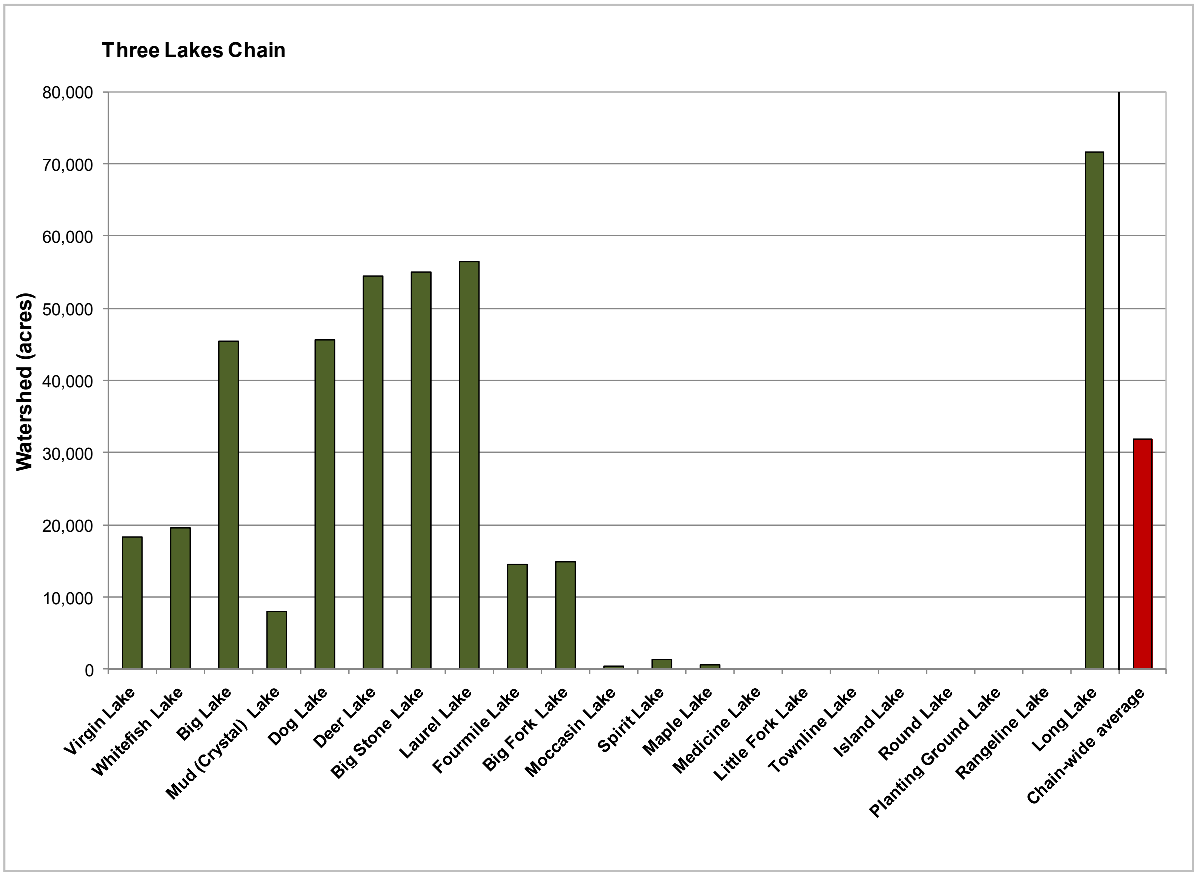



**Figure 3.2-1. Three Lakes Chain watershed size, in acres.** Lakes are arranged in approximate order of furthest upstream to furthest downstream.

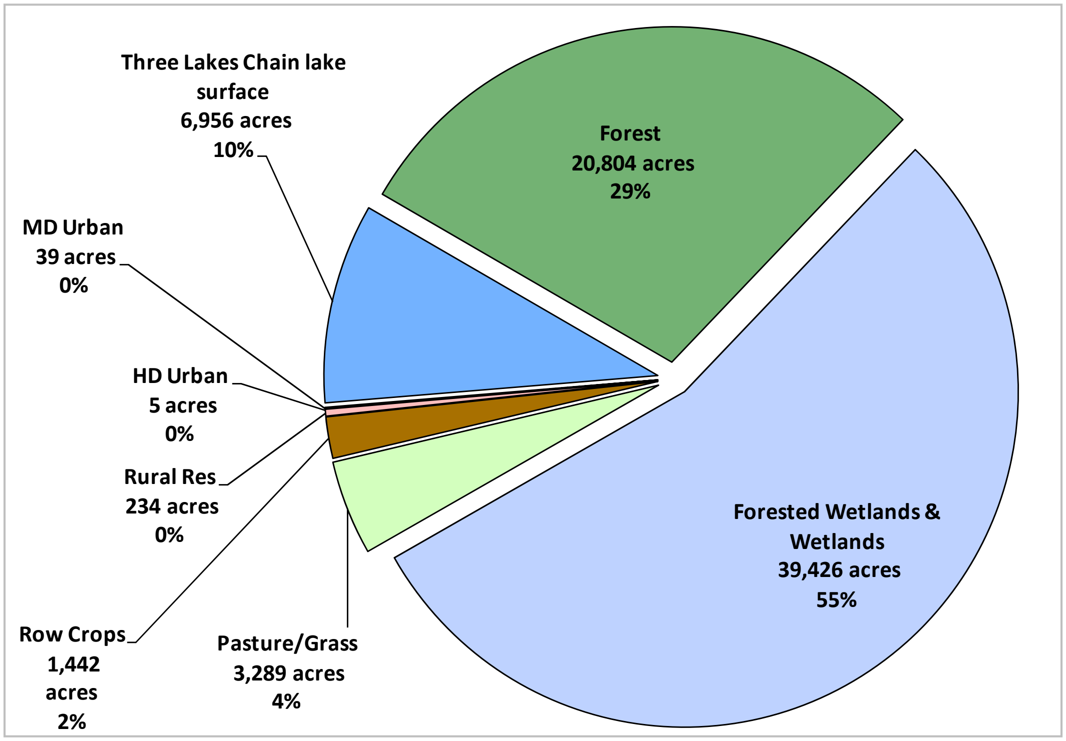



**Figure 3.2-2. Three Lakes Chain watershed land cover types in acres.** Based upon National Land Cover Database (NLCD – Fry et. al 2011).

*Phosphorus loading chart will be included here once completed*.

**Figure 3.2-3. Three Lakes Chain of Lakes watershed phosphorus loading in pounds.** Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

## 3.3 Shoreland Condition

### *The Importance of a Lake's Shoreland Zone*

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

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

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

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

### Shoreland Zone Regulations

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

**Wisconsin-NR 115: Wisconsin's Shoreland Protection Program**

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted 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.

In 2015, legislators raised concerns about the ability of counties to adopt more restrictive regulatory standards and proposed changes to NR 115. At the time of this writing, details on these proposed changes had not been finalized".

**Wisconsin Act 31**

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

## Shoreland Research

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

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:

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Improves the aquatic ecosystem through species diversification and habitat enhancement.<br>• Assists native plant populations to compete with exotic species.<br>• Increases natural aesthetics sought by many lake users.<br>• Decreases sediment/nutrient loads entering the lake from developed properties.<br>• Reduces bottom sediment re-suspension and shoreland erosion.<br>• Lower cost compared to rip-rap/seawalls.<br>• Restoration projects can be completed in phases to spread out costs.<br>• 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.<br>• 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.<br>• Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in.<br>• Monitoring and maintenance are required to assure that newly planted areas will thrive.<br>• Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established. |

## Three Lakes Chain of Lakes Shoreland Zone Condition

### Shoreland Development

The lakes within the Three Lakes Chain were surveyed as a part of this project to determine the extent of their degree of development. Lakes were visited during each appropriate phase, generally during the late summer to conduct this survey. A lake's shoreland zone can be classified based upon the amount of human disturbance (vegetation removal, construction of rip-rap or seawalls, etc.). 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.

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


**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.**

The Three Lakes Chain of Lakes has stretches of shoreland that fit all of the five shoreland assessment categories. Some of the lakes surveyed had more areas of natural shoreline than others. In all, the Phase I - IV Three Lakes Chain lakes contain approximately about 32.6 miles of natural/undeveloped and developed-natural shoreline (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. Approximately 10.5 miles of urbanized and developed–unnatural shoreline were recorded during field surveys. Figure 3.3-3 provides a breakdown of each Phase I - IV lake's shoreland condition, while each individual lake section discusses the shoreline condition further. Maps of each lake and the location of these categorized shorelands are included within each individual lake section as well.

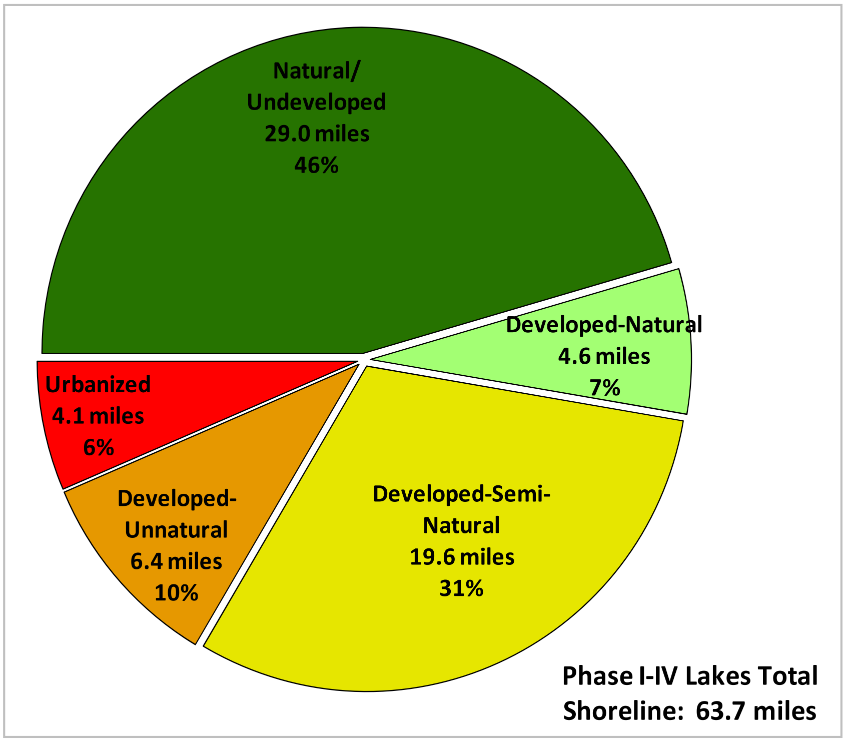



**Figure 3.3-2. Phase I-IV Three Lakes Chain total shoreland classification.** Based upon field surveys conducted in late summer on each project lake.

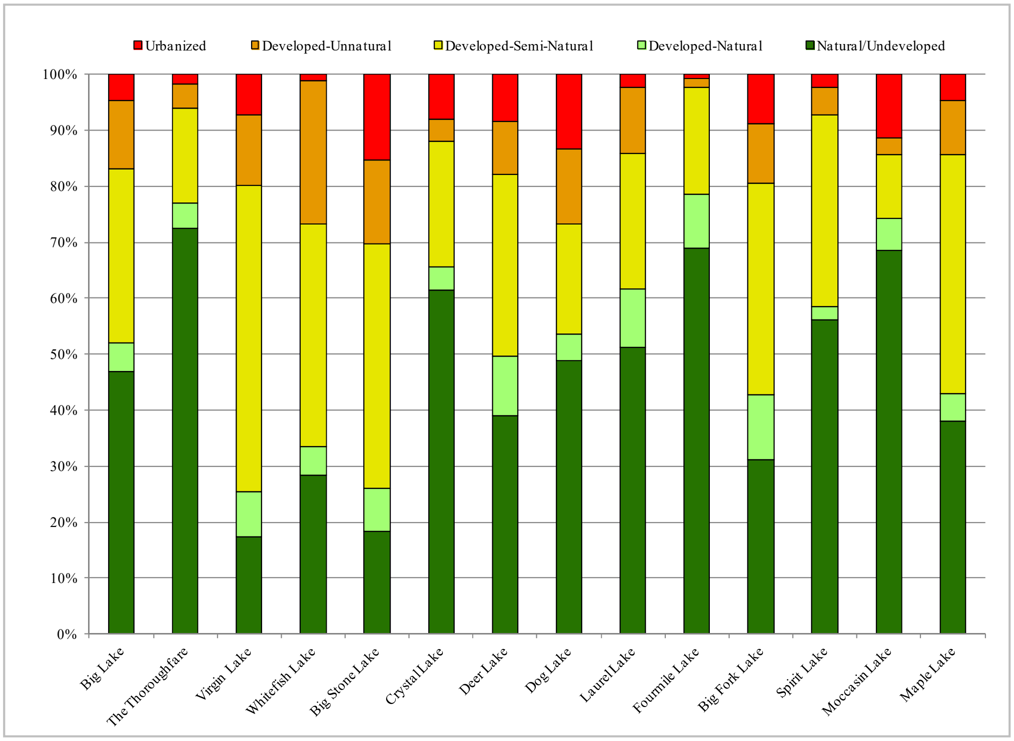



**Figure 3.3-3. Phase I-IV Three Lakes Chain shoreline condition breakdown.** Based upon late summer 2010-2013 field surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

While producing a completely natural shoreline 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.

One factor that influences the diversity and species richness of the aquatic plant community of a lake is the "development factor" of the shoreline. 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 shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline 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 shoreline 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 shoreline complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind. The shoreline complexity value for each lake within the Three Lakes Chain is reported within its respective individual lake section.

## Coarse Woody Habitat

The Three Lakes Chain was surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified based upon both size and complexity (branching) as these are important variables identified in the literature. Coarse woody habitat complexity was divided into four branching categories: no branches, minimal branches, moderate branches, and full canopy. Three size categories were distinguished: 2-8 inches diameter, >8 inches diameter, and a "cluster" (grouping of numerous overlapping pieces). 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 these surveys, a total of 1,138 pieces of coarse woody habitat were observed along 62.9 miles of shoreline, which gives this section of the Three Lakes Chain a coarse woody habitat to shoreline mile ratio of 18:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on each individual lake coarse woody habitat map, while Figures 3.3-4 and 3.3-5 display the breakdown of coarse woody habitat by project lake in terms of complexity and size

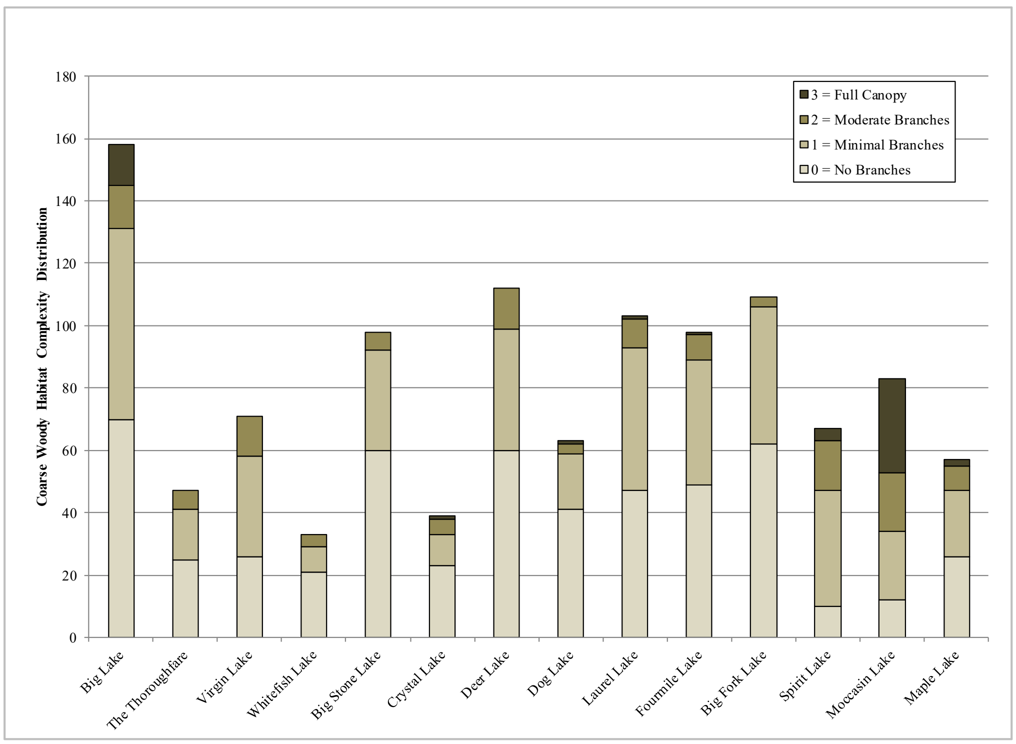



**Figure 3.3-4. Phase I-IV Three Lakes Chain coarse woody habitat complexity distribution by lake.** Based upon field surveys conducted in late summer on each project lake.

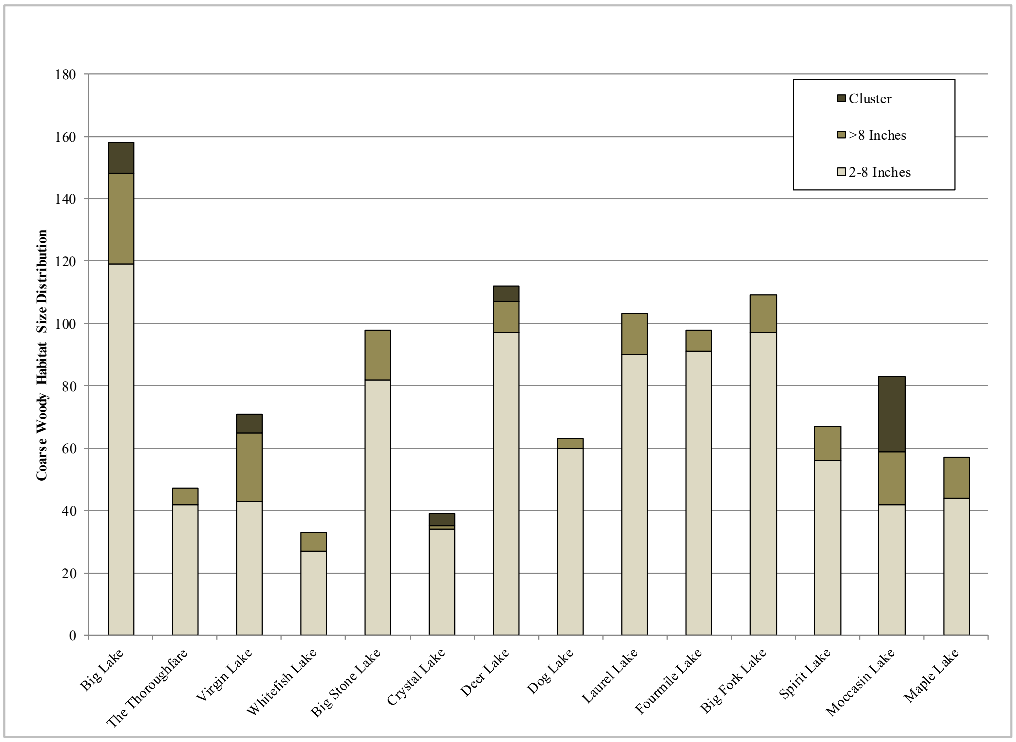



**Figure 3.3-5. Phase I-IV Three Lakes Chain coarse woody habitat size distribution by lake.** Based upon field surveys conducted in late summer on each project lake.

## 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.

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

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian 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.

*Special note*: wild rice is a plant of significant importance to Wisconsin lakes as well as Native American Communities. The plant is a valuable food source for many birds and mammals (including humans), and often provides important nursery, brooding and spawning habitat. It is a species of cultural significance to Ojibew Tribal Communities as well. Finally, perhaps one of the most often overlooked benefits of wild rice is its ability to utilize excessive nutrients, stabilize sediments and form natural wave-breaks. Because of its significance, wild rice is protected from many of the management actions discussed below and its harvesting is regulated. For more information on wild rice, it is recommended that the reader contact WDNR or GLIFWC representatives.

## 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.

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

## Bottom Screens

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

**Cost**

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

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

## Water Level Drawdown

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

**Cost**

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Inexpensive if outlet structure exists.<br>• May control populations of certain species, like Eurasian water-milfoil for a few years.<br>• Allows some loose sediment to consolidate, increasing water depth.<br>• May enhance growth of desirable emergent species.<br>• 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.<br>• Has the potential to upset the lake ecosystem and have significant effects on fish and other aquatic wildlife.<br>• Adjacent wetlands may be altered due to lower water levels.<br>• Disrupts recreational, hydroelectric, irrigation and water supply uses.<br>• May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).<br>• Permitting process may require an environmental assessment that may take months to prepare.<br>• Unselective. |

## 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.

**Costs**

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.<br>• Plant biomass and associated nutrients are removed from the lake.<br>• Select areas can be treated, leaving sensitive areas intact.<br>• Plants are not completely removed and can still provide some habitat benefits.<br>• Opening of cruise lanes can increase predator pressure and reduce stunted fish populations.<br>• Removal of plant biomass can improve the oxygen balance in the littoral zone.<br>• Harvested plant materials produce excellent compost. | • Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.<br>• Multiple treatments are likely required.<br>• Many small fish, amphibians and invertebrates may be harvested along with plants.<br>• There is little or no reduction in plant density with harvesting.<br>• Invasive and exotic species may spread because of plant fragmentation associated with harvester operation.<br>• 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, trageted 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.<br>• Herbicides can target large areas all at once.<br>• 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.<br>• Some herbicides can be used effectively in spot treatments.<br>• 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.<br>• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.<br>• 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.<br>• Many aquatic herbicides are nonselective.<br>• Some herbicides have a combination of use restrictions that must be followed after their application.<br>• 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.<br>• Likely environmentally safe and little risk of unintended consequences. | • Stocking and monitoring costs are high.<br>• This is an unproven and experimental treatment.<br>• 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.<br>• Once released, considerably less effort than other control methods is required.<br>• Augmenting populations many lead to long-term control. | • Although considered “safe,” reservations about introducing one non-native species to control another exist.<br>• 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 Three Lakes Chain of Lakes; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

### Primer on Data Analysis & Data Interpretation

**Species List**

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

**Frequency of Occurrence**

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

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

**Species Diversity and Richness**

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may be less diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

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

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

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

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

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

### Floristic Quality Assessment

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.

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 Three Lakes Chain of Lakes will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

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

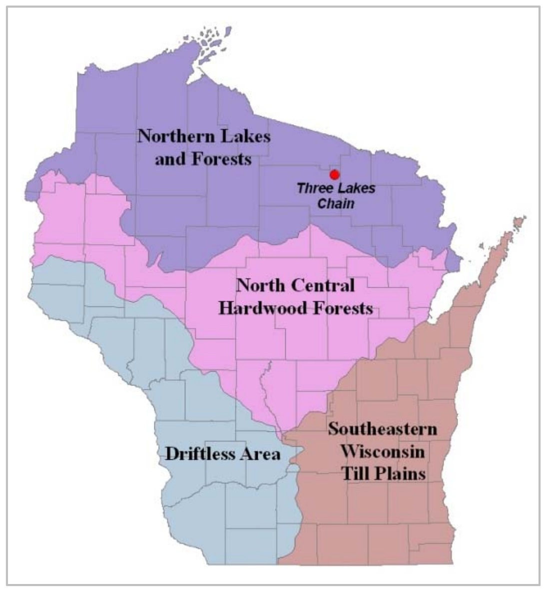



**Figure 3.4-1. Location of Three Lakes Chain within the ecoregions of Wisconsin.** After Nichols 1999.

### Community Mapping

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

**Exotic Plants**

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

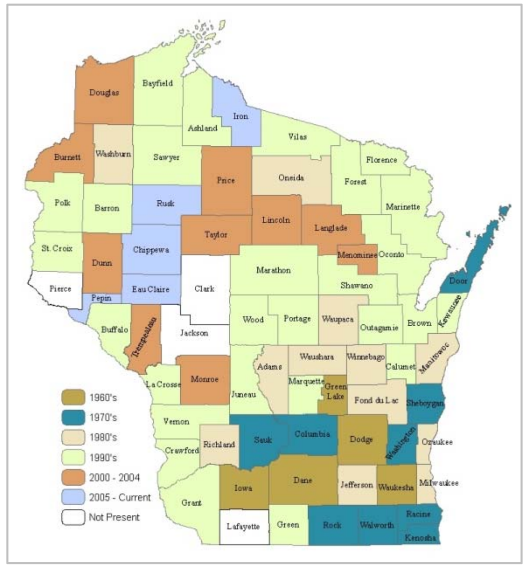



**Figure 3.4-2. Spread of Eurasian water milfoil within WI counties.** WDNR Data 2011 mapped by Onterra.

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

Numerous plant surveys were completed as a part of this project. In June of each year, early-season aquatic invasive species surveys were completed on each project lake for that year. T This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This meander-based survey did not locate any occurrences of curly-leaf pondweed within any of the project lakes. It is believed that this aquatic invasive species either does not occur in Three Lakes Chain of Lakes or exists at an undetectable level. However, curly-leaf pondweed does exist in several nearby lakes, including Little Saint Germain, Kentuck and Pine Lakes. On some project lakes, an emergent invasive plant – pale yellow iris (*Iris pseudocorus*) was spotted and its geospatial locations marked. Discussion of this plant takes place at the end of this section and in the appropriate individual lake sections.

The point intercept surveys were conducted on the Three Lakes Chain of Lakes in the months of July and August of each project year by Onterra. Additional surveys were completed during this time by Onterra to create the aquatic plant community maps (See "Aquatic Plant Community Map" after each individual lake section). Aquatic plant point-intercept survey data may be viewed in Appendix F.

A total of 105 different plant species were identified from the 11 Phase I-IV lakes involved with this project, as well as Long Lake, which completed a management planning project in 2009 (Figures 3.4-3, 3.4-4). The submergent pondweed species, clasping-leaf pondweed, was found within all 15 of these lakes. Three emergent or floating-leaf species were found within all 15 lakes as well. Many species were found only occasionally; 22 species were found within only one of the 12 lakes. This adds testament to the individuality of each of the lakes, even though essentially they are all part of the same chain of lakes. One aquatic plant located within eight of these lakes is considered to be particularly rare –Vasey's Pondweed (*Potamogeton vaseyi* – Photo 3.4-1). This species is listed as a species of special concern by the Natural Heritage Inventory Program. As the project continues on with the remaining phases of this project, this analysis will be expanded to encompass the lakes as they are studied.

Seven of the species found during the plant surveys are considered non-native species: Eurasian water milfoil was the only submergent exotic plant found within the chain (Virgin Lake and the Long Lake Channel). Several emergent exotic plants were found, including purple loosestrife, located on the margins of Laurel, Long, Big Stone and Big Lake, hybrid cattail, located along Long Lake, and Amur silver grass, located on the shoreline of Big Lake. In 2012, another invasive emergent plant, pale yellow iris, was found along much of the Big Fork Lake shoreline and in areas of Fourmile Lake as well. In 2013, pale yellow iris was found scattering the northern end of Spirit Lake. Also in 2013, pink water lily, a popular aquarium trade plant, was found in Moccasin Lake. Another species, sweetflag, was once classified as exotic (not quite "invasive"), but now is thought to have become naturalized with the native flora found in the upper United States. Because of their importance, the exotic species will be discussed in depth within the individual lake vegetation sections.

**Photo 3.4-1 Special concern species Vasey's pondweed (*Potamogeton vaseyi*).**

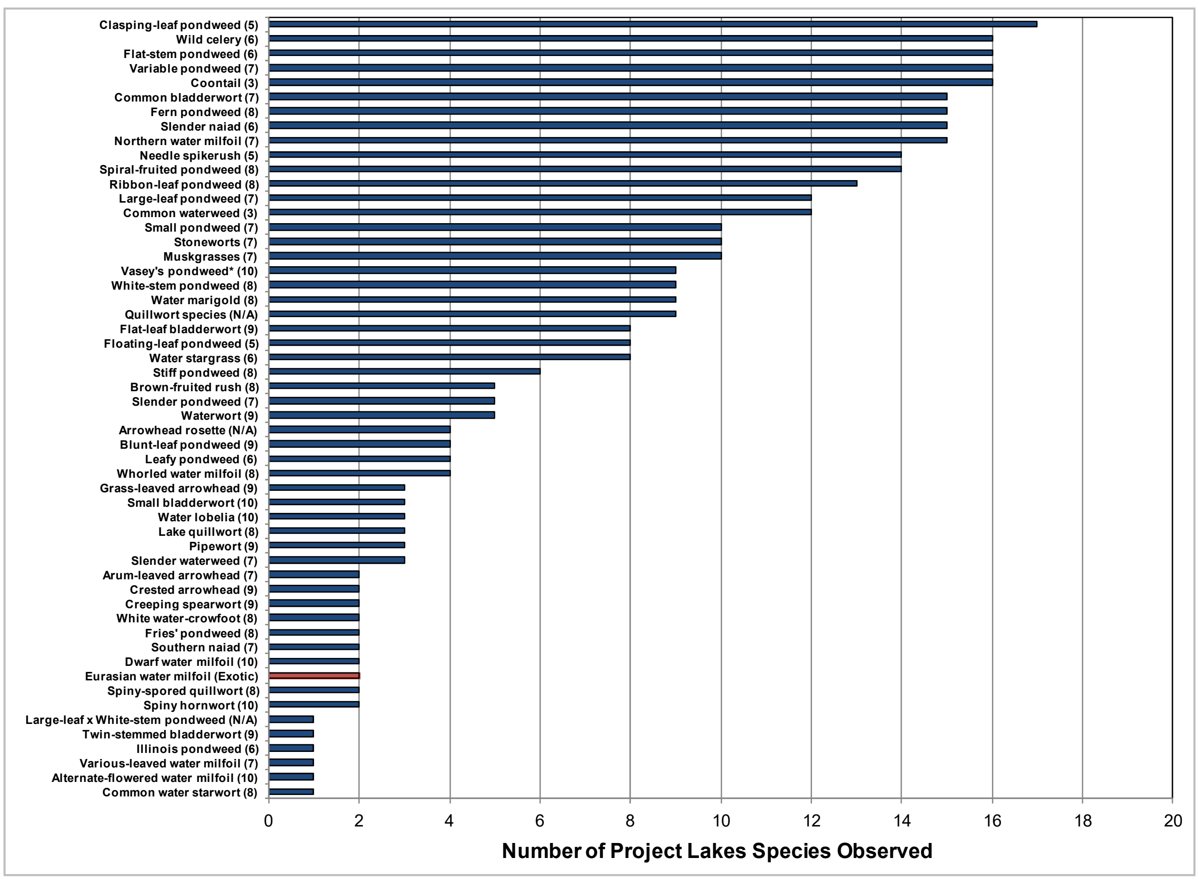



**Figure 3.4-3 Three Lakes Chain submergent aquatic plant species occurrence.** Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.

* *State species of special concern*

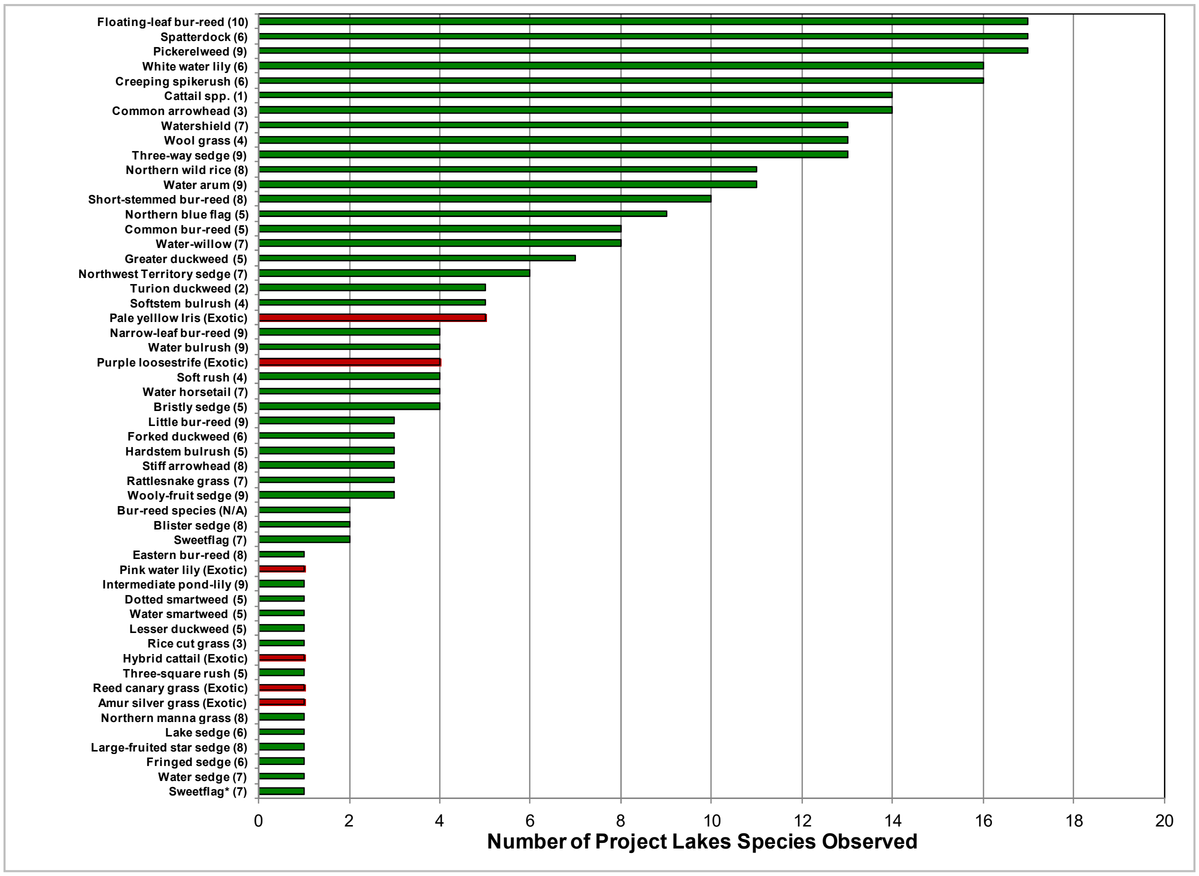



**Figure 3.4-4 Three Lakes Chain emergent, floating-leaf and free-floating aquatic plant species occurrence.** Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.
**Sweetflag, an exotic plant, is now thought to be naturalized in Wisconsin.*

The Three Lakes Chain of Lakes vary somewhat in their physical, biological and chemical attributes. Even though all of the lakes are connected, there is some variance in substrate, nutrient concentrations, algae concentrations, pH, clarity, alkalinity and watershed/shoreland characteristics. The substrate and water chemical composition of a lake influences aquatic plant species composition and abundance, and has the ability to create completely different plant communities among lakes that may be located across the street from each other. Generally speaking, lakes can be divided into two main groups based upon their plant community composition: 1) lakes that are dominated by plants of the isoetid growth form, and 2) lakes dominated by plants of the elodeid growth form.

Plant species of the isoetid growth form are small, slow growing, inconspicuous submerged plants that have evergreen leaves located in a rosette and are usually found growing in sandy soils within the near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000). Some isoetid species found in the Three Lakes Chain of Lakes include pipewort, brown-fruited rush and needle spikerush. Conversely, submerged species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column. The elodeid growth form includes plants such as common waterweed, coontail and many varieties of pondweeds and milfoils.

Alkalinity is the primary water chemistry factor determining whether a lake is dominated by plant species of the isoetid or elodeid growth form (Vestergaard and Sand-Jensen 2000). As mentioned in the Water Quality Section, alkalinity measures the concentration of calcium carbonate ($CaCO_3$) in the lake water and is a close descriptor of the amount of bicarbonate present. Isoetids, unable to use bicarbonate as source of carbon for photosynthesis, are typically found in lakes of lower alkalinity as they are adapted to grow in areas where carbon is limited. Through an extensive, permeable root system, isoetids are able to release oxygen into the sediment. This stimulates microbial decomposition while decreasing sediment pH (Urban et al. 2006). In turn, the decomposition process increases sediment carbon, which is not useable by plants of the elodeid growth form.

In lakes with higher alkalinity, elodeids grow in abundance as they are able to utilize the bicarbonate as a carbon source. In lakes with moderate alkalinity levels, both elodeids and isoetids may be found. While some of the project lakes displayed these alkalinity levels, most lakes were overwhelmingly dominated by elodeid plants, with instances of isoetid plants being found occasionally. While isoetid species are physically able to grow in lakes with higher alkalinity, their short stature makes them susceptible to shading from the much taller, leafy elodeid species which often restricts their growth to shallow, wave-exposed sites with course sediments (Vestergaard and Sand-Jensen 2000). Floating-leaf species, such as spatterdock and white water lily, obtain most of their carbon from the atmosphere, allowing them to be prevalent in most Wisconsin lakes.

Increases in alkalinity and sedimentation from residential development around a lake may result in creating a more suitable habitat for the taller elodeids, displacing isoetid species. As a result, many of the isoetid species have higher conservatism values as they are intolerant of disturbance and are indicators of high quality lake environments. Isoetid dominated lakes tend to be lower in species richness than elodeid dominated lakes. In general, the lakes within the Three Lakes Chain may be described as elodeid dominated lakes.

In the Three Lakes Chain of Lakes, the number of species observed per lake varied from 26 species in Crystal (Mud) Lake to 60 native species in Spirit Lake, with an average of 39 species per lake (Figure 3.4-5). Please note that Figure 3.4-5 displays the number of native plants found within the point-intercept survey, as well as the additional species found incidentally. The total number of species is a combination of these two, however in comparing to ecoregion and state medians and computing conservatism values (see discussion below) only the plants located during the point-intercept survey are considered. Using the point-intercept survey data alone, 14 of the 15 Phase I-IV lakes met or exceeded the Northern Lakes Ecoregion median for species richness. Crystal (Mud) Lake, with 12 native species, fell just short of this standard comparison level. Plant growth may be limited in this lake due to its exceptionally discolored water and mucky substrate, which limits the depth and available littoral habitat for some plant species.

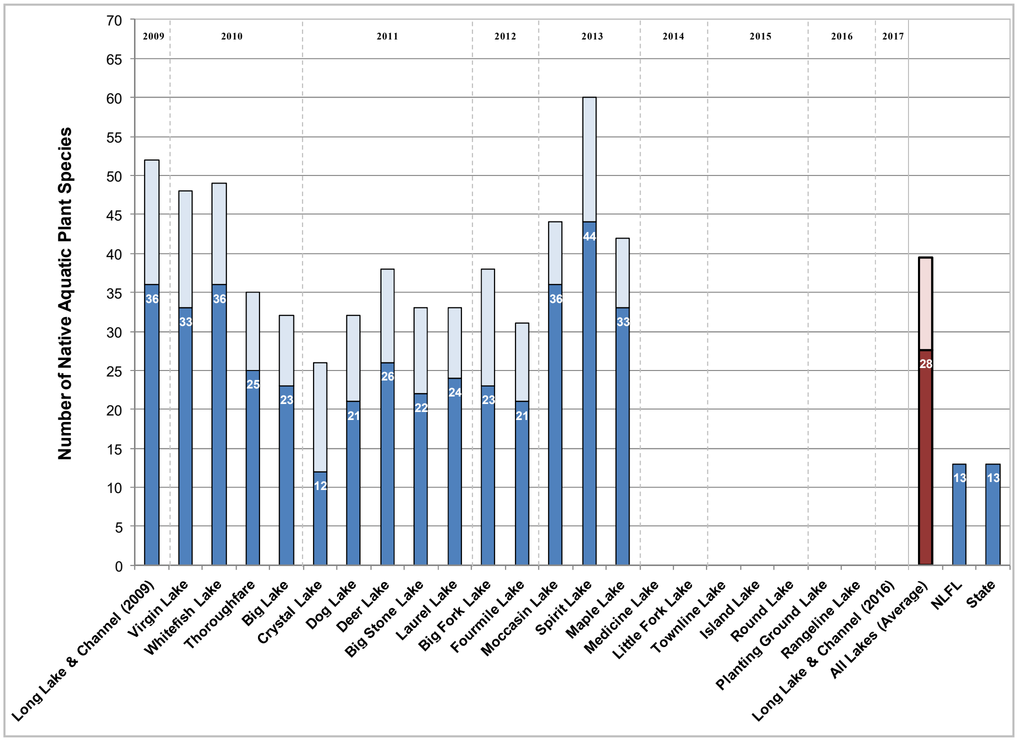



**Figure 3.4-5 Three Lakes Chain native species richness.** Created using data from summer point-intercept and community mapping surveys. Chart includes incidental species (light colored bars). Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

Like species richness, the Three Lakes Chain of Lakes had a wide range of plant species diversity (Figure 3.4-6). As discussed earlier, how evenly the species are distributed throughout the system and species richness together influence species diversity. In other words, a lake with many species is not necessarily diverse, and a lake with few species is not necessarily lacking diversity. Simpson's diversity index (1-D) is used to make this distinction.

Species diversity ranged from 0.65 to 0.95 in the Three Lakes Chain of Lakes (Figure 3.4-6). Big Stone Lake, even with having moderate species richness, has a relatively low diversity value due to the distribution of plants within the lake. As discussed within the Big Stone Lake Aquatic Plant Section, wild celery dominates the plant community with a relative frequency of 58%. In comparison, Spirit Lake (Simpson's Diversity value of 0.95) has high distribution of the most commonly found plants, in addition to a high species richness.
While a method of characterizing diversity values as "Fair" or "Poor", etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the Three Lakes Chain of lakes' scores rank. Using data obtained from WDNR Science Services, median values and upper/lower quartiles were calculated for 109 lakes within the Northern Lakes and Forests ecoregion (Figure 3.4-6). Ten of the Phase I-IV lakes rank above the median for the ecoregion, and thirteen of the lakes are either within the upper and lower quartile value range, or above it.

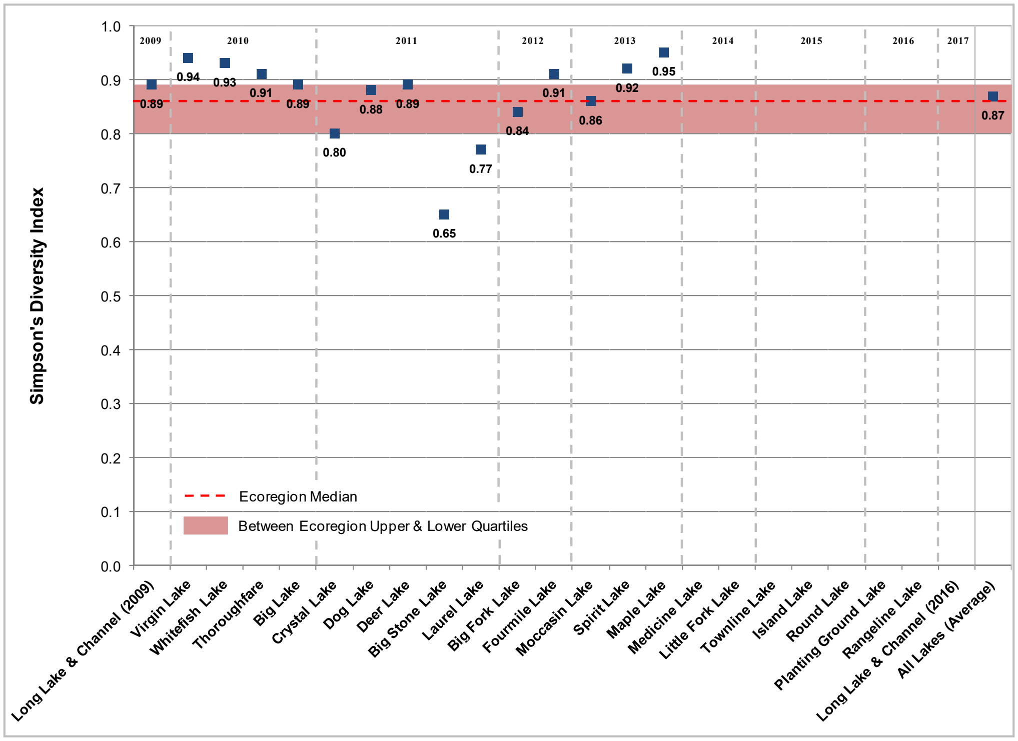



**Figure 3.4-6 Three Lakes Chain species diversity index.** Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Data collected from the aquatic plant surveys indicated that many of the lakes met or exceed the Northern Lakes Ecoregion median and all project lakes surveyed met or exceeded the state median for average plant species' conservatism values (Figure 3.4-7). This means the majority of the project lakes have plant communities that are more indicative of a pristine condition than those found in most lakes in the state and the ecoregion. The lakes that fell below the ecoregion median had higher nutrient levels and reduced light availability, supporting mainly disturbance-tolerant plant species (e.g., coontail, flat-stem pondweed) and fewer sensitive species.

Combining the species richness and average conservatism values for each project lake to produce the Floristic Quality Index (FQI) resulted in a range of values from 22.2 to 47.6, with an average of 36.1 (Figure 3.4-8). The equation for the FQI analysis is shown below. All of the project lakes but Crystal (Mud) Lake exceed the state and ecoregion median FQI value. Again, this illustrates that the Three Lakes Chain of lakes have high quality plant communities.

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

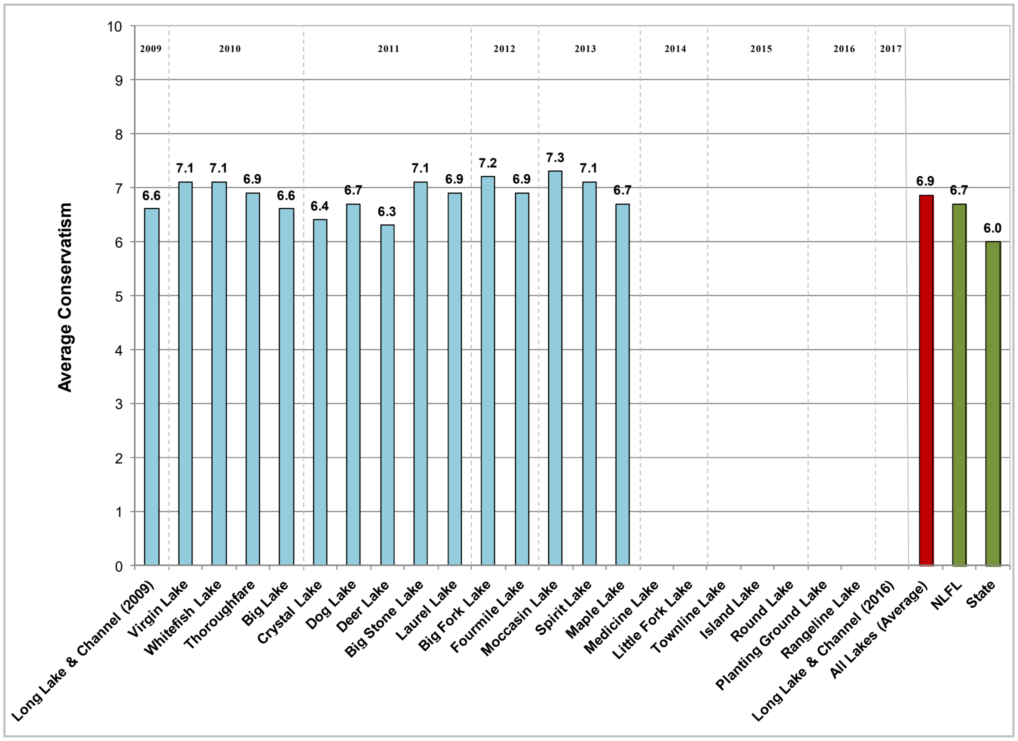



**Figure 3.4-7 Three Lakes Chain average native species' coefficients of conservatism.** Created using data from summer point-intercept surveys. Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

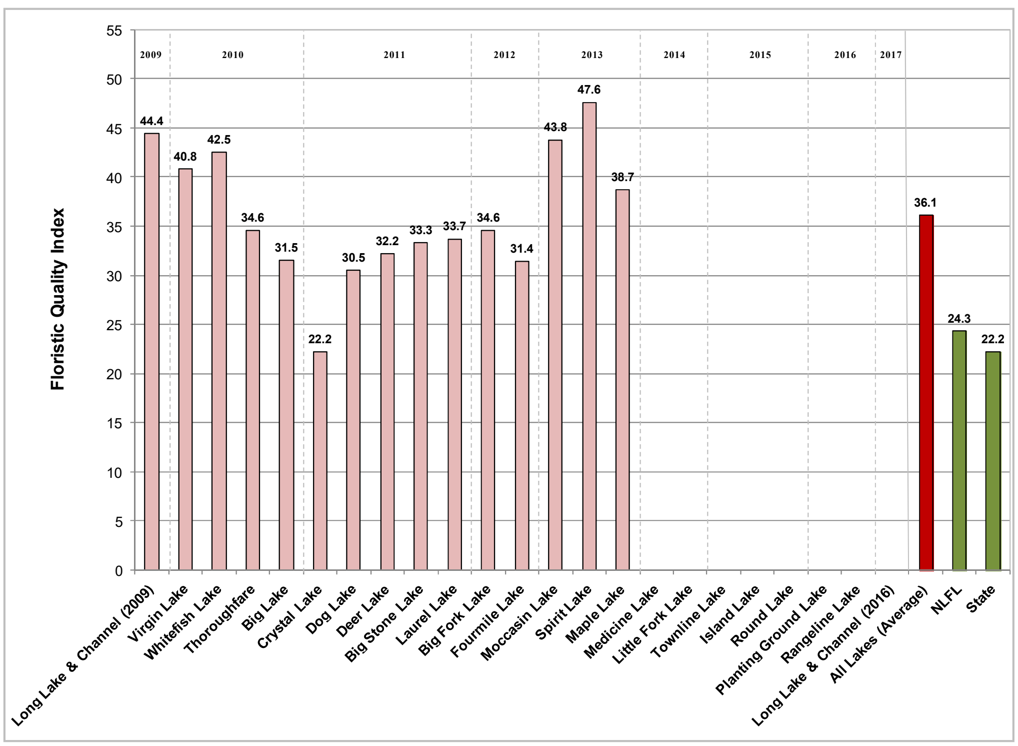



**Figure 3.4-8. Three Lakes Chain Floristic Quality Assessment.** Created using data from summer point-intercept surveys. Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

As illustrated in the analyses above, the plant communities within the Three Lakes Chain are generally of high quality. One of the biggest advantages of having a healthy plant community in a lake is the habitat value it provides. Areas of emergent and floating-leaf plant communities provide valuable fish and wildlife habitat important to the ecosystem both inside and outside of the lake. These areas are utilized by adult fish for spawning, by juvenile fish as a nursery, and by forage fish for protection from predators. Wading birds can be found in these areas hunting fish and insects, and escaping dangerous predators. Finally, these communities protect shorelines from eroding, as they temper the energy on the waves approaching the shoreline from the interior of the lake.

Many of the Three Lakes Chain lakes contain large areas of these plant communities. Figure 3.4-9 displays the percent of lake acreage occupied by either emergent, floating-leaf, or a combined emergent and floating-leaf plant communities. The Thoroughfare, a shallow passageway between Whitefish Lake and Big Lake, has an incredible 93% of its total acreage covered by both emergent and floating-leaf plant communities. Big Fork Lake, a large, open waterbody with fairly steeply sloped banks only has 1% of its acreage covered by these community types. Should a community mapping survey be completed again in the future, data may be compared to tell, qualitatively and quantitatively, if any changes in these plant communities have occurred. Currently, Long Lake is scheduled for a management plan update in 2017.

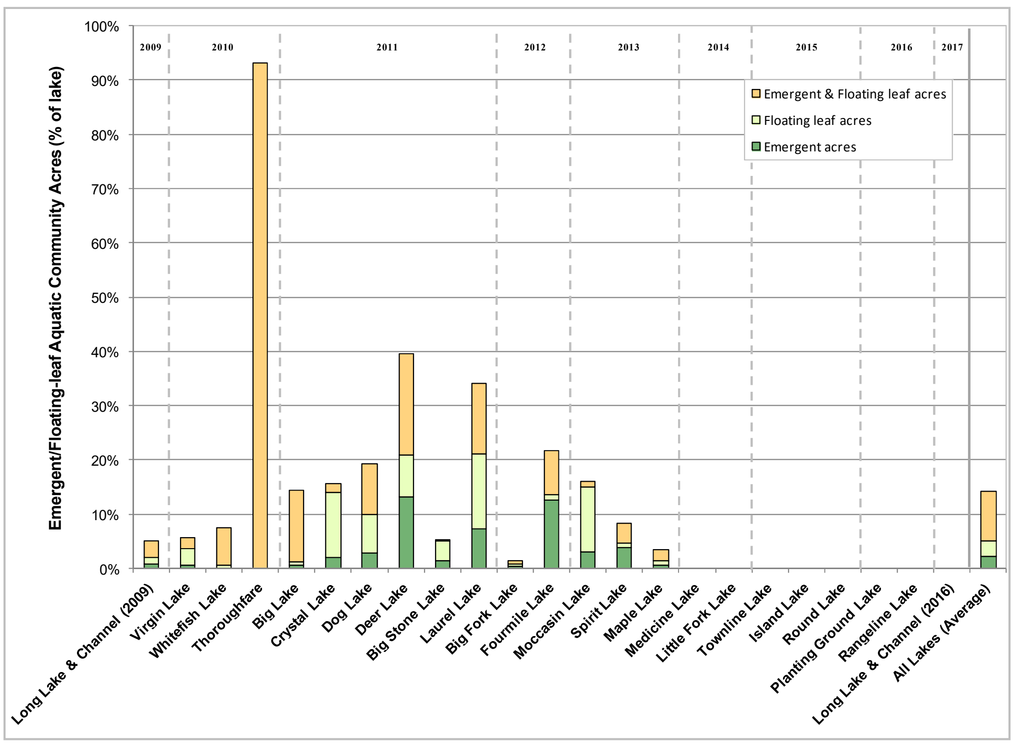



**Figure 3.4-9. Three Lakes Chain emergent and floating-leaf aquatic plant communities.** Created using data from summer community mapping surveys.

## 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 Three Lakes Chain of Lakes. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the TLWA 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 2012A and 2012B).

**Three Lakes Chain of Lakes Fishing Activity**

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest ranked important or enjoyable activity on the Three Lakes Chain of Lakes (Question #10). Approximately 69% of these same respondents believed that the quality of fishing on the lake is fair or good (Question #7); however, approximately 87% believe that the quality of fishing has remained the same or gotten worse since they started fishing the lake (Question #8).

Table 3.5-1 is a list of popular game fish that are present in many northern Wisconsin lakes. The Three Lakes Chain of Lakes is host to many of these species. On some northern Wisconsin lakes, management actions aimed at controlling exotic plant species or excessive native aquatic plant species are utilized and include either herbicide applications or mechanical harvesting. While the Implementation Plan will discuss these specific management actions as they relate to any of the Three Lakes Chain of Lakes, it should be noted that these measures are planned in a manner that reduces their potential impact on the system's fishery. Herbicide applications usually occur in May when the water temperatures are below 65°F, while mechanical harvesting occurs in mid-June and later. The goal is to reduce the impact upon the spawning environment which would be to remove the submergent plants that are actively growing at these low water temperatures. Species that spawn in late spring or early summer may be impacted as water temperatures and spawning locations often overlap, and vital nursery areas for emerged fry could become vulnerable. Yellow perch and muskellunge are examples of species that could potentially be affected by early season herbicide applications, as the treatments could eliminate spawning substrate or nursery areas for the emerged fry.

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 Three Lakes Chain of Lakes 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 piscovores 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.

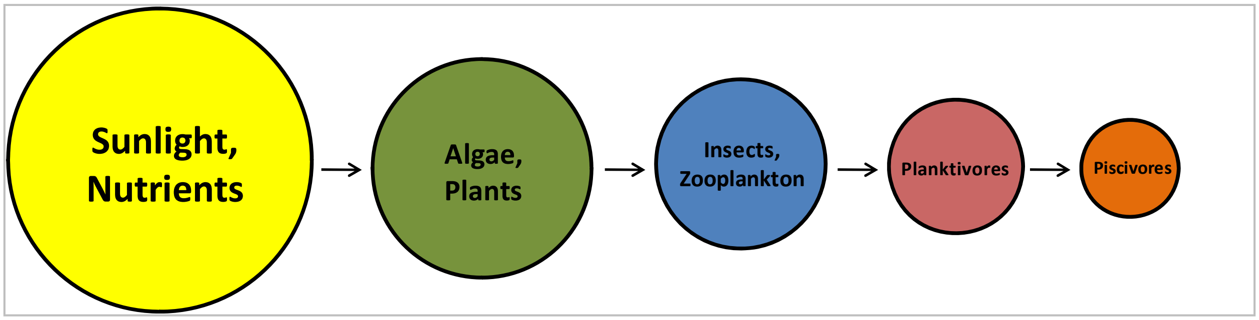



**Figure 3.5-1. Aquatic food chain.** Adapted from Carpenter et. al 1985.

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

**Table 3.5-1. Common gamefish present in Northern Wisconsin Lakes with biological information** (Becker, 1983)**.**

| Common Name | Scientific Name | Max Age (yrs) | Spawning Period | Spawning Habitat Requirements | Food Source |
|---|---|---|---|---|---|
| Black Bullhead | *Ictalurus melas* | 5 | April - June | Matted vegetation, woody debris, overhanging banks | Amphipods, insect larvae and adults, fish, detritus, algae |
| Black Crappie | *Pomoxis nigromaculatus* | 7 | May - June | Near *Chara* or other vegetation, over sand or fine gravel | Fish, cladocera, insect larvae, other invertebrates |
| Bluegill | *Lepomis macrochirus* | 11 | Late May - Early August | Shallow water with sand or gravel bottom | Fish, crayfish, aquatic insects and other invertebrates |
| 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 course sand or gravel, 1 cm - 1 m deep | Crustaceans, insect larvae, and other invertebrates |
| Smallmouth Bass | Micropterus dolomieu | 13 | Mid May - June | Nests more common on north and west shorelines over gravel | Small fish including other bass, crayfish, insects (aquatic and terrestrial) |
| Walleye | Sander vitreus | 18 | Mid April - Early May | Rocky, wavewashed shallows, inlet streams on gravel bottoms | Fish, fly and other insect larvae, crayfish |
| White Crappie | Pomoxis annularis | 13 | May - June | Within 10 m from shore, over hard clay, gravel, or roots | Crustaceans, insects, small fish |
| Yellow Bullhead | Ameiurus natalis | 7 | May - July | Heavy weeded banks, beneath logs or tree roots | Crustaceans, insect larvae, small fish, some algae |
| Yellow Perch | Perca flavescens | 13 | April - Early May | Sheltered areas, emergent and submergent veg | Small fish, aquatic invertebrates |


**Figure 3.5-2. Location of Three Lakes Chain within the Native American Ceded Territory (GLIFWC 2012A).** This map was digitized by Onterra; therefore it is a representation and not legally binding.

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 3.5-2). The Three Lakes Chain 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. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an "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% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The allowable catch number is then 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". 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, or declaration. This result is called the quota, 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 quota 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). 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 (GLIFWC 2012B). This regulation limits the harvest of the larger, spawning female walleye.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2012B). 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 quota 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 quota is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

While a safe harvest level and quota have been established on all lakes at some time between 1989 and present time, not all lakes within the chain have experienced a spearfishing harvest. Lakes with no recorded walleye harvest over this time period include Deer, Dog, Maple, Moccasin, Crystal (Mud), Rangeline and Townline Lakes. Table 3.5-2 displays the walleye and muskellunge harvest frequency during the past 24 years in which data has been recorded. As seen on this table, the lakes that have historically seen a higher spear harvest include most of the larger bodied lakes in the chain – Big, Big Fork, Big Stone, Little Fork, Long, Medicine, and Planting Ground lakes.

**Table 3.5-2. Native American spear harvest frequency on the Three Lakes Chain.** The table summarizes the years in which each lake has experienced a walleye or muskellunge harvest. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

| Lake | Years of walleye harvest, 1989-2013 | Years of muskellunge harvest, 1989-2013 |
|---|---|---|
| Planting Ground | 24 | 5 |
| Big Stone | 22 | 1 |
| Big | 21 | 2 |
| Big Fork | 21 | 3 |
| Medicine | 18 | 2 |
| Long | 14 | 2 |
| Little Fork | 12 | |
| Island | 7 | 2 |
| Laurel | 7 | 2 |
| Whitefish | 5 | |
| Spirit | 4 | 1 |
| Virgin | 4 | 1 |
| Fourmile | 3 | |
| Round | 1 | |
| Deer | | |
| Dog | | |
| Maple | | |
| Moccasin | | |
| Mud (Crystal) | | |
| Range line | | |
| Townline | | |

Individual lake Native American spearing statistics are displayed in Appendix G. The relationship between the safe harvest number, declaration and actual harvest is displayed on a chain-wide basis for walleye (Figure 3.5-3) and muskellunge (Figure 3.5-4). Once a safe harvest number is set for a given lake, tribal leaders may declare a quota of fish they may spear in the upcoming season. From 1989 to 2013, tribal spearers have claimed a walleye quota that is between 53% and 82% of the safe harvest. On average, Native American spear fishermen have harvested 49% of the declared quota on the Three Lakes Chain of Lakes with respect to walleye.

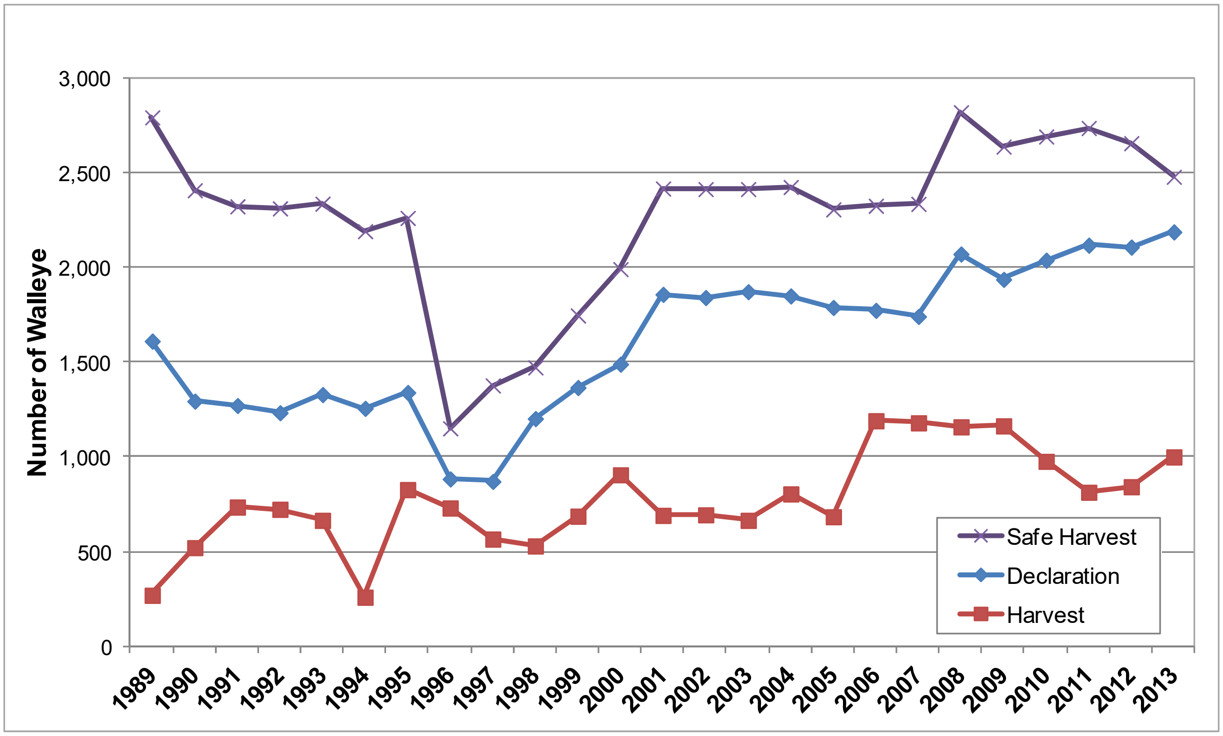



**Figure 3.5-3. Total chain-wide walleye spear harvest by year.** Annual Native American walleye spear harvest statistics are summarized for 21 lakes in the Three Lakes Chain of Lakes. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1989. Muskellunge spear harvests have been minimal on the Three Lakes Chain of Lakes; since 1989 an average of one muskellunge per year has been harvested on the entire chain during the open water spear fishery. This harvest has been as high as four fish (2004) and spear fishermen have rarely surpassed 4% of their allotted declaration (Figure 3.5-4).

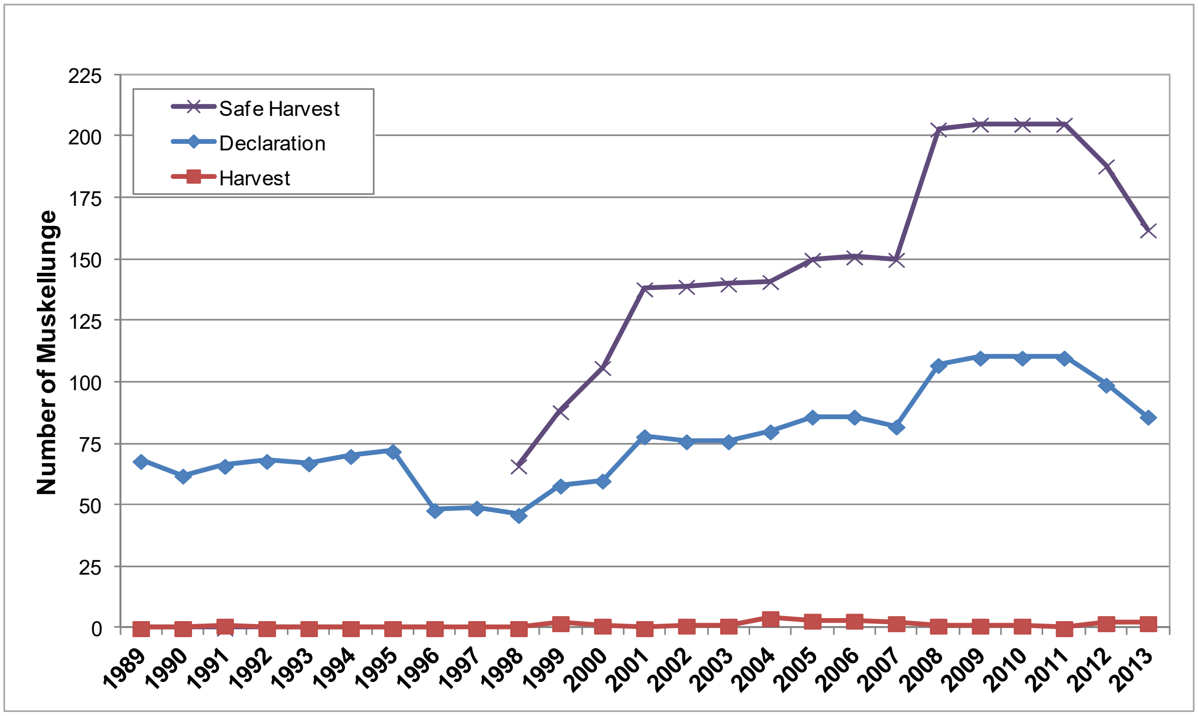



**Figure 3.5-4. Total chain-wide muskellunge spear harvest by year.** Annual Native American muskellunge spear harvest statistics are summarized for 21 lakes in the Three Lakes Chain of Lakes. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

**Three Lakes Chain of Lakes Fishing Regulations**

Because Three Lakes Chain of Lakes 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 Three Lakes Chain of Lakes. For 2014-2015, the daily bag limit is set for either 2 or 3 walleye for most lakes on the chain. On the Three Lakes Chain of Lakes, recent review of the fishery and its regulations resulted in changes of the minimum length limit for harvesting walleyes. Currently, there is no minimum length limit on walleye, but only one fish over 14" is allowed for most lakes within the chain. WDNR fisheries biologist established this regulation in 2010 to maintain walleye size structure, provide increased opportunity for angler harvest and allow harvest of males over 14" in length (WDNR Correspondence/Memorandum, Appendix G). On Maple Lake, three walleye may be kept and they must be at least 18".

For smallmouth bass, a catch-and-release season from early May to mid-June exists. Once the regular season begins in mid-June, the minimum length limit is 14" and a daily bag limit is limited to five fish (in total along with largemouth bass). The Three Lakes Chain of Lakes is in the northern half of the muskellunge and northern pike management zone. Muskellunge must be 34" to be harvested, with a daily bag limit of one fish, while no minimum length limit exists for northern pike and only five pike may be kept in a single day. Statewide regulations apply for all other fish species.

Table 3.5-3 displays the 2014-2015 fishing regulations, while Table 3.5-4 displays the 2014-2015 adjusted walleye bag limits. The walleye bag limits are revised according to the percent of the safe harvest levels determined for the Native American spearfishing season. Please note that these tables are intended to be for reference only, and that anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit local bait and tackle shops to receive a free fishing pamphlet that would contain this information. These regulations will be updated for the 2015-2016 season, effective April 1, 2015.

**Table 3.5-3. WDNR fishing regulations for the Three Lakes Chain, 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, 2014 | The minimum length limit is 14" and the daily bag limit is 5. |
| 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 14" and the daily bag limit is 5 (in total with largemouth bass). |
| 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, 2014 | No minimum length limit and the daily bag limit is 5. |
| Walleye, sauger, and hybrids | May 3, 2014 to March 1, 2015 | One fish over 14” permitted, daily bag limit of 5 unless otherwise specified. On Maple Lake, 3 walleye may be kept though they must be at least 18”. See Table 3.5-4 for remaining chain lakes bag limits. |
| Rock, yellow, and white bass | Open All Year | No minimum length limit and the daily bag limit is unlimited. |
| Rough fish | Open All Year | No minimum length limit and the daily bag limit is unlimited. |

**Table 3.5-4. WDNR 2014-2015 revised ceded territory walleye bag limits.**

| Lake | 2014-2015 Season Walleye Bag Limit |
|---|---|
| Big Fork Lake | 3 |
| Big Lake | 2 |
| Big Stone Lake | 3 |
| Fourmile Lake | 3 |
| Island Lake | 3 |
| Laurel Lake | 3 |
| Little Fork Lake | 3 |
| Long Lake | 3 |
| Maple Lake | 3 |
| Medicine Lake | 3 |
| Planting Ground Lake | 3 |
| Virgin Lake | 3 |

**Three Lakes Chain of Lakes Fish Stocking**

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults.

Currently, "maintenance" stocking of muskellunge is done on the Three Lakes Chain of Lakes to maintain this population. Stocking of this species occurs at a rate of 0.25 fish per acre, every other year. Nine of the 18 lakes within the chain have been stocked with muskellunge as recently as 2010 or 2012, and four other lakes within the chain have been stocked historically, but not in recent years. The WDNR does not stock walleye in the Three Lakes Chain of Lakes because the population has high recruitment which has resulted in a high-density fishery. Thus, there is little need to supplement the population with stocking. Stocking summaries for the Three Lakes Chain of Lakes can be viewed in Appendix G.

**Three Lakes Chain Walleye Population Monitoring**

Periodically, the WDNR will conduct spring surveys on the Three Lakes Chain to understand the population of walleye on these lakes. These surveys were last conducted in 1994, 2004, 2007 and again in 2014. Population estimates are obtained through a mark-recapture study, a well known and accepted method utilized to measure population structures in a variety of ecological settings. During this study, fish are captured initially and marked, typically by clipping a small portion of a fin. These individuals are returned to the lake and the population is sampled once again. The number of recaptured individuals is documented, as well as new individuals. Mathematical formulas are then used to estimate what the total population would be in a given lake.

This study was conducted on 10 lakes within the Three Lakes Chain in 2014. Population estimates from these efforts were calculated and are presented in Figure 3.5-5. Note that estimates are presented in a unit of fish per lake acre, and total estimates are divided amongst several size classes. Two additional lakes, Laurel and Dog, were assessed in 2014 but are not included in this chart as recaptures collected in the study were low and thus the population estimate holds low validity with fisheries biologists.

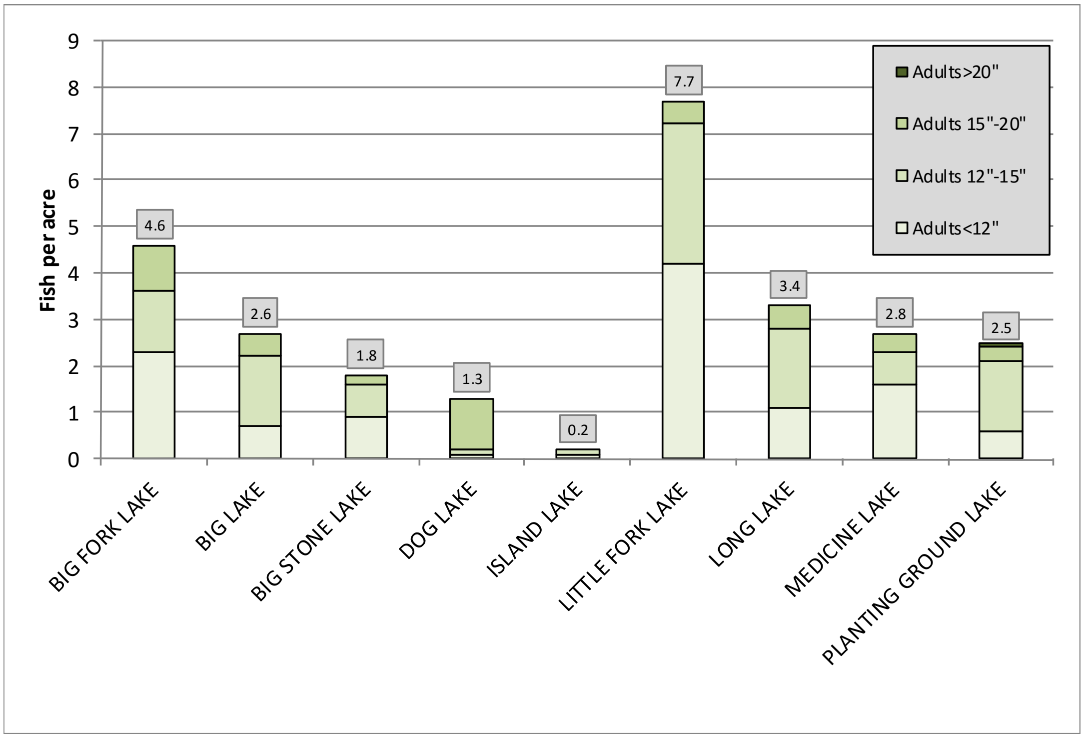



**Figure 3.5-5. Three Lakes Chain walleye population estimates, 2014.** Population estimates completed by WDNR fisheries staff through 2014 spring surveys (WDNR 2014).

**Three Lakes Chain of Lakes Substrate Type**

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.

According to the point-intercept survey conducted by Onterra, the lakes within the Three Lakes Chain varied quite a bit in terms of their substrate type. Some of the lakes contained mostly a soft, mucky bottom, while others were dominated by sand (Table 3.5-5). Some of the lakes had a good mixture of both substrates, and incorporated some rocky areas as well.

**Table 3.5-5. Substrate types for the Three Lakes Chain.** Data collected during point intercept surveys by Onterra (2009-2016).

| Project Phase | Lake | % Muck | % Sand | % Rock |
|---|---|---|---|---|
| Long Lake (2009) | Long Lake | 66 | 28 | 6 |
| Phase I - 2010 | Virgin Lake | 34 | 51 | 15 |
| | Whitefish Lake | 24 | 74 | 3 |
| | The Thoroughfare | 95 | 5 | 0 |
| | Big Lake | 37 | 59 | 4 |
| Phase II - 2011 | Laurel Lake | 63 | 36 | 1 |
| | Big Stone Lake | 4 | 92 | 5 |
| | Dog Lake | 24 | 75 | 0 |
| | Crystal (Mud) Lake | 91 | 9 | 0 |
| | Deer Lake | 60 | 39 | 1 |
| Phase III - 2012 | Fourmile Lake | 30 | 61 | 10 |
| | Big Fork Lake | 10 | 77 | 14 |
| Phase IV - 2013 | Moccasin Lake | 89 | 11 | 0 |
| | Spirit Lake | 56 | 44 | 0 |
| | Maple Lake | 88 | 10 | 2 |
| Phase V - 2014 | Little Fork Lake | | | |
| | Medicine Lake | | | |
| Phase VI - 2015 | Round Lake | | | |
| | Island Lake | | | |
| | Townline Creek | | | |
| | Townline Lake | | | |
| Phase VII - 2016 | Planting Ground Lake | | | |
| | Range Line Lake | | | |

# 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 Three Lakes Chain of Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within each lake, if any were found.
3) Collect sociological information from Three Lakes Chain of Lakes stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

Completing a comprehensive management plan for a large and diverse ecosystem such as the Three Lakes Chain of Lakes is a tremendous undertaking. By splitting this project into numerous phases, the TLWA, Town of Three Lakes, WDNR, and Onterra ecologists were able to give individualized attention to several lakes of the chain at a time and address specific issues that came about during this planning project. This is important, as during the studies it was learned that each lake has its own unique ecology as well as both positive facets and known challenges. In addressing each lake in a phased manner, a greater understanding was achieved about this ecosystem as a whole also. Though the chain has seen some human disturbance, the lakes are largely in good condition and need protection to ensure that they remain this way.

The large quantity of water the Three Lakes Chain of Lakes holds is the result of a large area of land that drains to these lakes. Over 72,000 acres of land drains towards these lakes. The large watershed consists of primarily natural land cover types, such as forest, forested wetlands, wetlands, etc. These land cover types are the most ecologically beneficial within a lakes watershed, as they allow water to permeate the ground as opposed to allowing more surface water runoff. This creates a naturally occurring filtering process and reduces the amount of nutrients and pollutants entering the lakes. In other watersheds, large amounts of urban and agricultural land reduce this filtration process and increase the amount of surface water pollution a lake receives.

Immediately surrounding each of the Three Lakes Chain of Lakes is the shoreland zone, which serves as an important buffer area for surface water runoff as well as habitat for many terrestrial and aquatic organisms. As the Three Lakes Chain of Lakes is a heavily visited and utilized system, it is not surprising that the shoreland zone shows a large amount of human disturbance. Restoring these disturbed shoreland areas, and protecting the natural shoreland areas that currently exist, may benefit each lake ecosystem and help in creating a natural, picturesque “up north” feel to the Three Lakes Chain of Lakes.

While the watershed is largely responsible for determining the general water quality in a lake or chain of lakes ecosystem, the biological, chemical and physical parameters of the water in a lake may in turn be the largest single factor in determining the health of a lake, including its aquatic plant community, fishery, etc. These components, contributing to the lake’s overall water quality, are an important aspect for recreational activities as well. The water within the Three Lakes Chain of Lakes is moderate to low in terms of its water clarity; however, this is primarily determined by the natural staining color that is derived from the decomposition of plant material in the watershed. So, considering this interesting aspect, the clarity measured on the Three Lakes

Chain of Lakes is not unexpected. Nutrient levels were assessed on the project lakes also, and turned up some interesting results – particularly with phosphorus. Phosphorus concentrations were found to vary amongst the project lakes, and this is partially due to differences in the morphology (deep drainage lakes vs. shallow drainage lakes) and placement of the lakes (higher or lower) in the chain. As eluded to within several individual lake plans and discussed within the Implementation Plan, there is an unaccounted for phosphorus source in some of the project lakes that requires additional research if a source of this nutrient input is to be discovered.

A major component of this project's studies included assessments of the native and if applicable, non-native aquatic species in each project lake. It is interesting to note that although these lakes are interconnected, and very close in proximity to each other, each project lake contains some similar species yet has its own unique aquatic plant community as well. Along with water quality differences, factors such as shoreline condition, substrate type, and lake morphology can determine the amount and type of habitat for aquatic plant species. As described in the Aquatic Plant Section, there is a great diversity of these habitat conditions so it is not surprising that a species rich aquatic plant community exists. Altogether, a total of 88 different plant species were identified from Long Lake as well as the nine Phase I and Phase II lakes associated with this project. The plant communities showed some variance between lakes in terms of their diversity index value and coefficient of conservatism as well. These values are typically used to assess the level of human disturbance.

Another indication of human disturbance is the presence of non-native species. Currently, aquatic invasive species, primarily Eurasian water milfoil, is the largest ecological threat facing the integrity of the Three Lakes Chain of Lakes. An aggressive, ongoing battle has been fought on the Long Lake Burnt Rollways channel targeting this invasive plant. While the plant has largely been kept under control, resurgence has been documented each year since the plant was first discovered (2006). In Virgin Lake, a lake in which native milfoils grow quite prolifically, the Eurasian water milfoil colony that was first discovered in 2010 has become largely unmanageable by passive (hand-harvesting) techniques and in 2012 required an herbicide treatment to reduce fragmentation and spreading of this plant. Moving into the future, these infestations must be monitored diligently to ensure that management efforts are successful in containing the spread to other locations. Additionally, as outlined within the Implementation Plan, continued efforts must be conducted to monitor these lakes for new infestations, as an early infestation is always easier to manage than a previously undetected, advanced-stage infestation.

The Three Lakes Chain of Lakes is a unique resource that many individuals with many different interests utilize. It provides for an outstanding recreational facility that anglers, boaters, swimmers, connoisseurs of nature and others can enjoy. Billed as part of "the largest freshwater chain of lakes in the world", it is a large and complex ecosystem that inspires one with its picturesque beauty and serene, "up north" feeling. With the knowledge that has been gained through this series of studies, the TLWA and their lake management partner, the Town of Three Lakes, now have a strategic plan in place to maximize the positive attributes of each lake, address the negative attributes, and effectively and efficiently manage the entire ecosystem as a whole. The Chain Wide Implementation Plan that follows is a result of the hard work of many Three Lakes Chain of Lakes stakeholders, and can be applied to each and every lake within the chain. Lakes with added attention or specific issues that were brought forth during this study will have their own Lake Specific Implementation Plan which is located at the end of each individual lake section.

# 5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the TLWA and ecologist/planners from Onterra. It represents the path the TLWA 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 Three Lakes Chain of Lakes 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 continuous review and adjustment depending on the condition of the chain lakes, the availability of funds, level of volunteer involvement, and the needs of the stakeholders. While the TLWA is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee of the TLWA (e.g. Education & Communication Committee, Water Quality Committee, and Invasive Species Committee). The TLWA will be responsible for deciding whether the formation of sub-committees is needed to achieve the various management goals.

## *Management Goal 1:* Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant in Diagnostic/Feasibility Studies category.

**Description:** The Three Lakes Waterfront Association and Town of Three Lakes have been diligent about protecting the Three Lakes Chain of Lakes and preserving it as a recreational yet natural resource. They realize that the best way to protect the waterbodies in the chain is to fully understand their current level of health so that proper planning and management may occur.

The Three Lakes Waterfront Association, with assistance from their partner the Town of Three Lakes, will continue to develop comprehensive management plans for each lake in the chain. This phased project will continue within the timeframe projected in Map 1. These studies may be completed with the assistance of state funds through the WDNR's Lake Management Protection Grant program.

**Action Steps:**

1. Apply for WDNR grants annually to continue state financial assistance in management planning projects.
2. Retain qualified consultant to conduct science-based studies and facilitate management planning.

## *Management Goal 2:* Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Timeframe:** In progress.

**Facilitator:** Board of Directors along with TLWA Clean Boats/Clean Waters coordinators.

**Description:** The Three Lakes Chain of Lakes includes over 6,100 acres of water, 14 public boat landings (eight more on the Lower Eagle River Chain) one tracked boat-lift system, numerous resorts and several fishing tournaments. With so many public access opportunities, the threat of the introduction of AIS is greatly heightened. As outlined in the Table 2.0-1, most of the lakes within the chain hold at least one or two invasive species. Currently, several waterbodies, are known to hold small populations of Eurasian water milfoil.

The Clean Boats/Clean Waters (CBCW) program supplies both paid and volunteer boat inspectors at 10 public landings on the chain, including monitoring at the Burnt Rollways boat lift to assure removal of vegetation from boats coming over the dam. Typically, 1,700 – 1,900 boats are inspected at the Burnt Rollways Dam, an effort facilitated in coordination with WVIC. The TLWA inspected nearly 12,000 boats and contacted nearly 33,000 people in over 9,500 hours of work during a timespan from 2005 – 2013 (WDNR CBCW website, data accessed November 2013). This is a tremendous effort to coordinate, but the Town of Three Lakes and TLWA have proven that this program can be completed effectively.

The CBCW boat inspections at these public access points have undoubtedly played a great role in reducing the introduction of invasive species to the Three Lakes Chain of Lakes. Furthermore, opportunities of species from the Three Lakes Chain elsewhere have certainly been diminished. CBCW inspectors cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of its spread.

**Action Steps:**

1. Members of the TLWA periodically attend CBCW training session through CBCW coordinator to update their skills to current standards.
2. Begin inspections during high-risk weekends
3. Report results to WDNR and TLWA.
4. Promote enlistment and training of Three Lakes Chain volunteers to broaden volunteer base and ensure program survival.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Timeframe:** In progress.

**Facilitator:** TLWA in coordination with Lake Captains and lake residents.

**Description:** In lakes with Eurasian water milfoil or other invasive species, early detection of pioneer colonies commonly leads to successful control. While efforts to control Eurasian water milfoil within Virgin Lake and the Eagle River channel of Long Lake have been successful, eradication of this hearty and resilient invasive plant is very difficult. Therefore, it is crucial for locations of new plants to be promptly identified before they reproduce.

The TLWA has initiated a strategy in which lake residents are coordinated to search the lakeshore area for invasive plant species. These efforts take place on many lakes within the Three Lakes Chain of Lakes. In fact, TLWA volunteers have logged roughly 2,000 hours in this program since 2006. A Lake Captain (a member of the planning committee) is responsible for recruiting riparian property owners to participate in these shoreline patrols. Although most shorelines have been patrolled on an annual basis over the last several years, more volunteers are needed to assure future coverage. Volunteers also intensively cover the area near the Burnt Rollways Dam in the Long Lake channel, as this is a point of special interest due to Eurasian water milfoil being located here.

**Action Steps:**

1. Volunteers from TLWA update their skills by attending a training session conducted by WDNR/UW-Extension through the AIS Coordinator for Oneida County (Michele Sadauskas – 715.365.2750).
2. Trained volunteers recruit and train additional association members.
3. Complete lake surveys following protocols.
4. Report results to WDNR and TLWA.

## *Management Goal 3:* Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety, and quality of life on the Three Lakes Chain of Lakes.

**Timeframe:** Begin Summer 2013.

**Facilitator:** Board of Directors to form Education Committee.

**Description:** Education represents an effective tool to address issues that impact water quality such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. An Education Committee will be created to promote lake protection through a variety of educational efforts.

Currently, the TLWA regularly distributes newsletters to association members and has launched a website (http://www.threelakeswaterfrontassociation.com) which allow for exceptional communication within the lake group. This level of communication is important within a management group because it builds a sense of community while facilitating the spread of important association news, educational topics, and even social happenings. It also provides a medium for the recruitment and recognition of volunteers. Perhaps most importantly, the dispersal of a well-written newsletter can be used as a tool to increase awareness of many aspects of lake ecology and management among association members. By doing this, meetings can often be conducted more efficiently and misunderstandings based upon misinformation can be avoided. Educational pieces within the association newsletter may contain monitoring results, association management history, as well as other educational topics listed below.

In addition to creating regularly published association newsletters, a variety of educational efforts will be initiated by the Education Committee. These may include educational materials, awareness events and demonstrations for lake users as well as activities which solicit local and state government support.

*Example Educational Topics:*

- Specific topics brought forth in other management actions
- Aquatic invasive species identification & monitoring
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreland restoration and protection

- Septic system maintenance
- Fishing Rules
- Water quality topics

**Action Steps:**

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR Small-scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. The TLWA Board will identify a base level of annual financial support for educational activities to be undertaken by the Education Committee.

## *Management Goal 4:* Facilitate Partnerships with Other Management Entities and Stakeholders

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Timeframe:** Continuation of current effort.

**Facilitator:** Board of Directors to appoint TLWA representatives.

**Description:** As stated on the association website, the purpose of the TLWA is *to preserve and protect our waterways and shorelines…today and for generations to come*. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while other organizations are similar to the TLWA in that they rely on voluntary participation.

It is important that the TLWA engage with all management entities to enhance the association's understanding of common management goals and to participate in development of those goals. This also familiarizes all management entities with actions that others are taking to reduce the duplication of efforts. The primary management units regarding the Three Lakes Chain of Lakes include governmental units such as the WDNR, or Town of Three Lakes, but also include groups similar to the TLWA such as the Chamber of Commerce. Each entity is specifically addressed on the next page.

**Action Steps:**

1. See table guidelines on the next page.

| Partner | Contact Person | Role | Contact Frequency | Contact Basis |
|---|---|---|---|---|
| **Wisconsin Department of Natural Resources** | Fisheries Biologist (John Kubisiak – 715.365.8919) | Manages the fishery of the Three Lakes Chain. | Once a year, or more as issues arise. | Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery. |
| | Lakes Coordinator (Kevin Gauthier – 715.365.5211) | Oversees management plans, grants, all lake activities. | Once a year, or more as necessary. | Information on updating a lake management plans, submitting grants or to seek advice on other lake issues. |
| | Warden (Patrick Novesky – 715.365.8948) | Oversees regulations handed down by the state. | As needed. May contact WDNR Tip Line (1.800.847.9367) as needed also. | Suspected violations pertaining to recreational activity, including fishing, boating safety, ordinance violations, etc. |
| | CLMN Director (Sandra Wickman – 715.365.8951) | Training and assistance on CLMN activities. | Twice a year or more as needed. | Contact to arrange for training as needed, in addition to planning out monitoring and reporting of data. |
| **Oneida County** | AIS Coordinator (Michele Saduaskas – 715.365.2750) | Oversees AIS monitoring and prevention activities locally. | Twice a year or more as issues arise. | <u>Spring:</u> AIS training and ID, AIS monitoring techniques<br><u>Summer</u>: Report activities to Ms. Saduaskas. |
| **Town of Three Lakes** | Town Chair (Don Sidlowski - 715.546.331) | Supports TLWA, assists in lake management. | As needed. Visit website (http://www.townofthree lakes.com/home) often. | Contact regarding grant applications, projects such as CBCW, town events, etc. |
| **Three Lakes Chamber of Commerce** | Executive Chamber Director (Skip Brunswick – (715.546.3344) | Coordinates recreational and town-wide events, partner in managing lakes | As needed. | AIS project results may be shared, or displayed at public events, etc. Informative packets available at chamber of commerce. |
| **Oneida County Lakes & Rivers Association** | Secretary (Connie Anderson – 715.282.5798) | Protects Oneida Co. waters through facilitating discussion and education. | Twice a year or as needed. | Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oneida Co. waterways. |
| **UW-Extension** | Program Coordinator (Erin McFarlane –715.346.4978) | Clean Boats Clean Waters Program | As needed. | May be contacted to set up CBCW training sessions, report data, etc. |
| **Unified Lower Eagle River Chain of Lakes Commission** | Commission Chair (Jim Spring – 715.891.1095) | Oversees AIS management of the Lower Eagle River Chain of Lakes | Once a year or as needed. May visit website (http://eagleriverchain commission.org/index.htm) as needed. | May contact to coordinate Burnt Rollways Dam monitoring. A TLWA representative should attend annual meeting to keep communication flow between organizations. |
| **Wisconsin Valley Improvement Company** | Office number – 715.848.2976 | Burnt Rollways Dam operation and chain erosion concerns | Peter Hanson to be contacted for operations issues. Cathy Wendt and Ben Niffenegger contacted for environmental issues. | May be contacted regarding Burnt Rollways Dam operation and shoreline erosion concerns. |
| **Wisconsin Lakes** | General staff (800.542.5253) | Facilitates education, networking and assistance on lake issues. | As needed. May check website (www.wisconsinlakes.org) often for updates. | May attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, training, habitat enhancement techniques, etc. |

## *Management Goal 5*: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Timeframe:** Continuation and expansion of current effort.

**Facilitator:** Planning Committee.

**Description:** Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to discovering the reason as to why the trend is developing.

The Citizens Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers trained as a part of the CLMN program begin by collecting Secchi disk transparency data for at least one year, then if the WDNR has availability in the program, the volunteer may enter into the *advanced program* and collect water chemistry data including chlorophyll-a, and total phosphorus. The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. Note: as a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

Currently, some of the lakes within the Three Lakes Chain have active volunteers collecting data each year – either within the confines of the initial or advanced program. Ideally, all lakes within the chain would have advanced monitoring occurring each year; however, it is a more realistic goal to push for all lakes monitoring Secchi disk transparency for now. It is important to get volunteers on board with the base Secchi disk data CLMN program so that when additional spots open in the advanced monitoring program, volunteers from interested lakes will be ready to make the transition into more advanced monitoring.

It is the responsibility of the Planning Committee to coordinate new volunteers. When a change in the collection volunteer occurs, it will be the responsibility of the Planning Committee to contact Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff 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. See description above.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Timeframe:** Continuation of current effort.

**Facilitator:** Board of Directors to appoint Shoreland Representative(s).

**Description:** As the watershed section discusses, the Three Lakes Chain of Lakes watershed is in good condition. Additionally, over half of the Phase I-IV lakes (52%) shoreland are considered to be in a natural or minimally developed state. It is therefore very important that owners and land managers of these properties increase their awareness of the benefits that their shoreland is providing to these waterbodies and that these shorelands remain in a natural state.

The Shoreland Condition map of each individual lake report displays the locations of Natural and Developed-Natural shorelands on the Three Lakes Chain. These shorelands present opportunities for educational outreach initiatives and physical preservation. The TLWA will work with appropriate entities to research grant programs and other pertinent information that will aid in preserving the Three Lakes Chain's shoreland. This would be accomplished through education of property owners and land managers; and/or direct preservation of land through encouragement of conservation easements or land trusts.

Valuable resources for this type of conservation work include the WDNR, UW-Extension and Oneida County Land & Water Conservation Department. Several websites of interest include:

- Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands)
- Conservation easements or land trusts: (www.northwoodslandtrust.org; www.vclra.us)
- UW-Extension Shoreland Restoration: (http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)
- WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)

**Action Steps:**

1. Recruit a member of the Board of Directors or other interested person to be an advocate and facilitator for shoreline conservation and education.
2. Develop and/or disseminate educational outreach materials regarding shoreline importance and benefits of preservation. Material will include biological research as well as grant/funding opportunities.
3. Identify a contact person to assist residents that are interested in protecting shoreland areas by answering questions and directing interested residents to appropriate resources.

**Management Action:** Investigate restoration of developed shoreland areas on the Three Lakes Chain of Lakes.

**Timeframe:** Begin 2013.

**Facilitator:** Board of Directors to appoint Shoreland Representative(s).

**Grant Resources:**
1. Oneida County Cost Share Program (*contact Oneida County Conservationist Jean Hansen – 715-369-7835*)
2. Wisconsin's Healthy Lakes Implementation Plan (*contact Kevin Gauthier of WDNR – view Plan document at website below*)

http://dnr.wi.gov/news/input/documents/guidance/healthylakesguidancefinal.pdf

**Description:** While 52% of the Three Lakes Chain shoreland may be considered to be minimally developed or not developed at all, 17% of shoreline are classified as urbanized or developed-unnatural and the remaining 31% of the shoreline is categorized as an intermediate developed-semi-natural. In order to preserve the existing shoreland as well as to maintain the current level of water quality the chain has, a priority for the TLWA should be to spread awareness of shoreland development and investigate restoring developed areas of the chain.

The Shoreland Condition map for each project lake indicates the locations of disturbed shorelands. If restoration of the Three Lakes Chain of Lakes shoreland occurs, these areas should be considered a priority. Highly developed shorelands should be first priority while semi-developed shorelands may be targeted for restoration as well. An appointed representative(s) from the TLWA will work with the education initiative volunteer (this may also be the same person) to research grant programs, restoration techniques, and other pertinent information that will aid the TLWA in making enhancements to applicable shoreline areas. Several valuable resources for this type of conservation work include those listed in the previous management action (WDNR, UW-Extension, Oneida County, etc.).

During Phase IV of this project, concerns were expressed by lake residents on potential erosion along the lake shoreline from fluctuating water levels as well as runoff from nearby roadways. Erosion can occur from a number of factors, including water level fluctuations, wind-wave action, damage from ice shoves and from watershed runoff. It is of great importance for riparian property owners to act upon erosion before it develops to a greater degree. Cost share programs such as those listed above would help the TLWA and property owners implement restorations on even partially developed shoreland and reduce the chance of erosion occurring.

In the event that signs of erosion along area roads or the lakeshore are observed, Three Lakes Chain residents have resources they can contact.

1. For roadside erosion concerns, residents may contact State Patrol Superintendent Ben Rich at the Oneida County Highway

Department (715-493-0571)

2. For shoreland erosion concerns, residents may contact Environmental Specialist Ben Niffenegger of the Wisconsin Valley Improvement Company (715-848-2976). Photographs of the erosion area may be sent to Ben at Ben@wvic.com

**Action Steps:**

1. Recruit facilitator.
2. Facilitator assists residents that are interested in shoreland restoration with process of obtaining cost-sharing using previously mentioned Grant Resources and carrying out restoration plan.
3. Retain potential of having completed projects serve as a "model" for other residents who may be interested in restoration work.

**Management Action:** Investigate sources of phosphorus Big, Crystal (Mud), Rangeline and Townline Lakes.

**Timeframe:** Begin 2013.

**Facilitator:** Planning Committee.

**Description:** During the first Planning Meeting associated with this project, Onterra staff presented water quality results to the planning committee, including higher than expected phosphorus value results which had been obtained from sampling efforts conducted on Crystal (Mud) Lake. Discussions were then held about potential phosphorus sources within the Three Lakes Chain of Lakes watershed. The current level of baseline monitoring that has been conducted on Crystal (Mud) Lake, as well as within other Three Lakes Chain lakes, cannot pinpoint the exact cause of the elevated phosphorus. It is believed by lake stakeholders that elevated nutrients may be present within Big Lake and Townline Lake also, potentially stemming from upstream watershed practices. Though elevated nutrient levels were not captured on Big Lake during these studies, stakeholders presented Onterra staff with photographic evidence of large blue-green algal blooms which had occurred on the lake in the past.

The studies conducted on the Three Lakes Chain are designed to understand general ecosystem health and to provide a clue of potential issues that may be occurring. This was achieved during monitoring of Crystal (Mud) Lake. In order to identify the source of nutrients to Crystal (Mud) Lake, further studies must be conducted which would consist of higher interval sampling of the lake and tributary. These studies are recommended for Big Lake, Rangeline and Townline Lake and will help to determine the source of nutrient contribution to these lakes. Within further grants written as a part of the Three Lakes Chain Management Planning Project, time will be included for Onterra staff to research watershed activities and determine quantitative impacts to these lakes.

**Action Steps:**

1. See above description.

## *Management Goal 6:* Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Timeframe:** Ongoing.

**Facilitator:** Board of Directors.

**Description:** With over 6,900 acres of water, many residences and visitors and several fishing tournaments, it is safe to say the Three Lakes Chain of Lakes draws much attention from anglers both local and non-local. The ecosystem of the chain is in great shape currently, which is beneficial for producing a quality fishery for anglers to enjoy. However, with the amount of visitors the Three Lakes Chain of Lakes receives it remains important to continuously monitor the fish populations on the chain to ensure that exploitation is not occurring.

During discussions with the planning committees and others involved with the TLWA, it became clear that those who were anglers had concerns over walleye populations in the Three Lakes Chain of Lakes. WDNR biologists proposed a rule change, effective 2011 for the entire Three Lakes Chain of Lakes, which would initiate a no minimum length limit on walleye with a five fish daily bag limit, however only one fish longer than 14" could be kept. This adjustment would allow the fishery, which experiences high recruitment but slow growth, to produce a higher fishable and spawning stock.

Walleye are at the forefront of Three Lakes Chain anglers concerns. However, if a walleye fishery is to thrive anglers must keep in mind that balance with other fish species and quality habitat must be maintained. In other words, education of issues and enhancement of all fish populations must be enacted in order to sustain a quality walleye fishery. In order to keep informed of survey studies and stocking of the Three Lakes Chain of Lakes, a TLWA representative should be selected to contact WDNR fisheries biologist John Kubisiak (715.365.8919) at least once a year for an update, which can be published on the association's website and in periodic newsletters. During this conversation, the TLWA representative may discuss options for improving the fishery, such as collaborating with WDNR staff on habitat enhancement projects or new opportunities with fish stocking as they arise.

**Action Steps:**

1. See above description.

# 6.0 METHODS

## Lake Water Quality

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

| Parameter | Spring | | June | | July | | August | | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | B | S | B | S | B | S | B | 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 | ● | | | | | | | | | | | |

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was completed using a Hydrolab DataSonde 5.

## Watershed Analysis

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

## Aquatic Vegetation

### *Curly-leaf Pondweed Survey*

Surveys of curly-leaf pondweed were completed on the Three Lakes Chain of Lakes during mid to late June in order to correspond with the anticipated peak growth of the plant. Please refer to each individual lake section for the exact date in which each survey was conducted. Visual inspections were completed throughout the lake by completing a meander survey by boat.

## Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on the system to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (Hauxwell 2010) was used to complete the studies. Based upon advice from the WDNR, the following point spacing and resulting number of points comprised the surveys:

| Phase & Field Work Year | Lake | Point-intercept Resolution (meters) | Number of Points | Survey Dates |
|---|---|---|---|---|
| Phase I - 2010 | Virgin Lake | 54 | 361 | Aug. 5 & 9, 2010 |
| | Whitefish Lake | 42 | 449 | August 10, 2010 |
| | The Thoroughfare | 40 | 439 | Aug. 8 & 9, 2010 |
| | Big Lake | 68 | 738 | Aug. 5 & 9, 2010 |
| Phase II - 2011 | Laurel Lake | 48 | 436 | August 10, 2011 |
| | Big Stone Lake | 50 | 981 | August 10, 2011 |
| | Dog Lake | 45 | 404 | August 9, 2011 |
| | Deer Lake | 40 | 477 | August 4 & 9, 2011 |
| | Crystal (Mud) Lake | 38 | 324 | August 4 & 5, 2011 |
| Phase III - 2012 | Big Fork Lake | 56 | 855 | July 17, 2012 |
| | Fourmile Lake | 44 | 437 | July 17, 2012 |
| Phase IV – 2013 | Moccasin Lake | 41 | 212 | July 25, 2013 |
| | Spirit Lake | 47 | 632 | July 24-25, 2013 |
| | Maple Lake | 45 | 263 | July 24-25, 2013 |

### *Community Mapping*

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

# 7.0 LITERATURE CITED

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

Boston, H.L. and M.S. Adams. 1987. Productivity, growth, and photosynthesis of two small 'isoetid' plants, *Littorella uniflora*, and *Isoetes macrospora*. J. Ecol. 75: 333 – 350.

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

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

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

Dinius, S.H. 2207. Public Perceptions in Water Quality Evaluation. Journal of the American Water Resource Association. 17(1): 116-121.

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

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

Garn, H.S. 2001. Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from 2Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigations Report 02-4130.

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

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

Great Lakes Indian Fish and Wildlife Service. 2012A. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed March 2012.

Great Lakes Indian Fish and Wildlife Service. 2012B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Enforcement/regulations.html. Last accessed March 2012.

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

Hauxwell, J., S. Knight, K.I. Wagner, A. Mikulyuk, M.E. Nault, M. Porzky and S. Chase. 2010. Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data entry and Analysis, and Applications. WDNR, Madison, WI. PUB-SS-1068 2010.

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

Krueger, J. 1998-2009. Wisconsin Open Water Spearing Report (Annual). Great Lakes Indian Fish and Wildlife Commission. Administrative Reports. Available at: http://www.glifwc.org/Biology/reports/reports.htm. Last accessed March 2012.

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

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

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

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

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

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

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

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

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

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

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

Spangler, G.R. 2009. "Closing the Circle: Restoring the Seasonal Round to the Ceded Territories". Great Lakes Indian Fish & Wildlife Commission. Available at: *www.glifwc.org/Accordian_Stories/GeorgeSpangler.pdf*

United States Department of the Interior – Bureau of Indian Affairs. 2007. Fishery Status Update in the Wisconsin Treaty Ceded Waters. Fourth Edition.

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

Urban, R.A, Titus, J.E. and Z. Wei-Xing. 2003. An Invasive Macrophyte Alters Sediment Chemistry Due to Suppression of a Native Isoetid. Ecosystem Ecology. Oecologia, 148: 455-463.

Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

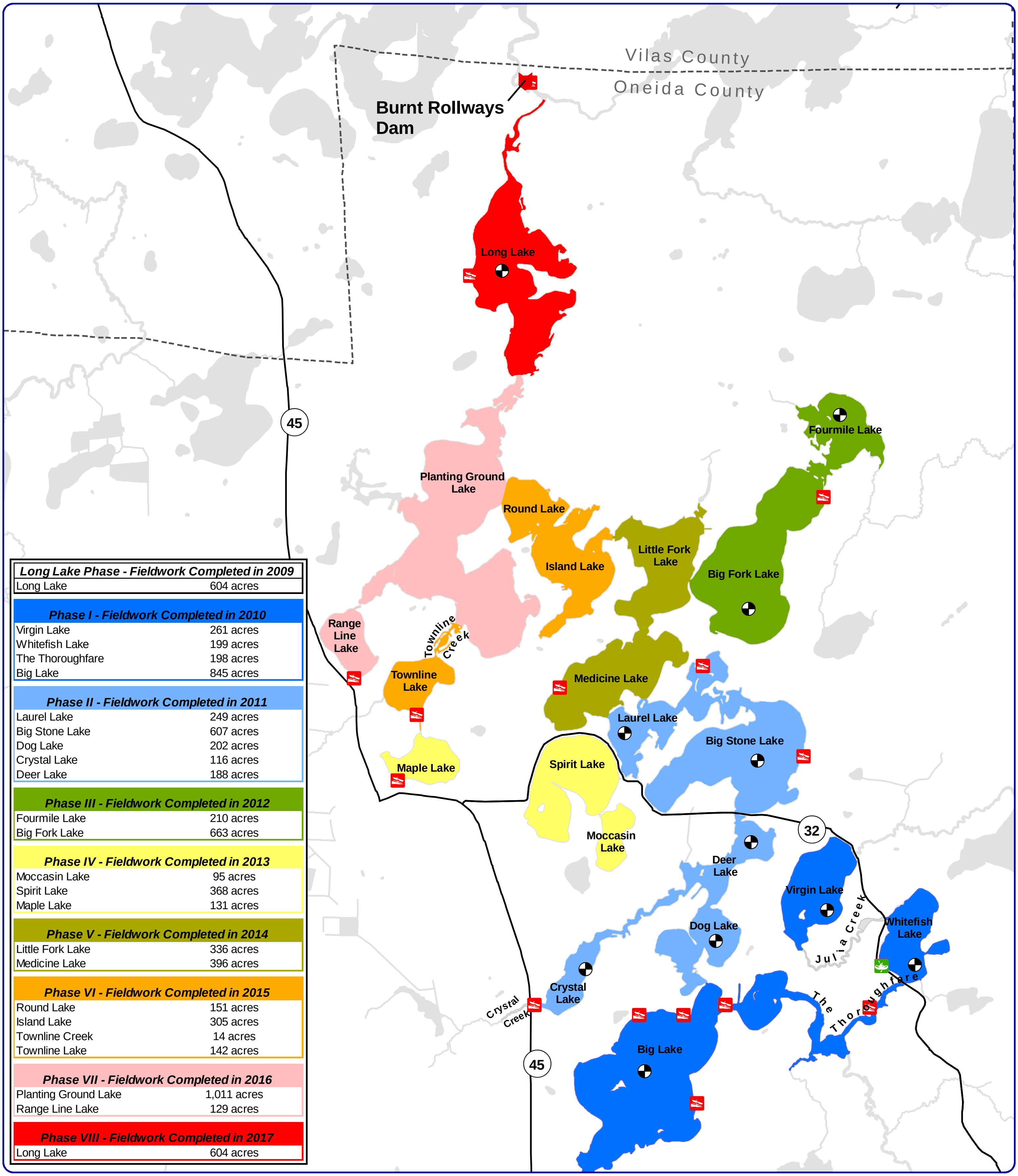
Vestergaard, O. and K. Sand-Jensen. 2000. Alkalinity and trophic state regulate aquatic plant distribution in Danish lakes. Aquatic Botany. (67) 85-107.

Wisconsin Department of Natural Resources. 2002. 2002-2003 Ceded Territory Fishery Assessment Report. Administrative Report #59.

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

Wisconsin Department of Natural Resources. 2014. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed March 2014.

Woodford, J.E. and M.W. Meyer. 2003. Impact of Lakeshore Development on Green Frog Abundance. Biological Conservation. 110, pp. 277-284.



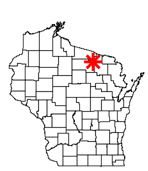

| Long Lake Phase - Fieldwork Completed in 2009 | |
|---|---|
| Long Lake | 604 acres |
| **Phase I - Fieldwork Completed in 2010** | |
| Virgin Lake | 261 acres |
| Whitefish Lake | 199 acres |
| The Thoroughfare | 198 acres |
| Big Lake | 845 acres |
| **Phase II - Fieldwork Completed in 2011** | |
| Laurel Lake | 249 acres |
| Big Stone Lake | 607 acres |
| Dog Lake | 202 acres |
| Crystal Lake | 116 acres |
| Deer Lake | 188 acres |
| **Phase III - Fieldwork Completed in 2012** | |
| Fourmile Lake | 210 acres |
| Big Fork Lake | 663 acres |
| **Phase IV - Fieldwork Completed in 2013** | |
| Moccasin Lake | 95 acres |
| Spirit Lake | 368 acres |
| Maple Lake | 131 acres |
| **Phase V - Fieldwork Completed in 2014** | |
| Little Fork Lake | 336 acres |
| Medicine Lake | 396 acres |
| **Phase VI - Fieldwork Completed in 2015** | |
| Round Lake | 151 acres |
| Island Lake | 305 acres |
| Townline Creek | 14 acres |
| Townline Lake | 142 acres |
| **Phase VII - Fieldwork Completed in 2016** | |
| Planting Ground Lake | 1,011 acres |
| Range Line Lake | 129 acres |
| **Phase VIII - Fieldwork Completed in 2017** | |
| Long Lake | 604 acres |

N W E S

6,250
Feet

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

Sources:
Roads & Hydro: WDNR
Map Date: December 7, 2012
Filename: Map1_3Lakes_Location.mxd



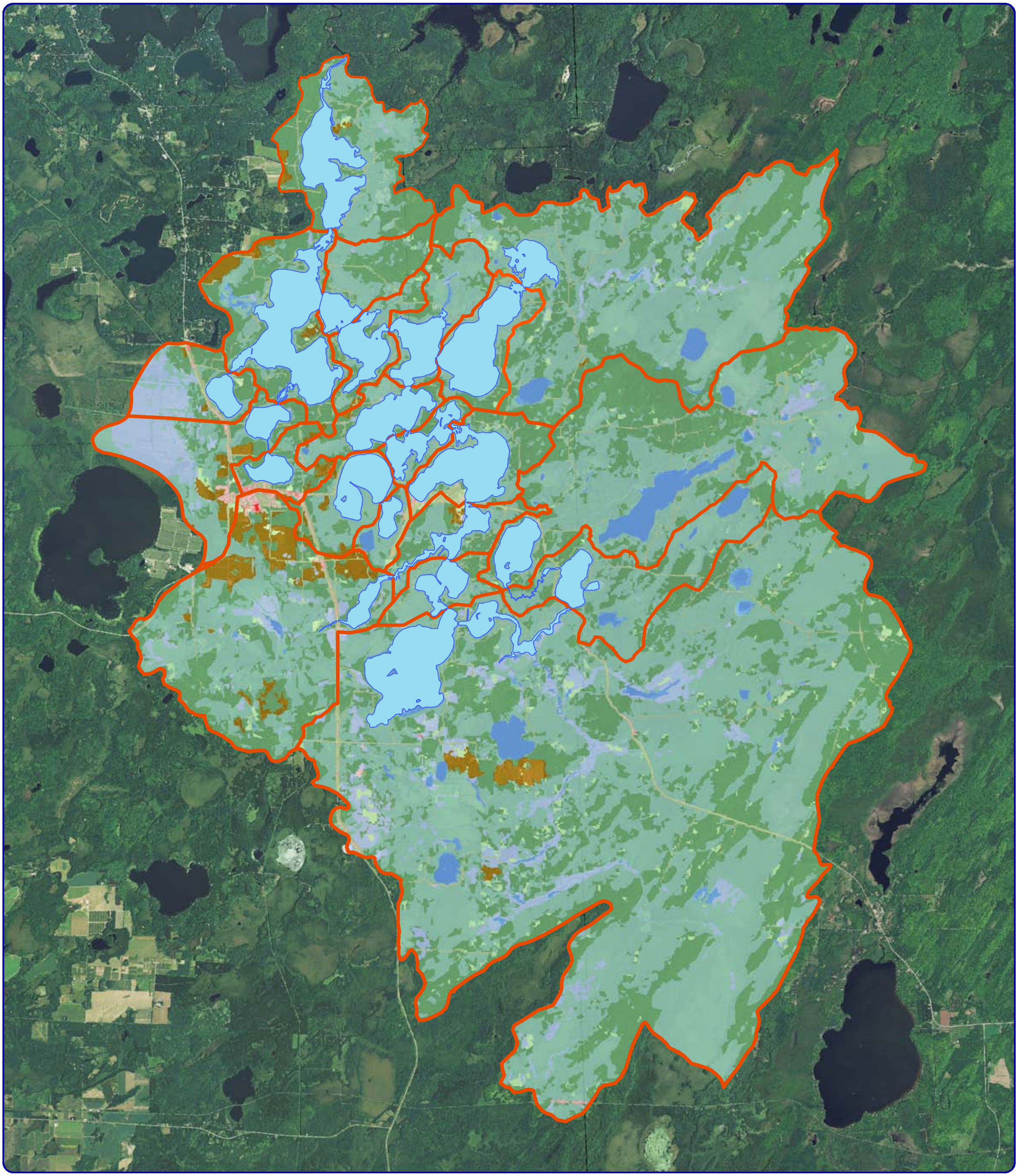
Extent of large map shown in red.

## Legend

- Public Access - Watercraft Landing
- Public Access - Carrry-in
- Water Quality Sampling Location
- Burnt Rollway Dam

Map 1
# Three Lakes Chain
Oneida County, Wisconsin

**Project Boundaries and Water Quality Sampling Locations**



N
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10,000
Feet

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

**Source:**
Watershed: WDNR & Onterra
Landcover: WISCLAND
Roads & Hydro: WDNR
Orthophotography: NAIP, 2010
**Map Date:** March 7, 2011
*File Name: Map2_3Lakes_WS.mxd*

Extent of large map shown in red.

**Legend**

Project Lake
Watershed Boundary

**Land Cover Types**

Forest
Forested Wetlands
Pasture/Grass
Open Water
Wetland
Row Crop Agriculture
Rural Open Space
Rural Residential
Urban - High Density
Urban - Medium Density

Map 2
Three Lakes Chain
Oneida County, Wisconsin
**Watershed and Land Cover Types**

**Note: Methodology, explanation of analysis and scientific background on Virgin Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.1 Virgin Lake

### *An Introduction to Virgin Lake*

Virgin Lake, Oneida County, is a drainage lake with a maximum depth of 31 feet and a surface area of 276 acres. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Virgin Lake contains 48 native plant species, of which flat-stem pondweed was the most common plant. One exotic plant, Eurasian water milfoil, was observed in 2010.

**Field Survey Notes**

*Many species observed during aquatic plant surveys. Several bryozoans* (aquatic invertebrates consisting of colonies of microscopic organisms called "zooids" – pictured to the right), *some relatively large in size, spotted as well.*

*Small colony of Eurasian water milfoil discovered during point-intercept survey, roughly 20 ft. in diameter. Area marked with GPS.*

**Photo 8.1 Bryozoan from Virgin Lake, Oneida County**

## Lake at a Glance* – Virgin Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 276 |
| Maximum Depth (ft) | 31 |
| Mean Depth (ft) | 13 |
| Volume (acre-feet) | 3,638 |
| Shoreline Complexity | 2.0 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 17, 2010 |
| Comprehensive Survey Date | August 4 & 5, 2010 |
| Number of Native Species | 48 |
| Threatened/Special Concern Species | *Potamogeton vaseyi* (Vasey's pondweed) |
| Exotic Plant Species | Eurasian water milfoil |
| Simpson's Diversity | 0.94 |
| Average Conservatism | 7.1 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, lowland drainage |
| Trophic State | Mesotrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 65:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.1.1 Virgin Lake Water Quality

Water quality data was collected from Virgin Lake on six occasions in 2010/2011. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity for almost two decades (1994-2011). These efforts provide a considerable amount of historical data, which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Virgin Lake.

Unfortunately, very limited data exists for the other two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. Some historical data from the mid 1980's exists, but these values represent spring and fall turnover samples. In 2010, average summer phosphorus concentrations (14.3 μg/L) were less than the median value (23.0 μg/L) for other deep, lowland drainage lakes in the state. Similarly, summer average chlorophyll-*a* concentrations (4.4 μg/L) were slightly less than the median value (7.0 μg/L) for other lakes of this type. Both of these values rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2010 visits to the lake, Onterra ecologists recorded field notes describing good water conditions, though slightly stained water. As explained below, the stained water is not due to nutrients or another form of pollution.

From the examination of two decades worth of Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Virgin Lake's water can be described as *Excellent* in most years (Figure 8.1.1-1). A weighted average over this timeframe is above the median value for other deep, headwater lowland lakes in the state. Secondly, with exception to 2011, there is very little variation seen in this data set. In 2011, Onterra ecologists noted exceptionally stained water during visits to monitor a small Eurasian water milfoil infestation (see the Aquatic Plant Section for more details on this). Similar stained water was observed on the other lakes in the Three Lakes Chain of lakes, as well as other lakes within the Northwoods of Wisconsin.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Virgin Lake as well as the other lakes in the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Virgin Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

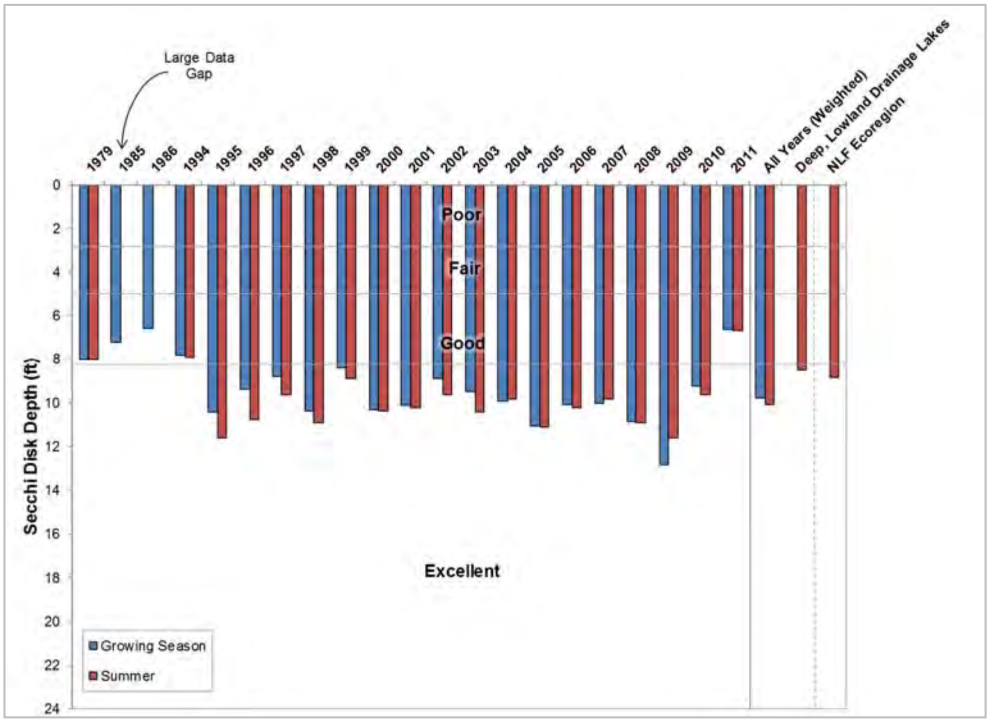



**Figure 8.1.1-1. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

**Virgin Lake Trophic State**

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.1.1-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Virgin Lake is in a mesotrophic state.

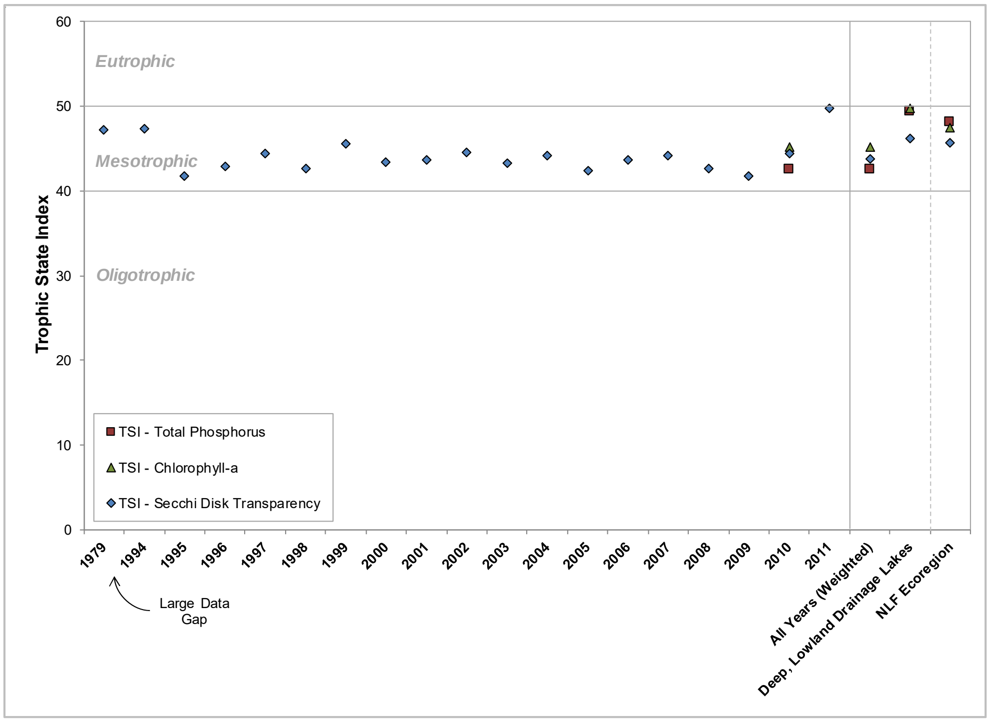



**Figure 8.1.1-2. Virgin Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Virgin Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Virgin Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.1-3 for all sampling events.

Virgin Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in fairly deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2011, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

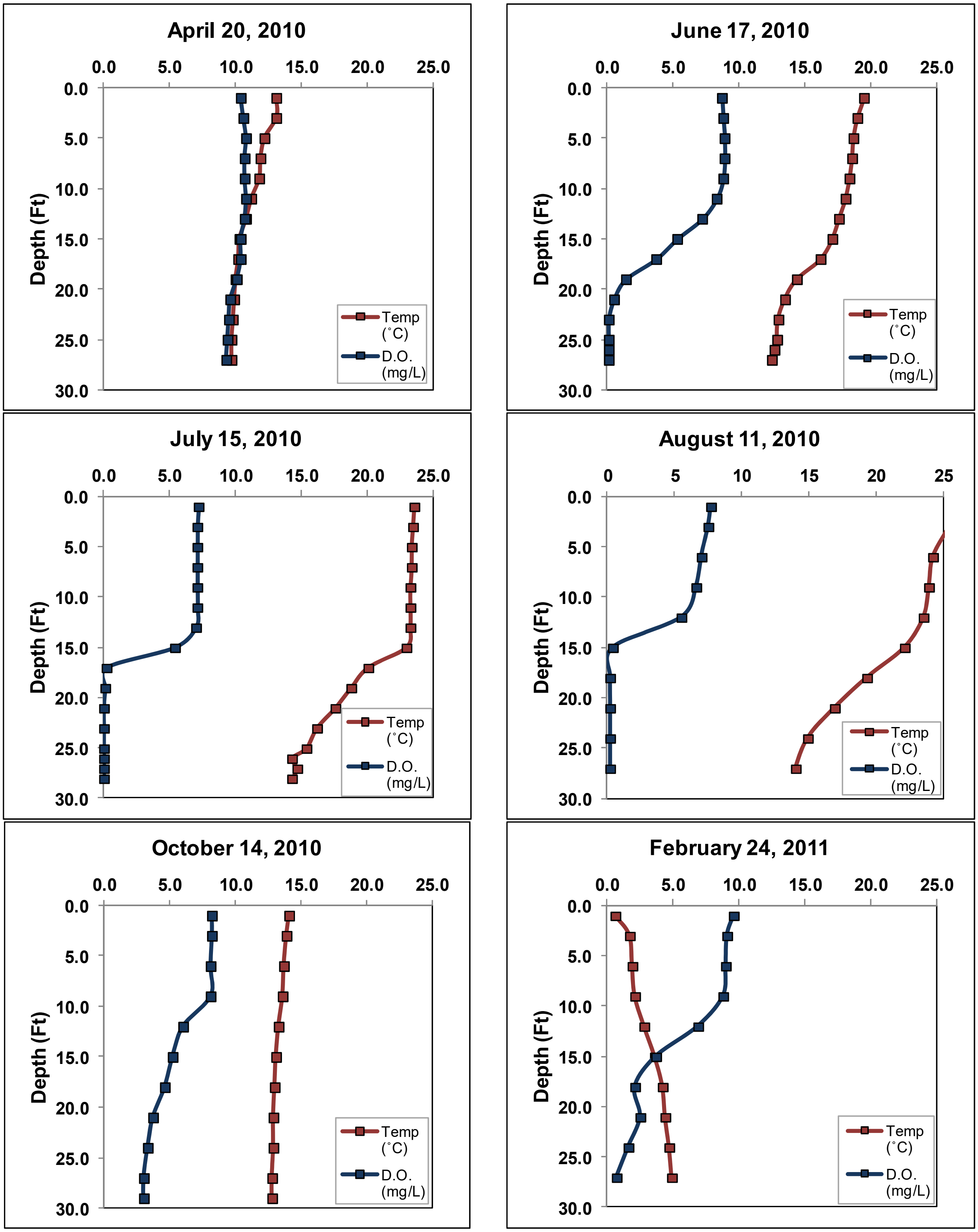



**Figure 8.1.1-3. Virgin Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Virgin 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 Virgin 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.

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Virgin Lake's surface water pH was measured at roughly 7.8 during summer 2010. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Virgin Lake was measured at 48.2 (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.

Samples of calcium were also collected from Virgin Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Virgin Lake's pH of 7.8 - 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Virgin Lake was found to be 12.0 mg/L, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (zebra mussels in the larval form) were found within these samples.

## 8.1.2 Virgin Lake Watershed Assessment

Virgin Lake's watershed is 18,268 acres in size. Compared to Virgin Lake's size of 205 acres, this makes for an incredibly large watershed to lake area ratio of 65:1.

Exact land cover calculation and modeling of nutrient input to Virgin Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

### 8.1.3 Virgin Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Virgin Lake's immediate shoreline was assessed in terms of its development. Virgin Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.9 miles (25% of the total shoreline) of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). 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, 0.6 miles of urbanized and developed–unnatural shoreline (20% of the total shoreline) was observed. If restoration of the Virgin Lake shoreline 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. Virgin Lake Map 1 displays the location of these shoreline lengths around the entire lake.

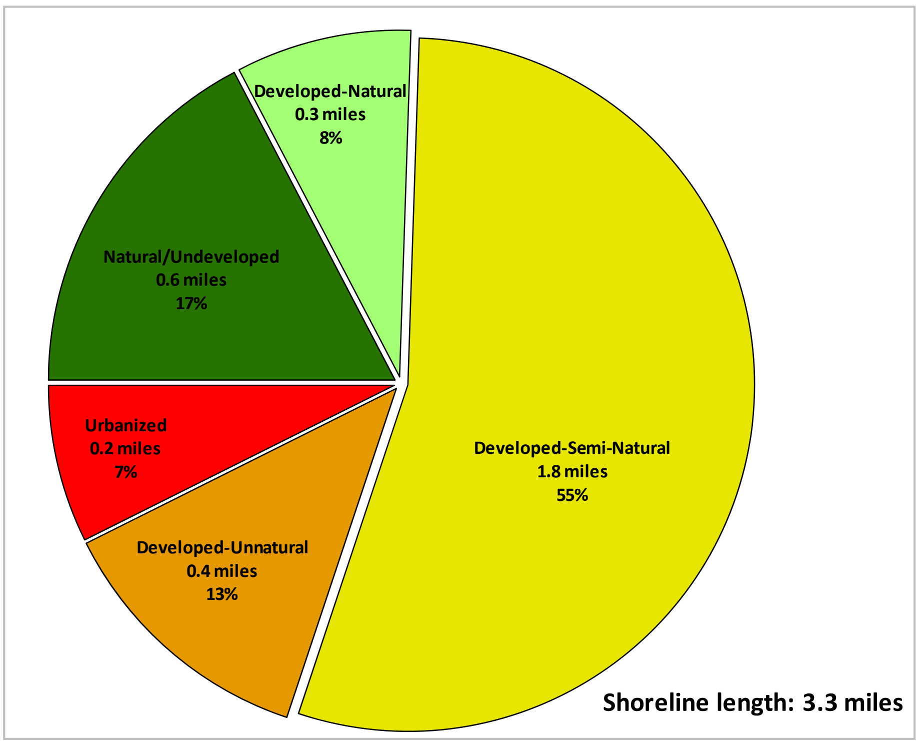



**Figure 8.1.3-1. Virgin Lake shoreland categories and total lengths.** Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Virgin Lake Map 1.

## Coarse Woody Habitat

Virgin Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 71 pieces of coarse woody habitat were observed along 3.3 miles of shoreline, which gives Virgin Lake a coarse woody habitat to shoreline mile ratio of 22:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Virgin Lake Map 2.

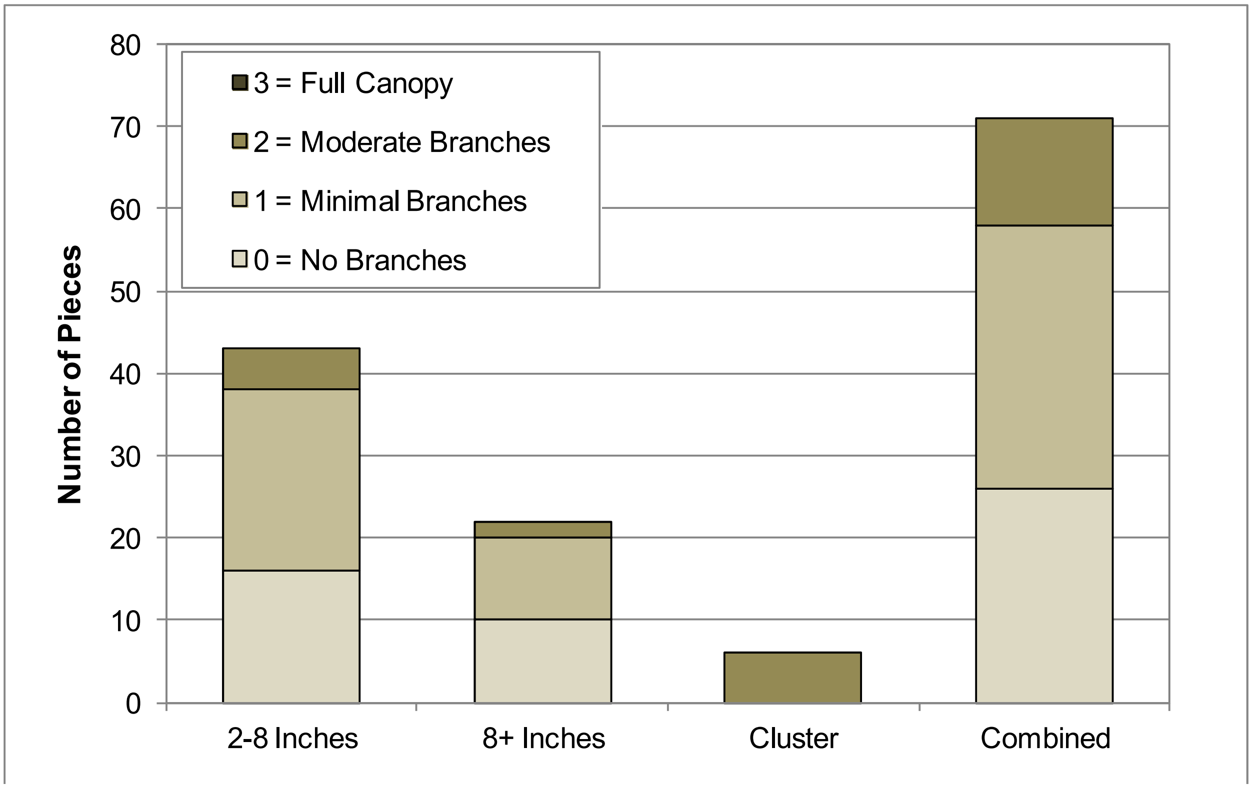



**Figure 8.1.3-2. Virgin Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Virgin Lake coarse woody habitat can be found on Virgin Lake Map 2.

### 8.1.4 Virgin Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Virgin Lake on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Virgin Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Virgin Lake on August 4 & 5, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Virgin Lake Map 2) during this time. During all surveys, 48 species of native aquatic plants were located in Virgin Lake (Table 8.1.4-1). 33 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 15 feet, which is deep relative to the other lakes within the Three Lakes Chain of lakes, where plants may be found growing to only six feet of water. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. One aquatic plant that was found during the 2010 surveys, Vasey's pondweed (*Potamogeton vaseyi*) is listed by the Natural Heritage Inventory (NHI) Program as a species of special concern in Wisconsin.

Of the 181 point-intercept locations sampled within the littoral zone, approximately 62% contained aquatic vegetation. Approximately 51% of the point-intercept sampling locations where sediment data was collected at were sand, 34% consisted of a fine, organic substrate (muck) and 15% were determined to be rocky.

**Table 8.1.4-1. Aquatic plant species located in the Virgin Lake during the 2010 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2010 (Onterra) |
|---|---|---|---|---|
| Emergent | *Carex lacustris* | Lake sedge | 6 | I |
| | *Carex lasiocarpa* | Wooly-fruit sedge | 9 | I |
| | *Carex utriculata* | Northwest Territory sedge | 7 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | X |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Schoenoplectus subterminalis* | Water bulrush | 9 | I |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 4 | I |
| | *Schoenoplectus acutus* | Hardstem bulrush | 5 | X |
| | *Zizania palustris* | Northern wild rice | 8 | I |
| FL | *Brasenia schreberi* | Watershield | 7 | I |
| | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| | *Polygonum punctatum* | Dotted smartweed | 5 | I |
| FL/E | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | I |
| Submergent | *Chara spp.* | Muskgrasses | 7 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Eriocaulon aquaticum* | Pipewort | 9 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Heteranthera dubia* | Water stargrass | 6 | X |
| | *Isoetes echinospora* | Spiny-spored quilwort | 8 | I |
| | *Isoetes lacustris* | Lake quillwort | 8 | X |
| | *Myriophyllum spicatum* | Eurasian water milfoil | Exotic | I |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Nitella sp.* | Stoneworts | 7 | X |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton obtusifolius* | Blunt-leaf pondweed | 9 | I |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton vaseyi* | Vasey's pondweed | 10 | X |
| | *Potamogeton foliosus* | Leafy pondweed | 6 | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X |
| | *Potamogeton friesii* | Fries' pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Ranunculus flammula* | Creeping spearwort | 9 | X |
| | *Ranunculus aquatilis* | White water-crowfoot | 8 | X |
| | *Sagitaria sp. (rosette)* | Arrowhead rosette | N/A | X |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | I |
| | *Vallisneria americana* | Wild celery | 6 | X |
| SE | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| | *Juncus pelocarpus* | Brown-fruited rush | 8 | X |
| | *Sagittaria cuneata* | Arum-leaved arrowhead | 7 | I |

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

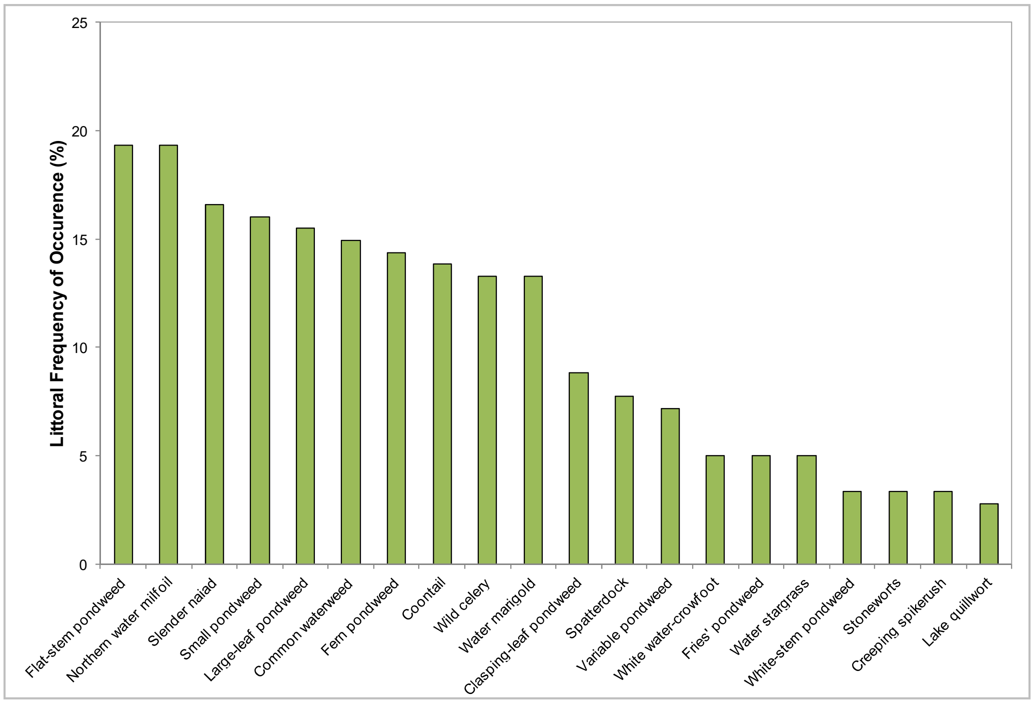



**Figure 8.1.4-1 Virgin Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.1.4-1 (above) shows that flat-stem pondweed, northern water milfoil, and slender naiad were the most frequently encountered plants within Virgin Lake. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, two (northern water milfoil and Eurasian water milfoil) were located from Virgin Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic. Eurasian water milfoil, an exotic relative of northern water milfoil, was found within Virgin Lake as well. Because of its significance, details of Eurasian water milfoil's presence in Virgin Lake will be discussed towards the end of this section and within the Implementation Plan.

An incredible 48 species of native aquatic plants (including incidentals) were found in Virgin Lake, along with one non-native plant. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Virgin Lake's plant community (0.94) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 northern water milfoil was found at 19% of the sampling locations, its relative frequency of occurrence is 9%. Explained another way, if 100 plants were randomly sampled from Virgin Lake, 9 of them would be northern water milfoil. This distribution can be observed in Figure 8.1.4-2, where together 10 species account for 71% of the population of plants within Virgin Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.1.4-1 as incidentals.

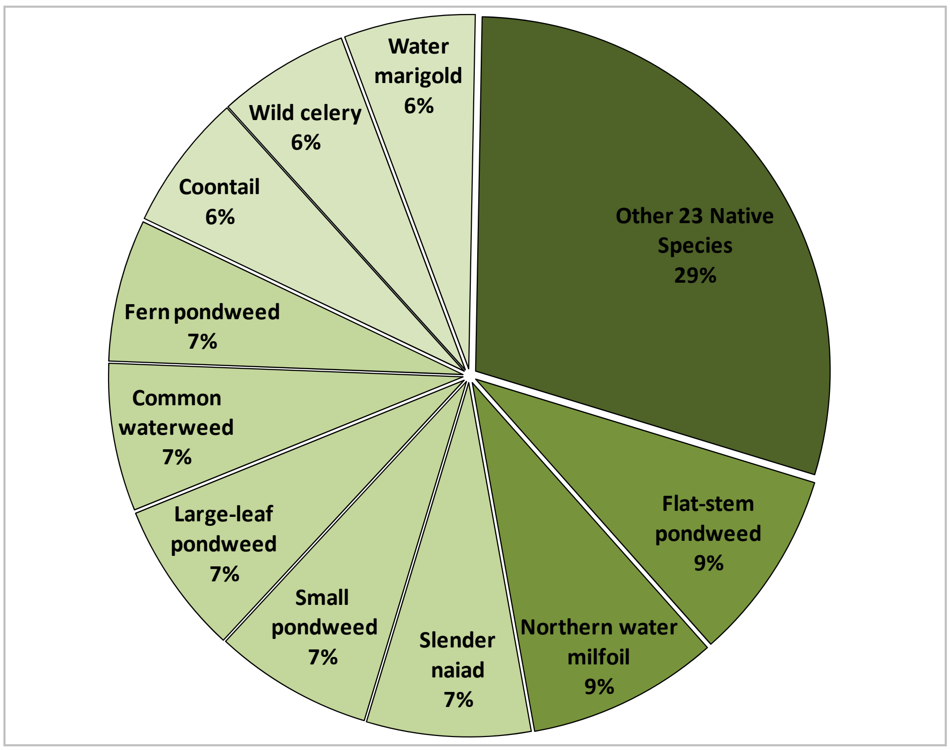



**Figure 8.1.4-2 Virgin Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2010 point-intercept survey.

Virgin Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Virgin Lake is indicative of an undisturbed system. This is not surprising considering Virgin Lake's plant community has great diversity and high species richness. Combining Virgin Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 40.8 which is well above the median values of the ecoregion and state.

The quality of Virgin Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.6 acres of the lake contains these types of plant communities (Virgin Lake

Map 3, Table 8.1.4-2). Fifteen floating-leaf and emergent species were located on Virgin Lake (Table 8.1.4-1), all of which provide valuable wildlife habitat.

**Table 8.1.4-2. Virgin Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 1.6 |
| Floating-leaf | 8.4 |
| Mixed Floating-leaf and Emergent | 5.6 |
| **Total** | 15.6 |

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

## Aquatic Invasive Species in Virgin Lake

During the point-intercept survey in August of 2010, Onterra staff located a small plant colony just south-west of the Virgin Lake island (Map 4). The original colony measured approximately 15-feet in diameter, and was located within a depth of about 8 to 9 feet. Although the colony was too large to remove from a boat using a rake, several plants located outside of the main colony were removed. Onterra staff marked the colony with GPS coordinates as well as temporary buoys, and the proper communications ensued with TWLA planning committee members and WDNR personnel. Shortly after that time, TWLA volunteers placed more permanent buoys around the colony to alert boaters to its presence, in hopes of reducing fragmentation of the plants.

On July 8, 2011, Onterra staff visited Virgin Lake to hand harvest Eurasian water milfoil plants located within the colony. Because of the relatively shallow depth, snorkeling gear was utilized. Two staff members repeatedly swam to the lake bottom and removed Eurasian water milfoil by the roots of the plant. Plants were carefully placed into mesh bags following extraction from the sediment. A third staff member remained in the boat, unloading the mesh bags periodically from the snorkelers and grabbing plant fragments from the water with a pool skimmer on an extendable pole. Weather conditions were good, however visibility into the water column and under the water was impaired by the naturally stained water of the lake. One laundry basket (approximately 50-70 plants) was filled following the removal efforts, which lasted a little over an hour, and no plants were observed on post-removal inspection of the area.

Following reports from TLWA members that more Eurasian water milfoil existed within the previously marked colony, Onterra staff members revisited the lake on September 8th to conduct plant removal again. This time, three staff slipped on donned snorkeling gear while a fourth staff member emptied mesh bags and scooped plant fragments from the surface with a pool skimmer on an extendable pole. About 35 plants were pulled during this time, though stained water was again an issue the snorkelers faced and some single plants were likely left behind.

**Photo 8.1.4-1 a) Virgin Lake Eurasian water milfoil hand harvesting,** and
**b) Hand harvesting results.** Hand harvesting occurred in July and September of 2011.

On July 3, 2012, Onterra staff once again visited Virgin Lake to hand remove Eurasian water milfoil plants. Donning SCUBA gear this time, three staff members entered the water hoping to spend more time near the substrate and get a better grasp on the extent of milfoil growth. A fourth staff member stayed aboard a nearby boat, coordinating the three SCUBA divers, emptying mesh harvesting bags and planning to catch stray fragments with a pool skimmer. Soon after the divers entered the water, they observed that the colony had expanded only slightly in size, but increased very much in density. In addition to many “tall” plants, a good number of plants were very short in stature and not visible from the surface. The biomass was too much to hand remove, so their attention turned towards determining the outer extents of the colony and identifying outlier plants by swimming transect lines from the center of the population.

Following this survey, discussions were held between Onterra staff, TLWA board members and WDNR staff. It was decided that an aggressive approach – a mid-summer 2,4-D herbicide application, was necessary in order to bring the rapidly expanding colony under control and reduce plant auto fragmentation. A treatment of 0.9 acres at 4.0 ppm 2,4-D herbicide, which is the maximum label rate, was conducted in mid-July of 2012. A follow-up treatment of 1.5 acres was treated at 4.0 ppm in early July of 2013.

The infestation of Eurasian water milfoil in Virgin Lake has been monitored since its initial discovery. In 2014, a new strategy involving a new control method was used. The TLWA contracted with Many Waters LLC to use their Diver Assisted Suction Harvest (DASH) system on the lake. DASH is a vacuum-like tool that a diver uses to bring hand-pulled plants from the bottom of a lake to the surface, where it is disposed of on a boat. Many Waters staff visited the lake several times during the summer, but unfortunately conditions were not preferable for using this system, with limited visibility and many native plants. As of September 2014, Eurasian water milfoil can be found in small occurrences in numerous areas of the lake (Map 5).

### 8.1.5 Virgin Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Virgin Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Virgin Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Virgin Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Virgin Lake's implementation plan is compiled by describing how Virgin Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Virgin Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Virgin Lake as part of this chain-wide management planning project, it is up to Virgin Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Virgin Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

### Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** Virgin Lake does not contain a public access and because of this, the threat of introduction of aquatic invasive species is reduced from transient boaters. However, in lakes without a single public access, often lake residents (and friends and family) access the lake on their individual properties. This essentially creates the potential to have numerous points on a lake where different boats with different owners may be entering occasionally.

Virgin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Virgin Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Virgin Lake or from Virgin Lake elsewhere. If a Virgin Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Virgin Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Because of the current population of Eurasian water milfoil on the lake, professional surveys are encouraged (see next management action), however having more "eyes on the water" increases the odds of spotting early pioneer colonies of Eurasian water milfoil should they develop.

**Management Action:** Continue aggressive control strategy for early-stage Eurasian water milfoil population

**Description:** As a part of Phase I of this project (2010), a small colony of Eurasian water milfoil was discovered within Virgin Lake. Because of its size, it is believed this is a very recent introduction. As outlined within the Aquatic Plant Section, the small colony was first addressed with hand-removal efforts, with several visits by Onterra ecologists in summer of 2011 and again in 2012. In 2012, four Onterra SCUBA certified ecologists visited the lake to hand harvest once again. Unfortunately, underwater observations indicated the biomass of the colony was more substantial than that which was observed the previous summer. The amount of plant encountered was in fact too much for hand removal, and an aggressive strategy was enacted to conduct an herbicide treatment upon the colony. This treatment occurred in July, which is somewhat atypical, but warranted given the rapidly growing/expanding nature of the colony.

The TLWA will continue to have professional monitoring conducted on the Eurasian water milfoil colony, as well as the rest of Virgin Lake. Continuing with an aggressive strategy on this early, relatively small population, the TLWA and Virgin Lake riparian property owners should be prepared to continue herbicide applications on the Eurasian water milfoil colony. Monitoring costs can be supported through a WDNR Aquatic Invasive Species Early Detection and Response grant, which would fund three years (2012, 2013 and 2014) of treatments and professional monitoring. Eurasian water milfoil management in Virgin Lake (monitoring and control) will combine an integrated approach of manual removal by certified SCUBA divers and volunteers as well as herbicide applications, and will be conducted in the following format:

*Spring Pretreatment Confirmation & Refinement Surveys (April/May)*

In April/May of each year during this project, Onterra ecologists would visit areas marked through the summer 2012 mapping survey to verify the growth of Eurasian water milfoil. A qualitative assessment would be completed at this time (prior to herbicide applications) to verify treatment area extents. This survey would determine if colonial expansion had occurred from the previous year and would be utilized to determine the final treatment areas. An herbicide treatment would occur in late spring/early summer of 2013 upon the colonies observed during this survey. Subsequent spring pretreatment surveys would deliver information about the Eurasian water milfoil colonies and from there, the appropriate strategy (herbicide treatment, hand-removal efforts, etc.) would be determined.

*Early-Season Aquatic Invasive Species Surveys (June)*

A survey would be conducted in June of each project year to search the entire littoral zone of Virgin Lake for aquatic invasive species. Water clarity is greater at this time of year, and native plants have just begun their growth and thus are lower in the water column than Eurasian water milfoil, which grows rapidly in the spring. Thus, this is an excellent time of year for spotting aquatic invasive species colonies. Locations of Eurasian water milfoil colonies identified during this survey would be marked with GPS technology. If only single plants or small clumps were encountered, hand-removal efforts by Onterra staff would be deployed to remove these plants from the lake. All occurrences would be refined by Onterra staff during the peak-biomass surveys discussed below.

*Summer Peak-biomass Mapping Surveys (August-September)*
As the name implies, the Eurasian water milfoil peak-biomass survey is completed when the plant is at its peak growth, allowing for a true assessment of the amount of the exotic within the lake. As with the early-season AIS survey, this survey would include a complete meander survey of the lake’s littoral zone by professional ecologists. Past findings from professional and volunteer surveys would be used as focus areas.

The re-treatment of previously treated areas is not uncommon in Eurasian water milfoil management as dense areas often require multiple years of treatment to significantly reduce a site’s density and/or size. The TLWA and Virgin Lake residents understand that multiple years of herbicide treatment and hand-removal will likely be needed on Virgin Lake. The results of the summer peak-biomass survey will help to shape management strategy for the next spring.

It is the responsibility of the TLWA to contract with a licensed commercial aquatic pesticide to conduct early season treatments of Eurasian water milfoil. The treatments would occur roughly each year before June 1 when water temperatures are between 55-65°F. Onterra would create the treatment areas in the form of polygons within their Geographic Information System (GIS) and then transmit them to the applicator in native shapefile format or similar format recognized by the applicator’s GPS technology. The association’s applicator would be responsible for completing the necessary permit applications.

*Letter Report (Winter)*
During the winter following each herbicide treatment, a brief letter report would be provided that would include an assessment of the prior spring’s treatment and guidance for the next year’s control strategy. A map depicting the peak-biomass survey results and recommended treatment areas would be included within the report. Those remedial actions may include further monitoring, manual harvesting (hand removal), herbicide treatments, or a combination of all three.

## *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Virgin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Virgin Lake and its stakeholders.

## *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Virgin Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## *Chain-wide Management Goal 5: Maintain Current Water Quality Conditions*

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, Virgin Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Virgin Lake is protected. Volunteers from Virgin Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Virgin Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

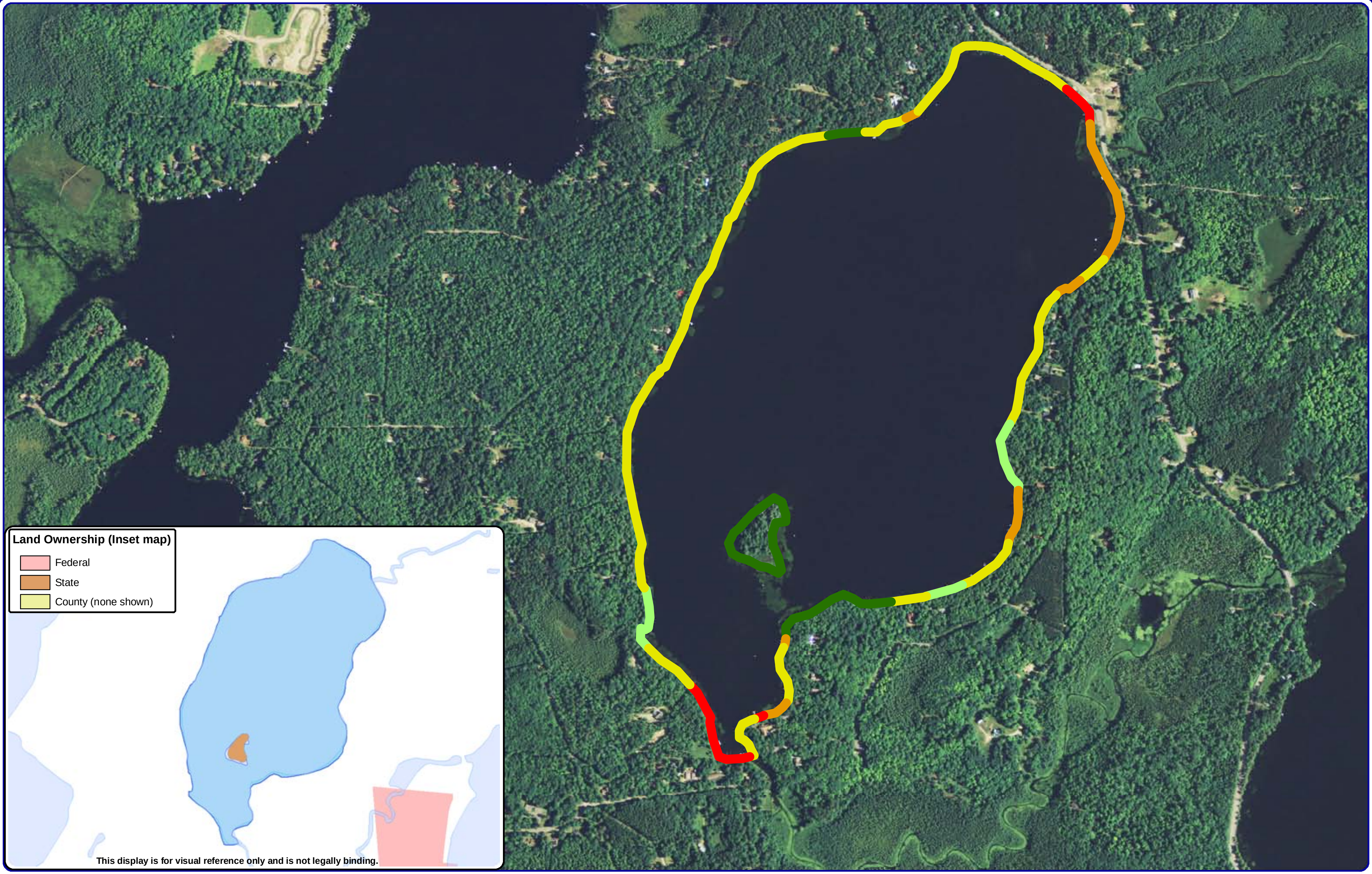
**Description:** As a part of this project, the entire Virgin Lake shoreline was categorized in terms of its development. According to the results from this survey, only 25% of the shoreline is in a natural or developed-natural state, while over half (55%) of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## *Chain-wide Management Goal 6: Improve Fishery Resource and Fishing*

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Virgin Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Virgin Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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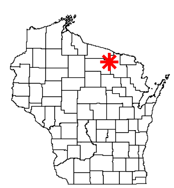
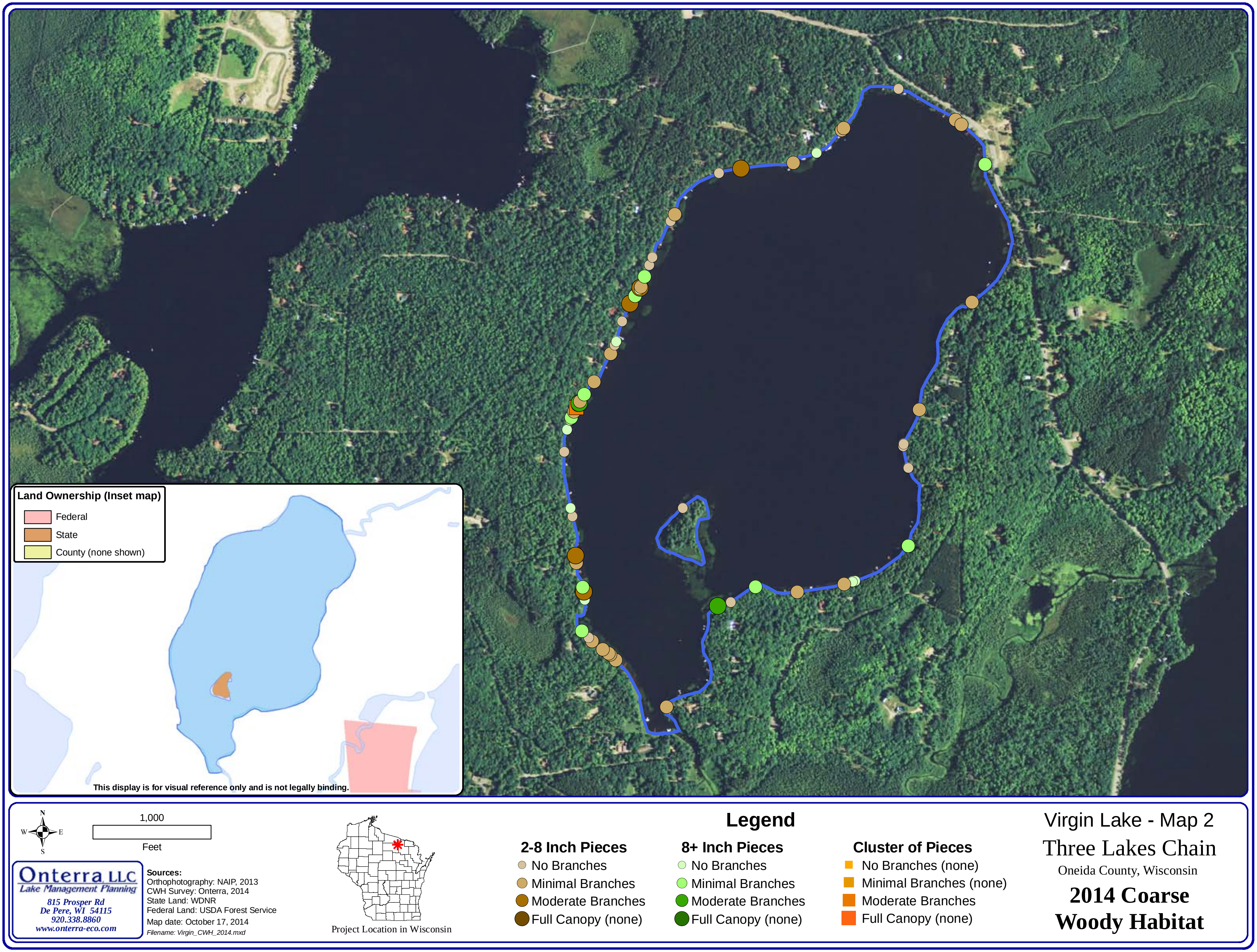
**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2014
State Land: WDNR
Federal Land: USDA Forest Service
Map date: March 7, 2012 updated Oct 31, 2014
*Filename: Virgin_Map1_SA_2010.mxd*


Project Location in Wisconsin

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

Virgin Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

**Shoreland Condition**


Land Ownership (Inset map)
Federal
State
County (none shown)
This display is for visual reference only and is not legally binding.
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Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
State Land: WDNR
Federal Land: USDA Forest Service
Map date: October 17, 2014
Filename: Virgin_CWH_2014.mxd
Project Location in Wisconsin
Legend
2-8 Inch Pieces
No Branches
Minimal Branches
Moderate Branches
Full Canopy (none)
8+ Inch Pieces
No Branches
Minimal Branches
Moderate Branches
Full Canopy (none)
Cluster of Pieces
No Branches (none)
Minimal Branches (none)
Moderate Branches
Full Canopy (none)
Virgin Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin
2014 Coarse
Woody Habitat


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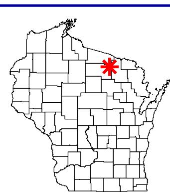
**Sources:**
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010
**Map Date:** March 7, 2012
*File Name: Virgin_Comm_2010.mxd*



Project Location in Wisconsin

**Legend**

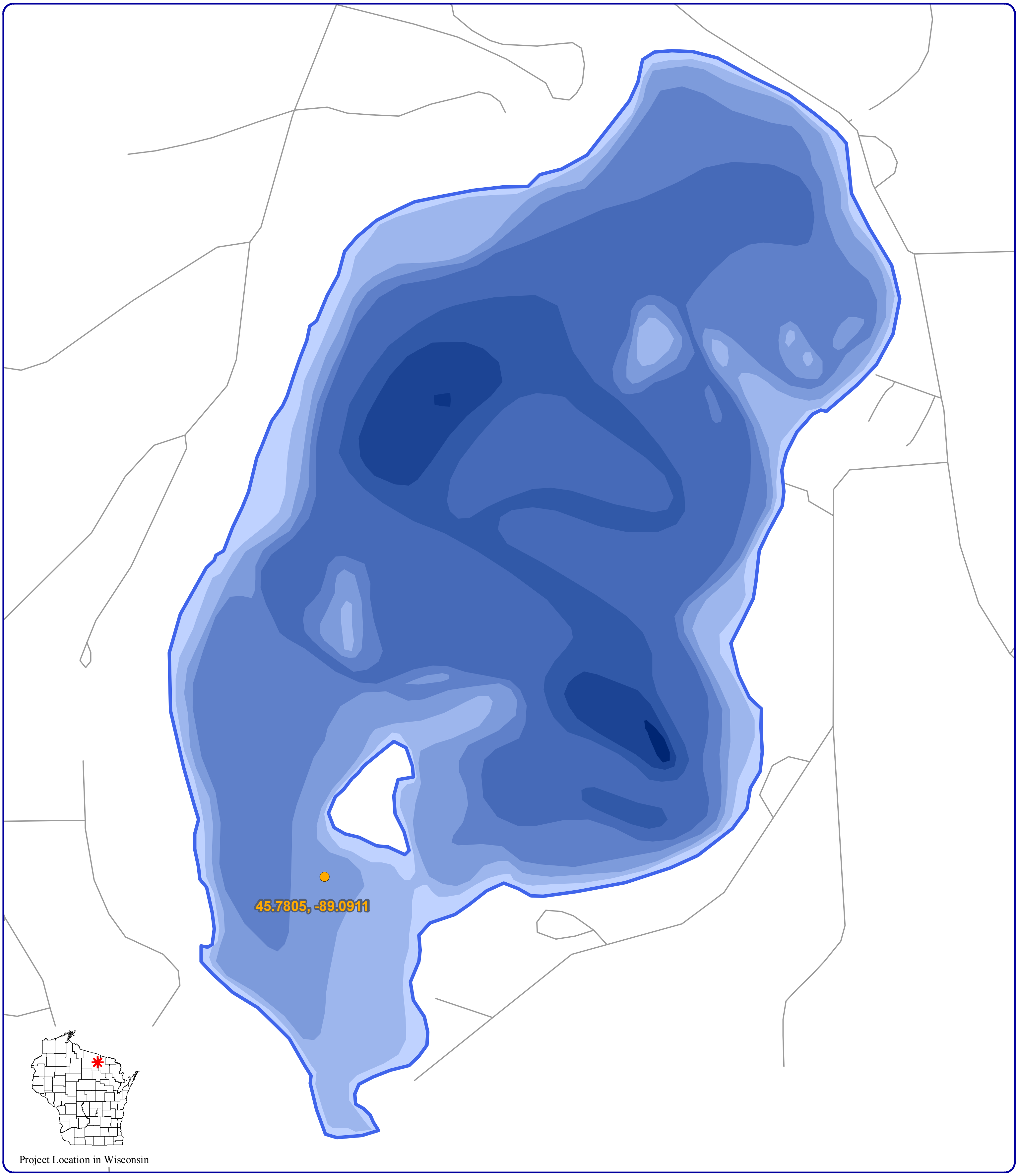
| Small Plant Communities | Large Plant Communities |
|---|---|
| Emergent | Emergent |
| Floating-leaf | Floating-leaf |
| Mixed Floating-leaf & Emergent | Mixed Floating-leaf & Emergent |

Virgin Lake - Map 3

Three Lakes Chain

Oneida County, Wisconsin

**Aquatic Plant Communities**

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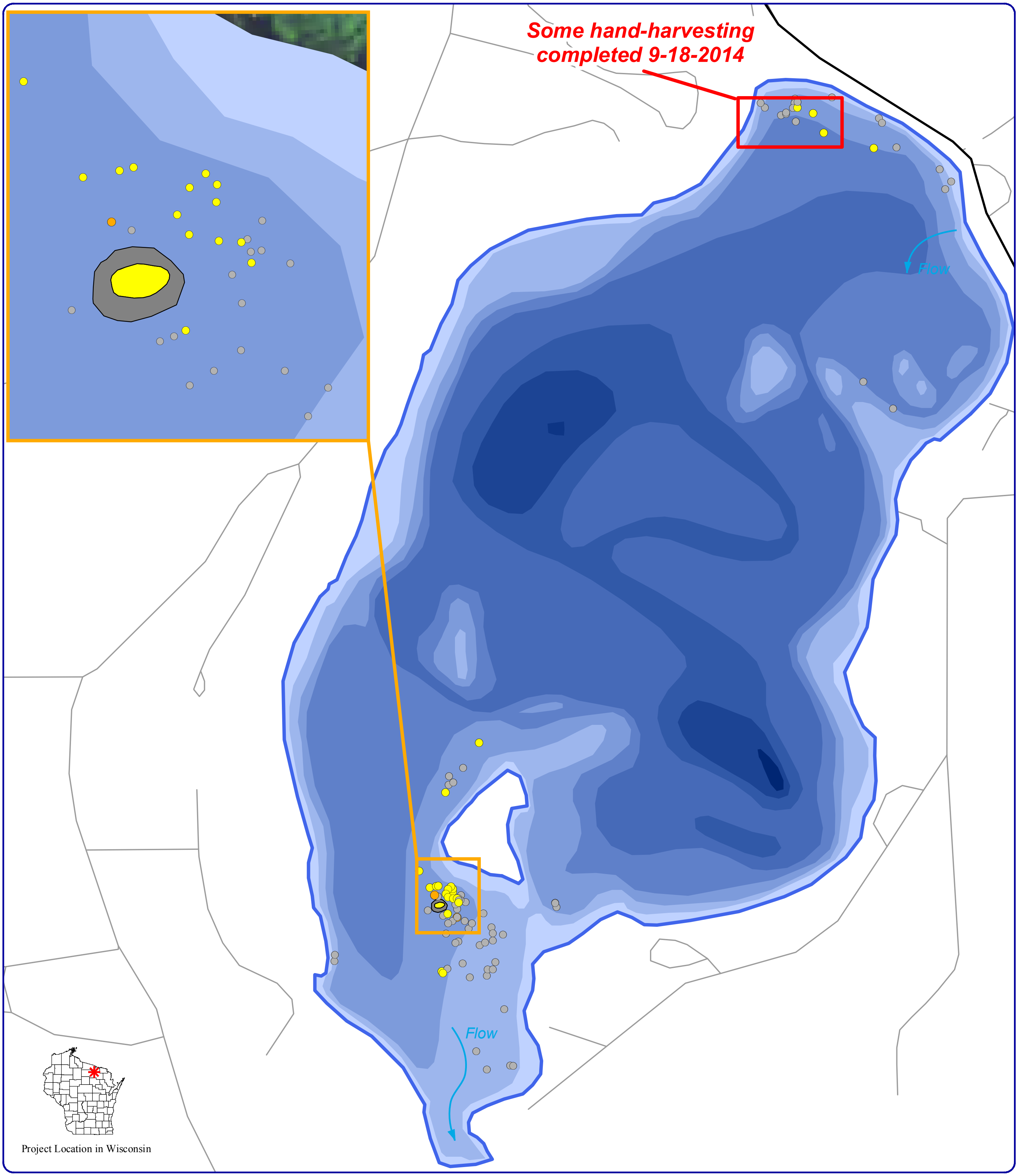
**Sources:**
Hydrology: WDNR
Ortho: NAIP, 2010
Aquatic Plant Survey - Onterra, 2010 & 2011
**Map Date:** March 7, 2012
*File Name: Virgin_EWM_2011.mxd*

**Legend**

EWM Small Plant Colony
*(Found August 2010, density and location confirmed September 2010)*

Virgin Lake - Map 4
Three Lakes Chain
Oneida County, Wisconsin
**Sept. 2010 Eurasian Water Milfoil Survey Results**

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**Sources:**
Roads and Hydro: WDNR
Orthophotography: NAIP, 2010
Aquatic Plants: Onterra, 2014
**Map Date:** October 3, 2014
*Filename: Virgin_EWM_Sept2014.mxd*

Virgin Lake - Map 5
Three Lakes Chain
Oneida County, Wisconsin

**Sept. 2014 Eurasian Water Milfoil Survey Results**

**Note: Methodology, explanation of analysis and scientific background on Whitefish Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.2 Whitefish Lake

### *An Introduction to Whitefish Lake*

Whitefish Lake, Oneida County, is a drainage lake with a maximum depth of 33 feet and a surface area of 205 acres. This mesotrophic lake has a relatively large watershed when compared to the size of the lake. Whitefish Lake contains 49 native plant species, of which wild celery is the most common plant. No exotic plants were observed during the 2010 lake surveys.

**Field Survey Notes**

*Difficulty accessing lake via Throoughfare in mid-April, due to lower water levels. Access was possible later in the month.*

*Many (49) aquatic plant species encountered during poin-intercept survey. Very large muskellunge spotted in shallow waters of isolated eastern bay.*

**Photo 8.2.1 Whitefish Lake, Oneida County**

### Lake at a Glance* – Whitefish Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 205 |
| Maximum Depth (ft) | 33 |
| Mean Depth (ft) | 16 |
| Volume (acre-feet) | 3,252 |
| Shoreline Complexity | 3.1 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 17, 2010 |
| Comprehensive Survey Date | August 10, 2010 |
| Number of Native Species | 49 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | - |
| Simpson's Diversity | 0.93 |
| Average Conservatism | 7.1 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, lowland drainage |
| Trophic State | Mesotrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 95:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.2.1 Whitefish Lake Water Quality

During 2011/2012, water quality data was collected from Whitefish Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity since 2006, with advanced monitoring (total phosphorus and chlorophyll-*a*) beginning in 2007. These efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Whitefish Lake for years to come.

During this time, summer average total phosphorus concentrations have ranged consistently between 14.5 and 25.0 µg/L (Figure 8.2.1-1). Some of these average annual concentrations rank within the TSI category of *Good*, with most ranking as *Excellent*. A weighted value across all years is lower than the median for deep, lowland drainage lakes in the state of Wisconsin. As with the total phosphorus values, average summer chlorophyll-*a* concentrations also rank within categories of *Good* and mostly *Excellent*, and a weighted average is less than the median concentration for similar lakes across the state (Figure 8.2.1-2).

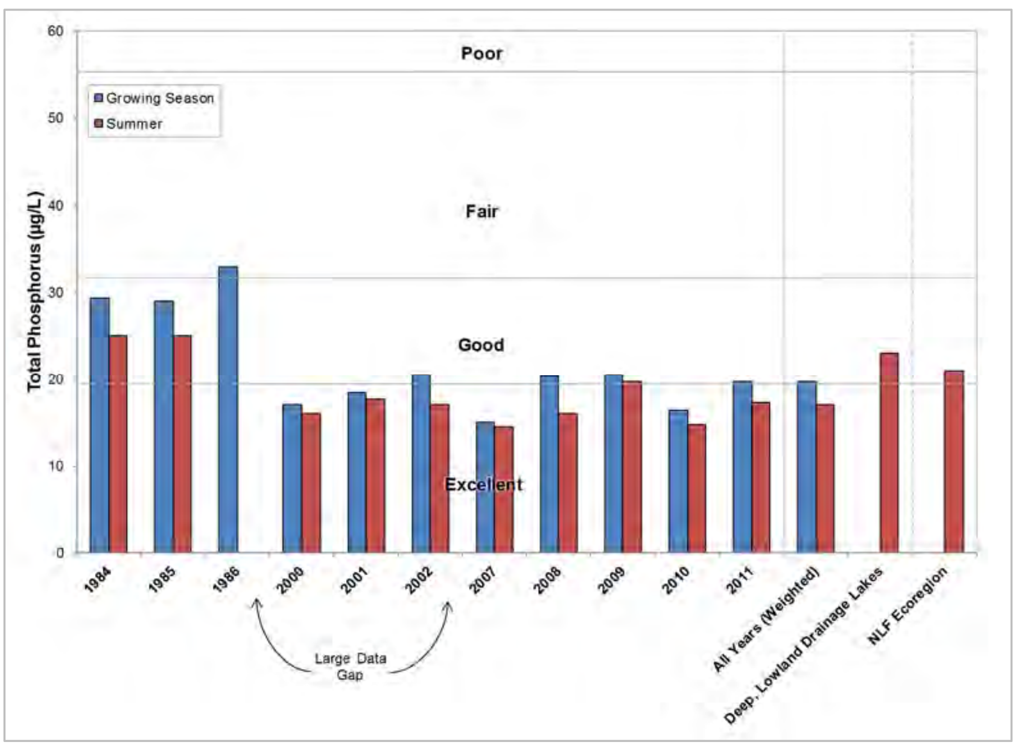


**Figure 8.2.1-1. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

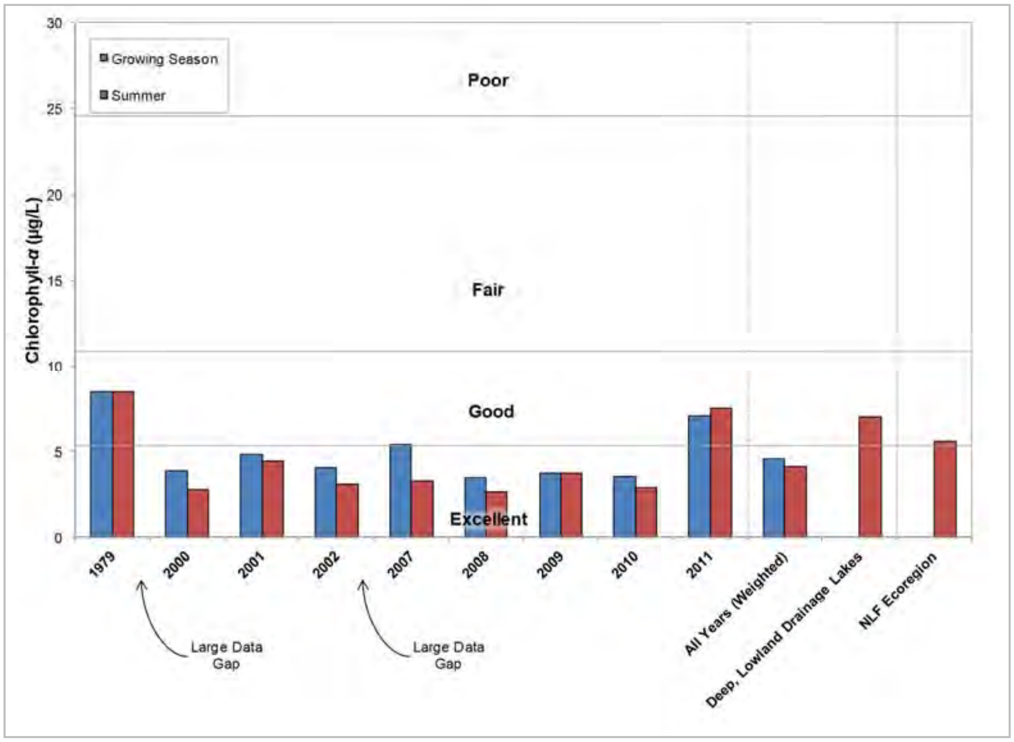


**Figure 8.2.1-2. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters (Figure 8.2.1-3). Summer averages lie mostly within the *Excellent* category. A weighted average across all years is slightly greater than the average for deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. Comparing the chlorophyll-*a* dataset with the Secchi disk clarity dataset, it is apparent that during most years the two parameters do indeed have an inverse relationship. For example, in 2010 chlorophyll-*a* concentrations were relatively low in the lake, and in that same year Secchi disk depth averages are fairly high. On the other hand, in 2011 average chlorophyll-*a* concentrations were particularly high for Whitefish Lake and, as a result, the average Secchi disk depth was fairly low during that time.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water also plays a role in light penetration, and thus water clarity, as well. The darker waters of Whitefish Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

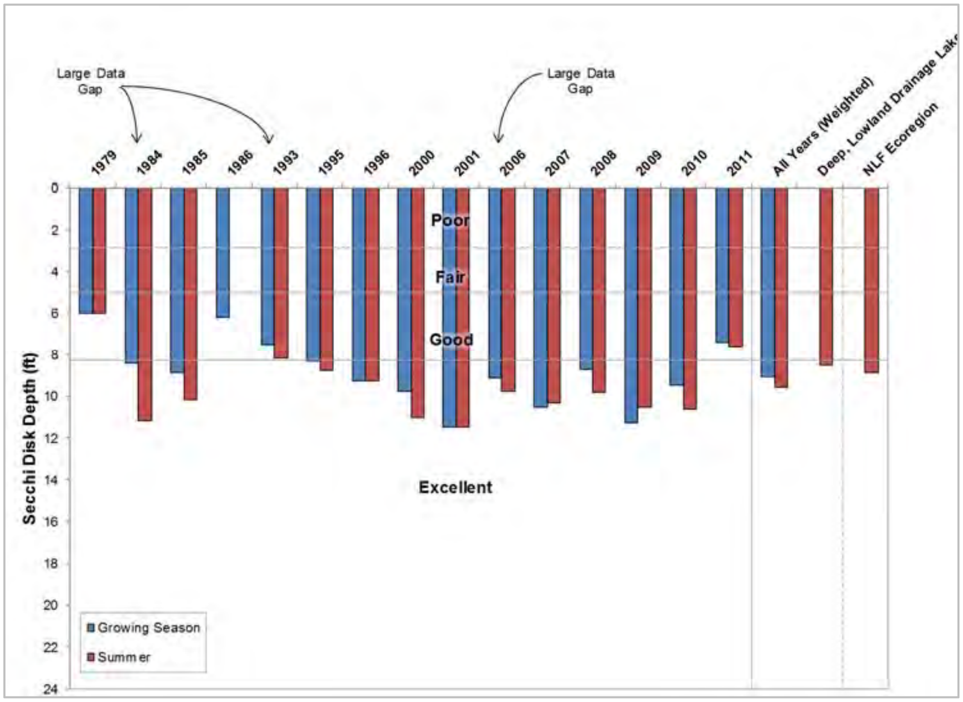


**Figure 8.2.1-3. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

### Whitefish Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.2.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Whitefish Lake is in a mesotrophic state.

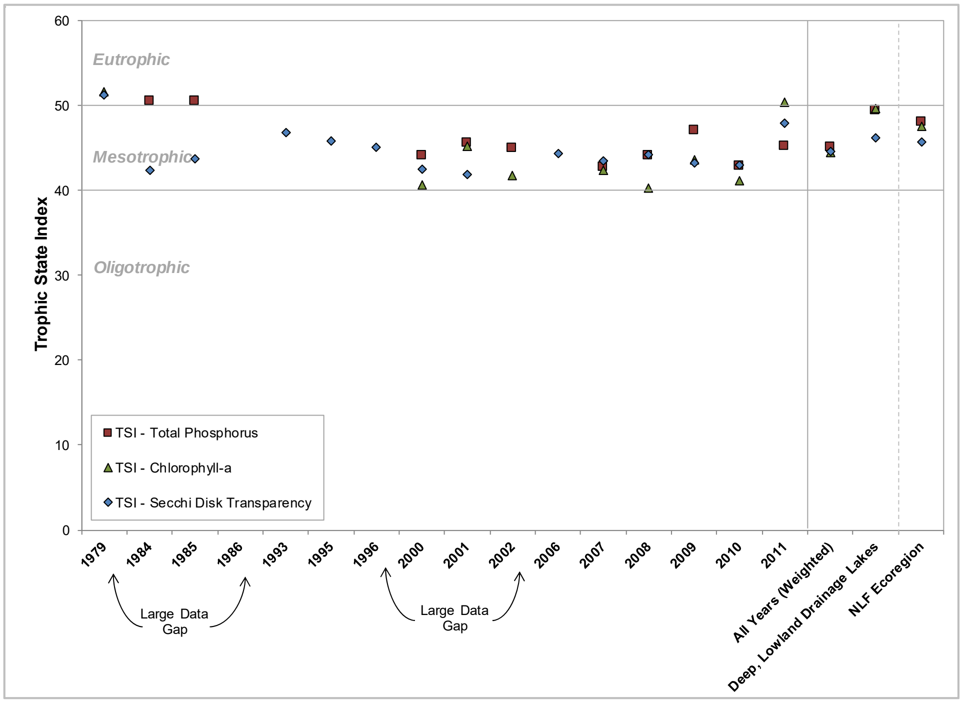


**Figure 8.2.1-4. Whitefish Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Whitefish Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Whitefish Lake by Onterra staff. Graphs of those data are displayed in Figure 8.2.1-5 for all sampling events.

Whitefish Lake was found to be thoroughly mixed during the spring, but quickly stratified once the weather warmed the uppermost layers of water in June. Throughout the summer months, the lake remained thermally stratified at about 15 feet. This is not uncommon in lakes that are moderate in size and fairly deep. Energy from the wind is sufficient to mix only the upper layer of water, allowing the cooler, denser water to remain below. Decomposition of organic matter along the lake bottom is the cause of the decrease in dissolved oxygen observed in the summer months. In October, the lake is mixed once again by fall winds and oxygen is restored throughout the water column. During the winter months, dissolved oxygen depletes within the lake because the water is not able to exchange oxygen with the air through the ice. Dissolved oxygen levels remained sufficient in the upper 15 feet of the water column year-round to support most aquatic life found in northern Wisconsin lakes.

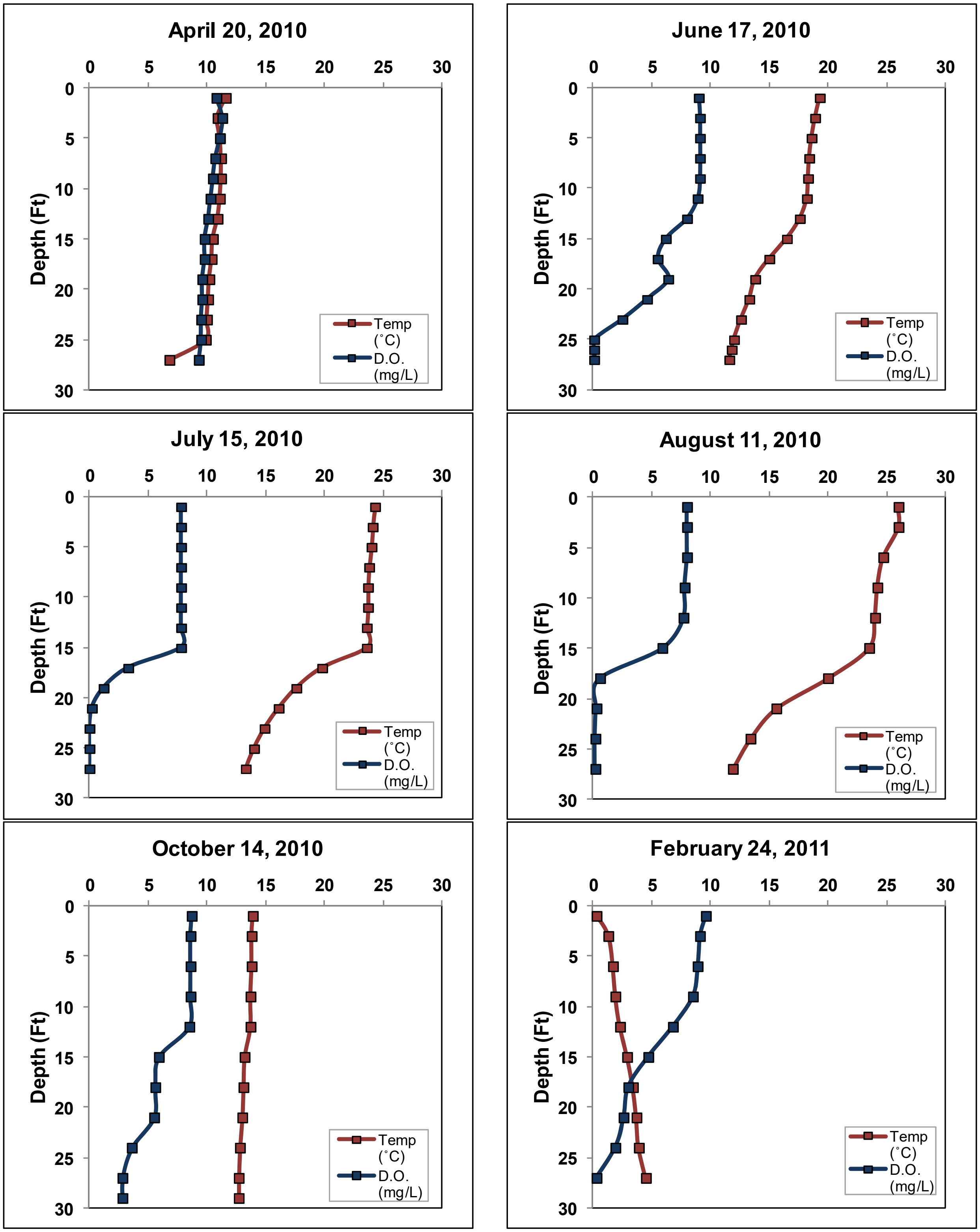


**Figure 8.2.1-5. Whitefish Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Whitefish 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 Whitefish 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Whitefish Lake's pH was measured at roughly 7.9 in the summer months of 2010. This value is above neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Whitefish Lake was measured at 44.5 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Whitefish Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Whitefish Lake's pH of 7.9 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Whitefish Lake was found to be 11.3 mg/L, falling just below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval mussels. No veligers (larval mussels) were found within these samples.

## 8.2.2 Whitefish Lake Watershed Assessment

Whitefish Lake's watershed is 19,630 acres in size. Compared to Whitefish Lake's size of 205 acres, this makes for an incredibly large watershed to lake area ratio of 95:1.

Exact land cover calculation and modeling of nutrient input to Whitefish Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.2.3 Whitefish Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Whitefish Lake's immediate shoreline was assessed in terms of its development. Whitefish Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.1 miles of natural/undeveloped and developed-natural shoreline (33% of the entire shoreline) were observed during the survey (Figure 8.2.3-1). 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, about 0.9 miles of urbanized and developed–unnatural shoreline (27% of the total shoreline) was observed. If restoration of the Whitefish Lake shoreline 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. Whitefish Lake Map 1 displays the location of these shoreline lengths around the entire lake.

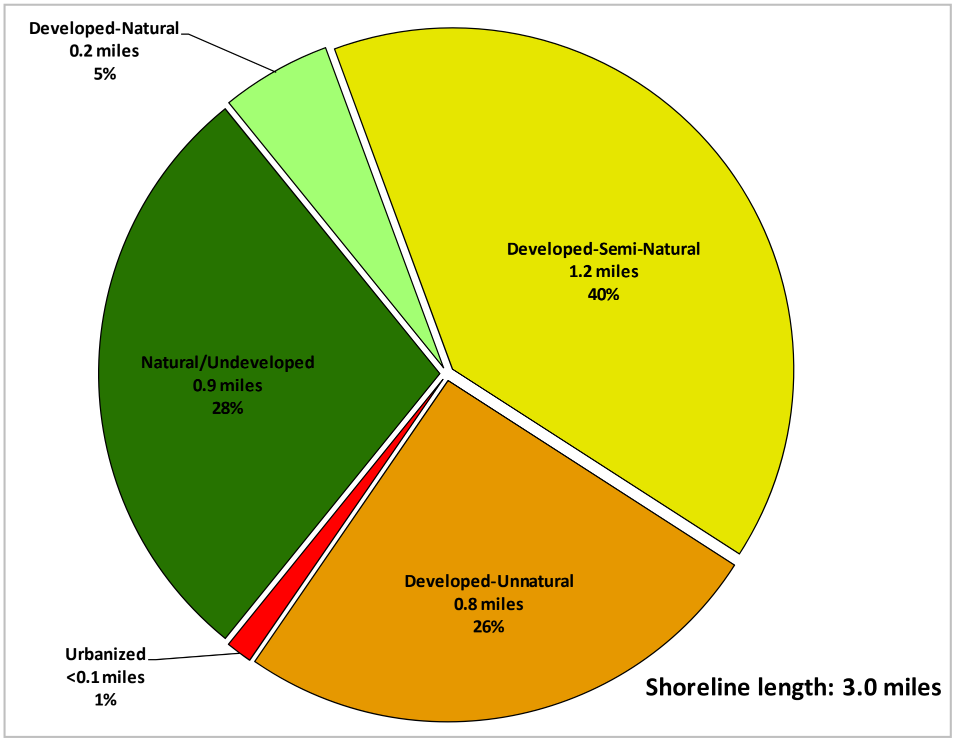


**Figure 8.2.3-1. Whitefish Lake shoreland categories and total lengths.** Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Whitefish Lake Map 1.

## Coarse Woody Habitat

Whitefish Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 33 pieces of coarse woody habitat were observed along 3.0 miles of shoreline, which gives Whitefish Lake a coarse woody habitat to shoreline mile ratio of 11:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Whitefish Lake Map 2.

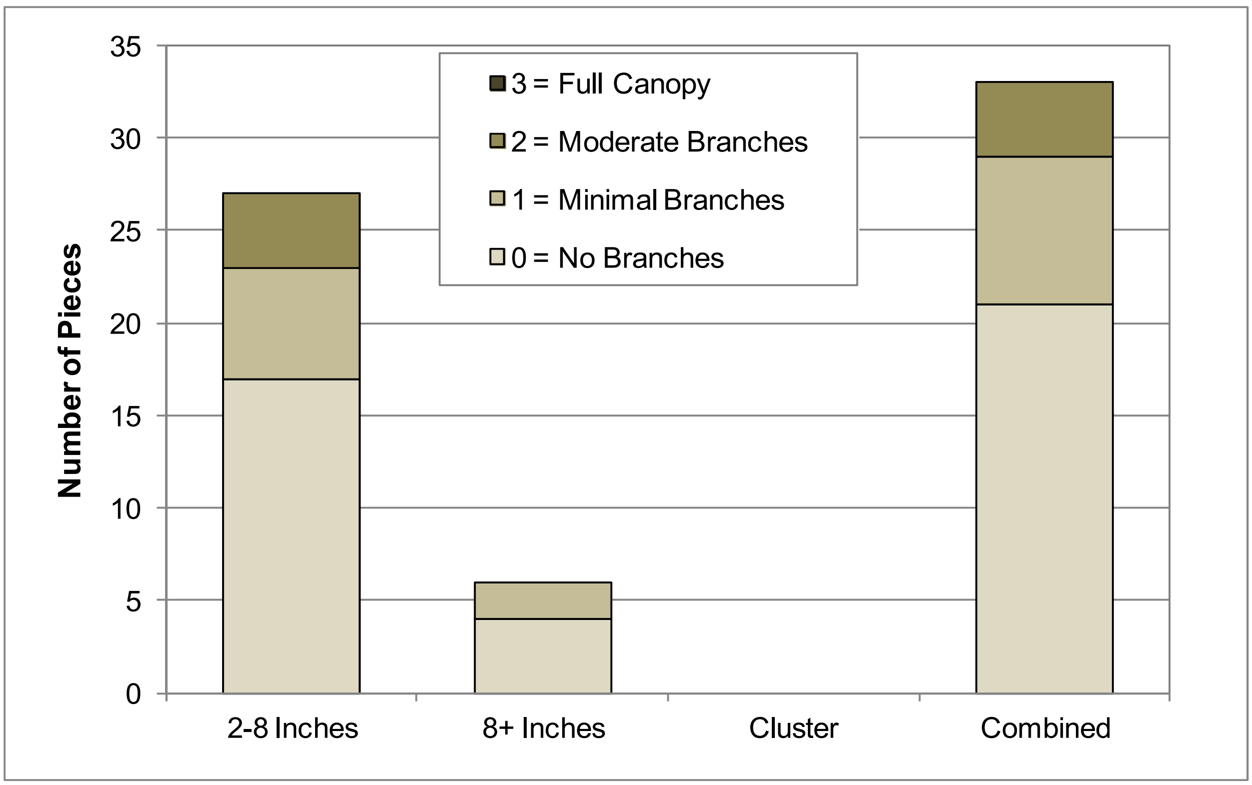


**Figure 8.2.3-2. Whitefish Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Whitefish Lake coarse woody habitat can be found on Whitefish Lake Map 2.

## 8.2.4 Whitefish Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Whitefish Lake on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Whitefish Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Whitefish Lake on August 10, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Whitefish Lake Community Map). During all surveys, 49 species of native aquatic plants were located in Whitefish Lake (Table 8.2.4-1). 36 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 14 feet, which is deep relative to the other lakes within the Three Lakes Chain of lakes, where plants may be found growing to only six feet of water. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 174 point-intercept locations sampled within the littoral zone, approximately 86% contained aquatic vegetation. Approximately 74% of the point-intercept sampling locations where sediment data was collected at were sand, 24% consisted of a fine, organic substrate (muck) and 3% were determined to be rocky.

**Table 8.2.4-1. Aquatic plant species located in the Whitefish Lake during the 2010 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2010 (Onterra) |
|---|---|---|---|---|
| Emergent | *Carex comosa* | Bristly sedge | 5 | I |
| | *Carex utriculata* | Northwest Territory sedge | 7 | I |
| | *Calla palustris* | Water arum | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Decodon verticillatus* | Water-willow | 7 | I |
| | *Iris versicolor* | Northern blue flag | 5 | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Schoenoplectus acutus* | Hardstem bulrush | 5 | I |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Schoenoplectus subterminalis* | Water bulrush | 9 | X |
| | *Typha spp.* | Cattail spp. | 1 | X |
| | *Zizania palustris* | Northern wild rice | 8 | X |
| FL | *Brasenia schreberi* | Watershield | 7 | I |
| | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium eurycarpum* | Common bur-reed | 5 | I |
| | *Sparganium angustifolium* | Narrow-leaf bur-reed | 9 | X |
| | *Sparganium emersum* | Short-stemmed bur-reed | 8 | X |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Chara spp.* | Muskgrasses | 7 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Heteranthera dubia* | Water stargrass | 6 | X |
| | *Isoetes lacustris* | Lake quillwort | 8 | X |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Nitella sp.* | Stoneworts | 7 | X |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | I |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | I |
| | *Potamogeton illinoensis* | Illinois pondweed | 6 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton obtusifolius* | Blunt-leaf pondweed | 9 | X |
| | *Potamogeton foliosus* | Leafy pondweed | 6 | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton friesii* | Fries' pondweed | 8 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Ranunculus aquatilis* | White water-crowfoot | 8 | X |
| | *Sagitaria sp. (rosette)* | Arrowhead rosette | N/A | X |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X |

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

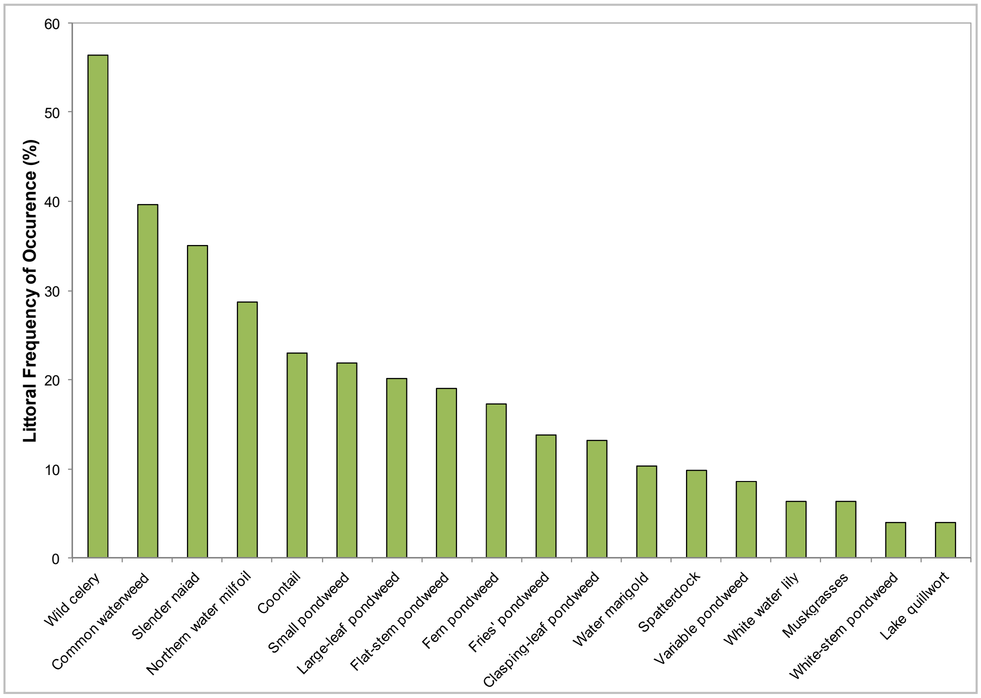


**Figure 8.2.4-1 Whitefish Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 3.0% only. Created using data from a 2010 point-intercept survey.

Figure 8.2.4-1 (above) shows that wild celery, common waterweed, and slender naiad were the most frequently encountered plants within Whitefish Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. Common waterweed is able to obtain most of its nutrients through the water and thus does not produce extensive root systems. Sometimes, this plant may produce structures similar to roots (rhizoids) or become partially buried in the sediment. Because of this, the plant is susceptible to being easily uprooted and migrated by water-action and movement. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was located from Whitefish Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

An incredible 49 species of aquatic plants (including incidentals) were found in Whitefish Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Whitefish Lake's plant community (0.93) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 wild celery was found at 56% of the sampling locations, its relative frequency of occurrence is 15%. Explained another way, if 100 plants were randomly sampled from Whitefish Lake, 15 of them would be wild celery. This distribution can be observed in Figure 8.2.4-2, where together nine species account for 72% of the population of plants within Whitefish Lake, and the other 27 species account for the remaining 28%. Thirteen additional species were found incidentally within the lake (not from of the point-intercept survey), and are indicated in Table 8.2.4-1 as incidentals.

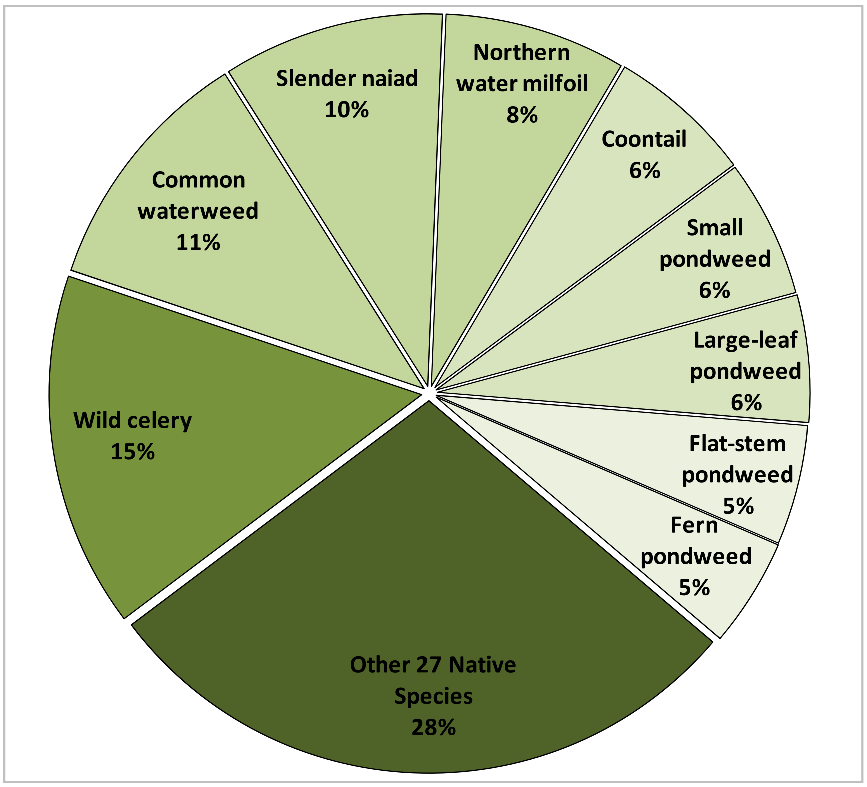


**Figure 8.2.4-2 Whitefish Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2010 point-intercept survey.

Whitefish Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Whitefish Lake is indicative of an undisturbed system. This is not surprising considering Whitefish Lake's plant community has great diversity and high species richness. Combining Whitefish Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 42.5 which is well above the median values of the ecoregion and state.

The quality of Whitefish Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.4 acres of the lake contains these types of plant communities (Whitefish Lake Map 2, Table 8.2.4-2). 18 floating-leaf and emergent species were located on Whitefish Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

**Table 8.2.4-2. Whitefish Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 0.1 |
| Floating-leaf | 1.2 |
| Mixed Floating-leaf and Emergent | 14.1 |
| **Total** | 15.4 |

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

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### 8.2.5 Whitefish Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Whitefish Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Whitefish Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Whitefish Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Whitefish Lake's implementation plan is compiled by describing how Whitefish Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Whitefish Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Whitefish Lake as part of this chain-wide management planning project, it is up to Whitefish Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Whitefish Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** Whitefish Lake contains a public carry-in access, and is accessible through the Thoroughfare which contains several public access points. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters. Therefore, both parties must be educated on the threat of aquatic invasive species.

Whitefish Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Whitefish Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Whitefish Lake or from Whitefish Lake elsewhere. If a Whitefish Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Whitefish Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Whitefish Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

### *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Whitefish Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Whitefish Lake and its stakeholders.

### *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Whitefish Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, Whitefish Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Whitefish Lake is protected. Volunteers from Whitefish Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Whitefish Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

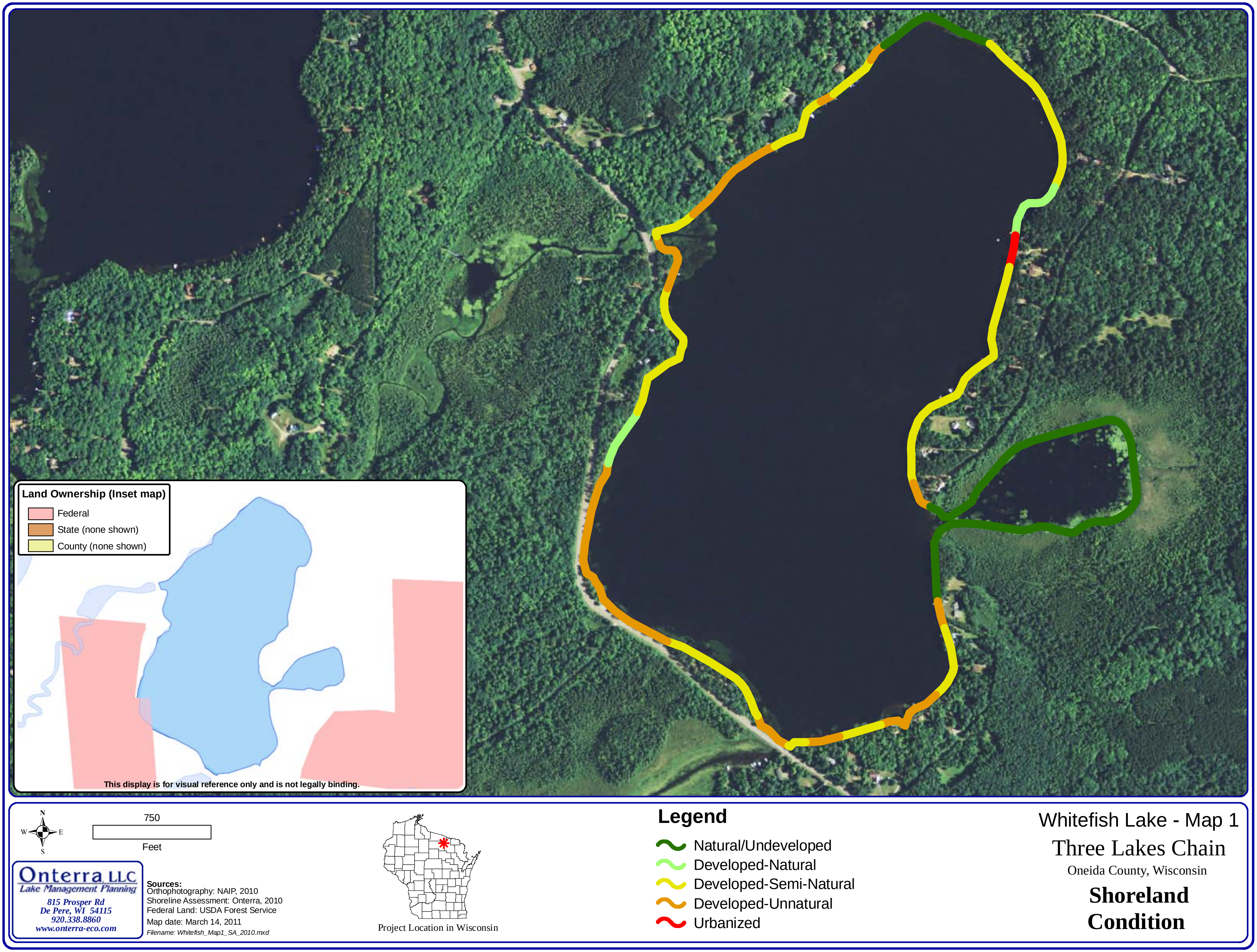
**Description:** As a part of this project, the entire Whitefish Lake shoreline was categorized in terms of its development. According to the results from this survey, 27% of the shoreline is in an urbanized or developed-unnatural state, while 40% is of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Whitefish Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Whitefish Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



Land Ownership (Inset map)
Federal
State (none shown)
County (none shown)
This display is for visual reference only and is not legally binding.
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Lake Management Planning
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920.338.8860
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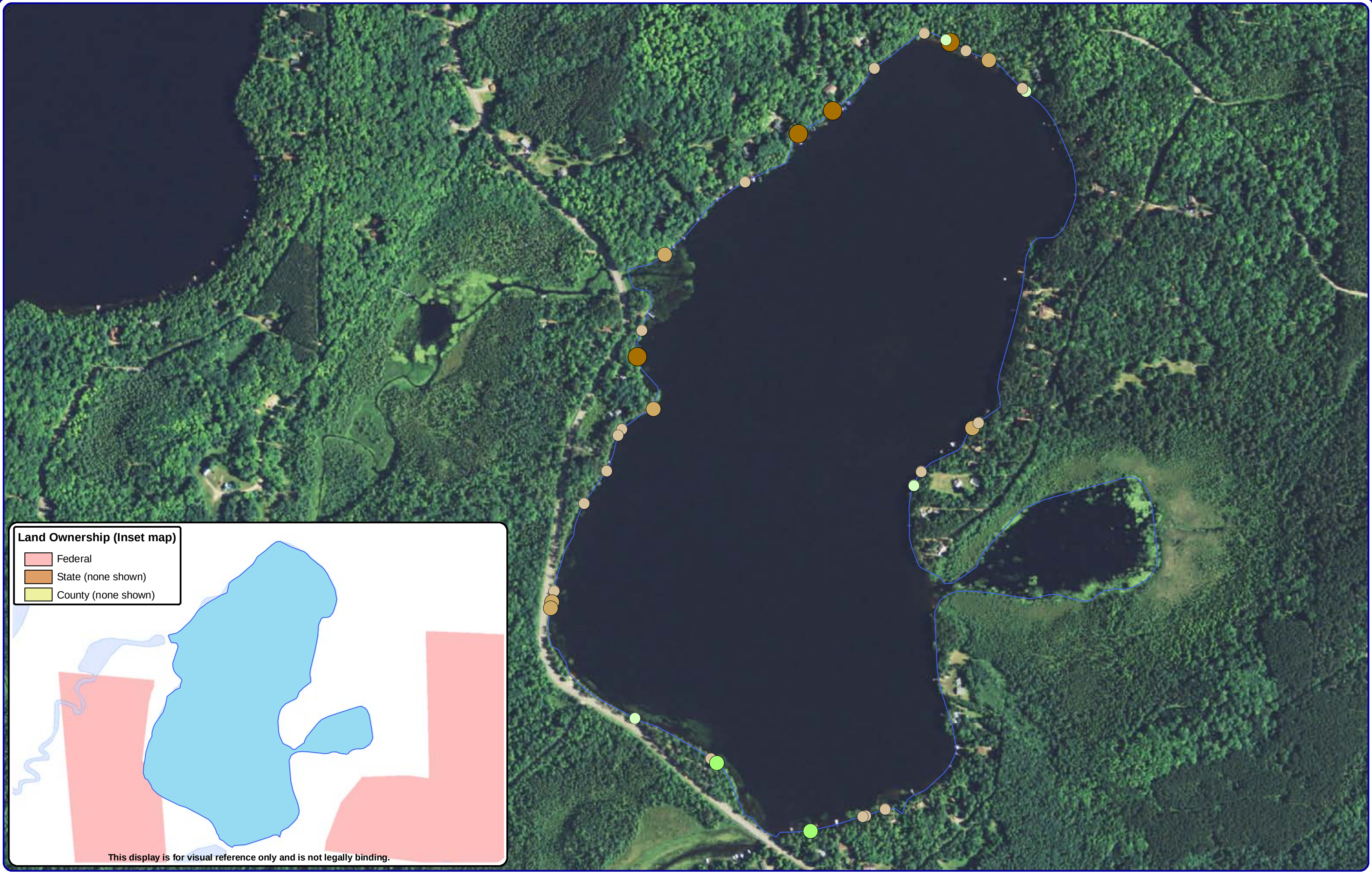
Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2010
Federal Land: USDA Forest Service
Map date: March 14, 2011
Filename: Whitefish_Map1_SA_2010.mxd
Project Location in Wisconsin
Legend
Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized
Whitefish Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin
Shoreland Condition

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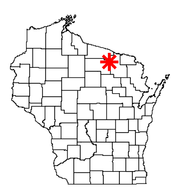
Map date: October 16, 2014
*Filename: Whitefish_CWH_2014.mxd*



Project Location in Wisconsin

## Legend

**2-8 Inch Pieces**
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy (none)

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

Whitefish Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

**2014 Coarse Woody Habitat**

Cattail sp.
Bristly sedge
Northern blue flag
Spatterdock
White water lily
Spatterdock
Spatterdock
Common bur-reed
Pickerelweed
Spatterdock
Water willow
Common arrowhead
Water arum
Spatterdock
Hardstem bulrush
Needle spikerush
Bristly sedge
Hardstem bulrush
Creeping spikerush
Soft rush
Spatterdock
White water lily
Floating-leaf bur-reed
Pickerelweed
Common bur-reed
Common arrowhead
Water willow
Northwest territory sedge
Floating-leaf bur-reed
Narrow-leaf bur-reed
Pickerelweed
Spatterdock
White water lily
Common arrowhead
Northern wild rice
Common bur-reed
Common bur-reed
Spatterdock
Spatterdock
Spatterdock
White water lily
Water willow
Pickerelweed
Cattail sp.
Bristly sedge
Common arrowhead
Creeping spikerush
Three-way sedge
Northern blue flag
Spatterdock
White water lily
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White water lily
Creeping spikerush
Common bur-reed
Pickerelweed
Narrow-leaf bur-reed
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Sources:
Aquatic Plants: Onterra, 2010
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Map Date: March 7, 2012
File Name: Whitefish_Comm_2010.mxd
Project Location in Wisconsin
Legend
Small Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Large Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Whitefish Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin
Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on The Thoroughfare studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.3 The Thoroughfare

### An Introduction to the Thoroughfare

The Thoroughfare, Oneida County, is a narrow passage-way that connects Big Lake to Whitefish Lake. It has a maximum depth of 12 feet and a surface area of 175 acres. The Thoroughfare contains 35 native plant species, of which coontail was the most common plant as determined through the point-intercept survey. Wild rice, an emergent species, was found in great abundance as well but was not accounted for as often using the point-intercept methodology. No exotic plants were observed during the 2010 lake surveys.

**Field Survey Notes**

*Much undeveloped shoreline observed along the Thoroughfare. Fluctuating water levels made access to Whitefish Lake difficult in mid-April.*

*Numerous emergent and floating-leaf aquatic plants observed during point-intercept survey, including wild rice, sedge species, cattails, white water lilies, spatterdock and watershield.*

**Photo 8.3.1 The Thoroughfare, Oneida County**

### Lake at a Glance* – The Thoroughfare

| | |
|---|---|
| **Morphology** | |
| Acreage | 175 |
| Maximum Depth (ft) | 12 |
| Shoreline Complexity | 13.5 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 17, 2010 |
| Comprehensive Survey Date | August 8 & 9 2010 |
| Number of Native Species | 35 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | - |
| Simpson's Diversity | 0.91 |
| Average Conservatism | 6.9 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

### 8.3.1 The Thoroughfare Water Quality

Water quality studies were not completed on the Thoroughfare as a part of this project.

## 8.3.2 The Thoroughfare Watershed Assessment

Because the Thoroughfare is more of a passage between lakes than a lake per se, watershed modeling was not conducted as a part of this project. A shoreline assessment, however, was completed as described in the next section.

## 8.3.3 The Thoroughfare Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, the Thoroughfare's immediate shoreline was assessed in terms of its development. The Thoroughfare has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.2 miles of natural/undeveloped and developed-natural shoreline (77% of the entire shoreline) were observed during the survey (Figure 8.3.3-1). 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, 0.4 miles of urbanized and developed–unnatural shoreline (6% of the total shoreline) was observed. If restoration of the Thoroughfare shoreline 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. The Thoroughfare Map 1 displays the location of these shoreline lengths around the entire lake.

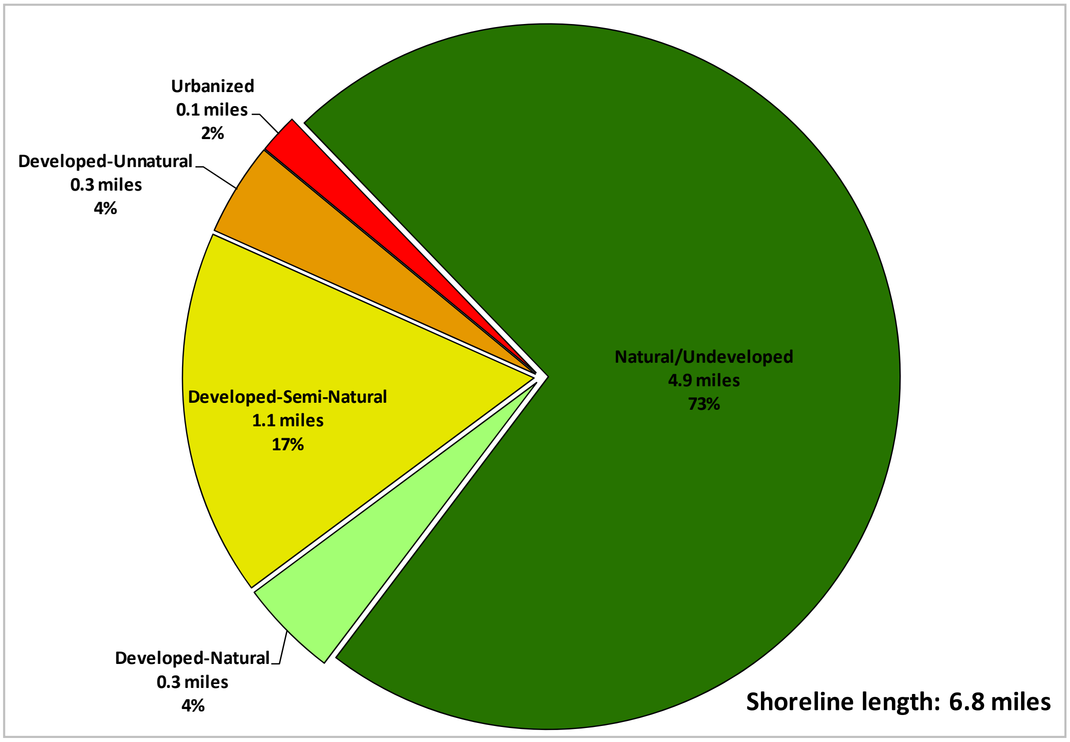


**Figure 8.3.3-1. The Thoroughfare shoreland categories and total lengths.** Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on the Thoroughfare Map 1.

## Coarse Woody Habitat

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

During this survey, a total of 47 pieces of coarse woody habitat were observed along 6.8 miles of shoreline, which gives the Thoroughfare a coarse woody habitat to shoreline mile ratio of 7:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Thoroughfare Map 2.

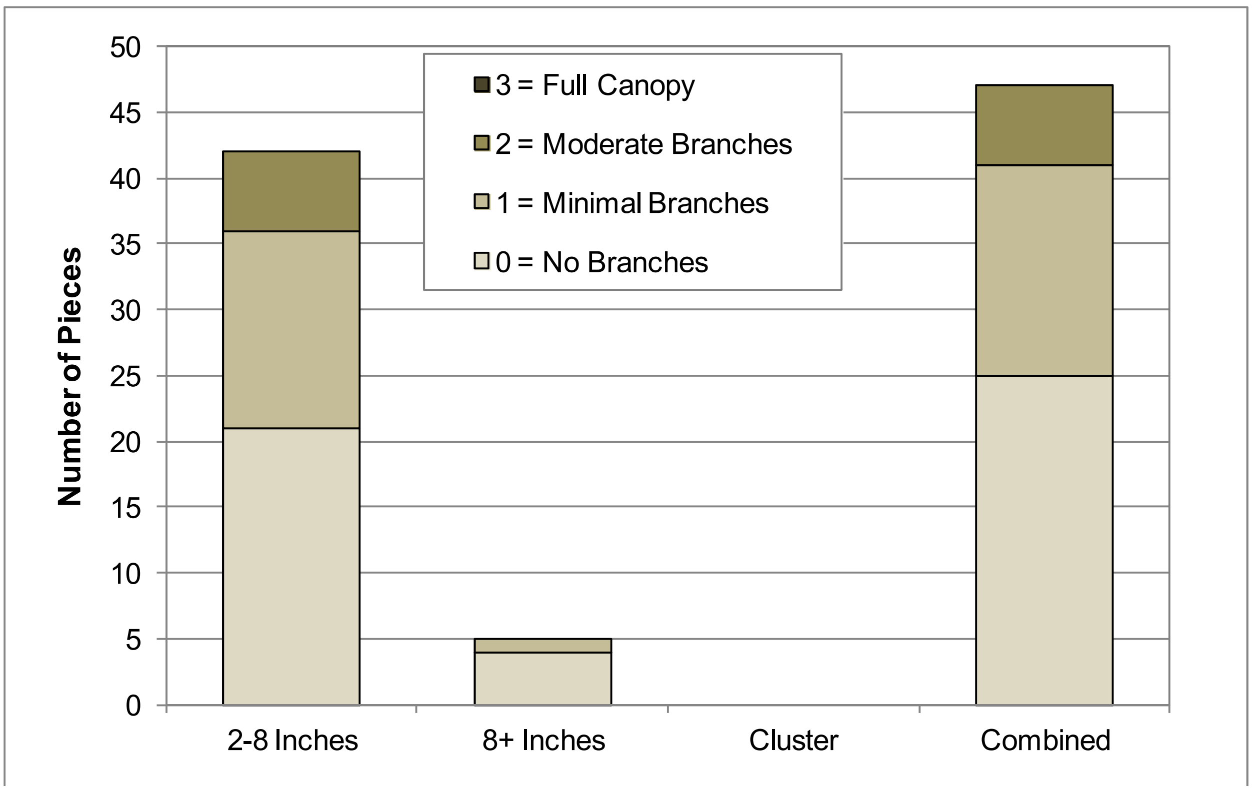


**Figure 8.3.3-2. The Thoroughfare coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of the Thoroughfare coarse woody habitat can be found on Thoroughfare Map 2.

## 8.3.4 The Thoroughfare Aquatic Vegetation

The curly-leaf pondweed survey was conducted on the Thoroughfare on June 17, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in the Thoroughfare or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on the Thoroughfare on August 8 & 9 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 10 to create the aquatic plant community map (The Thoroughfare Map 2) during this time. During all surveys, 35 species of native aquatic plants were identified in the Thoroughfare (Table 8.3.4-1). 25 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of nine feet. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 139 point-intercept locations sampled within the littoral zone, approximately 61% contained aquatic vegetation. Approximately 5% of the point-intercept sampling locations where sediment data was collected at were sand and 95% consisted of a fine, organic substrate (muck). No rocky areas where encountered.

**Table 8.3.4-1. Aquatic plant species located in the Thoroughfare during the 2010 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | Onterra 2010 |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | I |
| | *Carex aquatilis* | Water sedge | 7 | I |
| | *Carex utriculata* | Northwest Territory sedge | 7 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | X |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria rigida* | Stiff arrowhead | 8 | I |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Sagittaria latifolia* | Common arrowhead | 3 | X |
| | *Typha spp.* | Cattail spp. | 1 | I |
| | *Zizania palustris* | Northern wild rice | 8 | X |
| FL | *Brasenia schreberi* | Watershield | 7 | I |
| | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium emersum* | Short-stemmed bur-reed | 8 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Myriophyllum verticillatum* | Whorled water milfoil | 8 | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | X |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | I |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| SE | *Sagittaria cuneata* | Arum-leaved arrowhead | 7 | X |
| | *Sagittaria graminea* | Grass-leaved arrowhead | 9 | X |
| FF | *Lemna trisulca* | Forked duckweed | 6 | X |
| | *Lemna turionifera* | Turion duckweed | 2 | X |
| | *Spirodela polyrhiza* | Greater duckweed | 5 | 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*

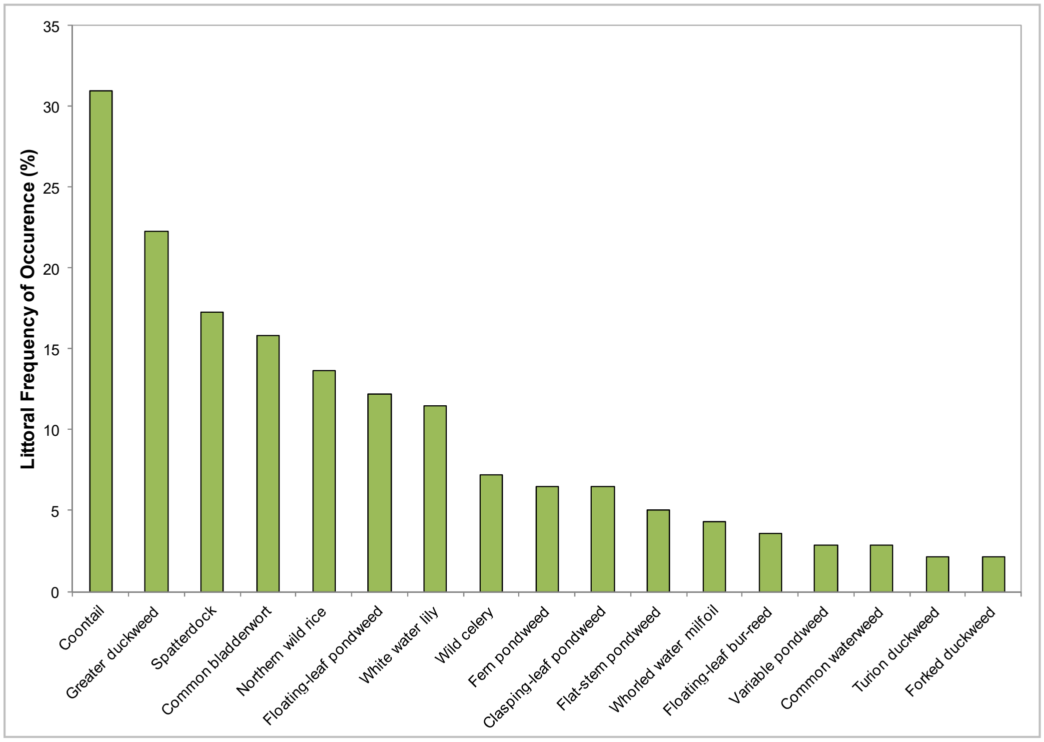


**Figure 8.3.4-1 The Thoroughfare aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 1.5% only. Created using data from a 2010 point-intercept survey.

Figure 8.3.4-1 (above) shows that coontail, greater duckweed, and spatterdock were the most frequently encountered plants within the Thoroughfare. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making them susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form mats. Greater duckweed has round to oval-shaped leaf bodies called fronds that float individually or in groups on the water surface. This plant can be found worldwide in freshwater habitats that are protected from the wind where wave action in minimal. Interestingly, duckweed is largely made up of metabolically active cells with very little fiber; the tissue contains twice the protein, fat, nitrogen and phosphorus as other vascular plants. This makes the plant very high in nutritional value, and is a preferred food choice by waterfowl. Spatterdock is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months. This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one was located within the Thoroughfare. Whorled water milfoil is a submerged milfoil plant with leaves in whorls of 4 to 5. The leaves have somewhat of a feathery appearance. It is often mistaken for other species of milfoil, such as northern water milfoil or the invasive Eurasian water milfoil. This plant is most readily distinguished from other milfoils by its overall size (whorled water milfoil is typically larger and more robust) and the length between leaf nodes, which is less than other species of milfoil (about 1 cm apart). Additionally, leaflet counts are helpful in identification – whorled water milfoil typically has 9-13 leaflet segments on each side of the midrib of the leaflet, while northern water milfoil has 5-10 and Eurasian water milfoil 12-24 leaflets.

35 species of aquatic plants (including incidentals) were found in the Thoroughfare and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for the Thoroughfare's plant community (0.91) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 31% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from the Thoroughfare, 18 of them would be coontail. This distribution can be observed in Figure 8.3.4-2, where together 7 species account for 71% of the population of plants within the Thoroughfare and the other 18 species account for the remaining 29%. Ten additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.3.4-1 as incidentals.

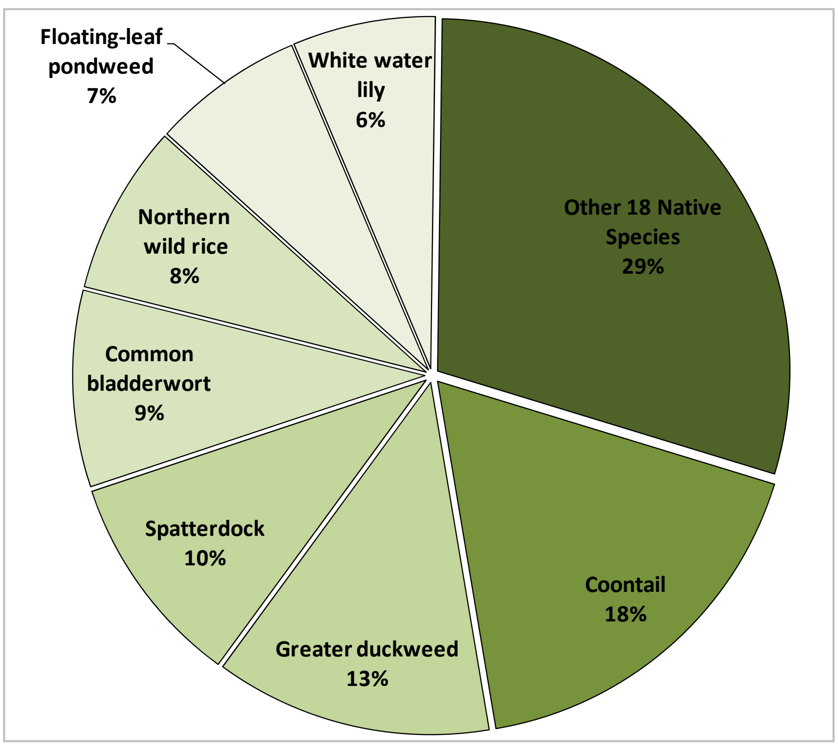


**Figure 8.3.4-2 The Thoroughfare aquatic plant relative frequency of occurrence analysis.** Created using data from 2010 point-intercept survey.

The Thoroughfare's average conservatism value (6.9) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of the Thoroughfare is indicative of an undisturbed system. This is not surprising considering the Thoroughfare's plant community has great diversity and high species richness. Combining the Thoroughfare's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 34.6 which is well above the median values of the ecoregion and state.

The quality of the Thoroughfare is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 162.9 acres of the lake contains these types of plant communities (The Thoroughfare Map 2, Table 8.3.4-2). Ten floating-leaf and emergent species were located on the Thoroughfare (Table 8.3.4-1), all of which provide valuable wildlife habitat.

**Table 8.3.4-2. The Thoroughfare acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 0 |
| Floating-leaf | 0 |
| Mixed Floating-leaf and Emergent | 162.9 |
| **Total** | 162.9 |

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

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## 8.3.5 The Thoroughfare Implementation Plan

The Implementation Plan below is a result of collaborative efforts between the Thoroughfare stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of the Thoroughfare and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including the Thoroughfare's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, the Thoroughfare's implementation plan is compiled by describing how the Thoroughfare stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to the Thoroughfare

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on the Thoroughfare as part of this chain-wide project, it is up to the Thoroughfare stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, the Thoroughfare may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## *Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes*

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** The Thoroughfare contains several public access points and is accessible from many other Three lakes Chain lakes by only a short boat ride. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters. Therefore, both parties must be educated on the threat of aquatic invasive species.

The Thoroughfare stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On the Thoroughfare, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to the Thoroughfare or from the Thoroughfare elsewhere. If a Thoroughfare property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** The Thoroughfare stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Thoroughfare riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** The Thoroughfare stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving the Thoroughfare and its stakeholders.

## Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, the Thoroughfare property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** This management action is not applicable to the Thoroughfare

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. The Thoroughfare stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

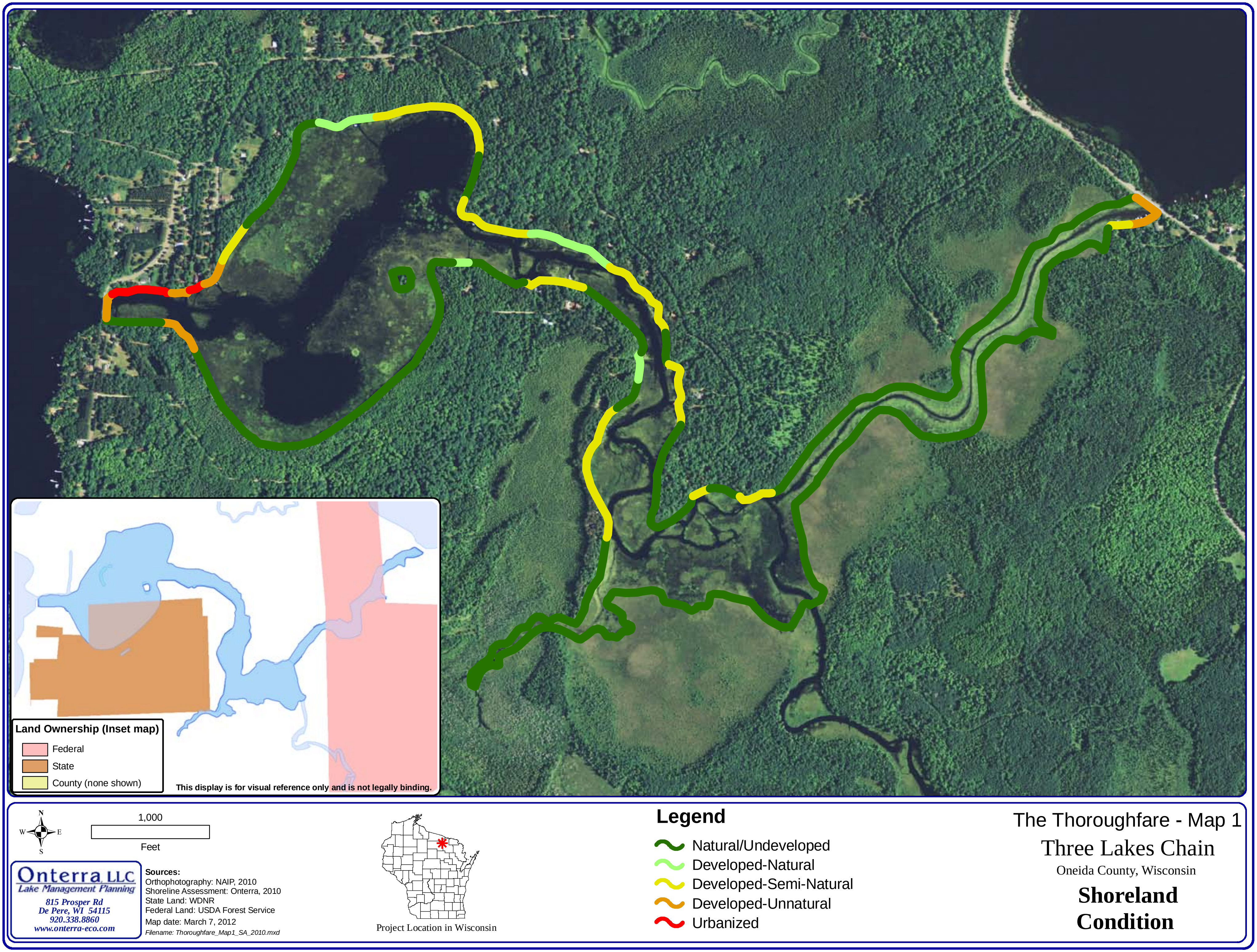
**Description:** As a part of this project, the entire Thoroughfare shoreline was categorized in terms of its development. According to the results from this survey, 73% of the Thoroughfare's nearly 7 miles of shoreline is in a natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

Restoring areas of the Thoroughfare shoreline is not imperative due to its already largely natural state, so educating riparian property owners on the benefits of conserving this natural land may be of more importance. However, if property owners are interested in restoring their property's shoreline a plan has been put into place to do so. The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## *Chain-wide Management Goal 6: Improve Fishery Resource and Fishing*

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Thoroughfare stakeholders have specific questions/concerns about the walleye population or the overall fishery of the Thoroughfare, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



Land Ownership (Inset map)
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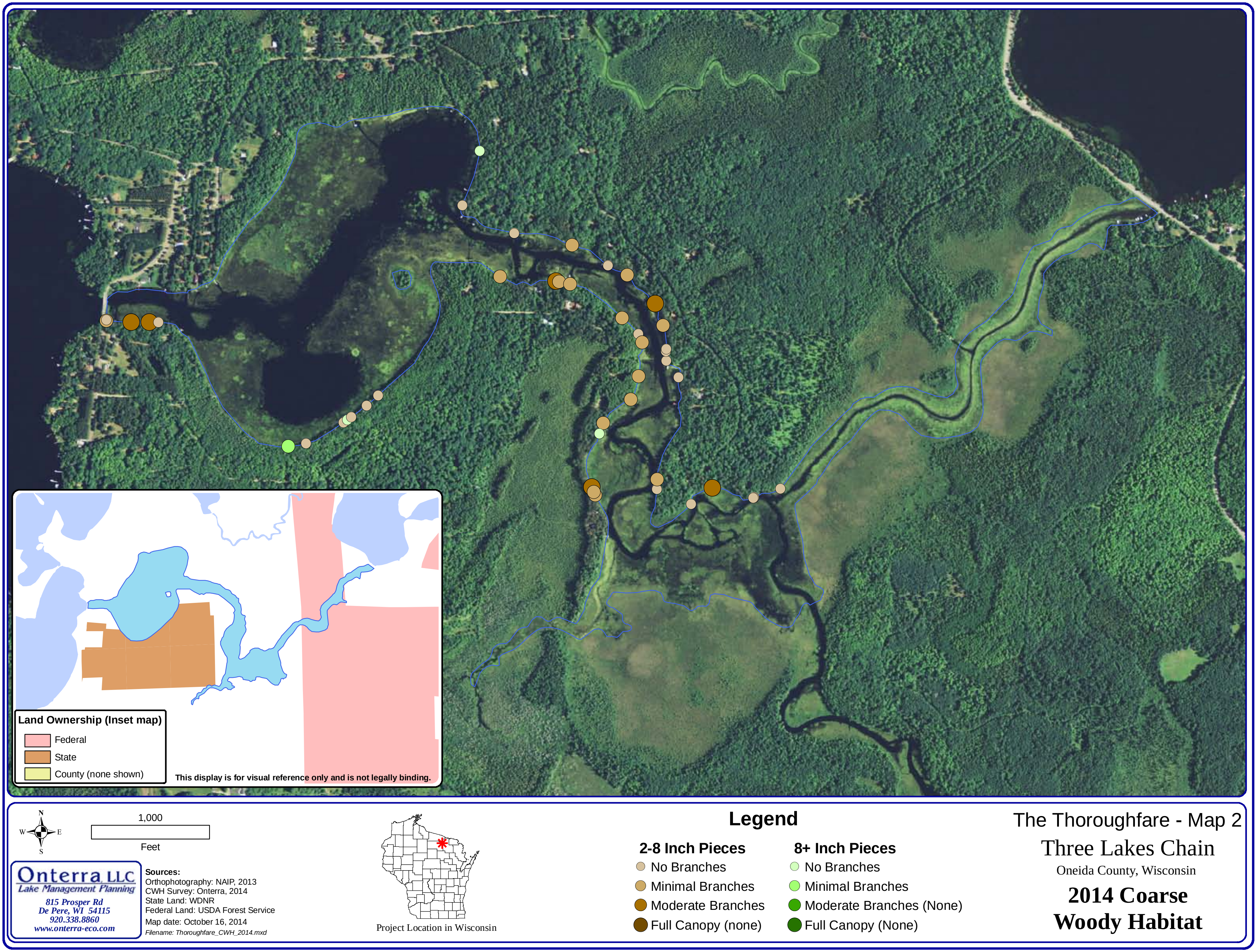

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Full Canopy (None)
The Thoroughfare - Map 2
Three Lakes Chain
Oneida County, Wisconsin
2014 Coarse Woody Habitat


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Lake Management Planning
815 Prosper Rd
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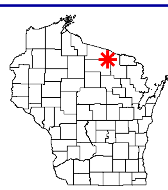
**Sources:**
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010
**Map Date:** March 7, 2012
*File Name: Thoroughfare_Comm_2010.mxd*


Project Location in Wisconsin

**Legend**

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

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

The Thoroughfare - Map 3

Three Lakes Chain

Oneida County, Wisconsin

**Aquatic Plant Communities**

**Note: Methodology, explanation of analysis and scientific background on Big Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.4 Big Lake

### *An Introduction to Big Lake*

Big Lake, Oneida County, is a drainage lake with a maximum depth of 27 feet and a surface area of 865 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Big Lake contains 32 native plant species, of which wild celery was the most common plant. Two wetland exotic plants were observed during the 2010 lake surveys.

**Field Survey Notes**

*Rough water conditions experienced during survey on August 5th. Several otters spotted near island – very playful critters!*

*Purple loosestrife plant located along shoreline. Plant was hand-pulled entirely, location marked with GPS coordinates.*

**Photo 8.4.1 Big Lake, Oneida County**

### Lake at a Glance* – Big Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 865 |
| Maximum Depth (ft) | 27 |
| Mean Depth (ft) | 12 |
| Volume (acre-feet) | 10,810 |
| Shoreline Complexity | 2.6 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 18, 2010 |
| Comprehensive Survey Date | August 5 & 9, 2010 |
| Number of Native Species | 32 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | Amur silver grass & Purple loosestrife |
| Simpson's Diversity | 0.89 |
| Average Conservatism | 6.6 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, lowland drainage lake |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 52:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.4.1 Big Lake Water Quality

Water quality data was collected from Big Lake on three occasions in summer of 2010. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water quality through an advanced monitoring program since 2006. These efforts provide a considerable amount of data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Big Lake.

During this time, summer average total phosphorus concentrations have fluctuated between 23.0 and 50.0 µg/L (Figure 8.4.1-1). These average values rank within the TSI categories of *Good* and *Excellent*, and a weighted value across all years is slightly lower than the median value for shallow, lowland drainage lakes in the state of Wisconsin. Average chlorophyll-*a* concentrations have shown some variation within the dataset (Figure 8.4.1-2). Most values fall within the TSI *Excellent* category, though some rank as *Good*. The weighted average across all years is similar to the median for other shallow, lowland drainage lakes statewide.

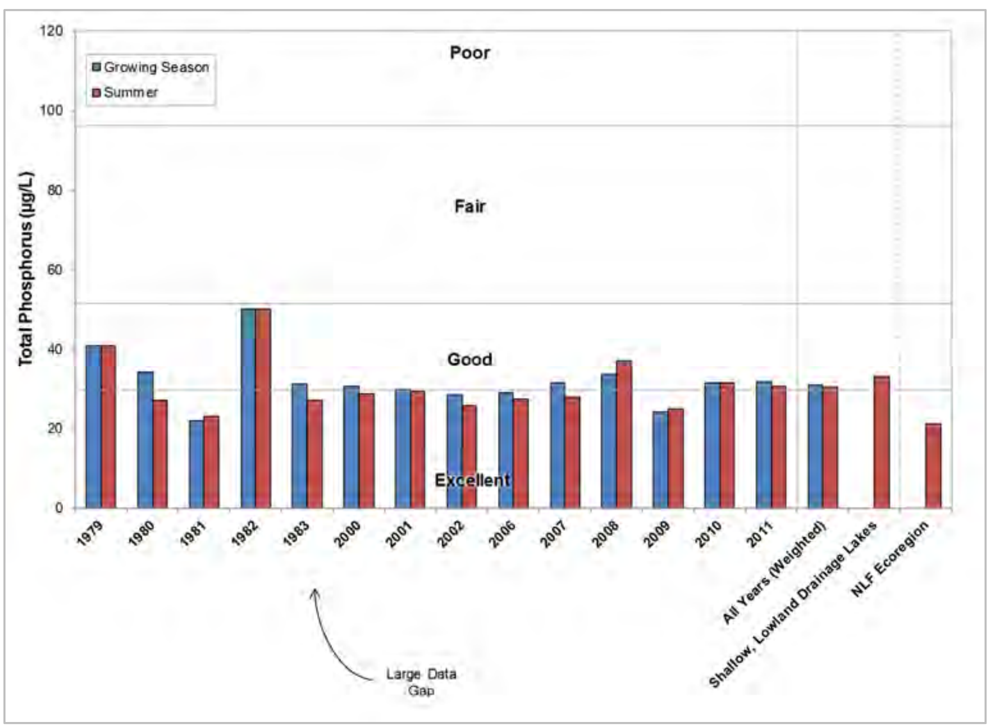



**Figure 8.4.1-1. Big Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

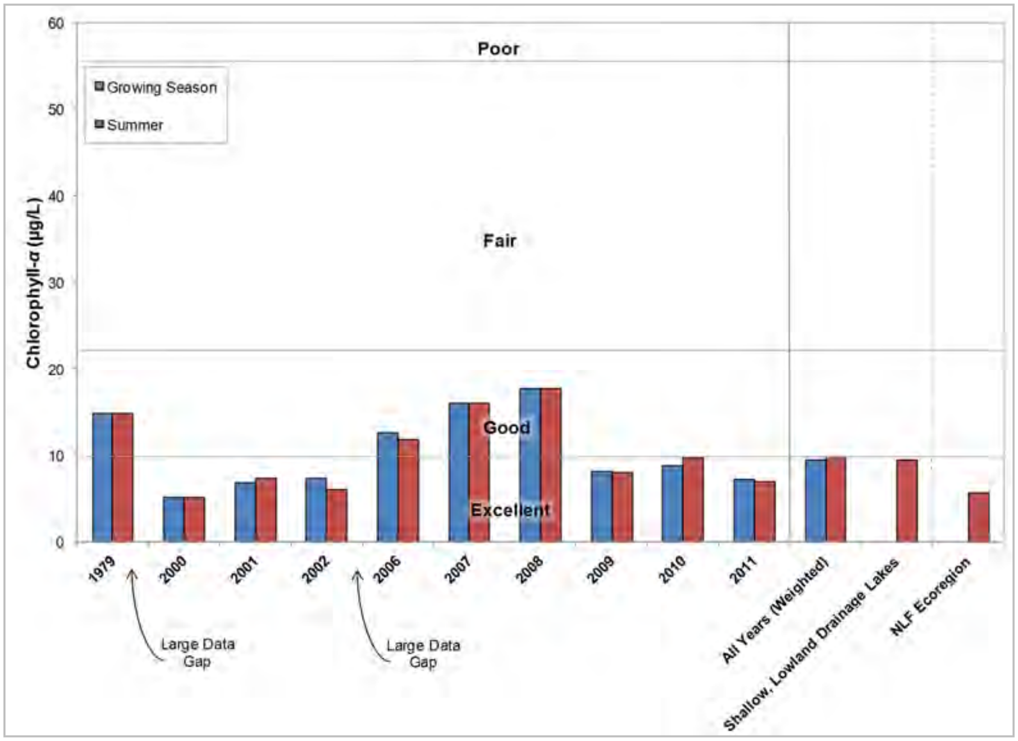



**Figure 8.4.1-2. Big Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-*a* concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters, and show little annual variance (Figure 8.4.1-3). All summer averages range between categories of *Fair* and *Good*, and a weighted average across all years is less than the median for shallow, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. It is likely, however, that another factor is limiting the water clarity in Big Lake.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. Indeed, during the point-intercept aquatic vegetation survey that took place on Big Lake in 2010, aquatic plants were found growing to a maximum depth of seven feet.

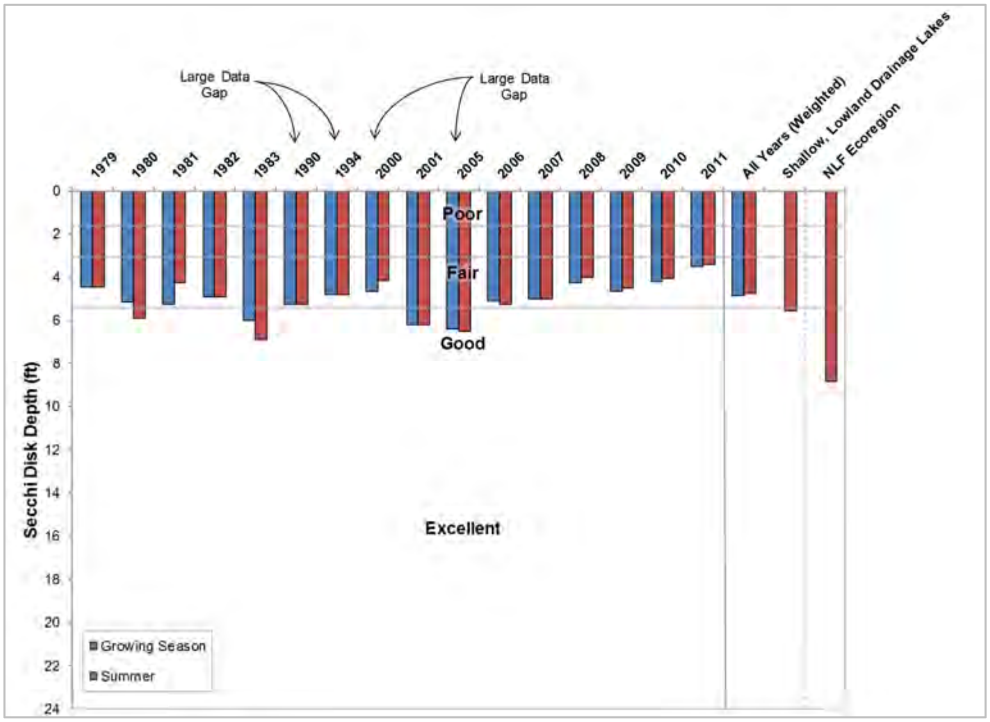



**Figure 8.4.1-3. Big Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

**Big Lake Trophic State**

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.4.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Big Lake is in a eutrophic state.

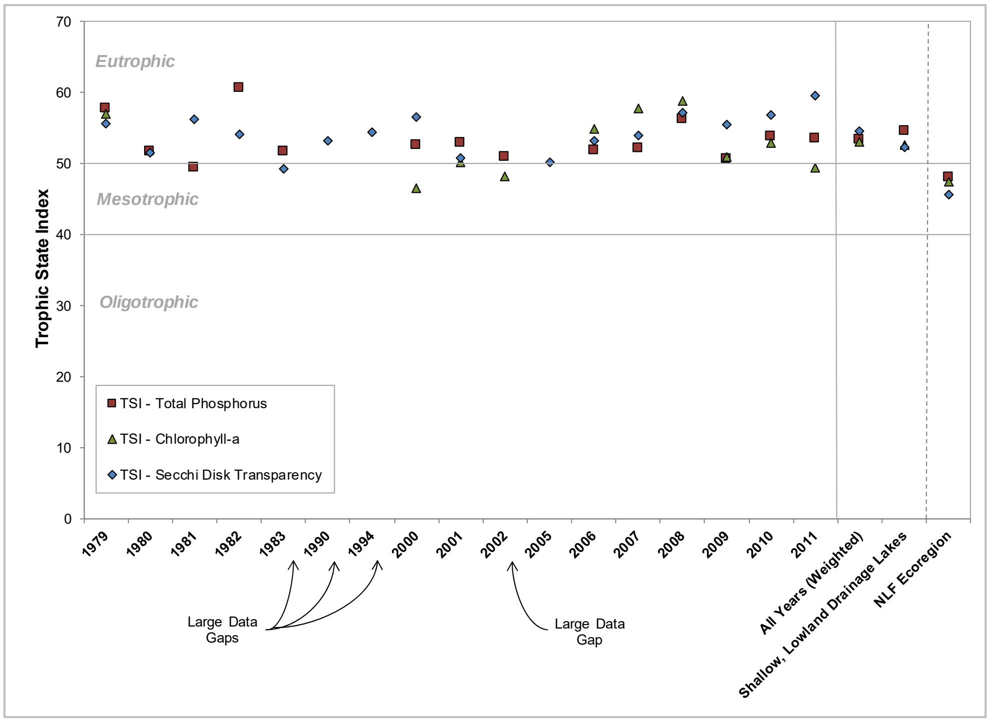



**Figure 8.4.1-4. Big Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Big Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Lake by Onterra staff. Graphs of those data are displayed in Figure 8.4.1-5 for all sampling events.

Big Lake remained thoroughly mixed throughout most of the summer months in 2010, though a small amount of stratification likely occurs periodically in the deeper portions of the lake as seen in the August profile. This is not uncommon in lakes that are large in size and moderately deep. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in the summer and winter months. Despite this decrease in oxygen near the bottom of the lake, levels remained sufficient to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen was also ample during the winter months of 2011, when oxygen may decrease due to ice cover on the lake and lack of oxygen production from plants and algae.

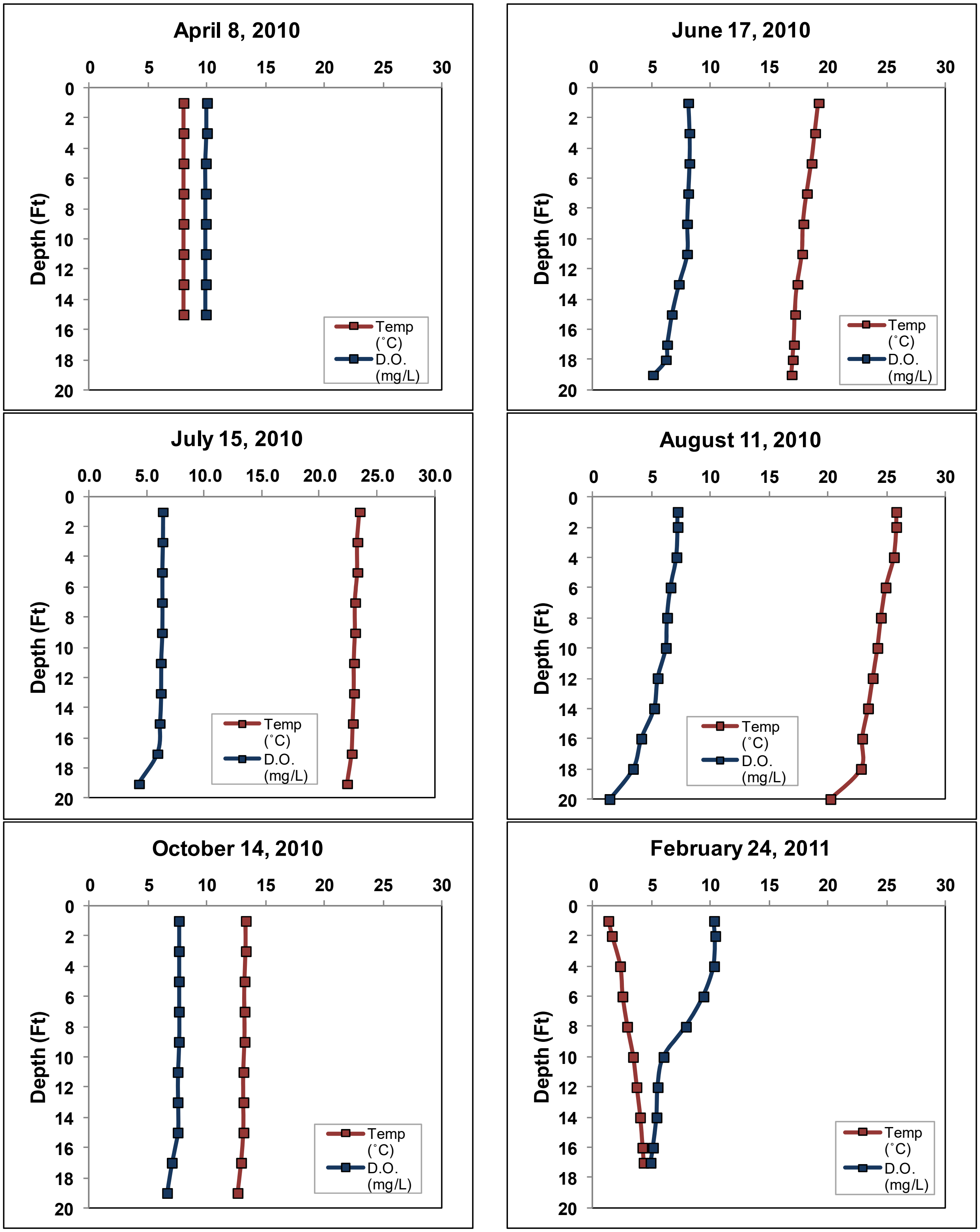



**Figure 8.4.1-5. Big Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Big 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 Big 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Big Lake's pH was measured at roughly 7.3 in the summer months of 2010. This value is near neutral and fall within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Big Lake was measured at 24.0 (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.

Samples of calcium were also collected from Big Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Lake's pH of 7.3 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Big Lake was found to be 8.0 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval mussels) were found within these samples.

## 8.4.2 Big Lake Watershed Assessment

Big Lake's watershed is 45,504 acres in size. Compared to Big Lake's size of 865 acres, this makes for a large watershed to lake area ratio of 52:1.

Exact land cover calculation and modeling of nutrient input to Big Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.4.3 Big Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2010, Big Lake's immediate shoreline was assessed in terms of its development. Big Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.7 miles of natural/undeveloped and developed-natural shoreline (52% of the shoreline) were observed during the survey (Figure 8.4.3-1). 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, 1.2 miles of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Big Lake shoreline 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. Big Lake Map 1 displays the location of these shoreline lengths around the entire lake.

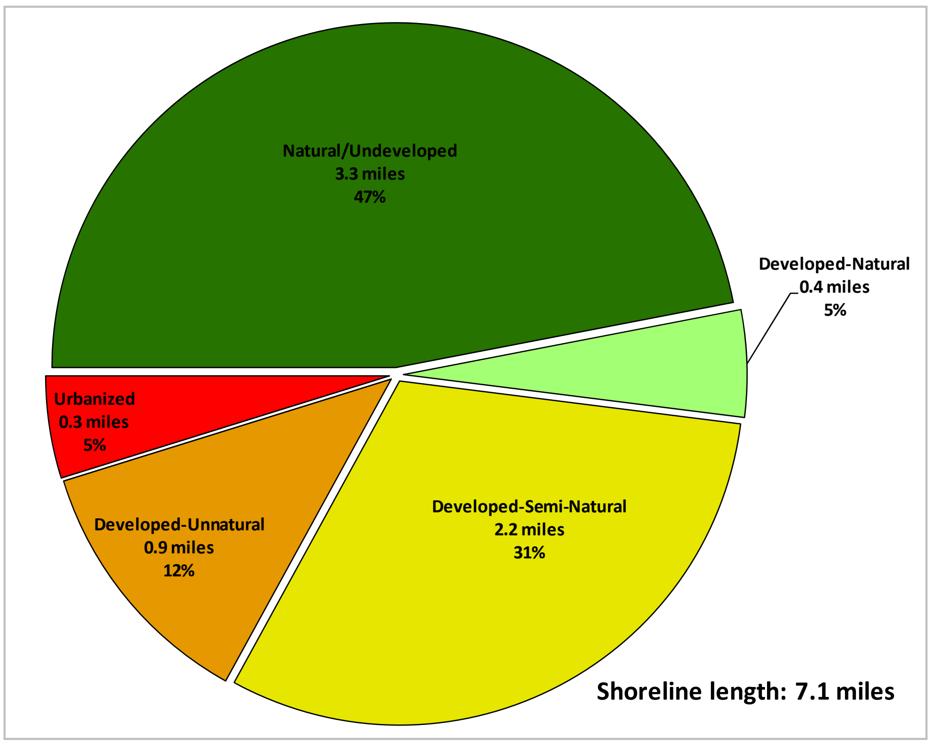



**Figure 8.4.3-1. Big Lake shoreland categories and total lengths.** Based upon a late summer 2010 survey. Locations of these categorized shorelands can be found on Big Lake Map 1.

## Coarse Woody Habitat

Big Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 158 pieces of coarse woody habitat were observed along 7.1 miles of shoreline, which gives Big Lake a coarse woody habitat to shoreline mile ratio of 22:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Big Lake Map 2.

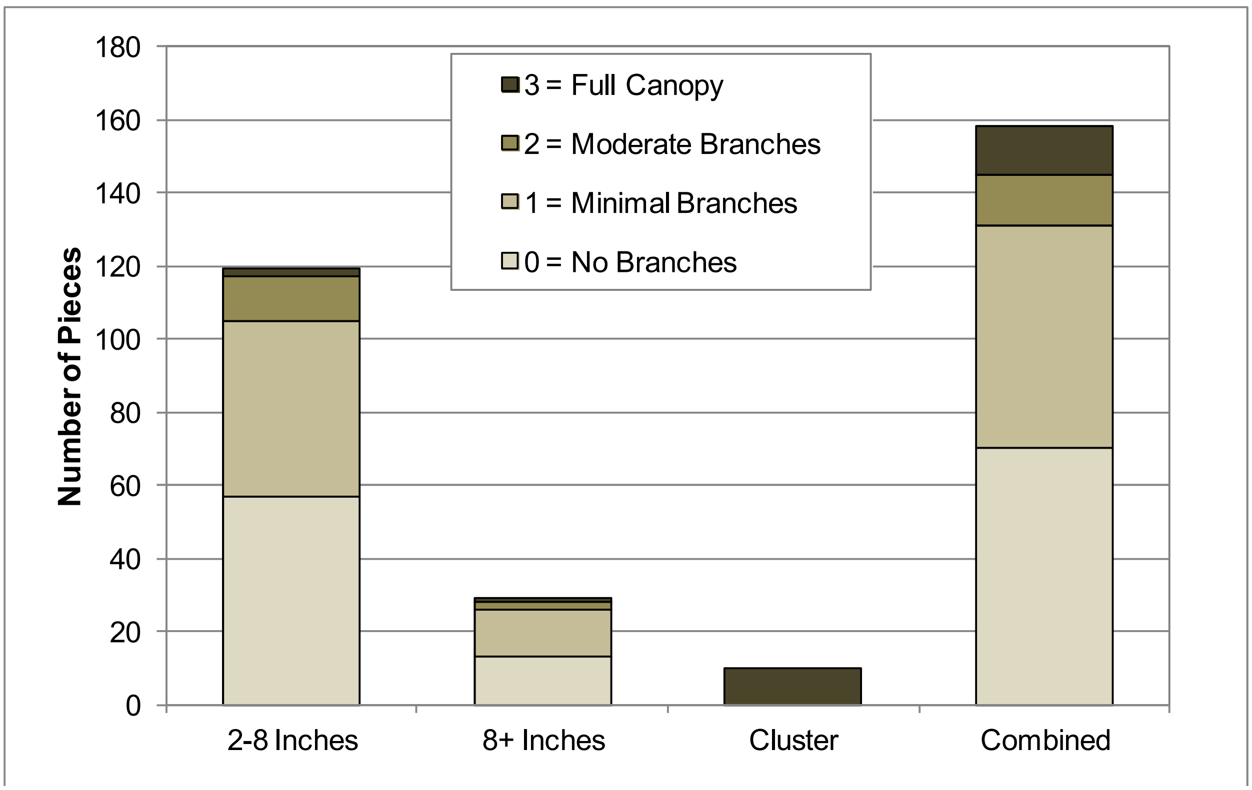



**Figure 8.4.3-2. Big Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Big Lake coarse woody habitat can be found on Big Lake Map 2.

## 8.4.4 Big Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Big Lake on June 18, 2010. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Big Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Big Lake on August 5 & 9, 2010 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 11 to create the aquatic plant community map (Big Lake Map 2). During all surveys, 32 species of native aquatic plants were located in Big Lake (Table 8.4.4-1). 23 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Additionally, two species of emergent exotic plants were found on the Big Lake shoreline – amur silver grass and purple loosestrife. Submergent aquatic plants were found growing to a depth of seven feet, which is not uncommon for lakes as heavily stained as Big Lake (see the Big Lake Water Quality Section for discussion on Big Lake's water clarity). As discussed later on within this section, many of the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 236 point-intercept locations sampled within the littoral zone, approximately 56% contained aquatic vegetation. Approximately 59% of the point-intercept sampling locations where sediment data was collected at were sand, 37% consisted of a fine, organic substrate (muck) and 4% were determined to be rocky.

**Table 8.4.4-1. Aquatic plant species located in the Big Lake during the 2010 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2010 (Onterra) |
|---|---|---|---|---|
| Emergent | *Carex crinita* | Fringed sedge | 6 | I |
| | *Carex utriculata* | Common yellow lake sedge | 7 | I |
| | *Calla palustris* | Water arum | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Equisetum fluviatile* | Water horsetail | 7 | X |
| | *Eleocharis palustris* | Creeping spikerush | 6 | X |
| | *Glyceria canadensis* | Rattlesnake grass | 7 | I |
| | *Lythrum salicaria* | Purple loosestrife | Exotic | I |
| | *Miscanthus sacchariflorus* | Amur silver grass | Exotic | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Scirpus cyperinus* | Wool-grass | 4 | I |
| | *Zizania palustris* | Northern wild rice | 8 | X |
| FL | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium eurycarpum* | Common bur-reed | 5 | X |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Isoetes echinospora* | Spiny-spored quilwort | 8 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Nitella sp.* | Stoneworts | 7 | X |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | I |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | I |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| SE | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| FF | *Lemna trisulca* | Forked duckweed | 6 | 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*

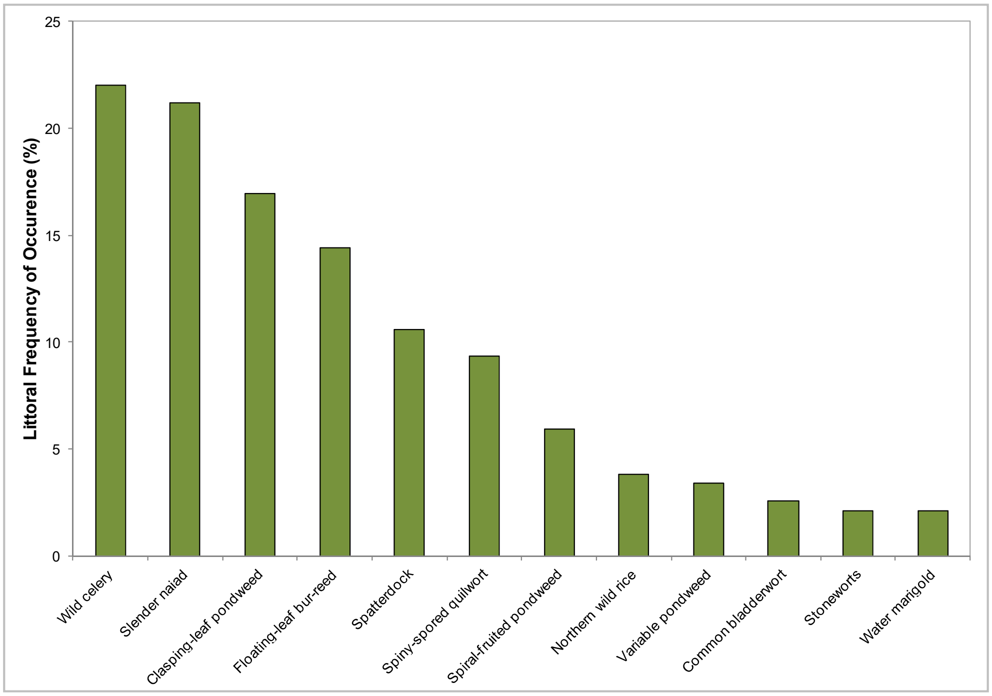



**Figure 8.4.4-1 Big Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2010 point-intercept survey.

Figure 8.4.4-1 (above) shows that wild celery, slender naiad and clasping-leaf pondweed were the most frequently encountered plants within Big Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is also a food source of waterfowl. Clasping-leaf pondweed is a submergent plant that has oval to somewhat lance-shaped leaves that "clasp" around one-half to three-quarters of the stem circumference. Unlike many other pondweeds, this plant does not produce floating leaves.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, one was located within Big Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

32 species of native aquatic plants (including incidentals) were found in Big Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Big Lake's plant community (0.89) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds good diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 wild celery was found at 22% of the sampling locations, its relative frequency of occurrence is 18%. Explained another way, if 100 plants were randomly sampled from Big Lake, 18 of them would be wild celery. This distribution can be observed in Figure 8.4.4-2, where together 10 species account for 88% of the population of plants within Big Lake, while the other 13 species account for the remaining 12%. Eleven additional species (native and non-native) were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.4.4-1 as incidentals.

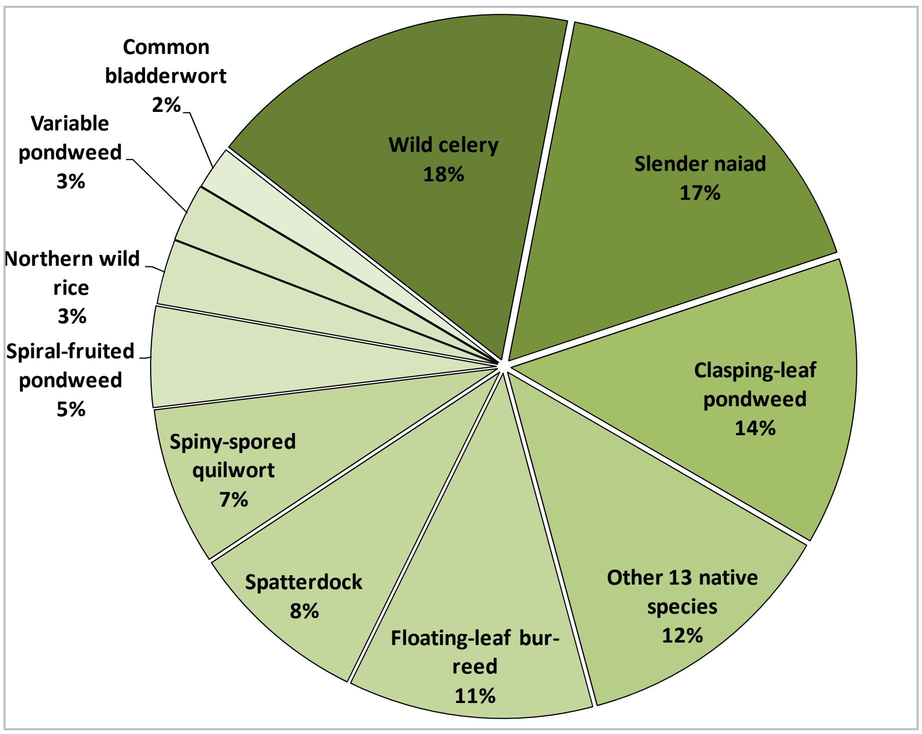



**Figure 8.4.4-2 Big Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2010 point-intercept survey.

Big Lake's average conservatism value (6.6) is higher than the state median (6.0) but slightly under the ecoregion median (6.7). This indicates that the plant community of Big Lake is indicative of a moderately disturbed system. This is not surprising considering Big Lake's plant community has good diversity and fairly high species richness. Combining Big Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.5 which is above the median values of the ecoregion and state.

The quality of Big Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2010 community map indicates that approximately 15.6 acres of the lake contains these types of plant communities (Big Lake Map 2,

Table 8.4.4-2). Fifteen floating-leaf and emergent species were located on Big Lake (Table 8.4.4-1), all of which provide valuable wildlife habitat.

**Table 8.4.4-2. Big Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 4.7 |
| Floating-leaf | 5.5 |
| Mixed Floating-leaf and Emergent | 114.9 |
| **Total** | 125.1 |

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

## Aquatic Invasive Species in Big Lake

During the 2011 community mapping survey, a single purple loosestrife plant was located on the shoreline of Big Lake (Big Lake Map 2). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

The single plant that was found on Big Lake was carefully pulled by Onterra staff. Volunteer monitoring of this location and the Big Lake shoreline in general is recommended to spot any other occurrences of purple loosestrife. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

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## 8.4.5 Big Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Lake's implementation plan is compiled by describing how Big Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Big Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Big Lake as part of this chain-wide management planning project, it is up to Big Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Big Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## *Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes*

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** Big Lake contains multiple public access points and is directly connected to the rest of the Three Lakes Chain of Lakes via Dog Lake and is also accessible by Whitefish Lake through the Thoroughfare. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Lake or from Big Lake elsewhere. If a Big Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Big Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

### *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Big Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Lake and its stakeholders.

### *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## *Chain-wide Management Goal 5: Maintain Current Water Quality Conditions*

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, Big Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Big Lake is protected. Volunteers from Big Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Big Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while 33% is of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

**<u>Management Action:</u>** Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

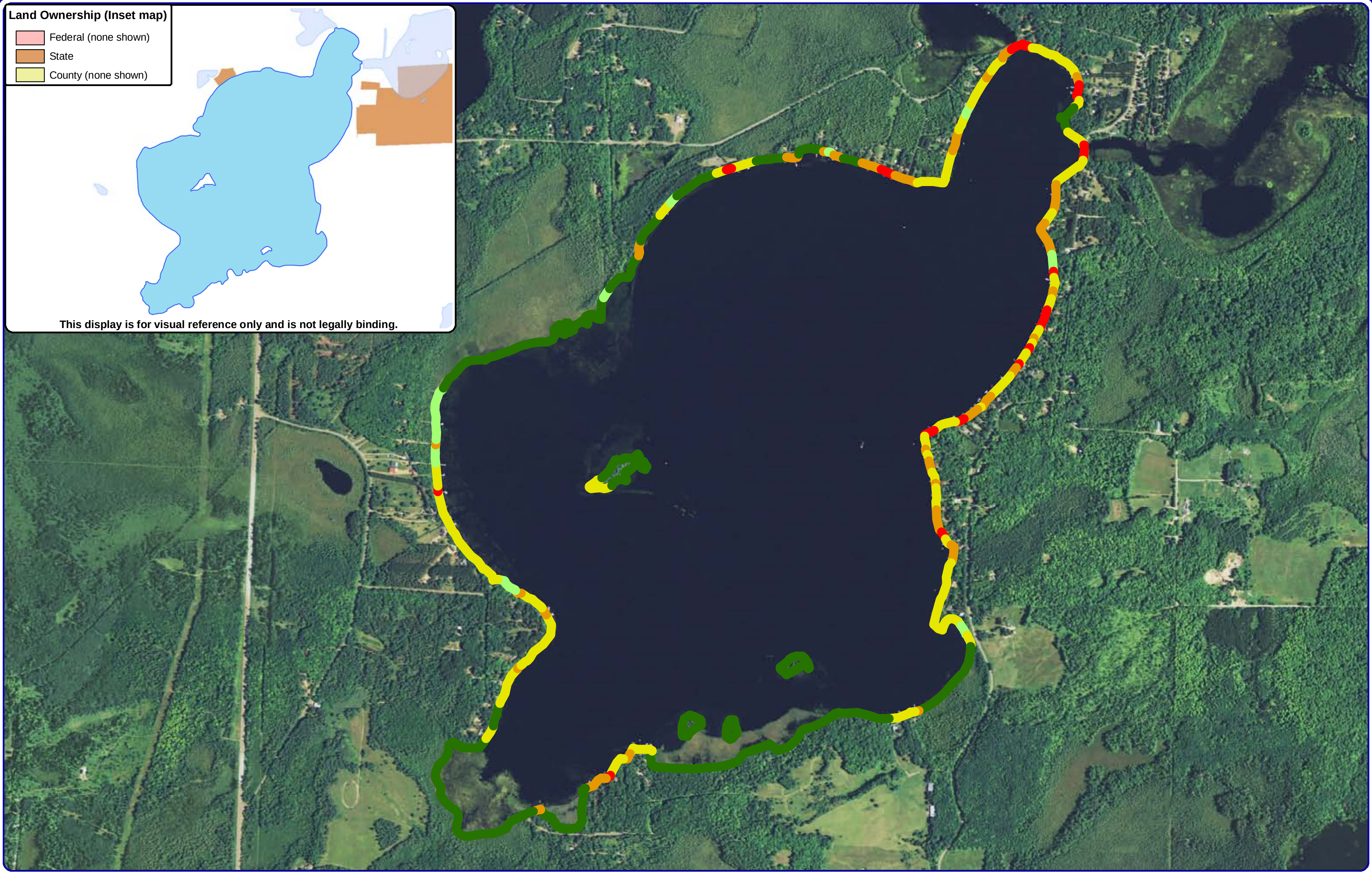
**Description:** As mentioned within the Chain-wide Implementation Plan, photographic evidence of sporadic blue-green algae blooms in Big Lake was discussed during planning meetings associated with this project. To begin understanding dynamics that may play a role in production of these algal blooms, further studies are needed to quantify nutrient inputs to the lake.

The TLWA, in coordination with Big Lake stakeholders, will retain a professional consultant to investigate nutrient contributions to the lake through tributary streams.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**<u>Management Action:</u>** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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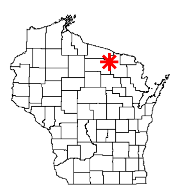
Feet

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

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2010
State Land: WDNR
Map date: July 13, 2011
*Filename: Big_Map1_SA_2010.mxd*



Project Location in Wisconsin

## Legend

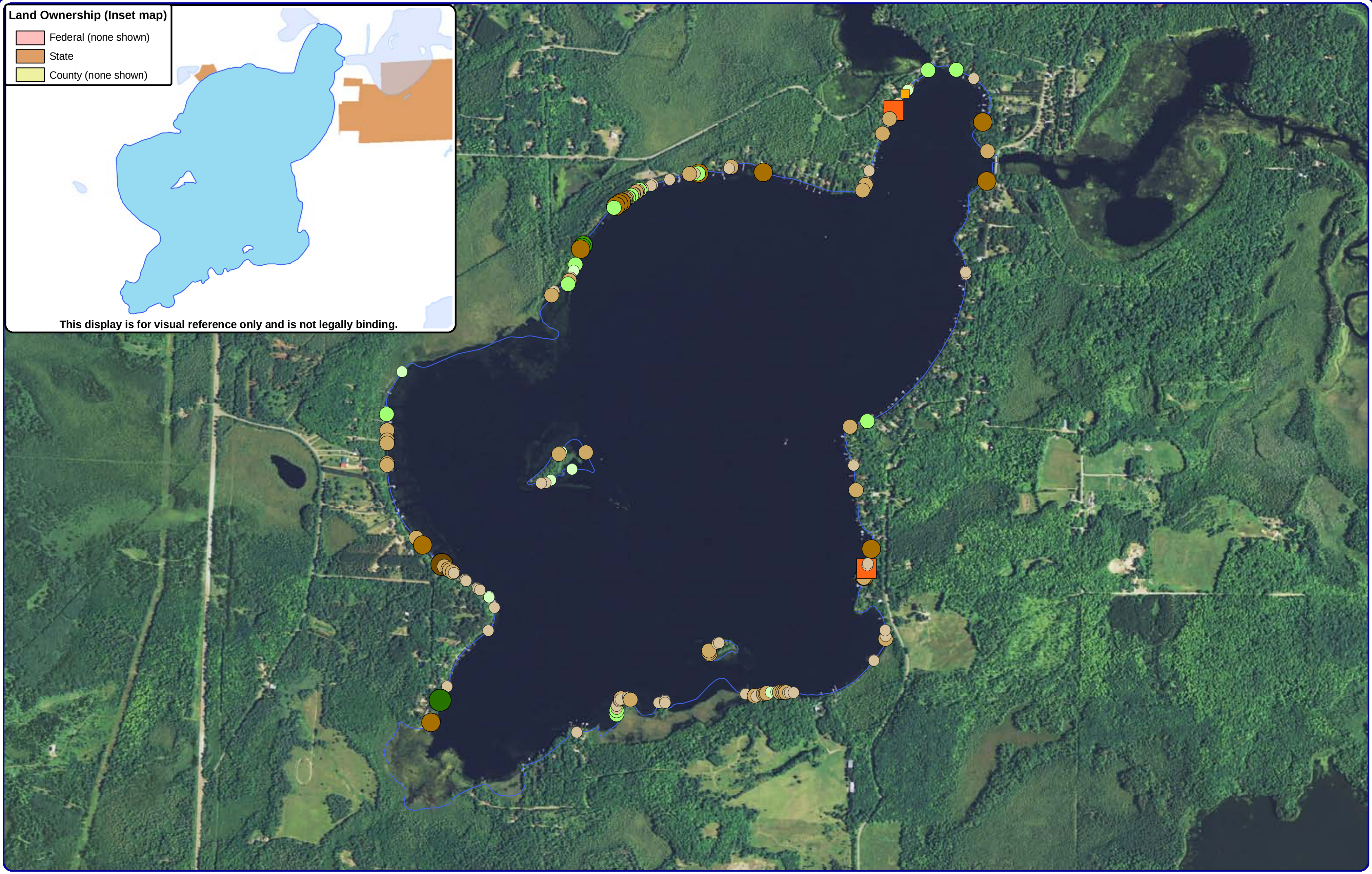
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Big Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

**Shoreland Condition**

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

Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
State Land: WDNR
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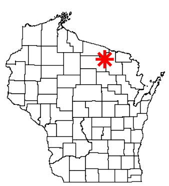

Project Location in Wisconsin

**Legend**

**2-8 Inch Pieces**
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy

**8+ Inch Pieces**
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy

**Cluster of Pieces**
- No Branches
- Minimal Branches (none)
- Moderate Branches (none)
- Full Canopy

Big Lake - Map 2

Three Lakes Chain

Oneida County, Wisconsin

**2014 Coarse Woody Habitat**


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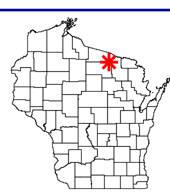
1,500
Feet


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


**Sources:**
Aquatic Plants: Onterra, 2010
Orthophotography: NAIP, 2010
**Map Date:** March 23, 2011
*File Name: Big_Comm_2010.mxd*



Project Location in Wisconsin

**Legend**

| Small Plant Communities | Large Plant Communities |
|---|---|
| Emergent | Emergent |
| Floating-leaf | Floating-leaf |
| Mixed Floating-leaf & Emergent | Mixed Floating-leaf & Emergent |
| Purple Loosestrife (Exotic) - Hand Removed | |

Big Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin
**Aquatic Plant Communities**

**Note: Methodology, explanation of analysis and scientific background on Dog Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.5 Dog Lake

### *An Introduction to Dog Lake*

Dog Lake, Oneida County, is a lowland drainage lake with a maximum depth of 22 feet and a surface area of 216 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Dog Lake contains 32 native plant species, of which wild celery was the most common plant. No exotic plants were observed during the 2011 lake surveys.

**Field Survey Notes**

*Unusually large community of water horsetail (Equisetum fluviatile) encountered during aquatic plant surveys* (pictured at right).

**Photo 8.5.1 Dog Lake, Oneida County**

**Lake at a Glance* – Dog Lake**

| | |
|---|---|
| **Morphology** | |
| Acreage | 216 |
| Maximum Depth (ft) | 22 |
| Mean Depth (ft) | 8 |
| Volume (acre-feet) | 1,710 |
| Shoreline Complexity | 3.2 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 21, 2011 |
| Comprehensive Survey Date | August 9, 2011 |
| Number of Native Species | 32 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | - |
| Simpson's Diversity | 0.88 |
| Average Conservatism | 6.7 |
| **Water Quality** | |
| Wisconsin Lake Classification | Shallow, lowland drainage |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 210:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.5.1 Dog Lake Water Quality

During 2011/2012, water quality data was collected from Dog Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Additionally, historical databases were searched for any prior data that may have been collected on Dog Lake. Unfortunately, Secchi disk clarity data had been collected only sporadically on Dog Lake in the past, making a long term trend analysis difficult. However, it is possible to make some comparisons from recent data to that which was collected years ago.

Dog Lake total phosphorus values can be found in Figure 8.5.1-1. In 2011, summer total phosphorus concentrations averaged 31.7 µg/L, which is slightly lower than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 µg/L). Limited chlorophyll-a data exists, with a single sample being collected in 1979 and five samples through this planning project. The 2011 average summer chlorophyll-*a* concentration (8.8 µg/L) is somewhat lower than the average for other shallow, lowland drainage lakes statewide (median = 9.4 µg/L). The total phosphorus average ranks as *Good* in the Trophic State Index, while the chlorophyll-*a* average value ranks as *Excellent*.

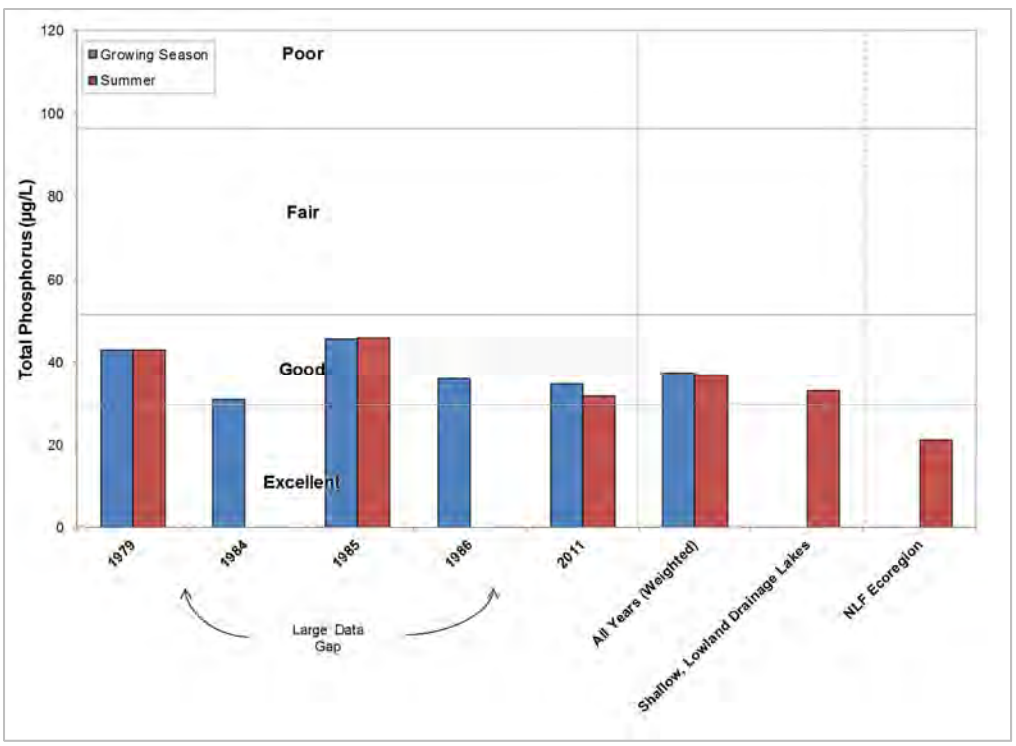



**Figure 8.5.1-1. Dog Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

The Secchi disk clarity dataset consists of readings collected in 1979, the mid-1980's, mid 1990's and during 2011 field visits (Figure 8.5.1-2). A weighted average across all summers ranks as *Good*, however is slightly below the median value for other shallow, lowland drainage lakes in Wisconsin. During the aquatic plant surveys that took place on Dog Lake in 2011, plants were found growing to a maximum depth of six feet; however, the vast majority of plants grew to only five feet of depth. This is an added testament to the low water clarity in Dog Lake.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Dog Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

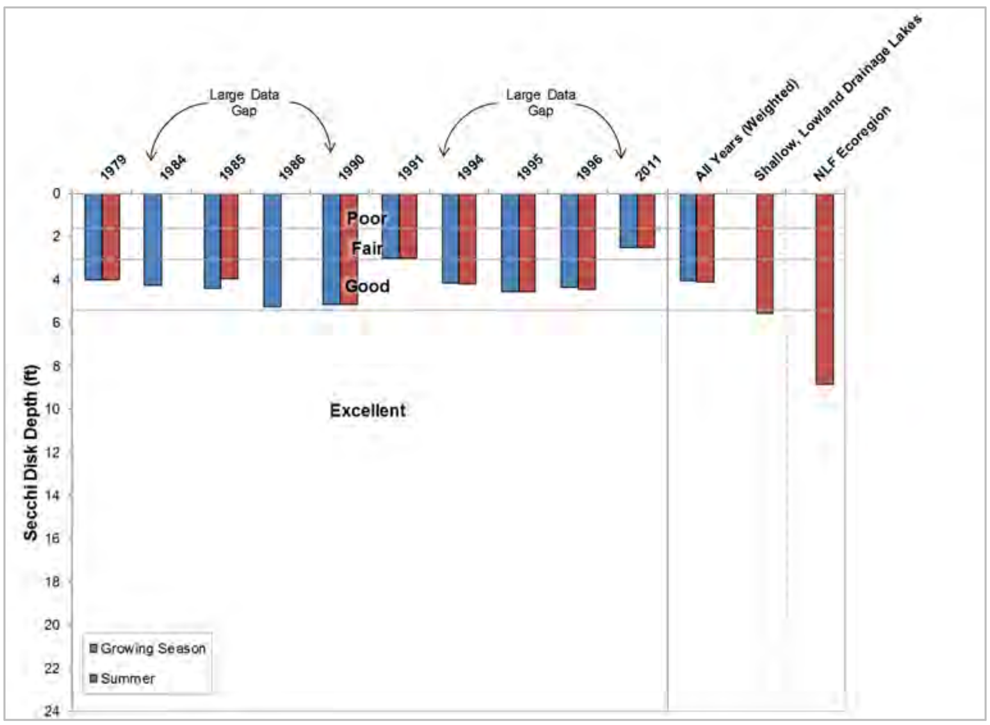



**Figure 8.5.1-2. Dog Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

### Dog Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.5.1-3). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Dog Lake is in a eutrophic state.

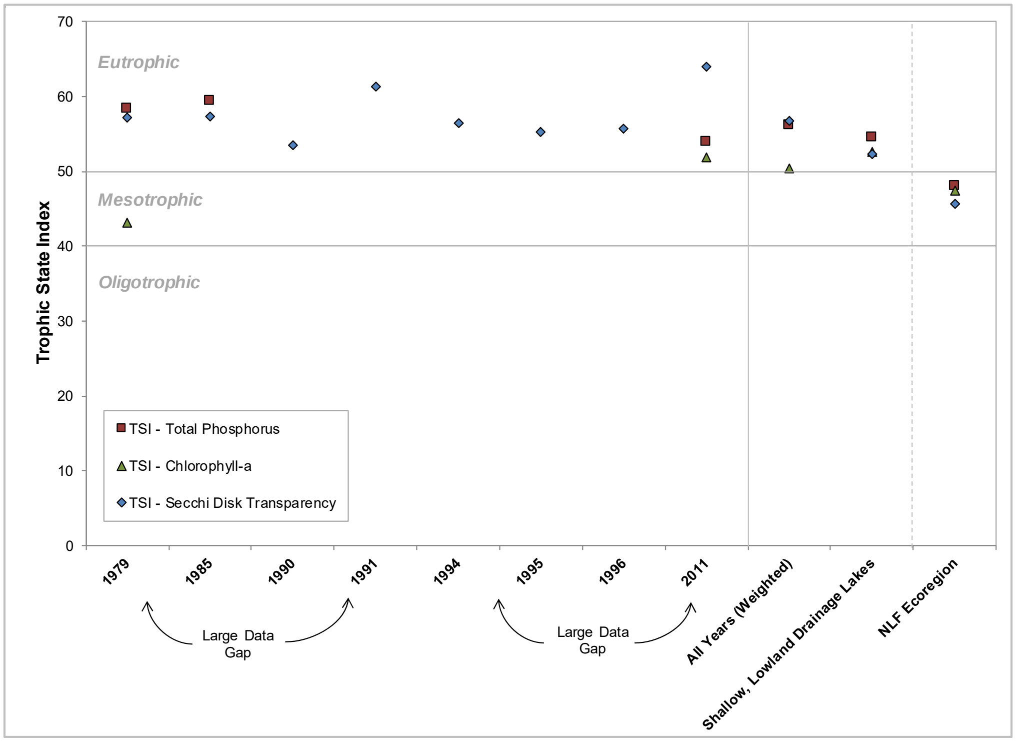



**Figure 8.5.1-3. Dog Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Dog Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Dog Lake by Onterra staff. Graphs of those data are displayed in Figure 8.5.1-4 for all sampling events.

Dog Lake remained thoroughly mixed throughout most of the summer months in 2011, though a small amount of stratification likely occurs periodically in the deeper portions of the lake. This is not uncommon in lakes that are moderate in size and depth. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column. Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in July. Despite this late summer dip, dissolved oxygen levels remained sufficient in the upper ~12 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen was also ample during the winter months of 2012, when oxygen may decrease due to ice cover on the lake and lack of oxygen production from plants and algae.

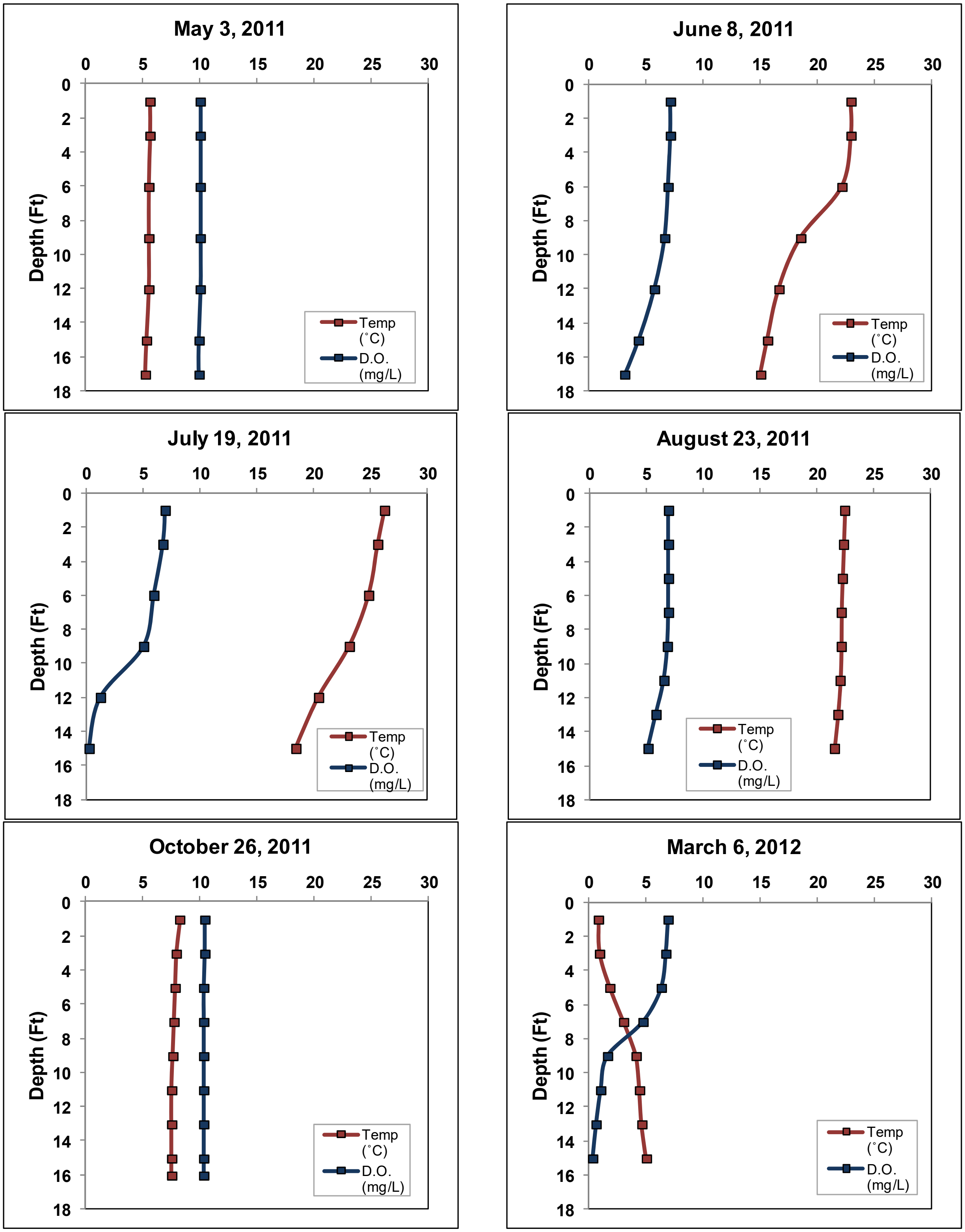



**Figure 8.5.1-4. Dog Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Dog 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 Dog 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Dog Lake's pH was measured at 7.0 during the summer months in 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Dog Lake was measured at 17.6 (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.

Samples of calcium were also collected from Dog Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Dog Lake's pH of 7.0 is at the bottom end 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 Dog Lake was found to be 5.5 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.5.2 Dog Lake Watershed Assessment

Dog Lake's watershed is 45,631 acres in size. Compared to Dog Lake's size of 216 acres, this makes for an incredibly large watershed to lake area ratio of 210:1.

Exact land cover calculation and modeling of nutrient input to Dog Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.5.3 Dog Lake Shoreline Condition

As mentioned previously in the Chain-wide Shoreline Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Dog Lake's immediate shoreline was assessed in terms of its development. Dog Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.0 miles of natural/undeveloped and developed-natural shoreline (54% of the entire shoreline) were observed during the survey (Figure 8.5.3-1). 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, 1.0 miles of urbanized and developed–unnatural shoreline (26% of the total shoreline) was observed. If restoration of the Dog Lake shoreline 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. Dog Lake Map 1 displays the location of these shoreline lengths around the entire lake.

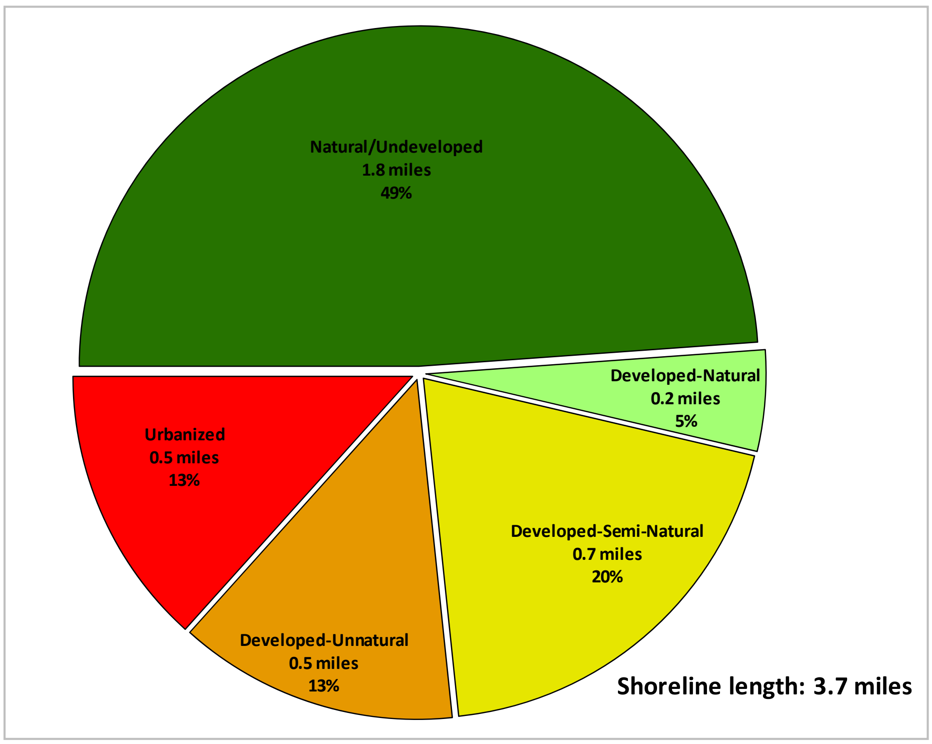



**Figure 8.5.3-1. Dog Lake shoreland categories and total lengths.** Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Dog Lake Map 1.

## Coarse Woody Habitat

Dog Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 63 pieces of coarse woody habitat were observed along 3.7 miles of shoreline, which gives Dog Lake a coarse woody habitat to shoreline mile ratio of 17:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Dog Lake Map 2.

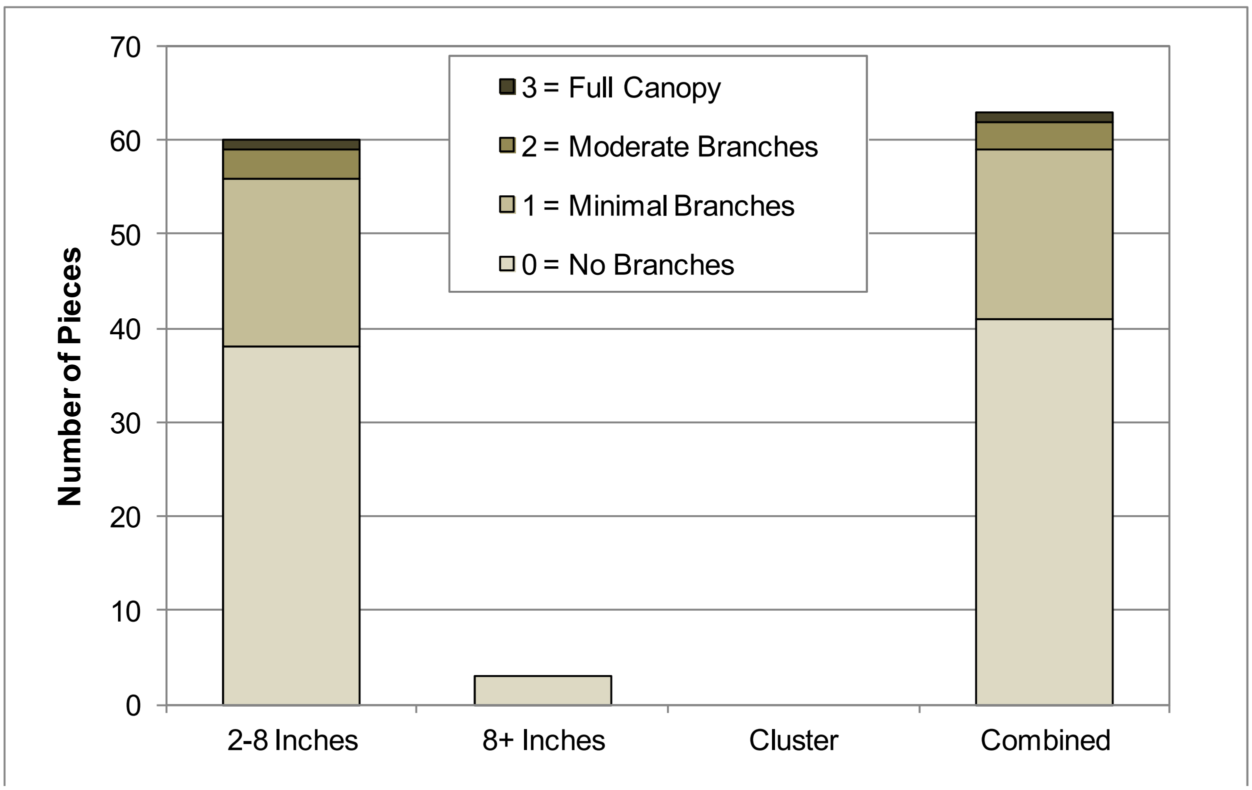



**Figure 8.5.3-2. Dog Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Dog Lake coarse woody habitat can be found on Dog Lake Map 2.

## 8.5.4 Dog Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Dog Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Dog Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Dog Lake on August 9, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 9 & 10 to create the aquatic plant community map (Dog Lake Map 2). During all surveys, 32 species of native aquatic plants were located in Dog Lake (Table 8.5.4-1). 21 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of six feet, which is common within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 116 point-intercept locations sampled within the littoral zone, approximately 56% contained aquatic vegetation. Approximately 75% of the point-intercept sampling locations where sediment data was collected at were sand, 24% consisted of a fine, organic substrate (muck) and no areas of rocky substrate were encountered.

**Table 8.5.4-1. Aquatic plant species located in the Dog Lake during the 2011 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2011 (Onterra) |
|---|---|---|---|---|
| Emergent | Acorus calamus | Sweetflag | 7 | I |
| | Dulichium arundinaceum | Three-way sedge | 9 | I |
| | Decodon verticillatus | Water-willow | 7 | I |
| | Equisetum fluviatile | Water horsetail | 7 | X |
| | Eleocharis palustris | Creeping spikerush | 6 | X |
| | Iris versicolor | Northern blue flag | 5 | I |
| | Juncus effusus | Soft rush | 4 | I |
| | Pontederia cordata | Pickerelweed | 9 | X |
| | Sagittaria latifolia | Common arrowhead | 3 | I |
| | Schoenoplectus tabernaemontani | Softstem bulrush | 4 | I |
| | Scirpus cyperinus | Wool grass | 4 | I |
| | Typha spp. | Cattail spp. | 1 | I |
| | Zizania palustris | Northern wild rice | 8 | X |
| FL | Nymphaea odorata | White water lily | 6 | X |
| | Nuphar variegata | Spatterdock | 6 | X |
| FL/E | Sparganium emersum | Short-stemmed bur-reed | 8 | I |
| | Sparganium eurycarpum | Common bur-reed | 5 | X |
| | Sparganium fluctuans | Floating-leaf bur-reed | 10 | X |
| Submergent | Elodea canadensis | Common waterweed | 3 | X |
| | Isoetes sp. | Quilwort species | N/A | X |
| | Myriophyllum sibiricum | Northern water milfoil | 7 | I |
| | Najas flexilis | Slender naiad | 6 | X |
| | Potamogeton pusillus | Small pondweed | 7 | X |
| | Potamogeton zosteriformis | Flat-stem pondweed | 6 | X |
| | Potamogeton epihydrus | Ribbon-leaf pondweed | 8 | X |
| | Potamogeton robbinsii | Fern pondweed | 8 | X |
| | Potamogeton gramineus | Variable pondweed | 7 | X |
| | Potamogeton spirillus | Spiral-fruited pondweed | 8 | X |
| | Potamogeton richardsonii | Clasping-leaf pondweed | 5 | X |
| | Utricularia vulgaris | Common bladderwort | 7 | X |
| | Vallisneria americana | Wild celery | 6 | X |
| SE | Eleocharis acicularis | Needle spikerush | 5 | X |

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

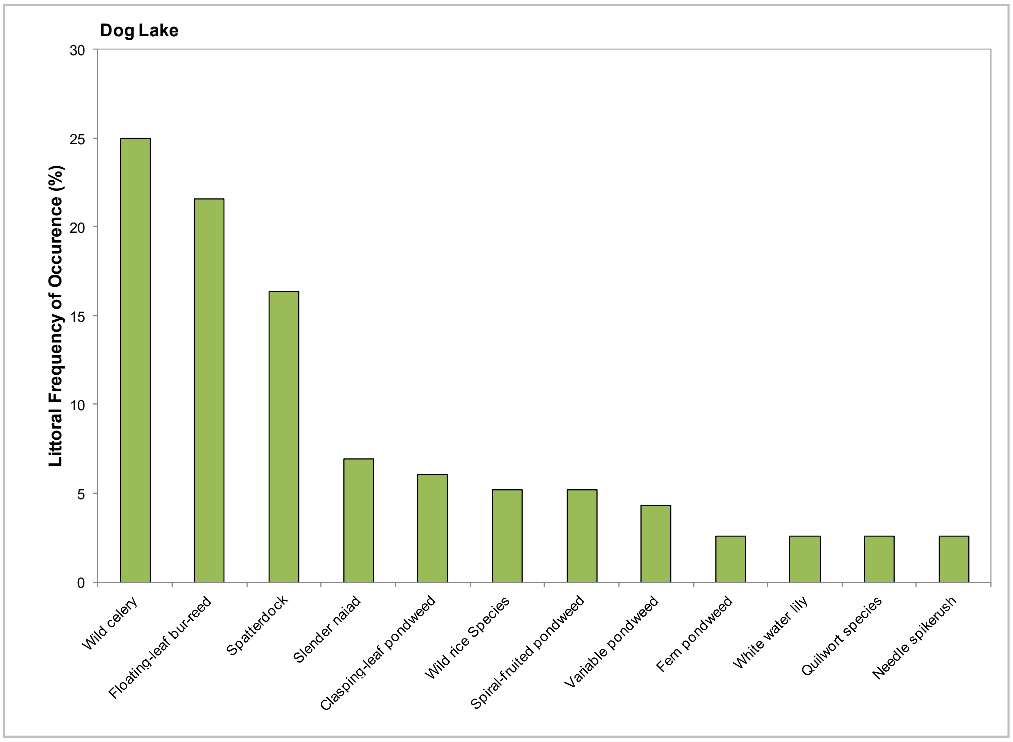



**Figure 8.5.4-1 Dog Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 2.5% only. Created using data from a 2011 point-intercept survey.

Figure 8.5.4-1 (above) shows that wild celery, floating-leaf bur-reed and spatterdock were the most commonly encountered species during the point-intercept survey. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Floating-leaf bur-reed is an aquatic plant which includes long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits. Spatterdock is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months. This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was found within Dog Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

32 species of aquatic plants (including incidentals) were found in Dog Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Dog Lake's plant community (0.88) lies slightly above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake has good diversity in its plant community.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 wild celery was found at 25% of the sampling locations, its relative frequency of occurrence is 23%. Explained another way, if 100 plants were randomly sampled from Dog Lake, 23 of them would be wild celery. This distribution can be observed in Figure 8.5.4-2, where together 10 species account for 71% of the population of plants within Dog Lake, while the other 23 species account for the remaining 29%. Fifteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.5.4-1 as incidentals.

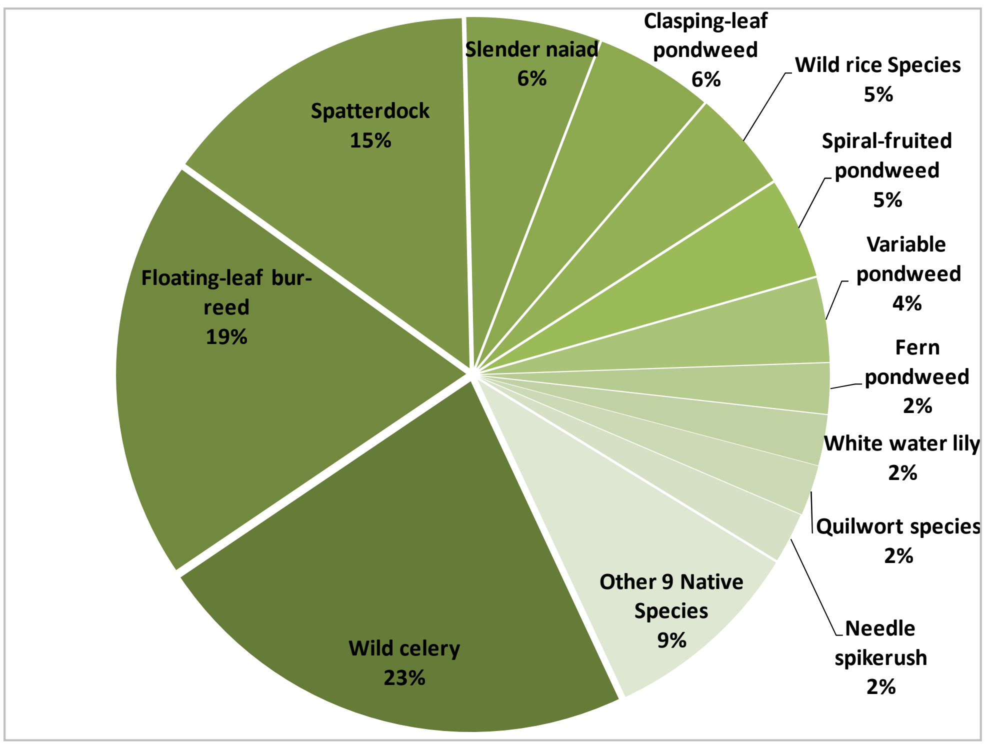



**Figure 8.5.4-2 Dog Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2011 point-intercept survey.

Dog Lake's average conservatism value (6.7) is equal to the ecoregion but larger than the state-wide median. This indicates that the plant community of Dog Lake is indicative of a moderately undisturbed system. This is not surprising considering Dog Lake's plant community has good diversity and high species richness. Combining Dog Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 30.5 which is above the median values of the ecoregion and state.

The quality of Dog Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 41.6 acres of the lake contains these types of plant communities (Dog Lake Map 2, Table 8.5.4-2). Seventeen floating-leaf and emergent species were located on Dog Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

**Table 8.5.4-2. Dog Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 6.3 |
| Floating-leaf | 15.0 |
| Mixed Floating-leaf and Emergent | 20.3 |
| **Total** | 41.6 |

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

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### 8.5.5 Dog Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Dog Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Dog Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Dog Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Dog Lake's implementation plan is compiled by describing how Dog Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Dog Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Dog Lake as part of this chain-wide management planning project, it is up to Dog Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Dog Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** While Dog Lake does not have a public access point, it is directly connected to the rest of the Three Lakes Chain of Lakes via Big Lake and Deer Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Dog Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Dog Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Dog Lake or from Dog Lake elsewhere. If a Dog Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Dog Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Dog Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Dog Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Dog Lake and its stakeholders.

## *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Dog Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Dog Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Dog Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Dog Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Dog Lake shoreline was categorized in terms of its development. According to the results from this survey, 49% of the shoreline is currently in a natural state, while 26% is in an urban or developed-unnatural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## *Chain-wide Management Goal 6: Improve Fishery Resource and Fishing*

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Dog Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Dog Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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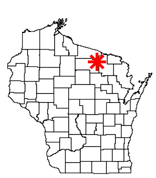
**Onterra LLC**
*Lake Management Planning*
*815 Prosper Rd*
*De Pere, WI 54115*
*920.338.8860*
*www.onterra-eco.com*

**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
*Filename: Dog_SA_2011.mxd*



Extent of large map shown in red.

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

Dog Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

**Shoreline Condition**


Onterra LLC
Lake Management Planning

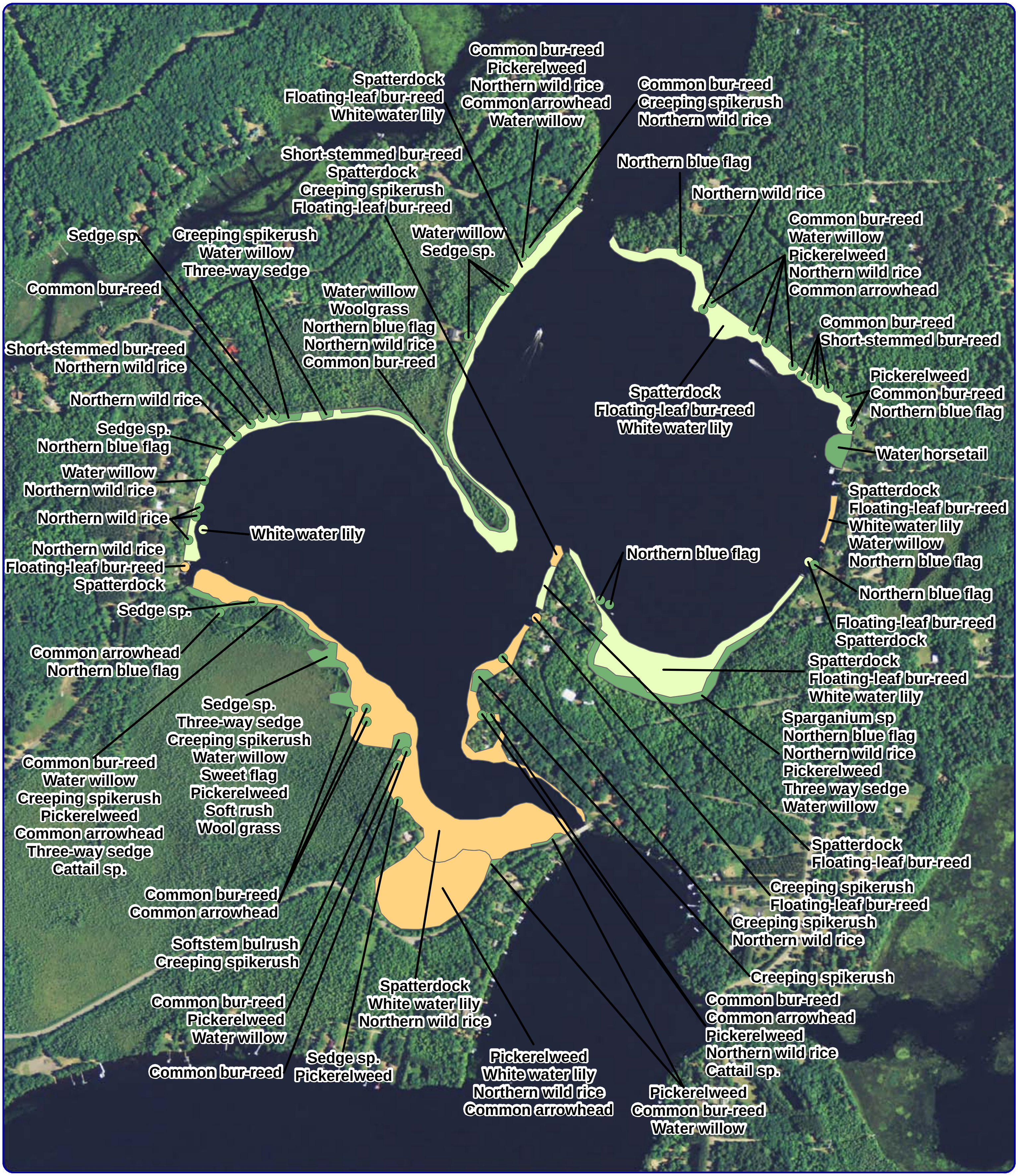
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Map date: October 16, 2014
Filename: Dog_CWH_2014.mxd

## Legend

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

# Dog Lake - Map 2
# Three Lakes Chain
Oneida County, Wisconsin
## 2014 Coarse Woody Habitat

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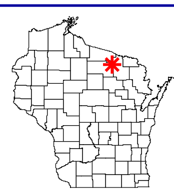
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

**Sources:**
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
**Map Date:** December 12, 2011
Filename: Dog_Comm_2011.mxd


Project Location in Wisconsin

**Legend**

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

Dog Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin

**Aquatic Plant Communities**

**Note: Methodology, explanation of analysis and scientific background on Crystal (Mud) Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.6 Crystal (Mud) Lake

### An Introduction to Crystal (Mud) Lake

Crystal (Mud) Lake, Oneida County, is a drainage lake with a maximum depth of nine feet and a surface area of 124 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Crystal (Mud) Lake contains 26 native plant species, of which floating-leaf bur-reed was the most common plant. No exotic plants were observed during 2011

**Field Survey Notes**

*A shallow, dark lake consisting primarily of mucky substrate. Few sampling locations held aquatic plants. No exotic aquatic plant species observed during 2011 field work.*

**Photo 8.6.1 Crystal (Mud) Lake, Oneida County**

### Lake at a Glance* – Crystal (Mud) Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 124 |
| Maximum Depth (ft) | 9 |
| Mean Depth (ft) | 5 |
| Volume (acre-feet) | 648 |
| Shoreline Complexity | 3.0 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 22, 2011 |
| Comprehensive Survey Date | August 4 & 5, 2011 |
| Number of Native Species | 26 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | - |
| Simpson's Diversity | 0.80 |
| Average Conservatism | 6.4 |
| **Water Quality** | |
| Wisconsin Lake Classification | Shallow, lowland drainage |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 63:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.6.1 Crystal (Mud) Lake Water Quality

During 2011/2012, water quality data was collected from Crystal (Mud) Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Additionally, historical databases were searched for any prior data that may have been collected on Crystal (Mud) Lake. Only a single historical record was turned up for each of the three water quality parameters – in 1979. No additional data was discovered, leaving only the 2011/2012 data available for analysis.

Crystal (Mud) Lake total phosphorus values can be found in Figure 8.6.1-1. In 2011, summer total phosphorus concentrations averaged 72.0 µg/L, which is considerably higher than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 µg/L). Chlorophyll-*a* data is available from 1979 and 2011 for Crystal (Mud) Lake. The 2011 average summer chlorophyll-*a* concentration (5.9 µg/L) is somewhat lower than the average for other shallow, lowland drainage lakes statewide (median = 9.4 µg/L). The total phosphorus average ranks as *Fair* within the WiSCALM narrative, while the chlorophyll-*a* average value ranks as *Excellent*.

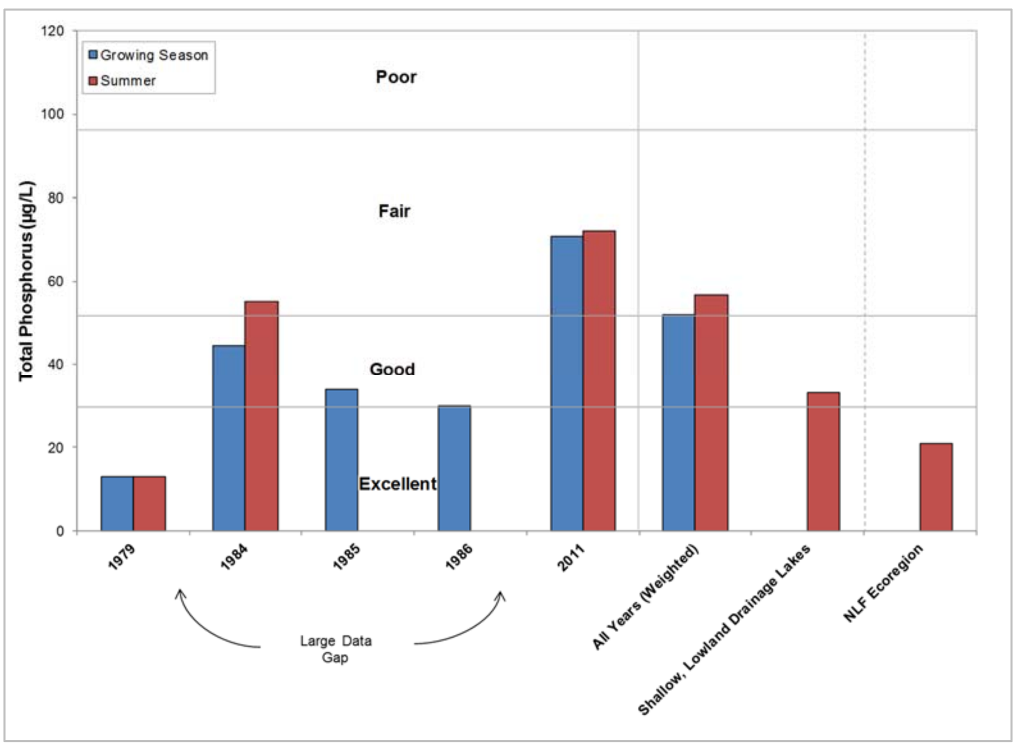



**Figure 8.6.1-1. Crystal (Mud) Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Measurements of Secchi disk clarity were taken in Crystal (Mud) Lake during 2011 field visits (Figure 8.5.1-2). The summer average was 1.5 feet, ranking as *Poor* within the Trophic State Index and falling below the median for other Wisconsin shallow, lowland drainage lakes (5.6 feet). It is interesting to note that while total phosphorus values are exceptionally high, an elevated abundance of algae was not picked up through chlorophyll-*a* sampling. It is possible that the water clarity of the lake is limiting the algal and plant growth, more so than the abundance of nutrients, which are sufficient for algae and plant growth. During the aquatic plant surveys that took place on Crystal (Mud) Lake in 2011, plants were found growing to a maximum depth of seven feet; however, the vast majority of plants grew to only 4 feet of depth. This is an added testament to the *Poor* water clarity in Crystal (Mud) Lake.

Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However, Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Crystal (Mud) Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Crystal (Mud) Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

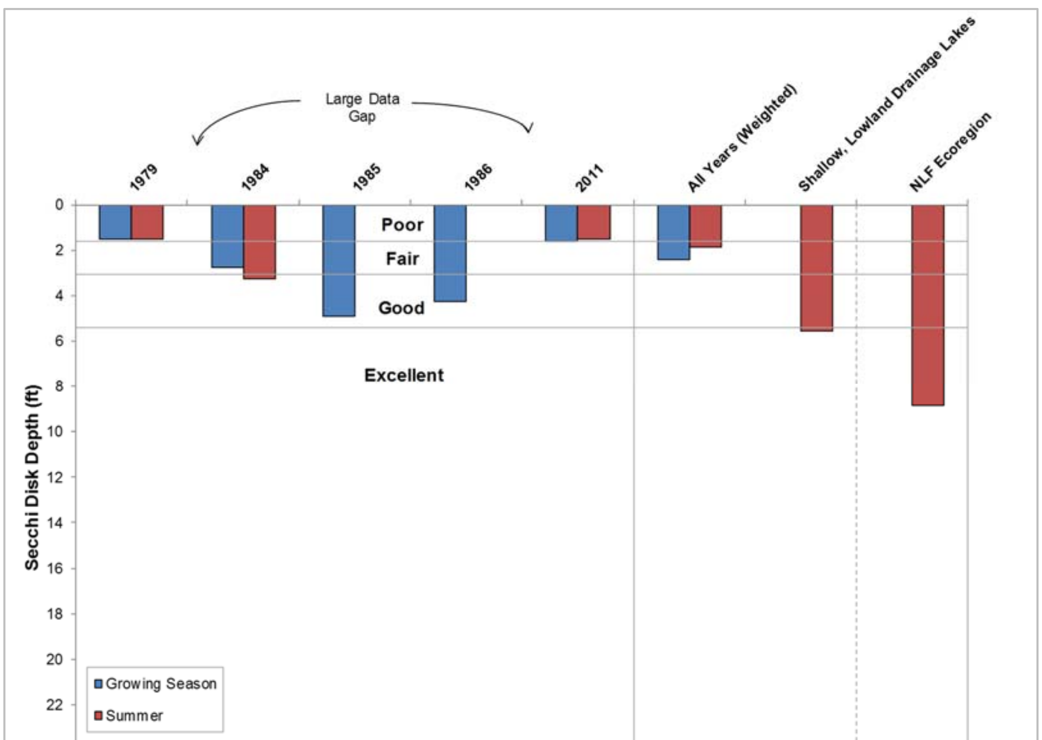



**Figure 8.5.1-2. Crystal (Mud) Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

## Crystal (Mud) Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values fall into categories of mesotrophic (chlorophyll-*a*) and eutrophic (phosphorus and Secchi disk clarity). Values above 50 are generally classified as being within the eutrophic category; two of Crystal (Mud) Lake's water quality parameters fall above this benchmark (Figure 8.6.1-3). Therefore, it can be concluded that Crystal (Mud) Lake is in a eutrophic state.

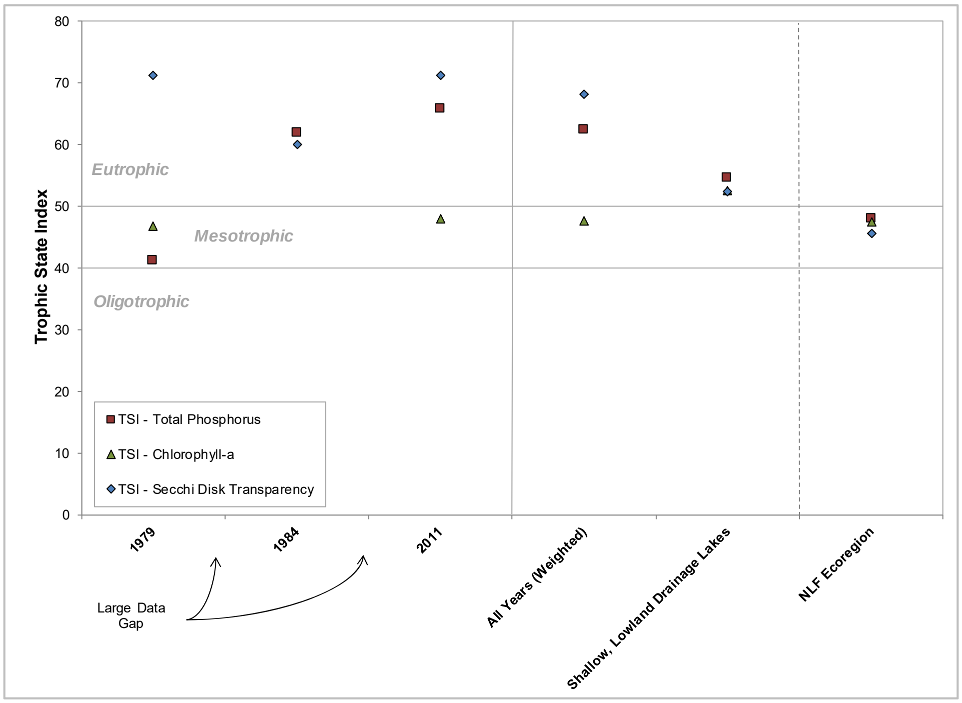



**Figure 8.5.1-3. Crystal (Mud) Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

## Dissolved Oxygen and Temperature in Crystal (Mud) Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Crystal (Mud) Lake by Onterra staff. Graphs of those data are displayed in Figure 8.6.1-4 for all sampling events.

Crystal (Mud) Lake remained thoroughly mixed throughout the spring, summer and fall months in 2011. This is not uncommon in lakes that are moderate in size and fairly shallow. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

Dissolved oxygen concentrations remained sufficient throughout the open water months for warm water fish species. In the winter months, when ice cover and limited oxygen production from plants reduces oxygen content of the water, there is often concern that the levels of oxygen may dip below what is necessary for fish in the lake. Although oxygen concentrations decreased near the bottom of Crystal (Mud) Lake, levels remained high enough in the upper half of the water column.

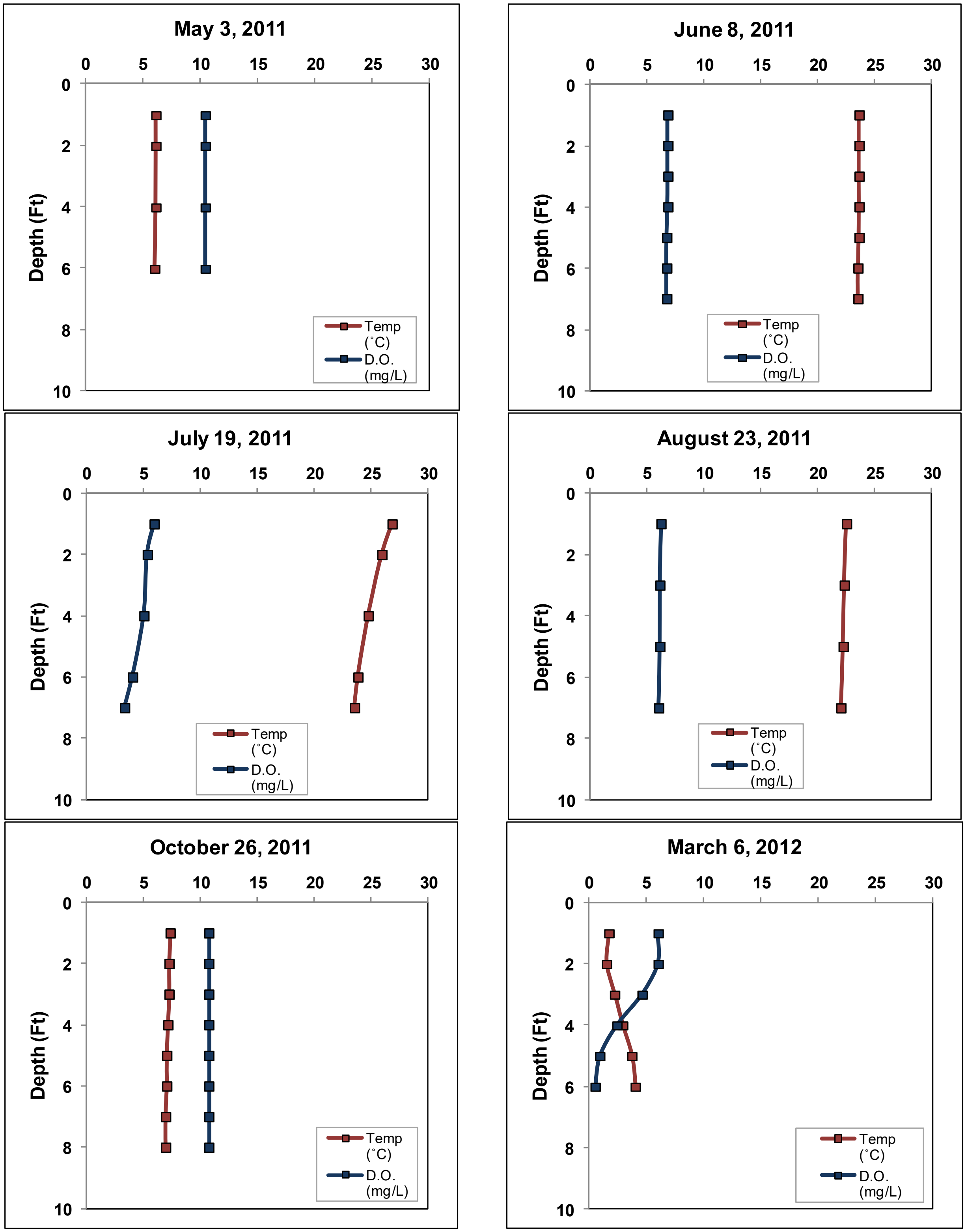



**Figure 8.6.1-4. Crystal (Mud) Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Crystal (Mud) 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 Crystal (Mud) 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Crystal (Mud) Lake's pH was measured at 6.8 in the summer months of 2011. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Crystal (Mud) Lake was measured at 15.9 (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.

Samples of calcium were also collected from Crystal (Mud) Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Crystal (Mud) Lake's pH of 6.8 falls slightly outside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Crystal (Mud) Lake was found to be 4.2 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.6.2 Crystal (Mud) Lake Watershed Assessment

Crystal (Mud) Lake's watershed is 7,964 acres in size. Compared to Crystal (Mud) Lake's size of 124 acres, this makes for an incredibly large watershed to lake area ratio of 63:1.

Exact land cover calculation and modeling of nutrient input to Crystal (Mud) Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.6.3 Crystal (Mud) Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Crystal (Mud) Lake's immediate shoreline was assessed in terms of its development. Crystal (Mud) Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.8 miles of natural/undeveloped and developed-natural shoreline (66% of the entire shoreline) were observed during the survey (Figure 8.6.3-1). 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, 0.3 miles of urbanized and developed–unnatural shoreline (12% of the total shoreline) was observed. If restoration of the Crystal (Mud) Lake shoreline 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. Crystal (Mud) Lake Map 1 displays the location of these shoreline lengths around the entire lake.

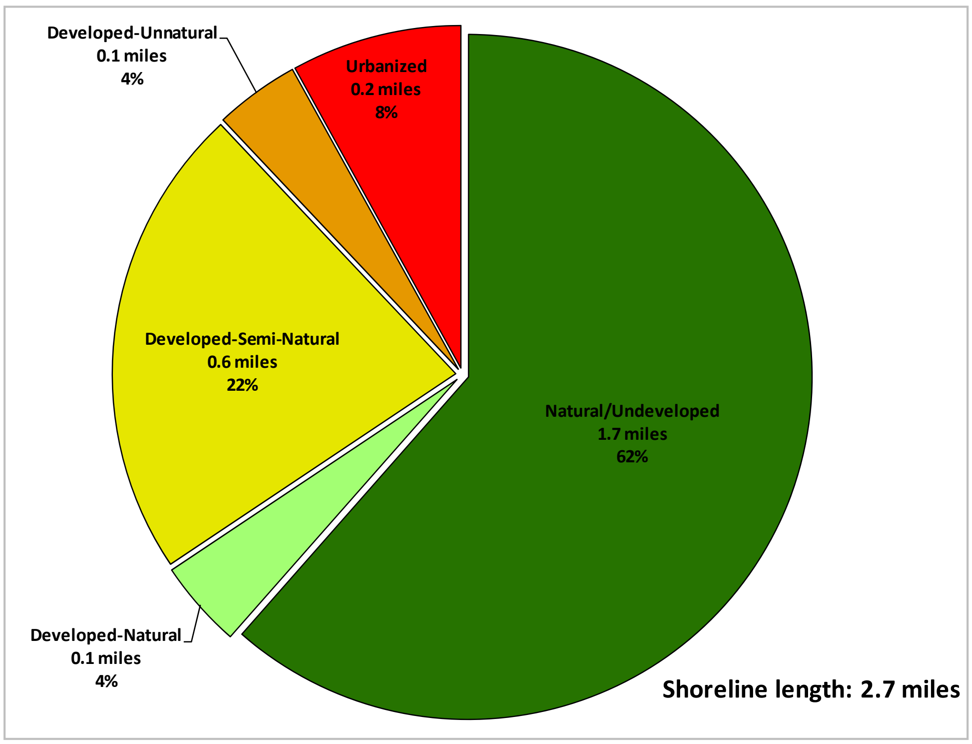



**Figure 8.6.3-1. Crystal (Mud) Lake shoreland categories and total lengths.** Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Crystal (Mud) Lake Map 1.

## Coarse Woody Habitat

Crystal (Mud) Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 39 pieces of coarse woody habitat were observed along 2.7 miles of shoreline, which gives Crystal (Mud) a coarse woody habitat to shoreline mile ratio of 15:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Crystal (Mud) Lake Map 2.

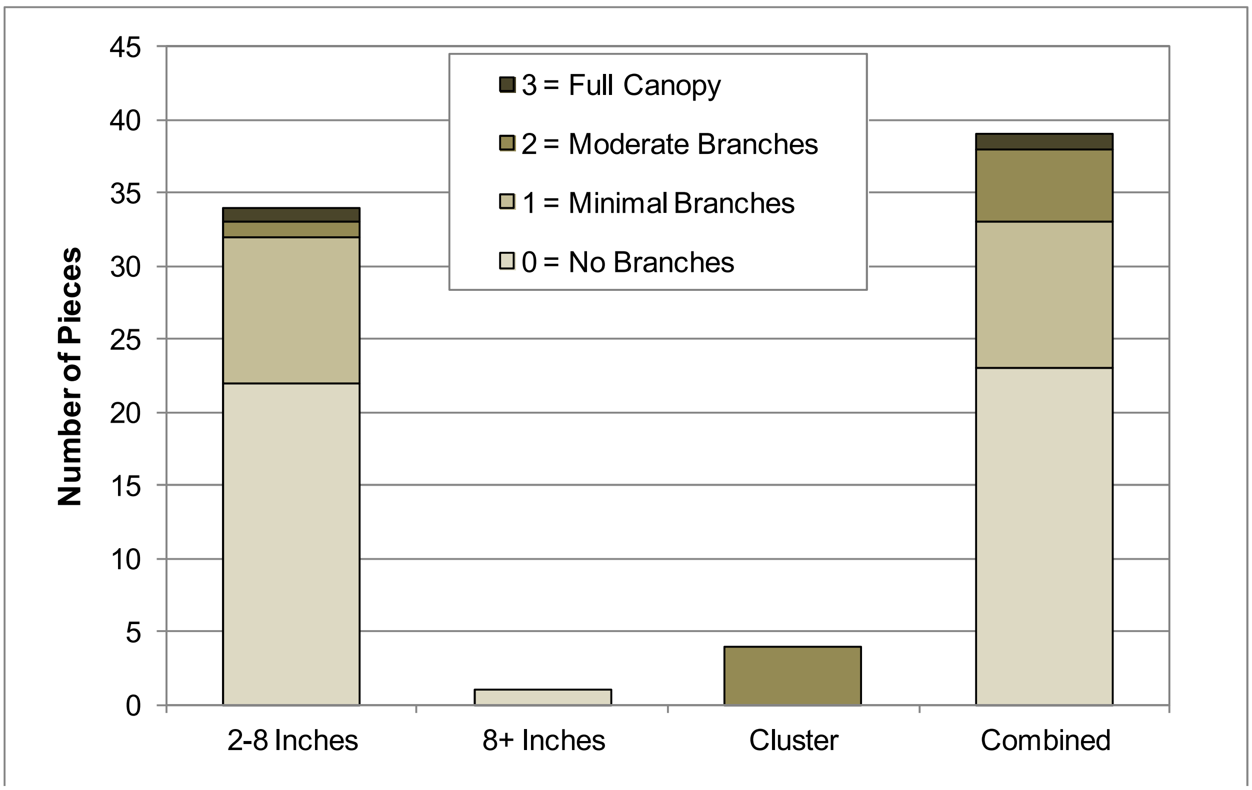



**Figure 8.6.3-2. Crystal (Mud) Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Crystal (Mud) Lake coarse woody habitat can be found on Crystal (Mud) Lake Map 2.

### 8.6.4 Crystal (Mud) Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Crystal (Mud) Lake on June 22, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Crystal (Mud) Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Crystal (Mud) Lake on August 4 & 5, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 8th to create the aquatic plant community map (Crystal (Mud) Lake Map 2). During all surveys, 26 species of native aquatic plants were located in Crystal (Mud) Lake (Table 8.6.4-1). 12 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of seven feet, which is comparable to the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and moderately diverse.

Of the 174 point-intercept locations sampled within the littoral zone, approximately 24% contained aquatic vegetation. Approximately 9% of the point-intercept sampling locations where sediment data was collected at were sand, 91% consisted of a fine, organic substrate (muck) while no rocky substrate was encountered.

**Table 8.6.4-1. Aquatic plant species located in the Crystal (Mud) Lake during the 2011 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2011 (Onterra) |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Decodon verticillatus* | Water-willow | 7 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | I |
| | *Iris versicolor* | Northern blue flag | 5 | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 4 | I |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Typha spp.* | Cattail spp. | 1 | I |
| | *Zizania palustris* | Northern wild rice | 8 | I |
| FL | *Brasenia schreberi* | Watershield | 7 | I |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| | *Nymphaea odorata* | White water lily | 6 | X |
| FL/E | *Sparganium eurycarpum* | Common bur-reed | 5 | I |
| | *Sparganium emersum* | Short-stemmed bur-reed | 8 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| FF | *Lemna turionifera* | Turion duckweed | 2 | X |
| | *Spirodela polyrhiza* | Greater duckweed | 5 | I |

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

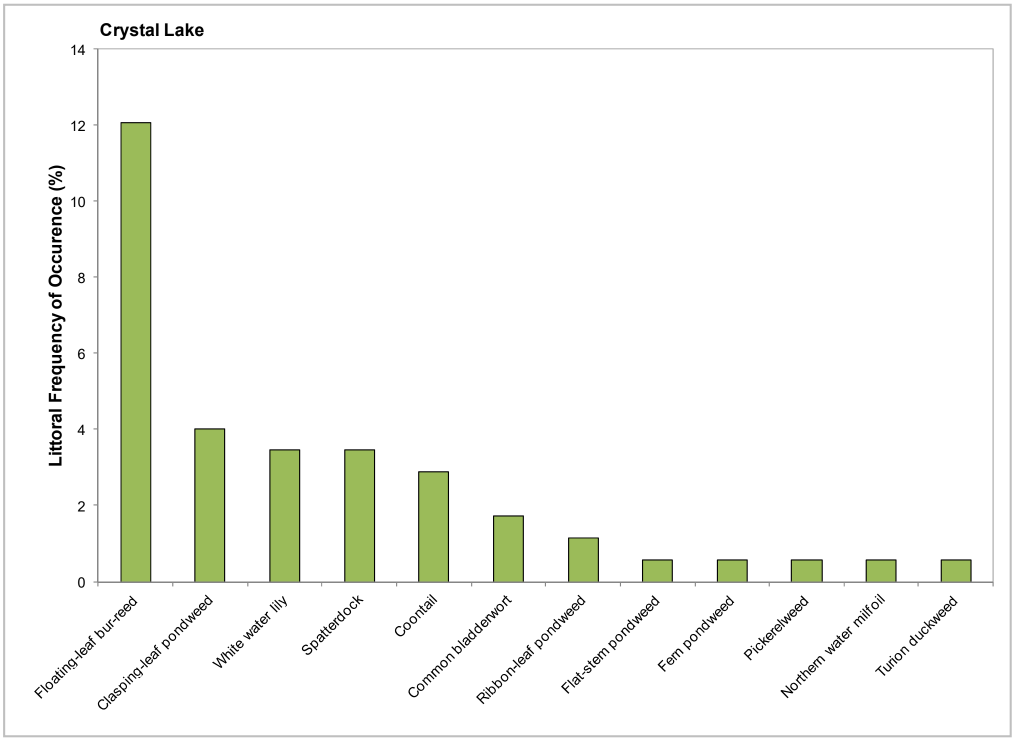



**Figure 8.6.4-1 Crystal (Mud) Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes all species encountered during the 2011 point-intercept survey.

Figure 8.6.4-1 (above) shows that floating-leaf bur-reed, clasping-leaf pondweed were the two species encountered most within the point-intercept survey. White water lily and spatterdock were encountered often as well. Floating-leaf bur-reed is an aquatic plant which includes long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits. Clasping-leaf pondweed has oval to somewhat lance-shaped leaves that "clasp" around one-half to three-quarters of the stem circumference. Leaves have 13-21 veins, which is a good characteristic to use in distinguishing this plant from other similar looking plants in the genus *Potamogeton*. White water lily and spatterdock are floating-leaf plants that are commonly found near the shoreline on Wisconsin lakes. White water lilies, as the name implies, are round in shape and produce a white flower. Spatterdock leaves resemble a heart shape and produce yellow roundish flowers in the summer months.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was found within Crystal (Mud) Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

26 species of aquatic plants (including incidentals) were found in Crystal (Mud) Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Crystal (Mud) Lake's plant community (0.80) lies below the Northern Lakes and Forests Lakes ecoregion median value (0.86).

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 floating-leaf bur-reed was found at 12% of the sampling locations, its relative frequency of occurrence is 38%. Explained another way, if 100 plants were randomly sampled from Crystal (Mud) Lake, 38 of them would be floating-leaf bur-reed. Floating-leaf bur-reed is therefore relatively dominant compared to other species within the lake. This distribution can be observed in Figure 8.6.4-2, where together seven species account for 91% of the population of plants within Crystal (Mud) Lake, while the other five species account for the remaining 9%. Fourteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.6.4-1 as incidentals.

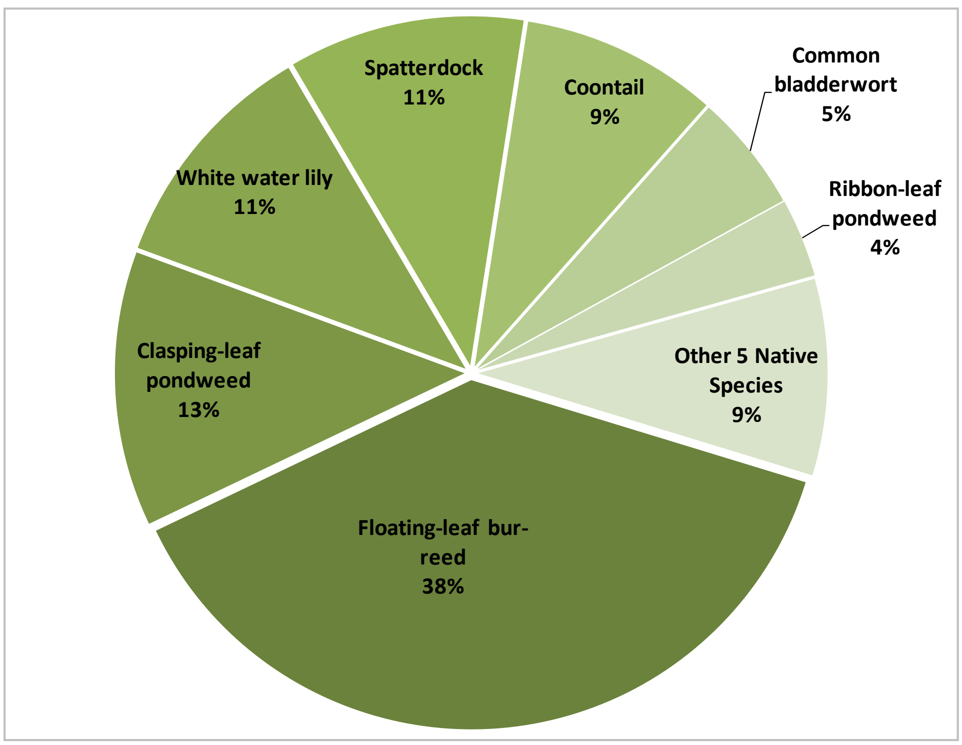



**Figure 8.6.4-2 Crystal (Mud) Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2011 point-intercept survey.

Crystal (Mud) Lake's average conservatism value (6.4) is lower than the ecoregion median, but higher than the state median. This indicates that the plant community of Crystal (Mud) Lake is indicative of moderately disturbed system. This is not surprising considering Crystal (Mud) Lake's plant community has moderate diversity and low species richness. Combining Crystal (Mud) Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 22.2 which is below the median value of the ecoregion and equal to the state median value.

Crystal (Mud) Lake holds numerous areas of emergent and floating-leaf plant communities. The 2011 community map indicates that approximately 19.3 acres of the lake contains these types of plant communities (Crystal (Mud) Lake Map 2, Table 8.6.4-2). Fifteen floating-leaf and emergent species were located on Crystal (Mud) Lake, all of which provide valuable wildlife habitat.

**Table 8.6.4-2. Crystal (Mud) Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 2.6 |
| Floating-leaf | 14.7 |
| Mixed Floating-leaf and Emergent | 2.0 |
| **Total** | 19.3 |

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

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## 8.6.5 Crystal (Mud) Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Crystal (Mud) Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Crystal (Mud) Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Crystal (Mud) Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Crystal (Mud) Lake's implementation plan is compiled by describing how Crystal (Mud) Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Crystal (Mud) Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Crystal (Mud) Lake as part of this chain-wide project, it is up to Crystal (Mud) Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Crystal (Mud) Lake Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## *Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes*

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** Crystal (Mud) Lake contains a single public access, and is directly connected to the rest of the Three Lakes Chain of Lakes via Deer Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Crystal (Mud) Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Crystal (Mud) Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Crystal (Mud) Lake or from Crystal (Mud) Lake elsewhere. If a Crystal (Mud) Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Crystal (Mud) Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Crystal (Mud) Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Crystal (Mud) Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Crystal (Mud) Lake and its stakeholders.

## Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Crystal (Mud) Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Crystal (Mud) Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Crystal (Mud) Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Crystal (Mud) Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Crystal (Mud) Lake shoreline was categorized in terms of its development. According to the results from this survey, 62% of the shoreline is currently in a natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

Restoring areas of the Crystal (Mud) Lake shoreline is not imperative due to its already largely natural state, so educating riparian property owners on the benefits of conserving this natural land may be of more importance. However, if property owners are interested in restoring their property's shoreline a plan has been put into place to do so. The

TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

**Management Action:** Investigate sources of phosphorus to Big, Crystal (Mud), Rangeline and Townline Lakes.

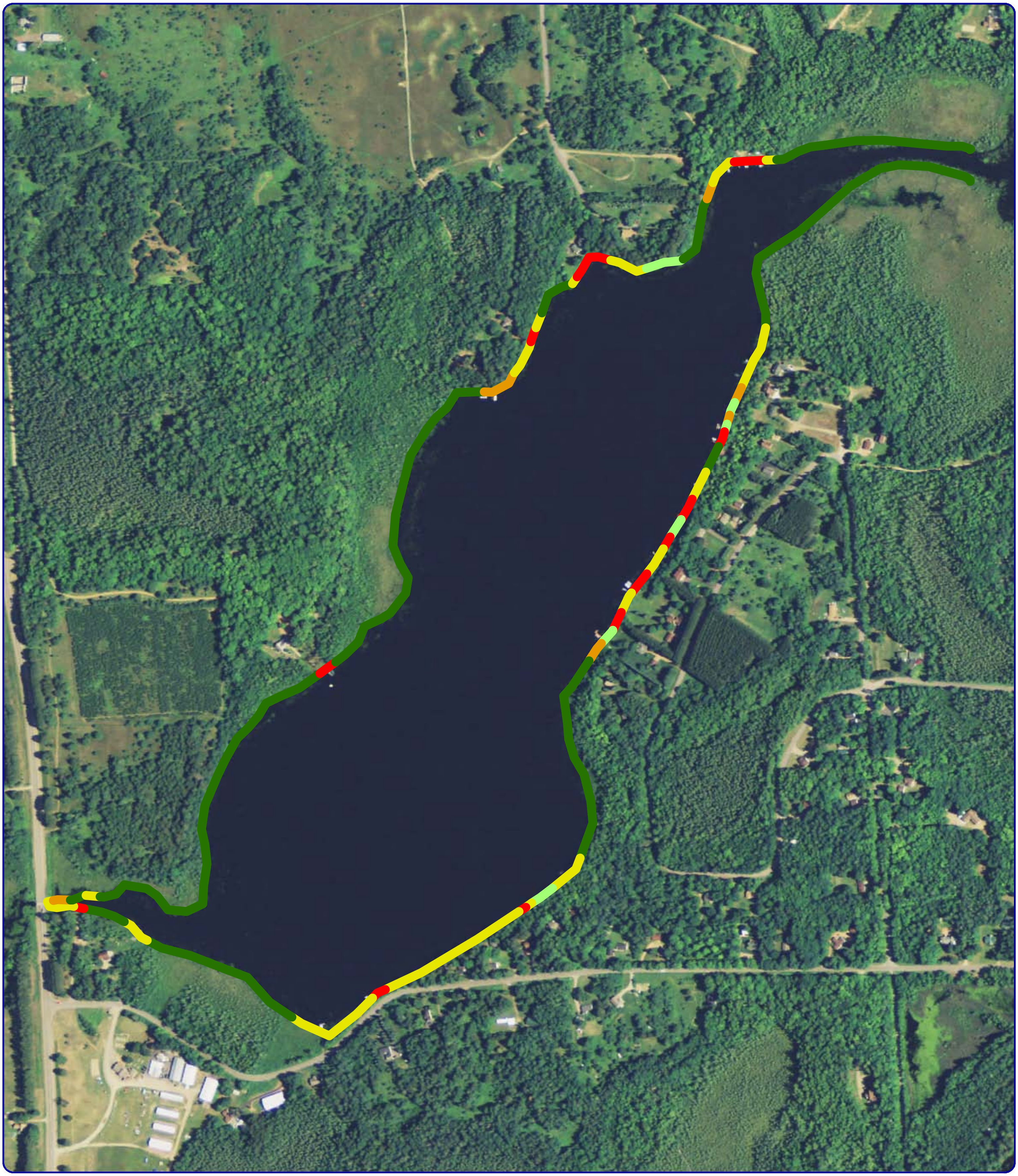
**Description:** As mentioned within the Chain-wide Implementation Plan, evidence of elevated nutrient levels in Crystal (Mud) Lake was discussed during planning meetings associated with this project. To begin understanding dynamics that may play a role in producing these high nutrient levels, further studies are needed to quantify nutrient inputs to the lake.

The TLWA, in coordination with Crystal (Mud) Lake stakeholders, will retain a professional consultant to investigate nutrient contributions to the lake through its tributary stream.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Crystal (Mud) Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Crystal (Mud) Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



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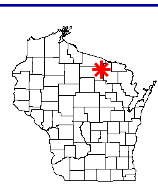
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
*Filename: Crystal_SA_2011.mxd*



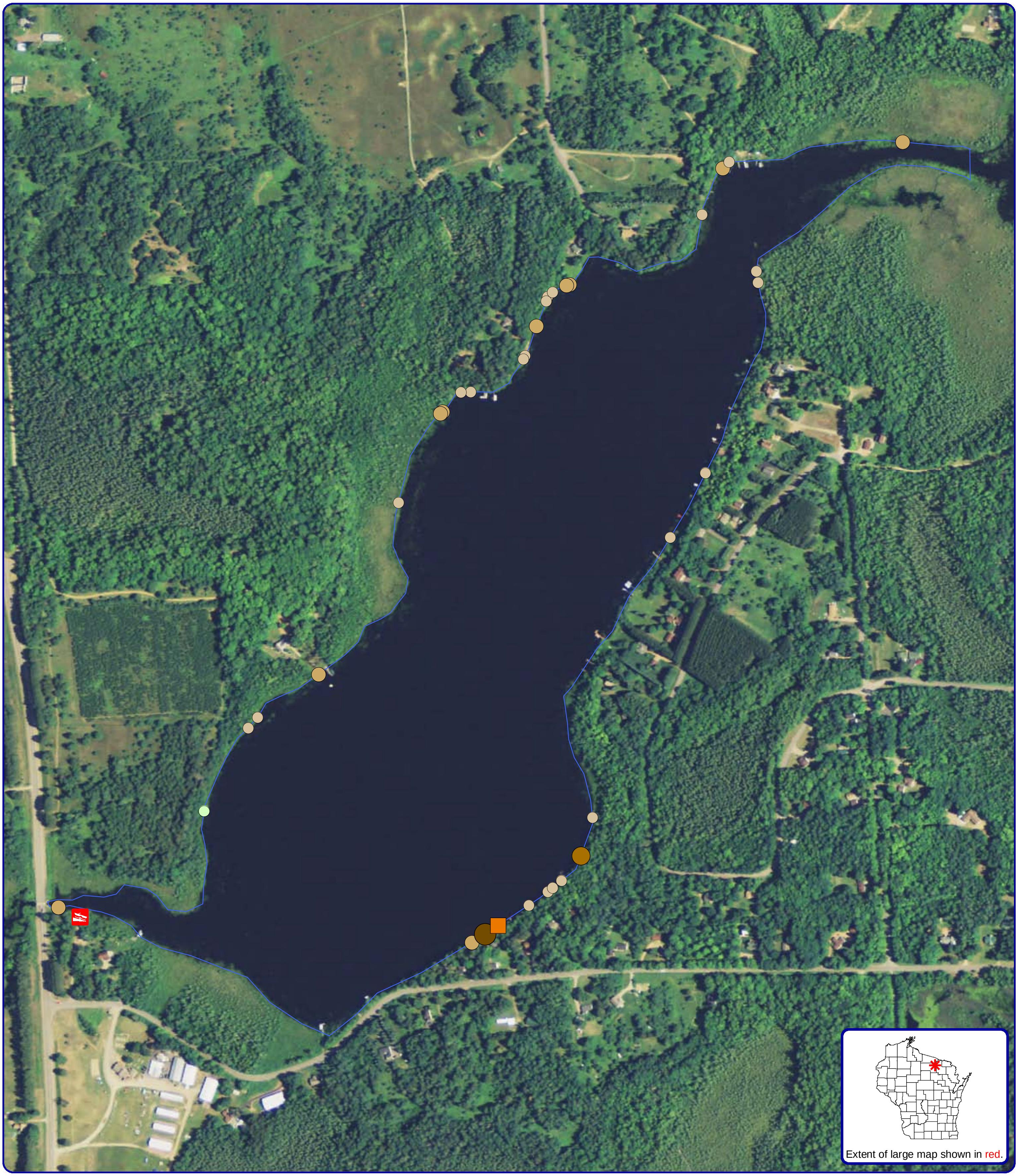
Extent of large map shown in red.

## Legend

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

# Crystal (Mud) Lake - Map 1
## Three Lakes Chain
Oneida County, Wisconsin

## Shoreline Condition

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## Legend

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

# Crystal (Mud) Lake - Map 2
## Three Lakes Chain
Oneida County, Wisconsin

## 2014 Coarse Woody Habitat

Onterra LLC
Lake Management Planning
815 Prosper Rd
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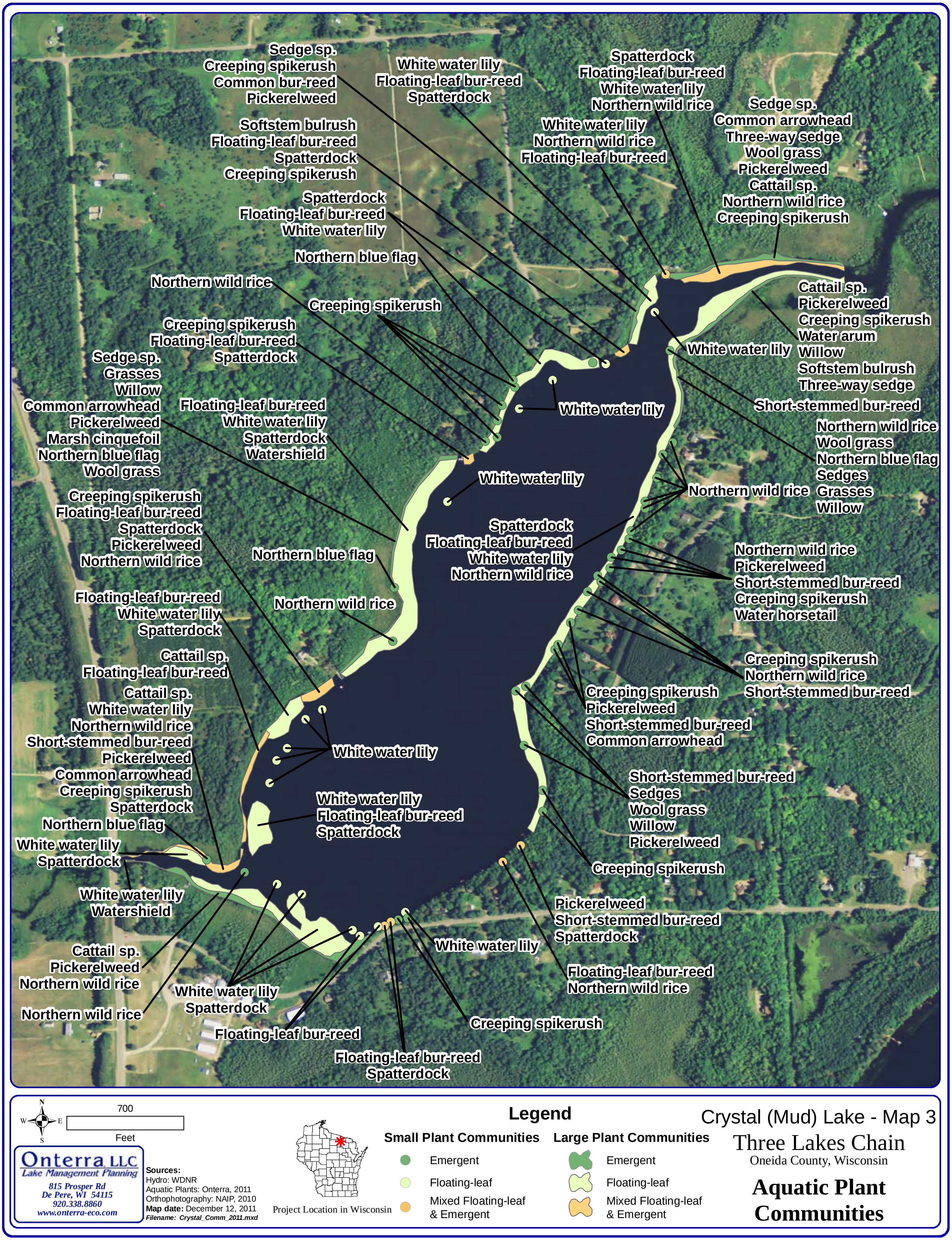
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Map date: October 16, 2014
Filename: Crystal_CWH_2014.mxd



Sedge sp.
Creeping spikerush
Common bur-reed
Pickerelweed
White water lily
Floating-leaf bur-reed
Spatterdock
Spatterdock
Floating-leaf bur-reed
White water lily
Northern wild rice
Sedge sp.
Common arrowhead
Three-way sedge
Wool grass
Pickerelweed
Cattail sp.
Northern wild rice
Creeping spikerush
Softstem bulrush
Floating-leaf bur-reed
Spatterdock
Creeping spikerush
White water lily
Northern wild rice
Floating-leaf bur-reed
Spatterdock
Floating-leaf bur-reed
White water lily
Northern blue flag
Northern wild rice
Creeping spikerush
Cattail sp.
Pickerelweed
Creeping spikerush
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Willow
Softstem bulrush
Three-way sedge
White water lily
Creeping spikerush
Floating-leaf bur-reed
Spatterdock
Sedge sp.
Grasses
Willow
Common arrowhead
Pickerelweed
Marsh cinquefoil
Northern blue flag
Wool grass
Floating-leaf bur-reed
White water lily
Spatterdock
Watershield
White water lily
Short-stemmed bur-reed
Northern wild rice
Wool grass
Northern blue flag
Sedges
Grasses
Willow
White water lily
Northern wild rice
Creeping spikerush
Floating-leaf bur-reed
Spatterdock
Pickerelweed
Northern wild rice
Spatterdock
Floating-leaf bur-reed
White water lily
Northern wild rice
Northern blue flag
Northern wild rice
Pickerelweed
Short-stemmed bur-reed
Creeping spikerush
Water horsetail
Floating-leaf bur-reed
White water lily
Spatterdock
Northern wild rice
Creeping spikerush
Northern wild rice
Short-stemmed bur-reed
Cattail sp.
Floating-leaf bur-reed
Creeping spikerush
Pickerelweed
Short-stemmed bur-reed
Common arrowhead
Cattail sp.
White water lily
Northern wild rice
Short-stemmed bur-reed
Pickerelweed
Common arrowhead
Creeping spikerush
Spatterdock
White water lily
Short-stemmed bur-reed
Sedges
Wool grass
Willow
Pickerelweed
White water lily
Floating-leaf bur-reed
Spatterdock
Northern blue flag
White water lily
Spatterdock
Creeping spikerush
White water lily
Watershield
Pickerelweed
Short-stemmed bur-reed
Spatterdock
White water lily
Cattail sp.
Pickerelweed
Northern wild rice
Floating-leaf bur-reed
Northern wild rice
White water lily
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Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map date: December 12, 2011
Filename: Crystal_Comm_2011.mxd
Project Location in Wisconsin
Legend
Small Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Large Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Crystal (Mud) Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin
Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on Deer Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.7 Deer Lake

### *An Introduction to Deer Lake*

Deer Lake, Oneida County, is a drainage lake with a maximum depth of 20 feet and a surface area of 177 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Deer Lake contains 38 native plant species, of which white water lily was the most common plant. No exotic plants were observed during the 2011 lake surveys.

**Field Survey Notes**

*Navigation tricky on west side of lake, where shallow water and thick floating-leaf aquatic plants were commonly encountered. Dark, stained water observed during surveys.*

**Photo 8.7.1 Deer Lake, Oneida County**

## Lake at a Glance* – Deer Lake

| Morphology | |
|---|---|
| Acreage | 177 |
| Maximum Depth (ft) | 20 |
| Mean Depth (ft) | 10 |
| Volume (acre-feet) | 1,794 |
| Shoreline Complexity | 9.7 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 21, 2011 |
| Comprehensive Survey Date | August 4 & 9, 2011 |
| Number of Native Species | 38 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | - |
| Simpson's Diversity | 0.89 |
| Average Conservatism | 6.3 |
| **Water Quality** | |
| Wisconsin Lake Classification | Shallow, lowland drainage |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 306:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.7.1 Deer Lake Water Quality

During 2011/2012, water quality data was collected from Deer Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water clarity since 2006, and various volunteers and agencies have taken Secchi readings on Deer Lake in the late 1980's and mid 1990's (Figure 8.7.1-1). These efforts provide a database of historical clarity data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Deer Lake. Unfortunately, only Secchi disk clarity has been monitored in the past, as monitoring for total phosphorus and chlorophyll-*a* requires additional sampling and funding and has not been sampled besides dates in 1979, in the mid-1980's and 2011.

In 2011, summer total phosphorus concentrations averaged 32.3 μg/L, which is slightly lower than the median value for other shallow, lowland drainage lakes in the state of Wisconsin (33.0 μg/L – Figure 8.6.1-1). 2011 average summer chlorophyll-*a* concentrations (7.3.0 μg/L) are lower than the median for other shallow, lowland drainage lakes statewide (9.4 μg/L). Both total phosphorus and chlorophyll-*a* average concentrations rank *Good* in the Trophic State Index.

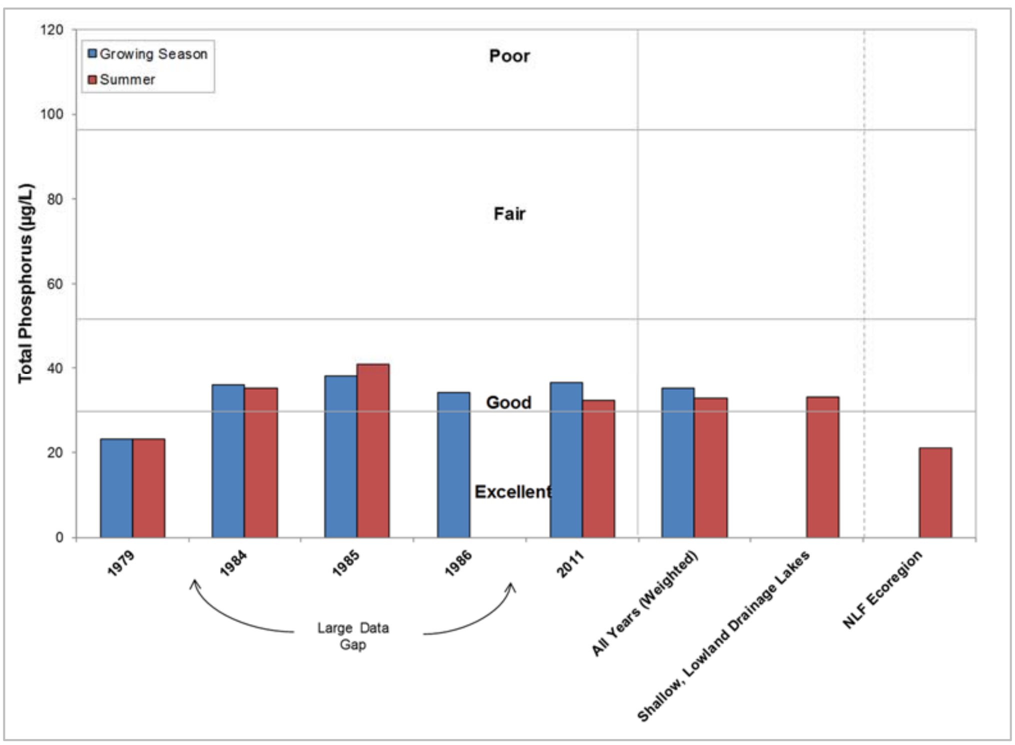


**Figure 8.7.1-1. Deer Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters, and show some variance between years (Figure 8.7.1-2). Summer averages fall mostly within categories of *Fair* and *Good*, and a weighted average across all years is less than the average for shallow, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However, Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Deer Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Deer Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. In 2011, aquatic plants were found growing to a depth of only six feet within the lake.

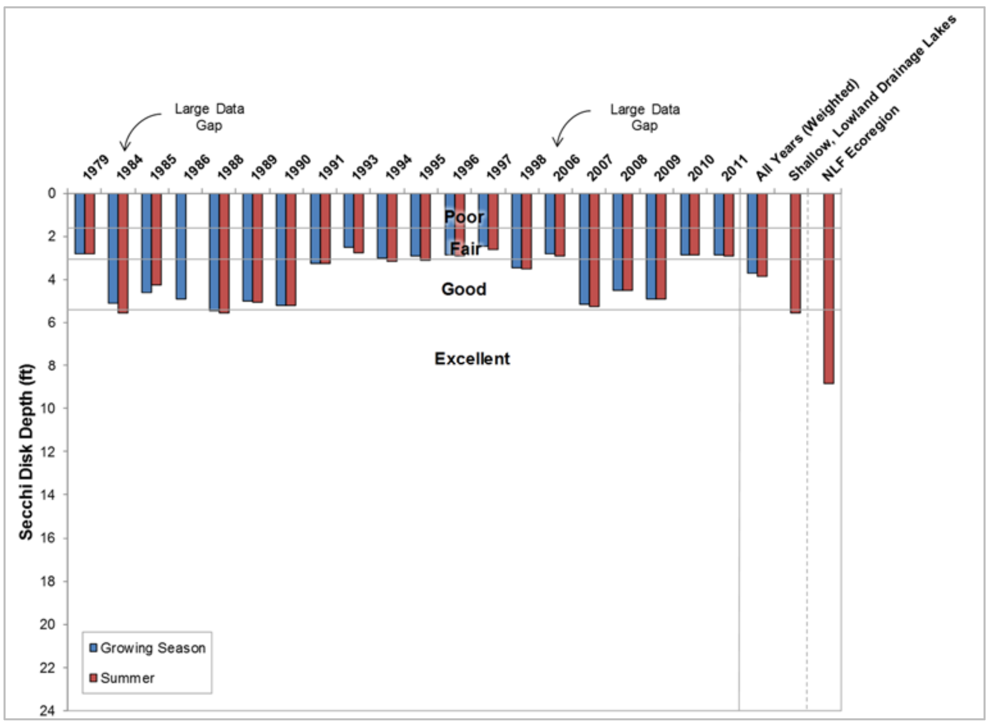


**Figure 8.7.1-2. Deer Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

### Deer Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.7.1-3). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Deer Lake is in a eutrophic state.

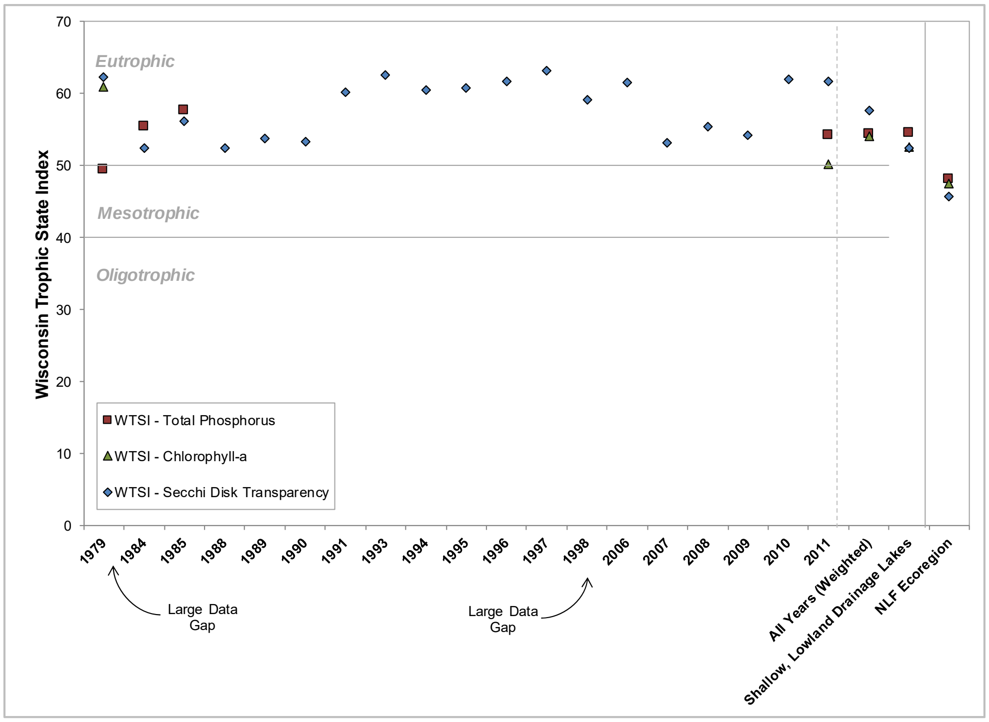


**Figure 8.7.1-3. Deer Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer and growing season surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Deer Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Deer Lake by Onterra staff. Graphs of those data are displayed in Figure 8.7.1-4 for all sampling events.

Deer Lake remained thoroughly mixed throughout most of the summer months in 2011, though a small amount of stratification likely occurs periodically in the deeper portions of the lake. This is not uncommon in lakes that are moderate in size and depth. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column.

Decomposition of organic matter along the lake bottom is likely the cause of the slight decrease in dissolved oxygen observed in the summer months. Despite this late summer dip, dissolved oxygen levels remained sufficient in the upper ~13 feet of the water column to support most aquatic life found in northern Wisconsin lakes. In the winter months, when ice cover and limited oxygen production from plants reduces oxygen content of the water, there is often concern that the levels of oxygen may dip below what is necessary for fish in the lake. Although oxygen concentrations decreased near the bottom of Deer Lake, levels remained high enough in the upper half of the water column.

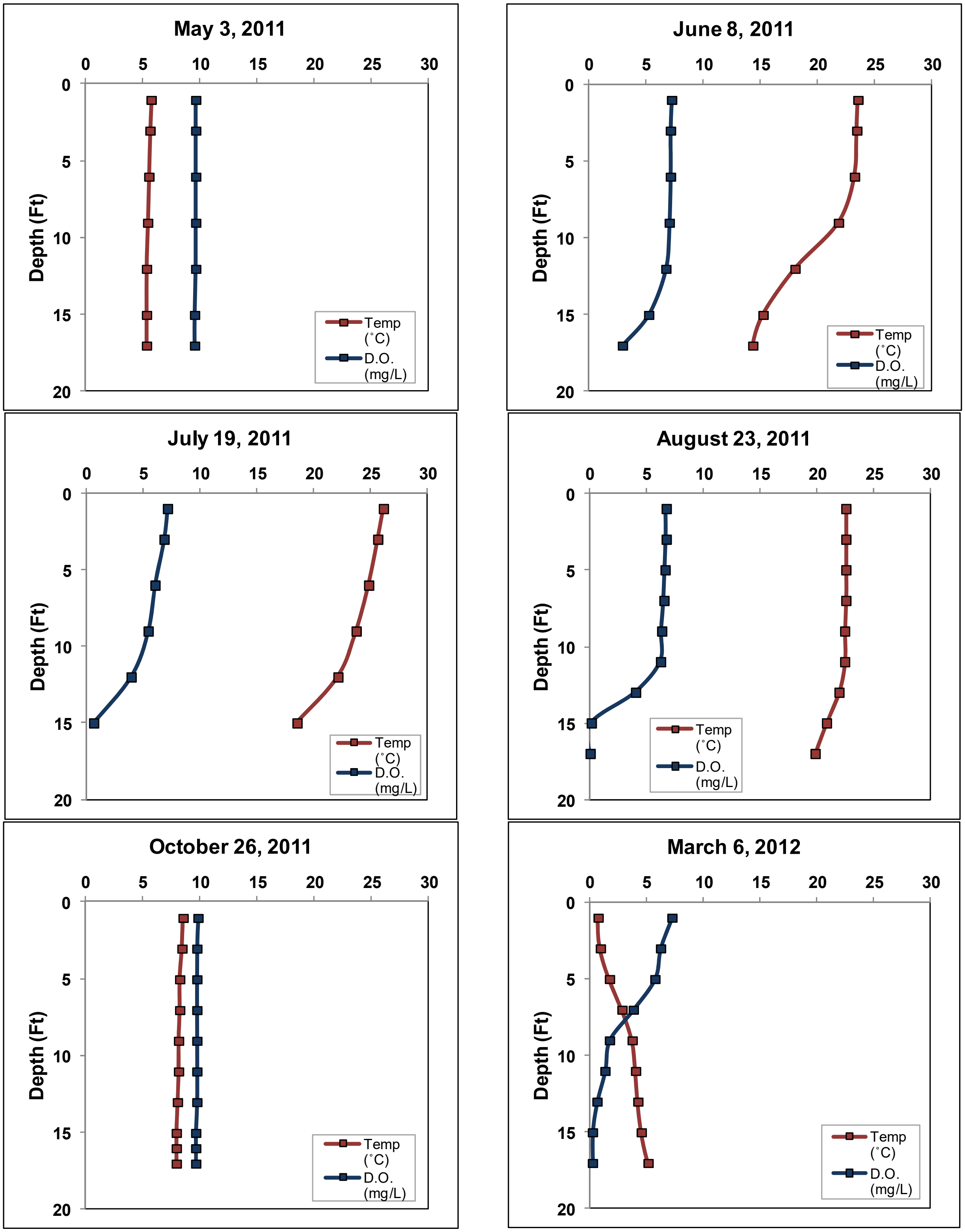


**Figure 8.7.1-4. Deer Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Deer 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 Deer 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Deer Lake's pH was measured at 7.0 during the summer months in 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Deer Lake was measured at 18.1 (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.

Samples of calcium were also collected from Deer Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Deer Lake's pH of 7.0 is at the bottom end 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 Deer Lake was found to be 5.6 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.7.2 Deer Lake Watershed Assessment

Deer Lake's watershed is 54,378 acres in size. Compared to Deer Lake's size of 177 acres, this makes for an incredibly large watershed to lake area ratio of 306:1.

Exact land cover calculation and modeling of nutrient input to Deer Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.7.3 Deer Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Deer Lake's immediate shoreline was assessed in terms of its development. Deer Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.9 miles of natural/undeveloped and developed-natural shoreline (50% of the entire shoreline) were observed during the survey (Figure 8.7.3-1). 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, 1.0 mile of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Deer Lake shoreline 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. Deer Lake Map 1 displays the location of these shoreline lengths around the entire lake.

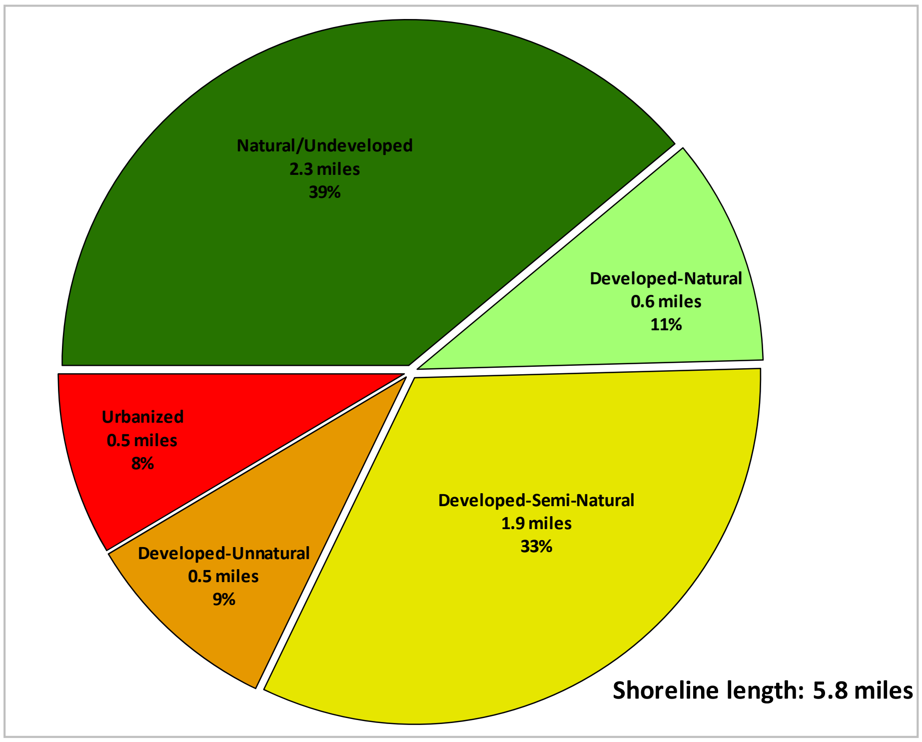


**Figure 8.7.3-1. Deer Lake shoreland categories and total lengths.** Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Deer Lake Map 1.

## Coarse Woody Habitat

Deer Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 112 pieces of coarse woody habitat were observed along 5.8 miles of shoreline, which gives Deer Lake a coarse woody habitat to shoreline mile ratio of 19:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Deer Lake Map 2.

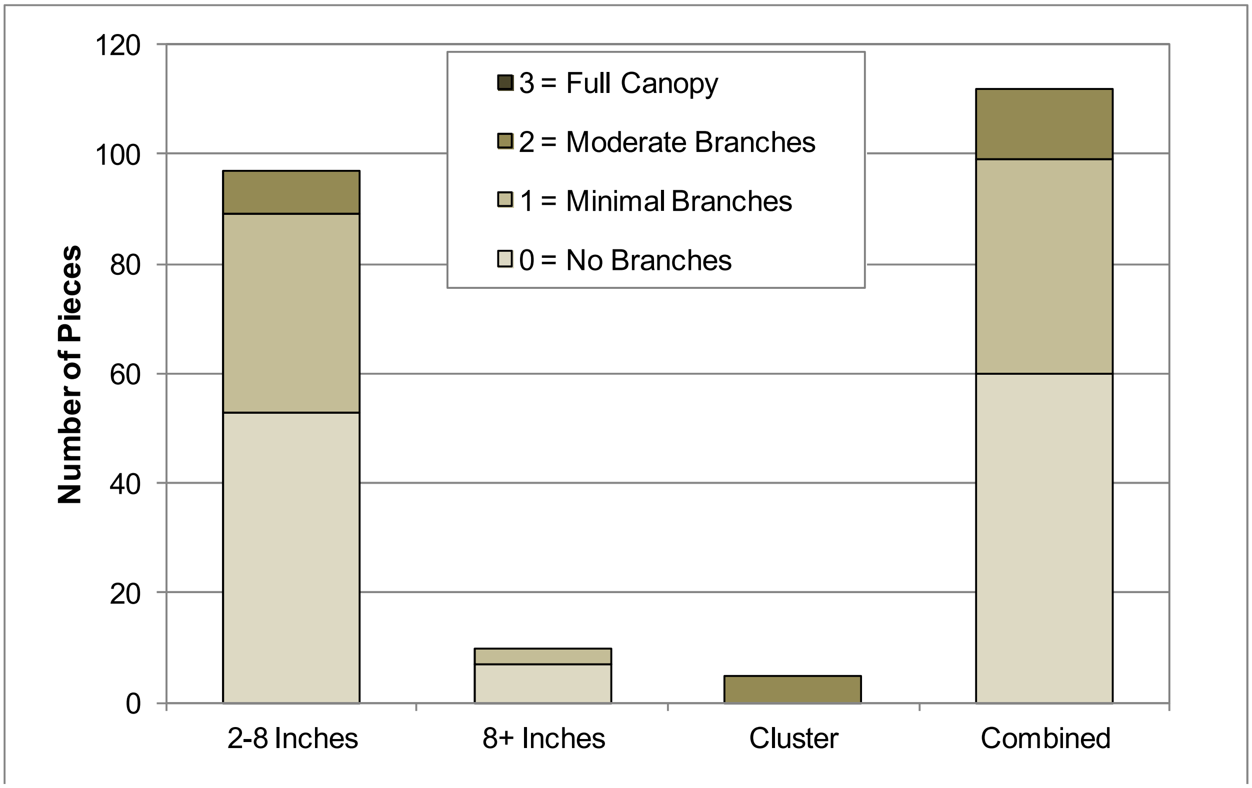


**Figure 8.7.3-2. Deer Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Deer Lake coarse woody habitat can be found on Deer Lake Map 2.

## 8.7.4 Deer Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Deer Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Deer Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Deer Lake on August 4 & 9, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 8 & 9 to create the aquatic plant community map (Deer Lake Map 2). During all surveys, 38 species of native aquatic plants were located in Deer Lake (Table 8.7.4-1). 26 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of six feet, which is comparable to the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 149 point-intercept locations sampled within the littoral zone, approximately 64% contained aquatic vegetation. Approximately 39% of the point-intercept sampling locations where sediment data was collected at were sand, 60% consisted of a fine, organic substrate (muck) and only 1% were determined to be rocky.

**Table 8.7.4-1. Aquatic plant species located in the Deer Lake during the 2011 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2011 (Onterra) |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Decodon verticillatus* | Water-willow | 7 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | X |
| | *Iris versicolor* | Northern blue flag | 5 | I |
| | *Juncus effusus* | Soft rush | 4 | X |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Typha spp.* | Cattail spp. | 1 | X |
| | *Zizania palustris* | Northern wild rice | 8 | X |
| FL | *Nuphar variegata* | Spatterdock | 6 | X |
| | *Nymphaea odorata* | White water lily | 6 | X |
| FL/E | *Sparganium emersum* | Short-stemmed bur-reed | 8 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Chara spp.* | Muskgrasses | 7 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elodea canadensis* | Common waterweed | 3 | I |
| | *Elodea nuttallii* | Slender waterweed | 7 | X |
| | *Isoetes sp.* | Quilwort species | N/A | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | I |
| | *Myriophyllum verticillatum* | Whorled water milfoil | 8 | I |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| SE | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| FF | *Lemna turionifera* | Turion duckweed | 2 | I |
| | *Lemna trisulca* | Forked duckweed | 6 | X |
| | *Spirodela polyrhiza* | Greater duckweed | 5 | I |

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

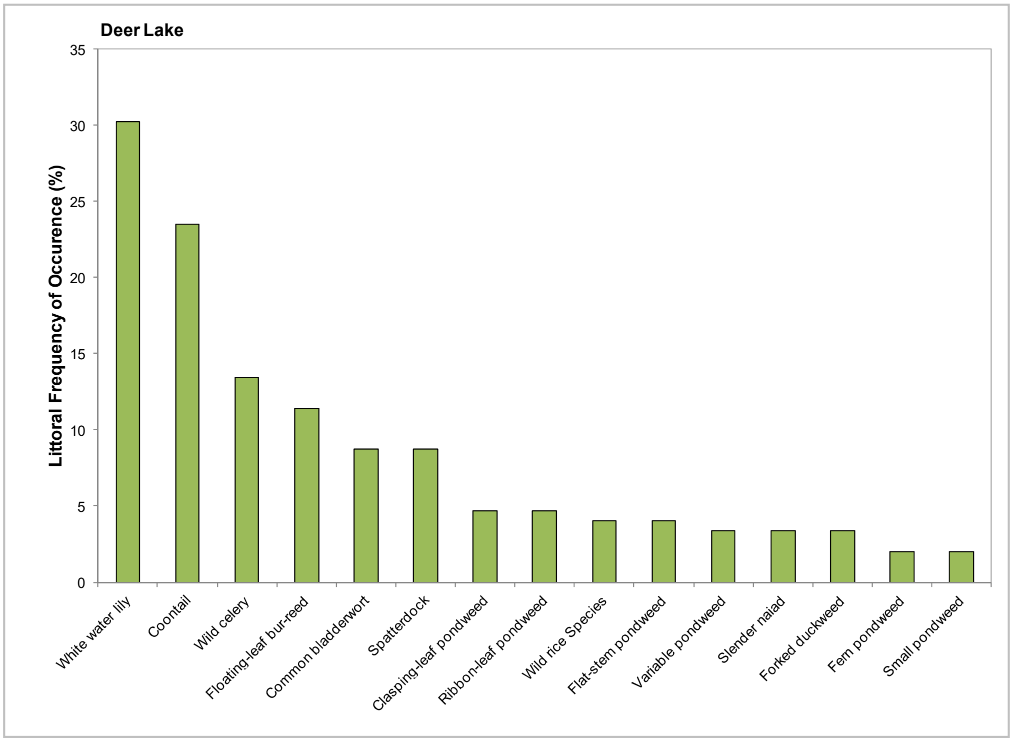


**Figure 8.7.4-1 Deer Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.7.4-1 (above) shows that white water lily, coontail and wild celery were the most frequently encountered plants within Deer Lake. White water lily is a floating-leaf species that produces broad, round leaves and a white flower. This plant is common in Wisconsin lakes around the shoreline, and in addition to creating shade for aquatic organisms it also serves as a food source. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making it susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. Coontail is tolerant to low-light conditions. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, two (northern water milfoil and whorled water milfoil) were located from Deer Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Whorled water milfoil is a submerged milfoil plant with leaves in whorls of 4 to 5. As with northern water milfoil, the leaves of this plant have somewhat of a feathery appearance. It is often mistaken for northern water milfoil or the invasive Eurasian water milfoil. This plant is most readily distinguished from other milfoils by its overall size (whorled water milfoil is typically larger and more robust) and the length between leaf nodes, which is less than other species of milfoil (about 1 cm apart). Additionally, leaflet counts are helpful in identification – whorled water milfoil typically has 9-13 leaflet segments on each side of the midrib of the leaflet, while northern water milfoil has 5-10 and Eurasian water milfoil 12-24 leaflets.

38 species of aquatic plants (including incidentals) were found in Deer Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Deer Lake's plant community (0.89) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds great diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 23% of the sampling locations, its relative frequency of occurrence is 17%. Explained another way, if 100 plants were randomly sampled from Deer Lake, 17 of them would be coontail. This distribution can be observed in Figure 8.7.4-2, where together 10 species account for 83% of the population of plants within Deer Lake, while the other 16 species account for the remaining 17%. Twelve additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.7.4-1 as incidentals.

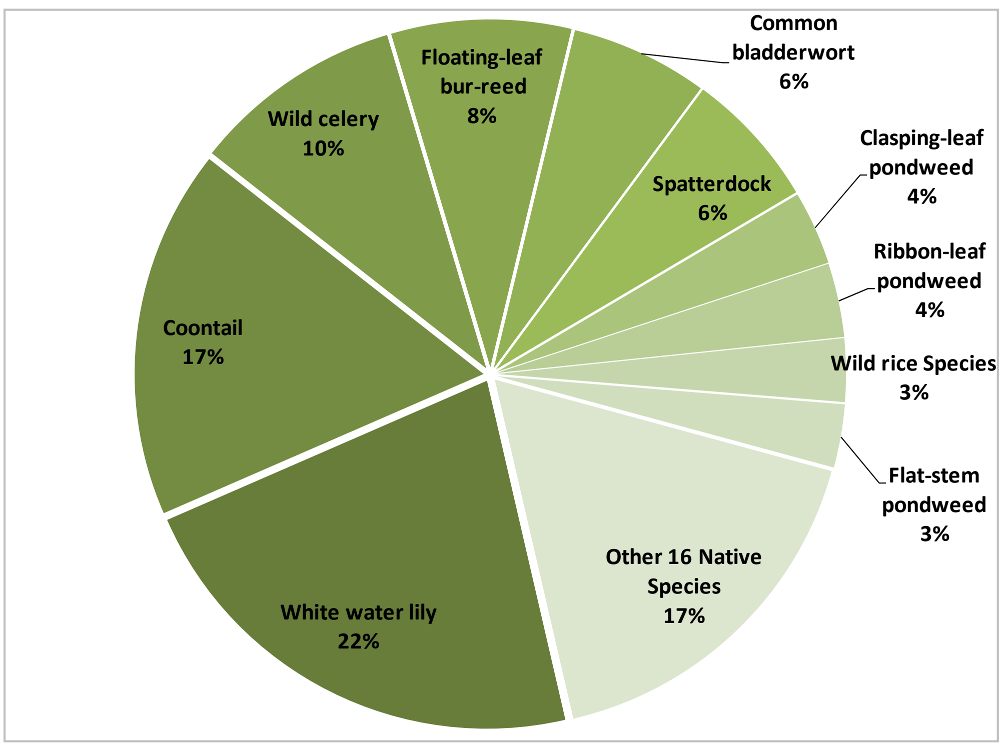


**Figure 8.7.4-2 Deer Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2011 point-intercept survey.

Deer Lake’s average conservatism value (6.3) is slightly higher than the state median value, but lower than the ecoregion median. This indicates that the plant community of Deer Lake is indicative of a moderately disturbed system. This is not surprising considering Deer Lake’s plant community has moderate diversity and species richness. Combining Deer Lake’s species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in value of 32.2 which is above the median values of the ecoregion and state.

The quality of Deer Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 70.2 acres of the lake contains these types of plant communities (Deer Lake Map 2, Table 8.7.4-2). Fifteen floating-leaf and emergent species were located on Deer Lake (Table 8.7.4-1), all of which provide valuable wildlife habitat.

**Table 8.7.4-2. Deer Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 23.2 |
| Floating-leaf | 13.9 |
| Mixed Floating-leaf and Emergent | 33.1 |
| **Total** | 70.2 |

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

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### 8.7.5 Deer Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Deer Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Deer Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Deer Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Deer Lake's implementation plan is compiled by describing how Deer Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Deer Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Deer Lake as part of this chain-wide project, it is up to Deer Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Deer Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** Deer Lake does not have a public access location, but is directly connected to the rest of the Three Lakes Chain of Lakes via Crystal (Mud), Dog and Big Stone Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Deer Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Deer Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Deer Lake or from Deer Lake elsewhere. If a Deer Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Deer Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Deer Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Deer Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Deer Lake and its stakeholders.

## *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Deer Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, Deer Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Deer Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Deer Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Deer Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Deer Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

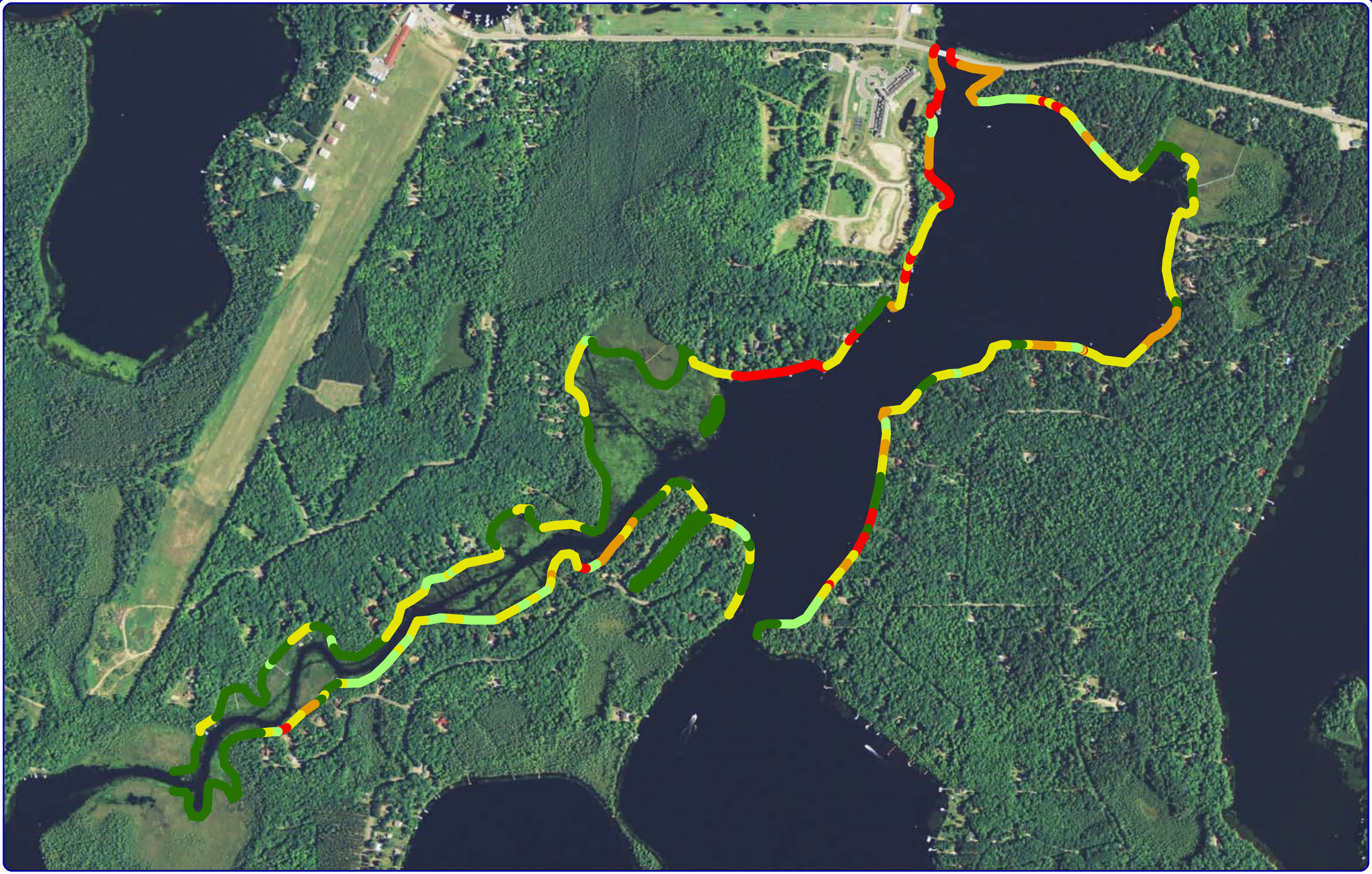
**Description:** As a part of this project, the entire Deer Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while 33% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## *Chain-wide Management Goal 6: Improve Fishery Resource and Fishing*

**<u>Management Action:</u>** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Deer Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Deer Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.



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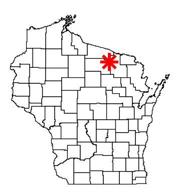
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Map date: March 7, 2012
*Filename: Deer_Map1_SA_2011.mxd*



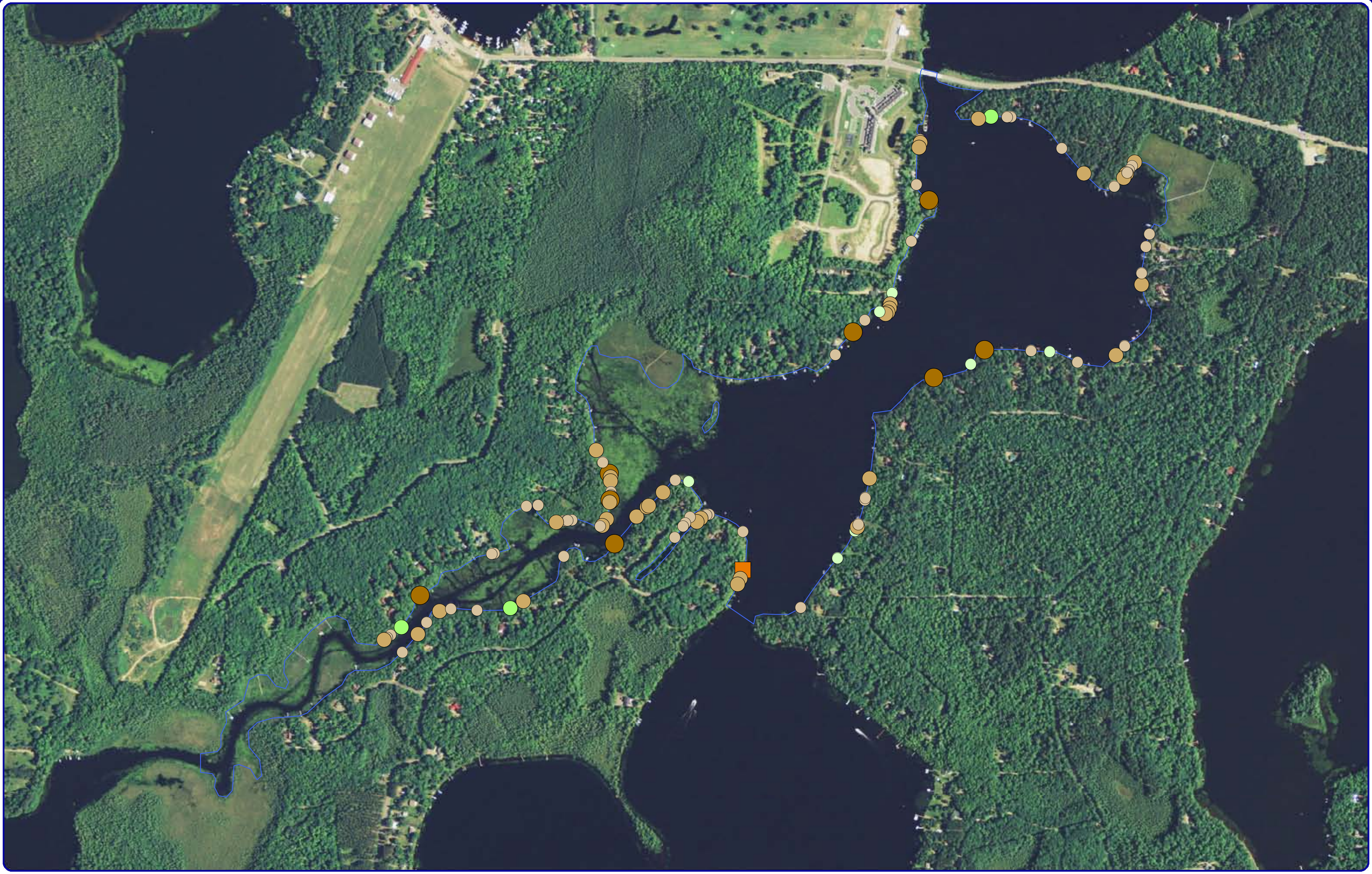
Project Location in Wisconsin

## Legend

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

Deer Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

**Shoreline Condition**



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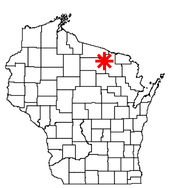
**Sources:**
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Map date: October 16, 2014
*Filename: Deer_CWH_2014.mxd*



Project Location in Wisconsin

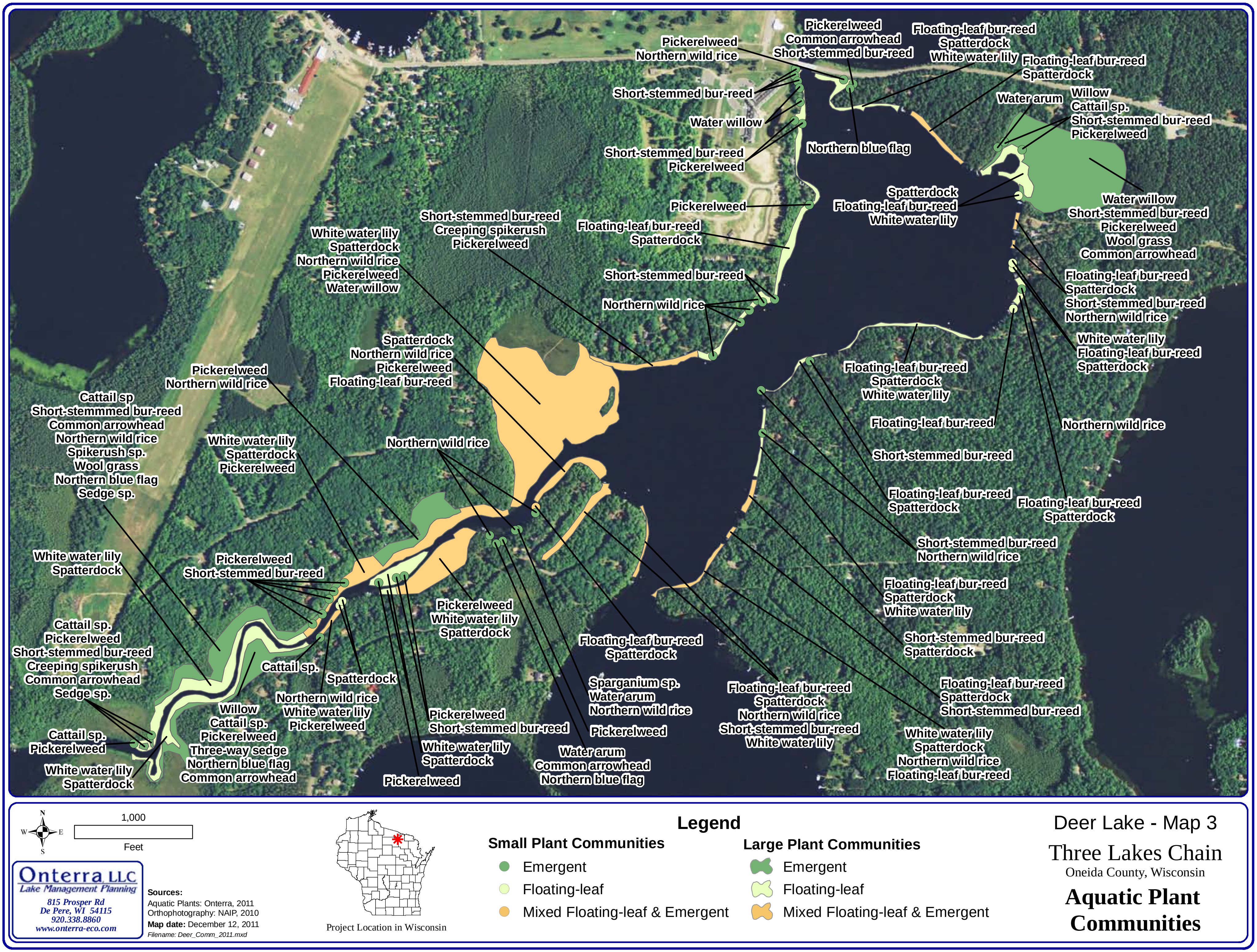
## Legend

**2-8 Inch Pieces**
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy (none)

**8+ Inch Pieces**
- No Branches
- Minimal Branches
- Moderate Branches (none)
- Full Canopy (none)

**Cluster of Pieces**
- No Branches (none)
- Minimal Branches (none)
- Moderate Branches
- Full Canopy (none)

Deer Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin
**2014 Coarse Woody Habitat**


Pickerelweed
Common arrowhead
Short-stemmed bur-reed
Floating-leaf bur-reed
Spatterdock
White water lily
Pickerelweed
Northern wild rice
Floating-leaf bur-reed
Spatterdock
Short-stemmed bur-reed
Water arum
Willow
Cattail sp.
Short-stemmed bur-reed
Pickerelweed
Water willow
Northern blue flag
Short-stemmed bur-reed
Pickerelweed
Spatterdock
Floating-leaf bur-reed
White water lily
Pickerelweed
Water willow
Short-stemmed bur-reed
Pickerelweed
Wool grass
Common arrowhead
Short-stemmed bur-reed
Creeping spikerush
Pickerelweed
Floating-leaf bur-reed
Spatterdock
White water lily
Spatterdock
Northern wild rice
Pickerelweed
Water willow
Short-stemmed bur-reed
Floating-leaf bur-reed
Spatterdock
Short-stemmed bur-reed
Northern wild rice
Northern wild rice
White water lily
Floating-leaf bur-reed
Spatterdock
Spatterdock
Northern wild rice
Pickerelweed
Floating-leaf bur-reed
Pickerelweed
Northern wild rice
Floating-leaf bur-reed
Spatterdock
White water lily
Cattail sp
Short-stemmmed bur-reed
Common arrowhead
Northern wild rice
Spikerush sp.
Wool grass
Northern blue flag
Sedge sp.
Floating-leaf bur-reed
Northern wild rice
White water lily
Spatterdock
Pickerelweed
Northern wild rice
Short-stemmed bur-reed
Floating-leaf bur-reed
Spatterdock
Floating-leaf bur-reed
Spatterdock
Short-stemmed bur-reed
Northern wild rice
White water lily
Spatterdock
Pickerelweed
Short-stemmed bur-reed
Floating-leaf bur-reed
Spatterdock
White water lily
Pickerelweed
White water lily
Spatterdock
Short-stemmed bur-reed
Spatterdock
Cattail sp.
Pickerelweed
Short-stemmed bur-reed
Creeping spikerush
Common arrowhead
Sedge sp.
Floating-leaf bur-reed
Spatterdock
Cattail sp.
Spatterdock
Sparganium sp.
Water arum
Northern wild rice
Floating-leaf bur-reed
Spatterdock
Northern wild rice
Short-stemmed bur-reed
White water lily
Floating-leaf bur-reed
Spatterdock
Short-stemmed bur-reed
Northern wild rice
White water lily
Pickerelweed
Willow
Cattail sp.
Pickerelweed
Three-way sedge
Northern blue flag
Common arrowhead
Pickerelweed
Short-stemmed bur-reed
Pickerelweed
Cattail sp.
Pickerelweed
White water lily
Spatterdock
White water lily
Spatterdock
Pickerelweed
Water arum
Common arrowhead
Northern blue flag
White water lily
Spatterdock
Northern wild rice
Floating-leaf bur-reed
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920.338.8860
www.onterra-eco.com
Sources:
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
Map date: December 12, 2011
Filename: Deer_Comm_2011.mxd
Project Location in Wisconsin
Legend
Small Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Large Plant Communities
Emergent
Floating-leaf
Mixed Floating-leaf & Emergent
Deer Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin
Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on Big Stone Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.8 Big Stone Lake

### *An Introduction to Big Stone Lake*

Big Stone Lake, Oneida County, is a drainage lake with a maximum depth of 57 feet and a surface area of 548 acres. This lake has a relatively large watershed when compared to the size of the lake. Big Stone Lake contains 33 native plant species, of which wild celery was the most common plant. Purple loosestrife, an invasive wetland plant, was observed during the 2011 lake surveys.

**Field Survey Notes**

*Much purple loosestrife observed in the southeastern wetland area of lake. Another colony spotted near Hwy 32.*

*Lake is quite deep. The littoral region is dominated by a sandy substrate. Primary plant species appears to be wild celery. Much unnatural shoreline observed during surveys.*

**Photo 8.8.1 Big Stone Lake, Oneida County**

**Lake at a Glance* – Big Stone Lake**

| | |
|---|---|
| **Morphology** | |
| Acreage | 548 |
| Maximum Depth (ft) | 57 |
| Mean Depth (ft) | 21 |
| Volume (acre-feet) | 11,701 |
| Shoreline Complexity | 4.4 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 21, 2011 |
| Comprehensive Survey Date | August 10, 2011 |
| Number of Native Species | 33 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | Purple loosestrife |
| Simpson's Diversity | 0.65 |
| Average Conservatism | 7.1 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, lowland drainage |
| Trophic State | Eutrophic / mesotrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 99:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

### 8.8.1 Big Stone Lake Water Quality

During 2011/2012, water quality data was collected from Big Stone Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored Secchi disk clarity since 2006, with advanced monitoring (total phosphorus and chlorophyll-*a*) beginning in 2007. These efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Big Stone Lake for years to come.

During this time, summer average total phosphorus concentrations have fluctuated, ranging between 8.0 and 42.0 µg/L (Figure 8.8.1-1). These values were recorded in 1981 and 1979, respectively; recent data shows less fluctuation in phosphorus values. Summer average values rank primarily within the TSI category of *Good,* with some *Fair* and *Excellent*. A weighted value across all years is nearly equal to the median for deep, lowland drainage lakes in the state. As with the total phosphorus values, average chlorophyll-*a* concentrations also rank in the *Good* category, and a weighted average is nearly equal to the median concentration for similar lakes across the state (Figure 8.8.1-2). Very little fluctuation is seen in this small dataset.

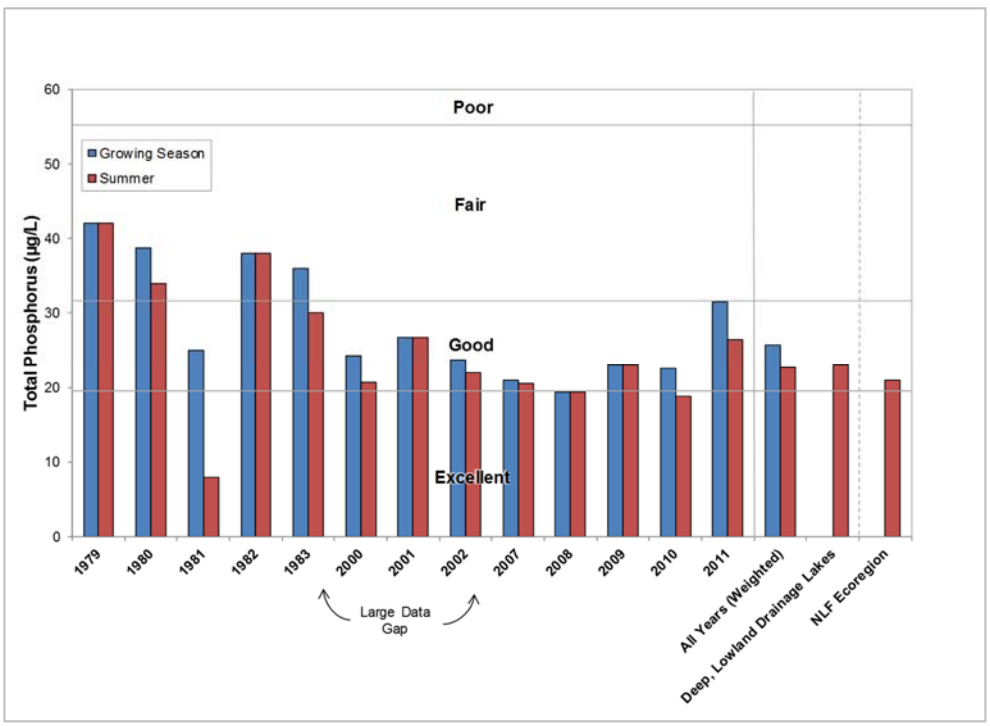



**Figure 8.8.1-1. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

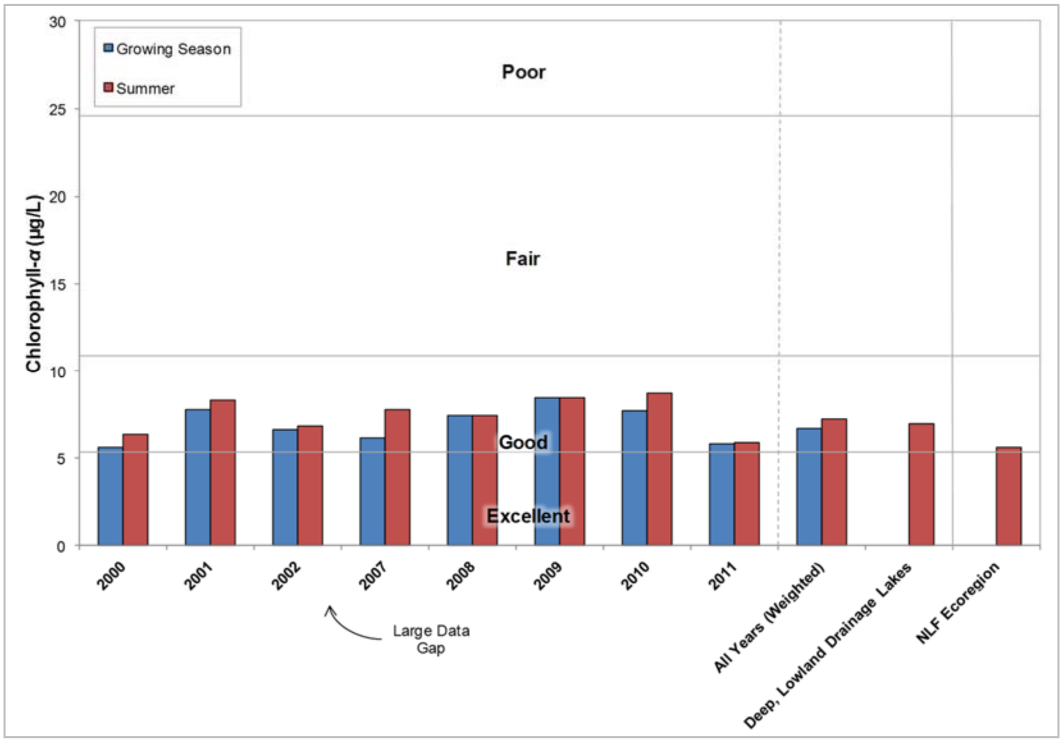



**Figure 8.8.1-2. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

Measurements of Secchi disk clarity span a similar timeframe as the other two primary water quality parameters, and show a little annual variance as well (Figure 8.8.1-3). All summer averages range between categories of *Fair* and *Good*, though a weighted average across all years is less than the median for deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However, other factors may influence the clarity of a lake's water as well. For example, in 2011 Onterra ecologists noted exceptionally dark water – more so than in previous years when studies had been completed on the Three Lakes Chain of lakes. As seen in Figure 8.8.3-1, nutrient levels were slightly higher in 2011, but chlorophyll-*a* concentrations were not elevated; in fact, they were slightly lower than in previous years (Figure 8.8.1-2). In that same year, the Secchi disk depth summer average was roughly 2.5 feet lower than in previous years (Figure 8.8.1-3). Clearly, presence or absence of algae is not the cause of the reduced water clarity in 2011.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Stone Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. It is possible that wetlands flushed the Three Lakes Chain with these organic acids in

2011. Even with higher-than-normal nutrients in the water column, the natural staining of the water reduced visibility as well as light penetration, which is likely the cause for relatively limited algal production in that year.

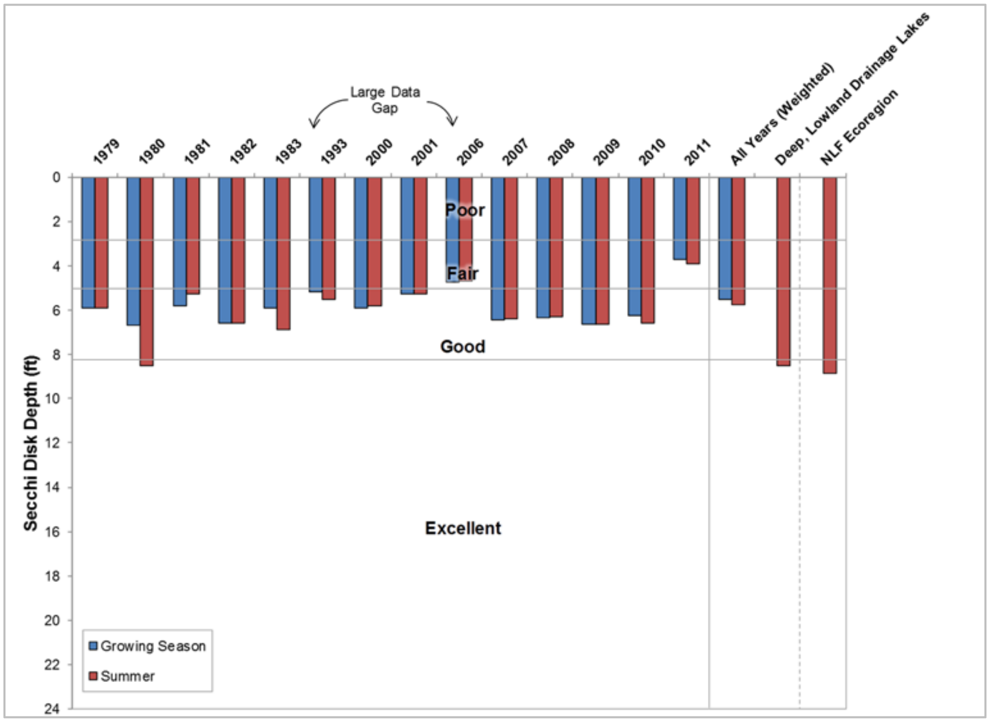



**Figure 8.8.1-3. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

**Big Stone Lake Trophic State**

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.8.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Big Stone Lake is in a borderline eutrophic/mesotrophic state.

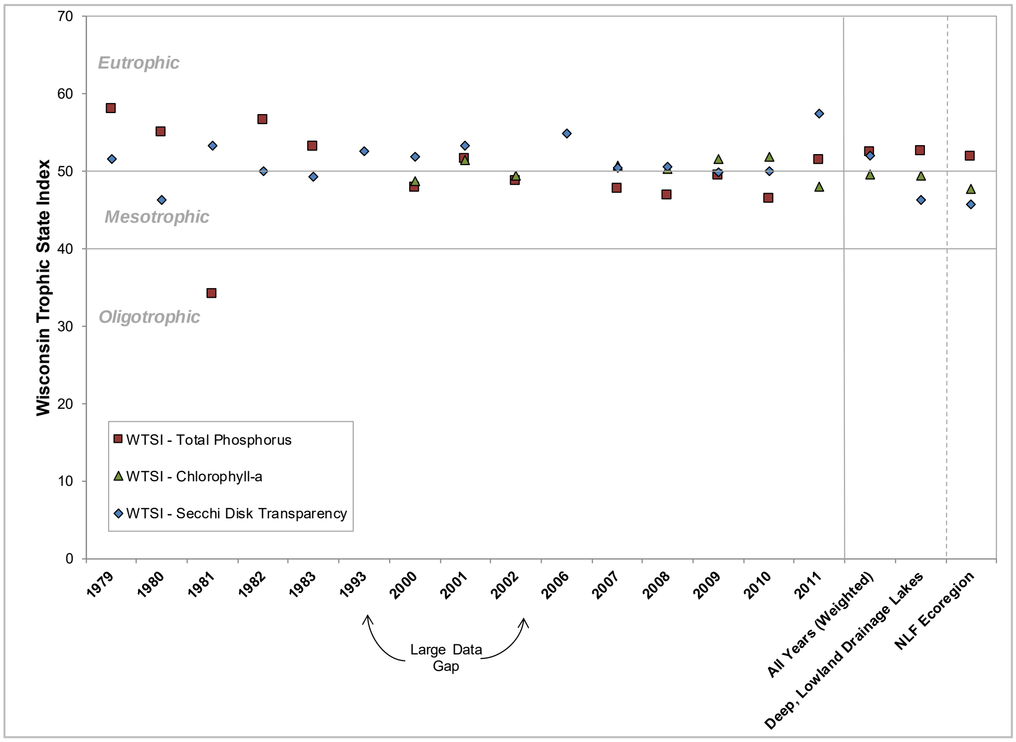



**Figure 8.8.1-4. Big Stone Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Big Stone Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Stone Lake by Onterra staff. Graphs of those data are displayed in Figure 8.8.1-5 for all sampling events.

Big Stone Lake mixed thoroughly during the spring (May) and fall (October) of 2011. This is the case in many Wisconsin lakes, as high winds and changing air temperatures during this time mix the water column up and distribute temperatures and oxygen throughout the lake. In the early summer months, the lake begins to stratify as temperatures increase in the top of the water column and remain constant towards the bottom. Dissolved oxygen is used by bacteria near the bottom of the lake to breakdown organic matter. As the decomposition occurs, oxygen is depleted and not replenished from the overlying water, which becomes stratified by June and continues through August. Once the fall winds begin, the lake mixes completely and oxygen is restored to the bottom of Big Stone Lake. Despite the late summer dip, dissolved oxygen levels remained sufficient in the upper 20 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Ample oxygen concentrations were also present within the winter months of 2012 as well, when dissolved oxygen is of most concern.

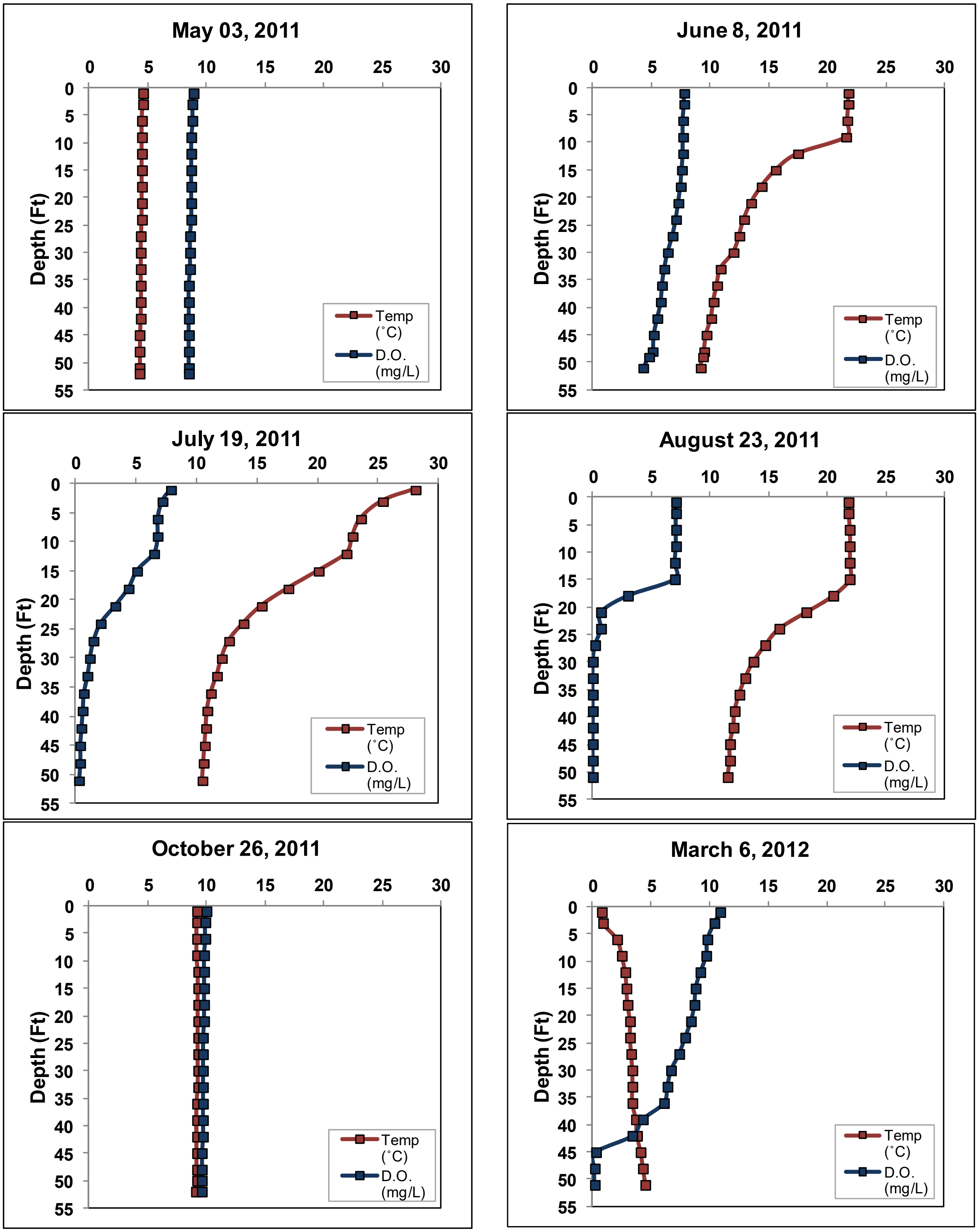



**Figure 8.8.1-5. Big Stone Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Big Stone 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 Big Stone 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Big Stone Lake's pH was measured at 7.0 during the summer months of 2011. This value is neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Big Stone Lake was measured at 21.3 (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.

Samples of calcium were also collected from Big Stone Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Stone Lake's pH of 7.0 falls at the lower end 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 Big Stone Lake was found to be 7.8 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. Results to be included in next draft.

## 8.8.2 Big Stone Lake Watershed Assessment

Big Stone Lake's watershed is 55,027 acres in size. Compared to Big Stone Lake's size of 548 acres, this makes for an incredibly large watershed to lake area ratio of 99:1.

Exact land cover calculation and modeling of nutrient input to Big Stone Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.8.3 Big Stone Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Big Stone Lake's immediate shoreline was assessed in terms of its development. Big Stone Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.8 miles of natural/undeveloped and developed-natural shoreline (26% of the entire shoreline) were observed during the survey (Figure 8.8.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.1 miles of urbanized and developed–unnatural shoreline (30% of the total shoreline) was observed. If restoration of the Big Stone Lake shoreline 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. Big Stone Lake Map 1 displays the location of these shoreline lengths around the entire lake.

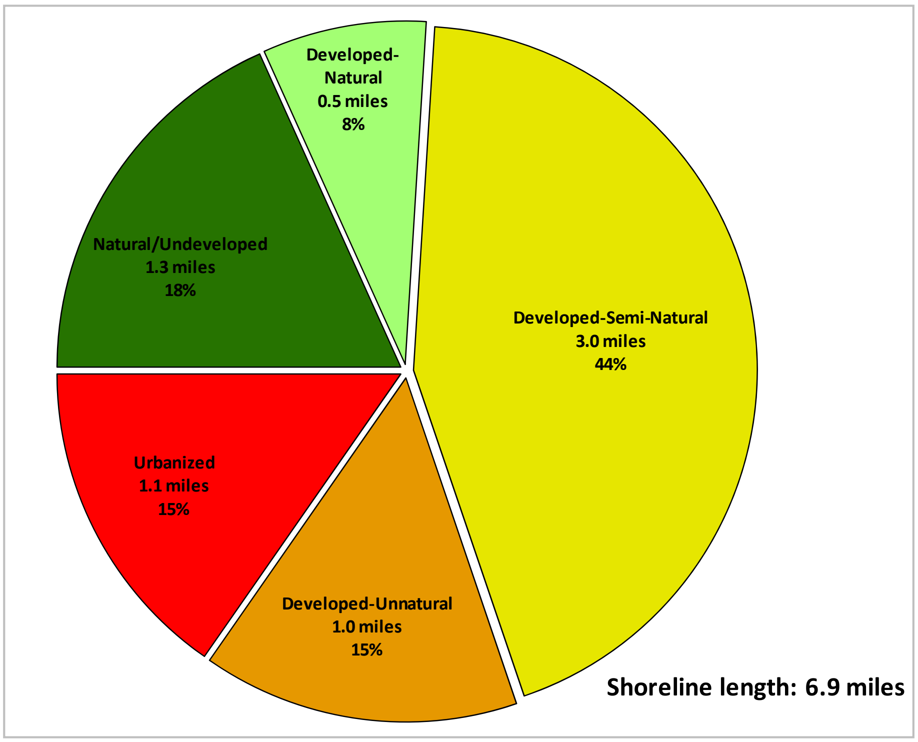



**Figure 8.8.3-1. Big Stone Lake shoreland categories and total lengths.** Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Big Stone Lake Map 1.

## Coarse Woody Habitat

Big Stone Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 98 pieces of coarse woody habitat were observed along 6.9 miles of shoreline, which gives Big Stone Lake a coarse woody habitat to shoreline mile ratio of 14:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Big Stone Lake Map 2.

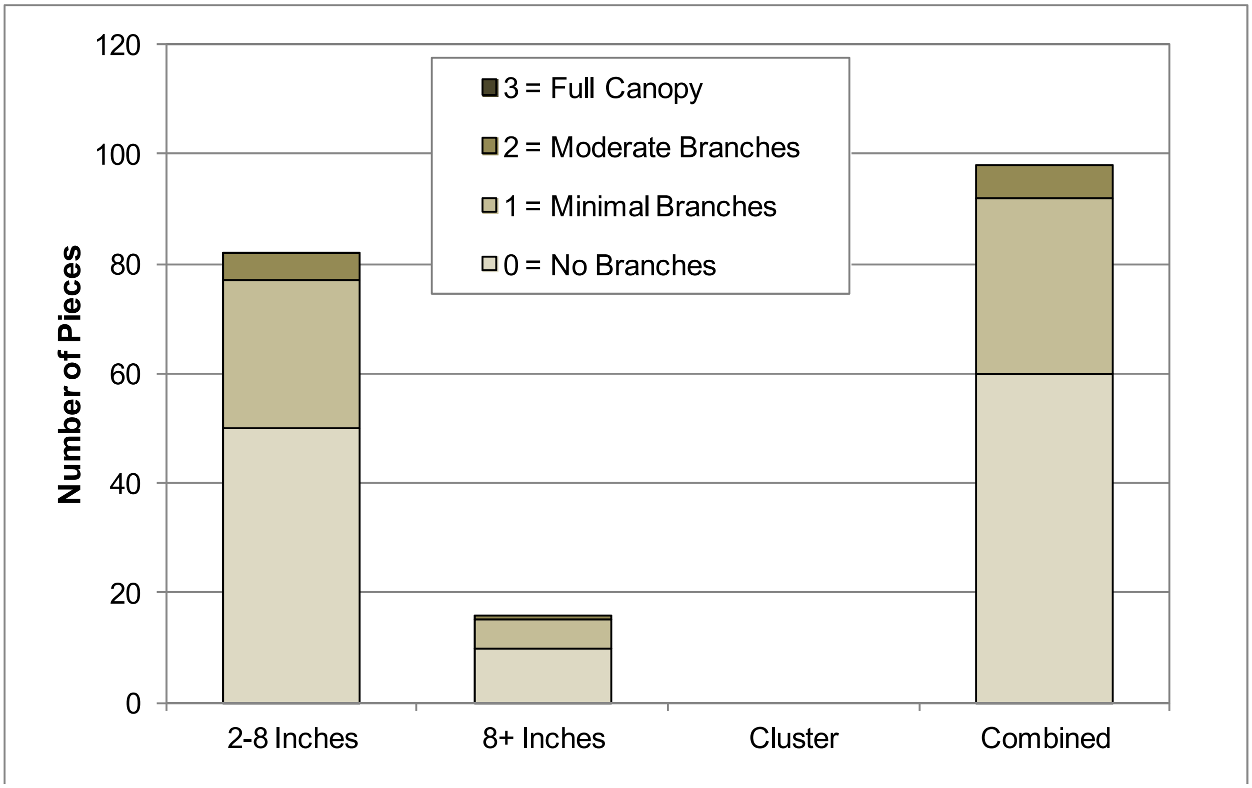



**Figure 8.8.3-2. Big Stone Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Big Stone Lake coarse woody habitat can be found on Big Stone Lake Map 2.

## 8.8.4 Big Stone Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Big Stone Lake on June 21, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not exist in Big Stone Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Big Stone Lake on August 10, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to create the aquatic plant community map (Big Stone Lake Map 2). During all surveys, 33 species of native aquatic plants were located in Big Stone Lake (Table 8.8.4-1). 22 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of seven feet, which is comparable to the maximum depth of plant growth within the other Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in these surveys indicate that the overall aquatic plant community is healthy and fairly diverse.

Of the 170 point-intercept locations sampled within the littoral zone, approximately 66% contained aquatic vegetation. Approximately 92% of the point-intercept sampling locations where sediment data was collected at were sand, 4% consisted of a fine, organic substrate (muck) and 5% were determined to be rocky.

**Table 8.8.4-1. Aquatic plant species located in the Big Stone Lake during the 2011 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2011 (Onterra) |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Decodon verticillatus* | Water-willow | 7 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | I |
| | *Iris versicolor* | Northern blue flag | 5 | I |
| | *Lythrum salicaria* | Purple loosestrife | Exotic | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Typha spp.* | Cattail spp. | 1 | I |
| | *Zizania palustris* | Northern wild rice | 8 | X |
| FL | *Brasenia schreberi* | Watershield | 7 | X |
| | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium emersum* | Short-stemmed bur-reed | 8 | I |
| | *Sparganium eurycarpum* | Common bur-reed | 5 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Callitriche palustris* | Common water starwort | 8 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | I |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton obtusifolius* | Blunt-leaf pondweed | 9 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton vaseyi* | Vasey's pondweed | 10 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| SE | *Eleocharis acicularis* | Needle spikerush | 5 | 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*

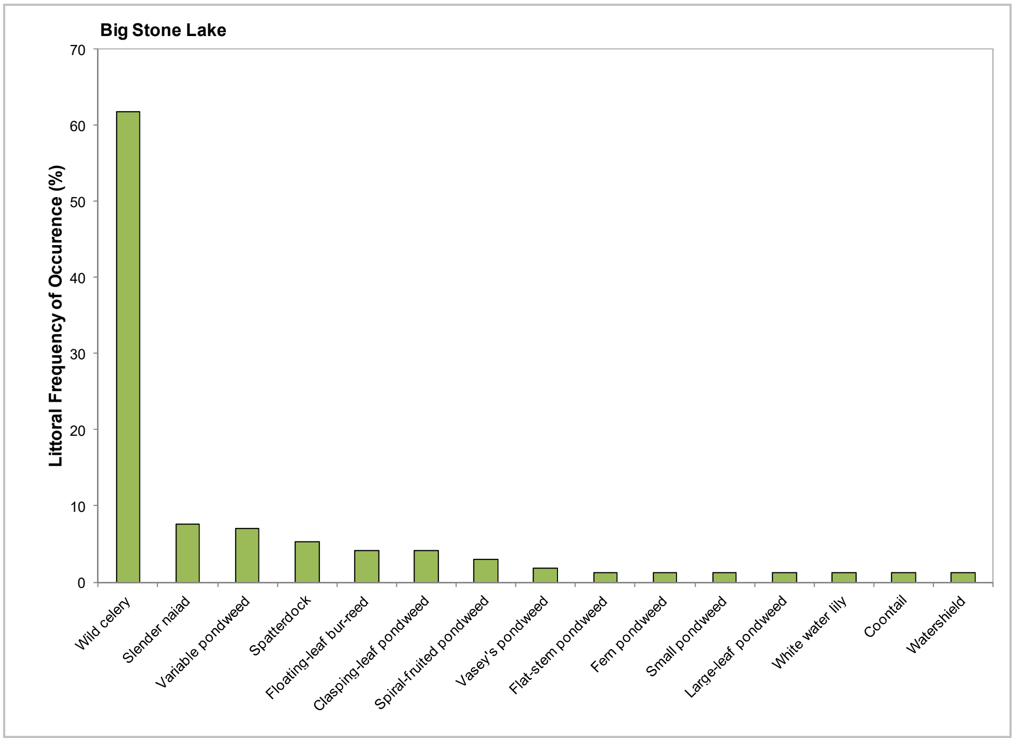



**Figure 8.8.4-1 Big Stone Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 1.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.8.4-1 (above) shows that wild celery, slender naiad and variable pondweed were the most frequently encountered plants within Big Stone Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Variable pondweed, is a submersed plant that produces a thin, cylindrical stem that has numerous branches. These branches produce linear leaves that grow anywhere from four to eleven centimeters long, and may produce three to seven veins per leaf. The floating leaves this plant produces are much more oval in shape, and may have 11 to 19 veins per leaf. This plant also hybridizes easily with other pondweed (*Potamogeton*) species; thus, this plant can appear quite variable in size and shape and is named appropriately.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only northern water milfoil were located from Big Stone Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. It was found only incidentally on Big Stone Lake; the presence of much hard substrate may be keeping this plant from establishing itself to a larger level. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

33 species of aquatic plants (including incidentals) were found in Big Stone Lake, which is more than the regional and state median value. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Big Stone Lake's plant community (0.65) lies below the Northern Lakes and Forests Lakes ecoregion median value (0.86), indicating the lake's plant community holds low diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 wild celery was found at 62% of the sampling locations, its relative frequency of occurrence is 58%. Explained another way, if 100 plants were randomly sampled from Big Stone Lake, 58 of them would be wild celery. This distribution can be observed in Figure 8.8.4-2, where together seven species account for 87% of the population of plants within Big Stone Lake, while the other 15 species account for the remaining 13%. Wild celery dominates the plan community, with a relative frequency of 58%. Eleven additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.8.4-1 as incidentals.

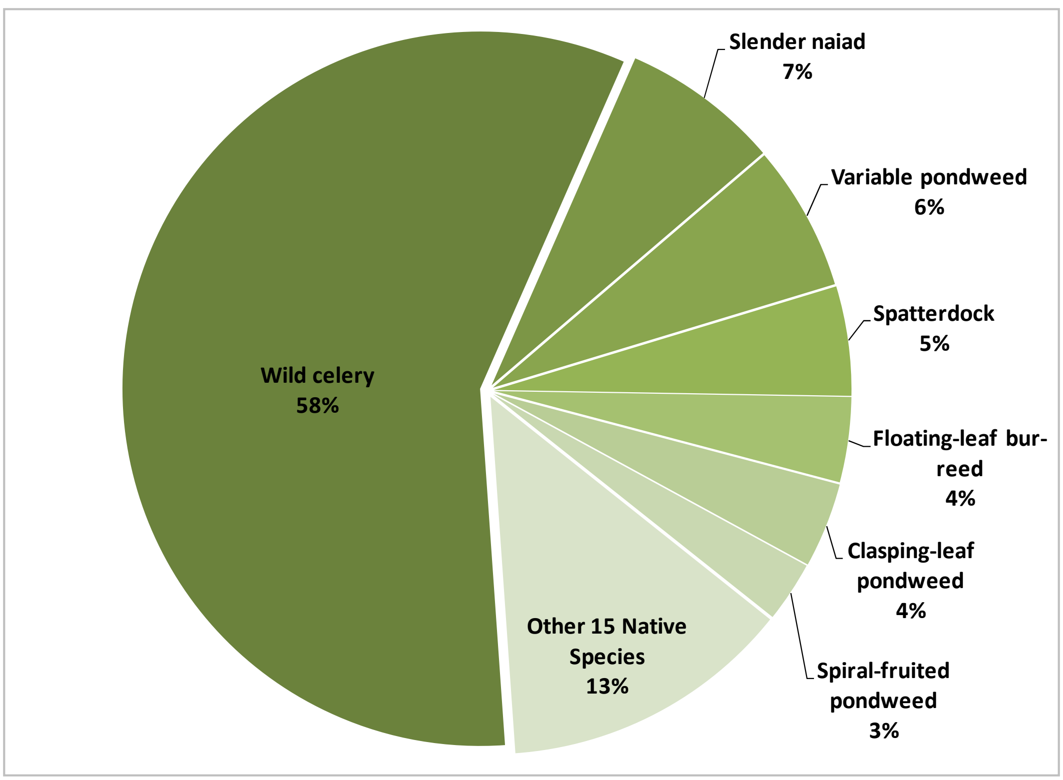



**Figure 8.8.4-2 Big Stone Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2011 point-intercept survey.

Big Stone Lake's average conservatism value (7.1) is higher than both the state and ecoregion median. This indicates that the plant community of Big Stone Lake is indicative of an undisturbed system. This is not surprising considering Big Stone Lake's plant community has moderate diversity but high species richness. Combining Big Stone Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.3 which is above the median values of the ecoregion and state.

The quality of Big Stone Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 27.5 acres of the lake contains these types of plant communities (Big Stone Lake Map 2, Table 8.8.4-2). Eleven floating-leaf and emergent species were located on Big Stone Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

**Table 8.8.4-2. Big Stone Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 8.2 |
| Floating-leaf | 19.3 |
| Mixed Floating-leaf and Emergent | 0.1 |
| **Total** | 27.5 |

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

## Aquatic Invasive Species in Big Stone Lake

During the 2011 community mapping survey, numerous occurrences of purple loosestrife were located along the shorelines of Big Stone Lake and within shallow emergent plant communities (Big Stone Lake Map 2, Table 8.8.4-2). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

Purple loosestrife has likely been present in Big Stone Lake for some time. There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Additional purple loosestrife monitoring during periods of control efforts would be required to ensure the eradication of the plant from the shorelines of Big Stone Lake. .

## 8.8.5 Big Stone Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Stone Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Stone Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Stone Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Stone Lake's implementation plan is compiled by describing how Big Stone Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Big Stone Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

| | |
|---|---|
| **Management Action:** | Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies. |
| **Timeframe:** | In progress. |
| **Facilitator:** | Board of Directors. |
| **Grant:** | Lake Management Protection Grant (Diagnostic/Feasibility Studies). |
| **Description:** | Though studies have been completed on Big Stone Lake as part of this chain-wide project, it is up to Big Stone Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.<br><br>In addition to current monitoring and protection, Big Stone Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc. |

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** Big Stone Lake contains a public access and is directly connected to the rest of the Three Lakes Chain of Lakes via Deer and Laurel Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Stone Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Stone Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Stone Lake or from Big Stone Lake elsewhere. If a Big Stone Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Big Stone Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Stone Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Big Stone Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Stone Lake and its stakeholders.

## *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Stone Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, Big Stone Lake is enrolled in the CLMN's advanced water quality monitoring program. This means that in addition to Secchi disk clarity, volunteers also monitor phosphorus and chlorophyll-*a* on the lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Big Stone Lake is protected. Volunteers from Big Stone Lake must be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Stone Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

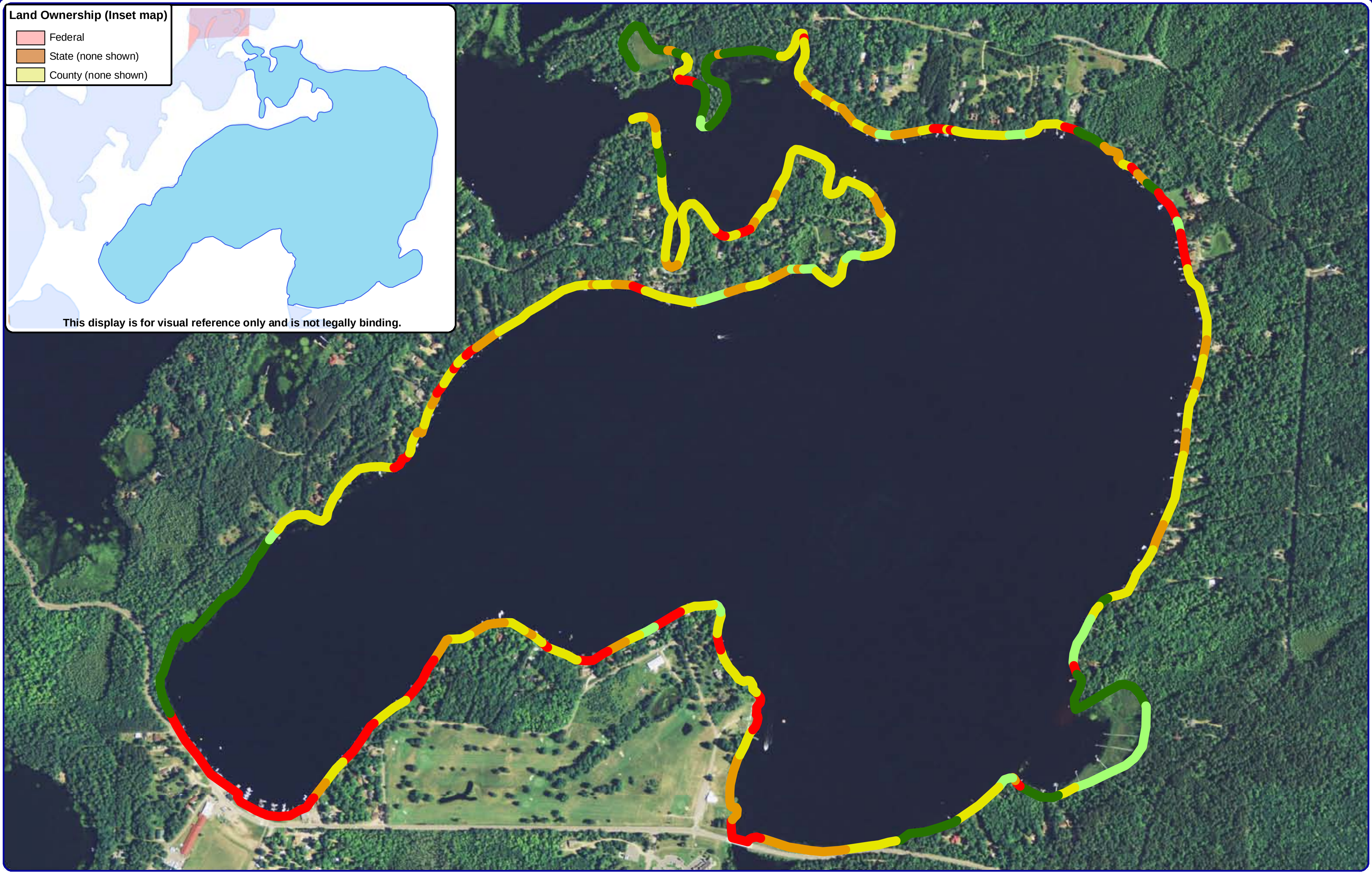
**Description:** As a part of this project, the entire Big Stone Lake shoreline was categorized in terms of its development. According to the results from this survey, 30% of the shoreline is in an urbanized or developed-unnatural state, while 44% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Stone Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Stone Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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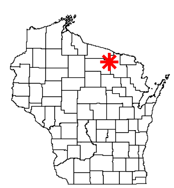
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Federal Land: USDA Forest Service
Map date: March 7, 2012
*Filename: BigStone_Map1_SA_2011.mxd*



Project Location in Wisconsin

## Legend

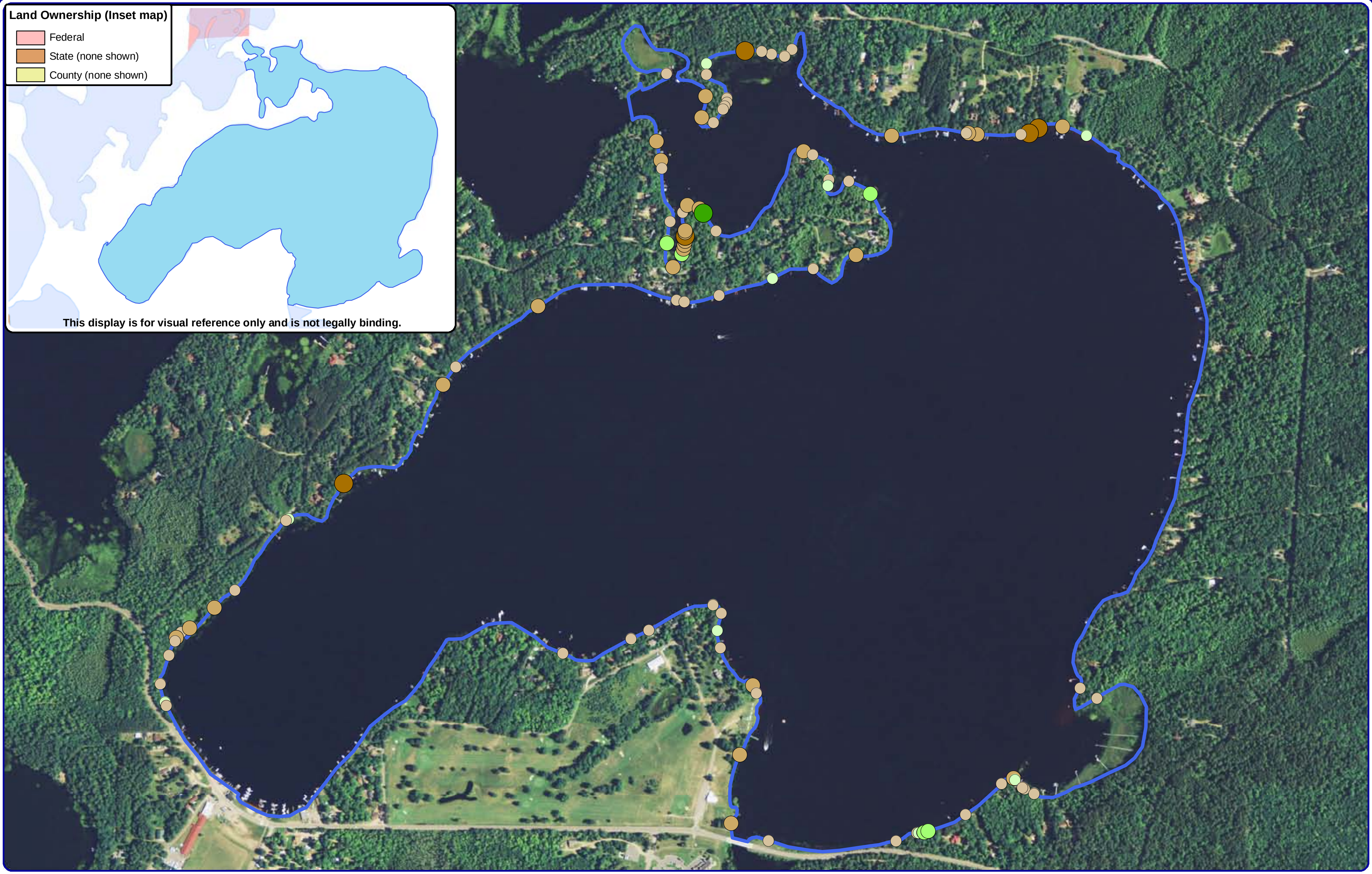
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Big Stone Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

**Shoreland Condition**

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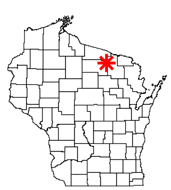
**Onterra LLC**
*Lake Management Planning*


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


**Sources:**
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Federal Land: USDA Forest Service
Map date: October 17, 2014
*Filename: BigStone_CWH_2014.mxd*



Project Location in Wisconsin

## 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 (none) | Moderate Branches |
| Full Canopy (none) | Full Canopy (none) | Full Canopy (none) |

Big Stone Lake - Map 2

# Three Lakes Chain

Oneida County, Wisconsin

**2014 Coarse Woody Habitat**


## Legend

**Small Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife

**Large Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Contains Purple Loosestrife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**Sources:**
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
**Map date:** December 13, 2011
*Filename: BigStone_Comm_2011.mxd*

# Big Stone Lake - Map 3

## Three Lakes Chain

Oneida County, Wisconsin

# Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on Laurel Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.9 Laurel Lake

### An Introduction to Laurel Lake

Laurel Lake, Oneida County, is a drainage lake with a maximum depth of 27 feet and a surface area of 232 acres. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Laurel Lake contains 33 native plant species, of which wild celery was the most common. Purple loosestrife, an exotic emergent wetland plant, was found along Laurel Lake.

**Field Survey Notes**

*Many emergent and floating-leaf plants as well as islands located in north-eastern section of lake – very diverse habitat, great for wildlife!*

**Photo 8.9.1 Laurel Lake, Oneida County**

### Lake at a Glance* – Laurel Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 232 |
| Maximum Depth (ft) | 27 |
| Mean Depth (ft) | *Not available* |
| Volume (acre-feet) | *Not available* |
| Shoreline Complexity | 7.4 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 22, 2011 |
| Comprehensive Survey Date | August 10, 2011 |
| Number of Native Species | 33 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | Purple loosestrife |
| Simpson's Diversity | 0.77 |
| Average Conservatism | 6.9 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, Lowland Drainage Lake |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 242:1 |

*These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.9.1 Laurel Lake Water Quality

During 2011/2012, water quality data was collected from Laurel Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Citizens Lake Monitoring Network (CLMN) volunteers have monitored water clarity since 2006. These efforts provide a database of historical clarity data which may be compared against recent data in an effort to detect any trends that may be occurring in the water quality of the lake. These efforts should be continued in order to understand trends in the water quality of Laurel Lake. Unfortunately, only Secchi disk clarity has been monitored in the past, as monitoring for total phosphorus and chlorophyll-*a* requires additional sampling and funding.

In 2011, summer total phosphorus concentrations averaged 29.3 µg/L, which is higher than the median value for other deep, lowland drainage lakes in the state of Wisconsin (23.0 µg/L). As with the total phosphorus values, 2011 average summer chlorophyll-*a* concentrations are also somewhat higher than the median for other deep, lowland drainage lakes statewide (Table 8.9.1-1). Both the total phosphorus and chlorophyll-*a* values rank as *Good* in the Trophic State Index.

**Table 8.9.1-1. Laurel Lake, state-wide deep, lowland drainage lakes, and regional values for water quality parameters.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

| | Secchi (feet) | | | | Chlorophyll-*a* (µg/L) | | | | Total Phosphorus (µg/L) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Growing Season | | Summer | | Growing Season | | Summer | | Growing Season | | Summer | |
| Year | Count | Mean | Count | Mean | Count | Mean | Count | Mean | Count | Mean | Count | Mean |
| 1979 | 1 | 4.6 | 1 | 4.6 | | | | | | | | |
| 1993 | 4 | 3.5 | 4 | 3.5 | | | | | | | | |
| 1994 | 7 | 4.4 | 4 | 4.6 | | | | | | | | |
| 2006 | 6 | 4.4 | 4 | 4.5 | | | | | | | | |
| 2007 | 8 | 6.5 | 7 | 6.6 | | | | | | | | |
| 2008 | 9 | 5.4 | 8 | 5.3 | | | | | | | | |
| 2009 | 7 | 7.0 | 7 | 7.0 | | | | | | | | |
| 2010 | 4 | 6.3 | 4 | 6.3 | | | | | | | | |
| 2011 | 10 | 3.4 | 7 | 3.6 | 5 | 8.6 | 3 | 9.6 | 5 | 31.0 | 3.0 | 29.3 |
| All Years (Weighted) | | 5.1 | | 5.3 | | 8.6 | | 9.6 | | 31.0 | | 29.3 |
| Deep, Lowland Drainage Lakes | | | | 8.5 | | | | 7.0 | | | | 23.0 |
| NLF Ecoregion | | | | 8.9 | | | | 5.6 | | | | 21.0 |

Measurements of Secchi disk clarity span a longer timeframe than the other two primary water quality parameters (Figure 8.9.1-1). All summer averages range between categories of *Fair* and *Good*; but a weighted average across all years is less than the median for other deep, lowland drainage lakes statewide. Secchi disk clarity is often tied to algal abundance – the more algae in the water column, the less clear the water will be. However Secchi disk clarity is influenced by many other factors which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Laurel Lake and the rest of the Three Lakes Chain of lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Laurel Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

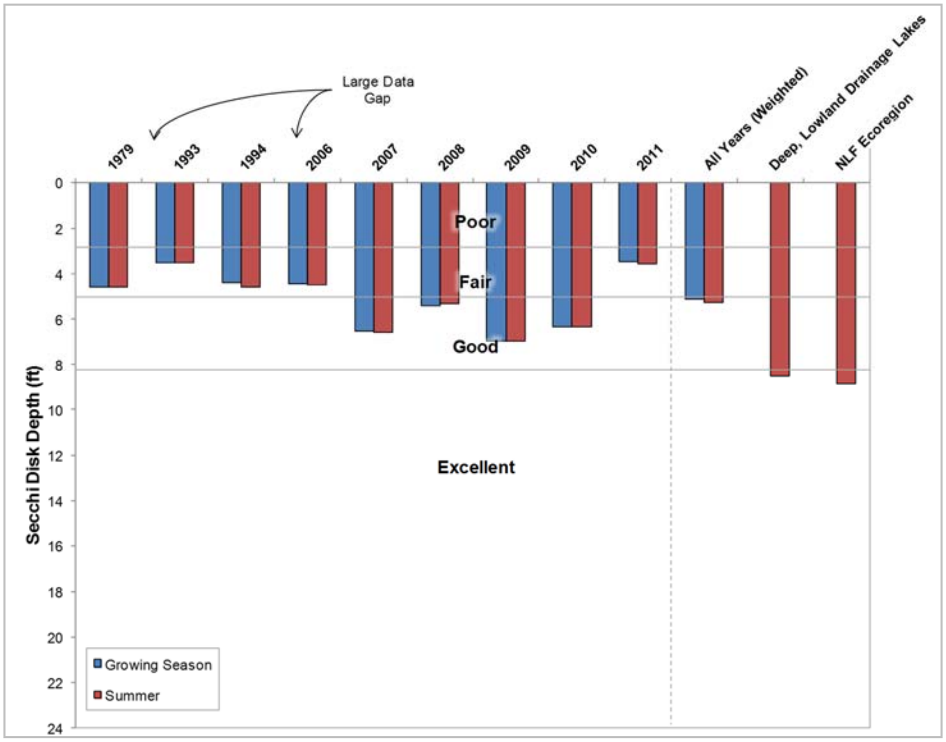



**Figure 8.9.1-1. Laurel Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

## Laurel Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.9.1-2). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Laurel Lake is in a eutrophic state.

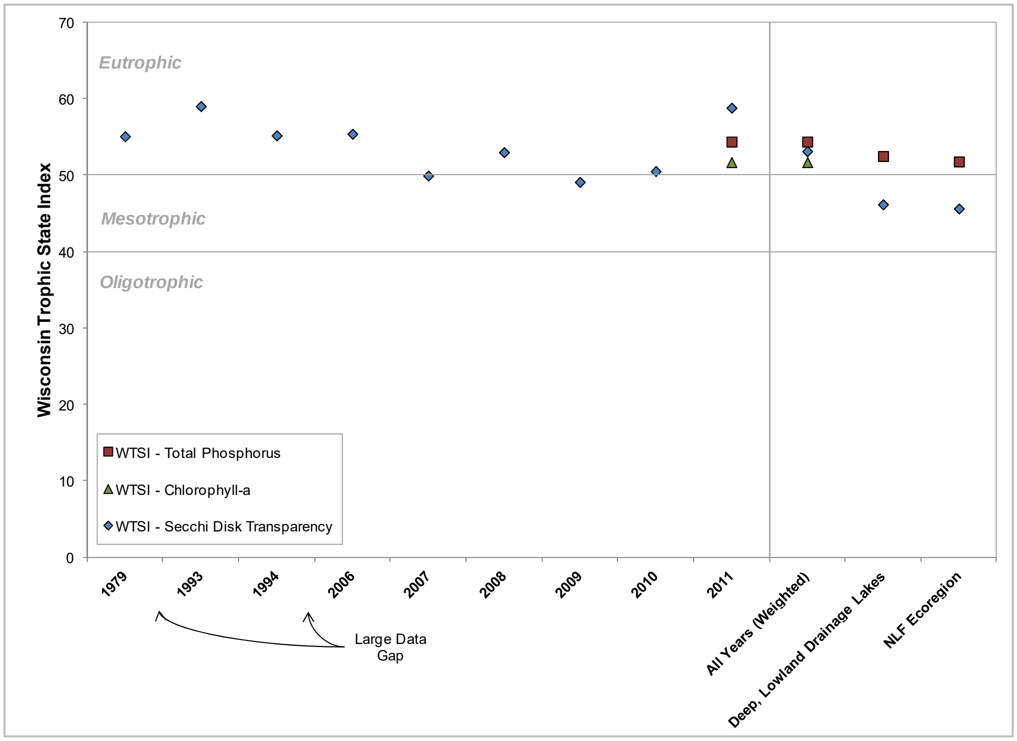



**Figure 8.9.1-2. Laurel Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer and growing season surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Laurel Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Laurel Lake by Onterra staff. Graphs of those data are displayed in Figure 8.9.1-3 for all sampling events.

Laurel Lake mixed thoroughly during the spring (May) and fall (October) of 2011. This is the case in many Wisconsin lakes, as high winds and changing air temperatures during this time mix the water column up and distribute temperatures and oxygen throughout the lake. In the early summer months, the lake begins to stratify as temperatures increase in the top of the water column and remain constant towards the bottom. Dissolved oxygen is used by bacteria near the bottom of the lake to breakdown organic matter. As the decomposition occurs, oxygen is depleted and not replenished from the overlying water, which has been fully stratified by August. Once the October winds begin, the lake mixes completely and oxygen is restored to the bottom of Laurel Lake.

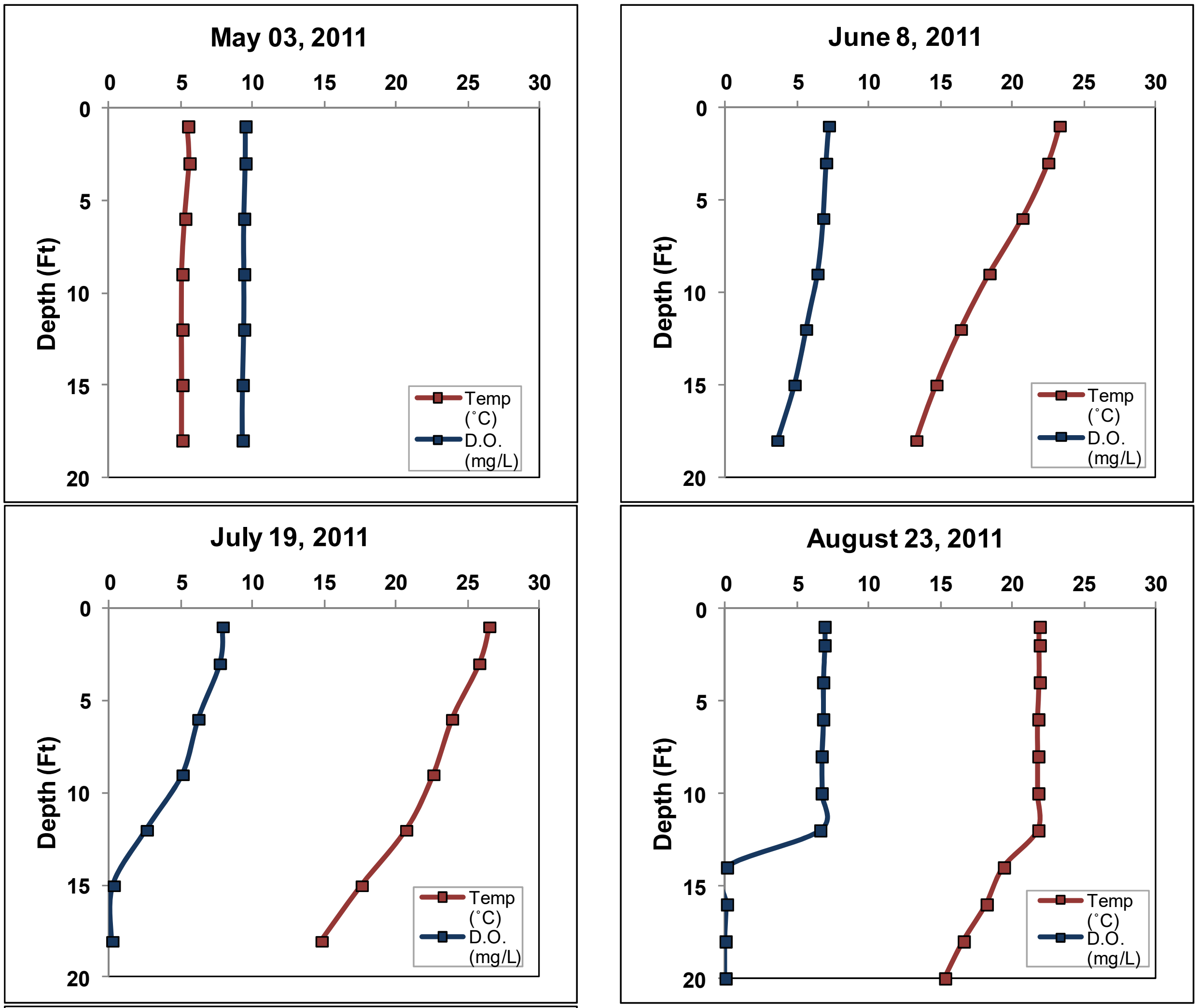
## Additional Water Quality Data Collected at Laurel Lake

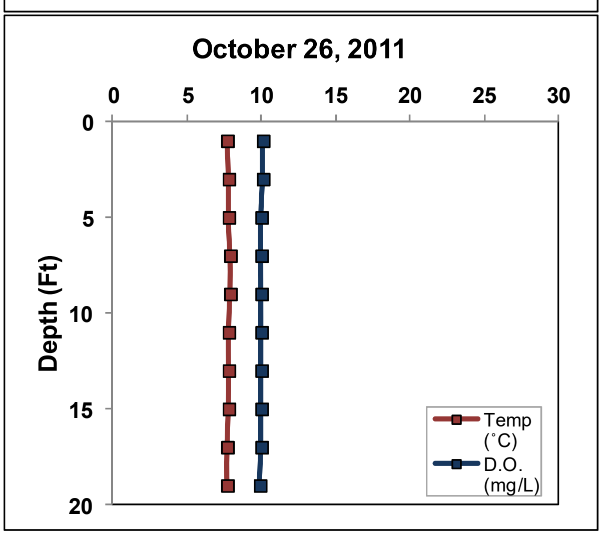
The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Laurel Lake's water quality and are recommended as a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

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Laurel Lake's pH was measured at about 7.3 during summer 2011 surveys. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Laurel Lake was measured at 22.1 (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.

Samples of calcium were also collected from Laurel Lake during the summer of 2011. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Laurel Lake's pH of 7.3 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Laurel Lake was found to be 7.5 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2011 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.




*No profile was taken during the winter WQ sampling due to equipment failure.*

**Figure 8.9.1-3. Laurel Lake dissolved oxygen and temperature profiles.**

## 8.9.2 Laurel Lake Watershed Assessment

Laurel Lake's watershed is 56,382 acres in size. Compared to Laurel Lake's size of 232 acres, this makes for an incredibly large watershed to lake area ratio of 242:1.

Exact land cover calculation and modeling of nutrient input to Laurel Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.9.3 Laurel Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2011, Laurel Lake's immediate shoreline was assessed in terms of its development. Laurel Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.1 miles of natural/undeveloped and developed-natural shoreline (61% of the entire shoreline) were observed during the survey (Figure 8.9.3-1). 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, 1.0 mile of urbanized and developed–unnatural shoreline (14% of the total shoreline) was observed. If restoration of the Laurel Lake shoreline 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. The Laurel Lake Map 1 displays the location of these shoreline lengths around the entire lake.

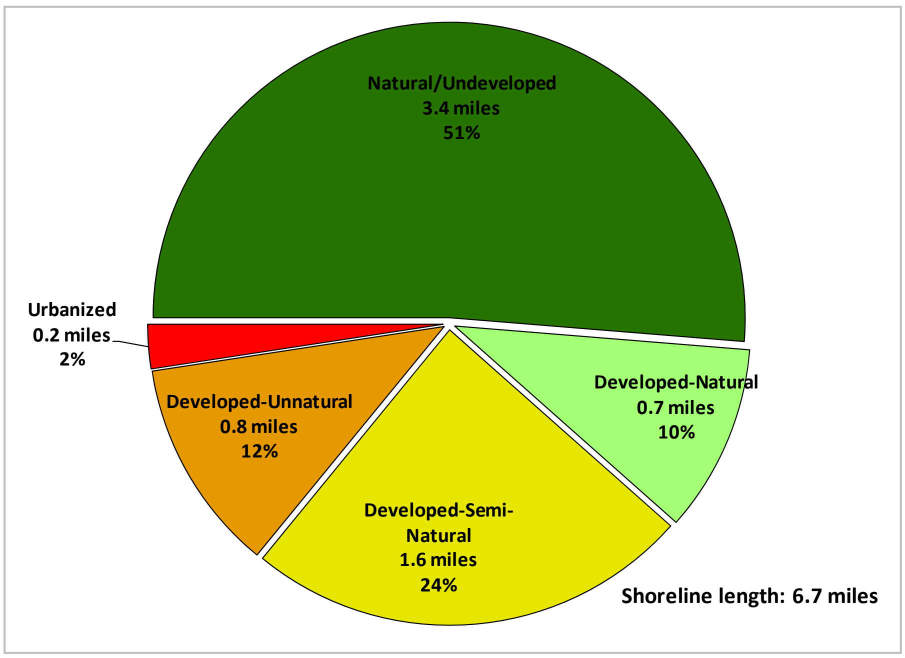



**Figure 8.9.3-1. Laurel Lake shoreland categories and total lengths.** Based upon a late summer 2011 survey. Locations of these categorized shorelands can be found on the Laurel Lake Map 1.

## Coarse Woody Habitat

Laurel Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 103 pieces of coarse woody habitat were observed along 5.8 miles of shoreline, which gives Laurel Lake a coarse woody habitat to shoreline mile ratio of 18:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Laurel Lake Map 2.

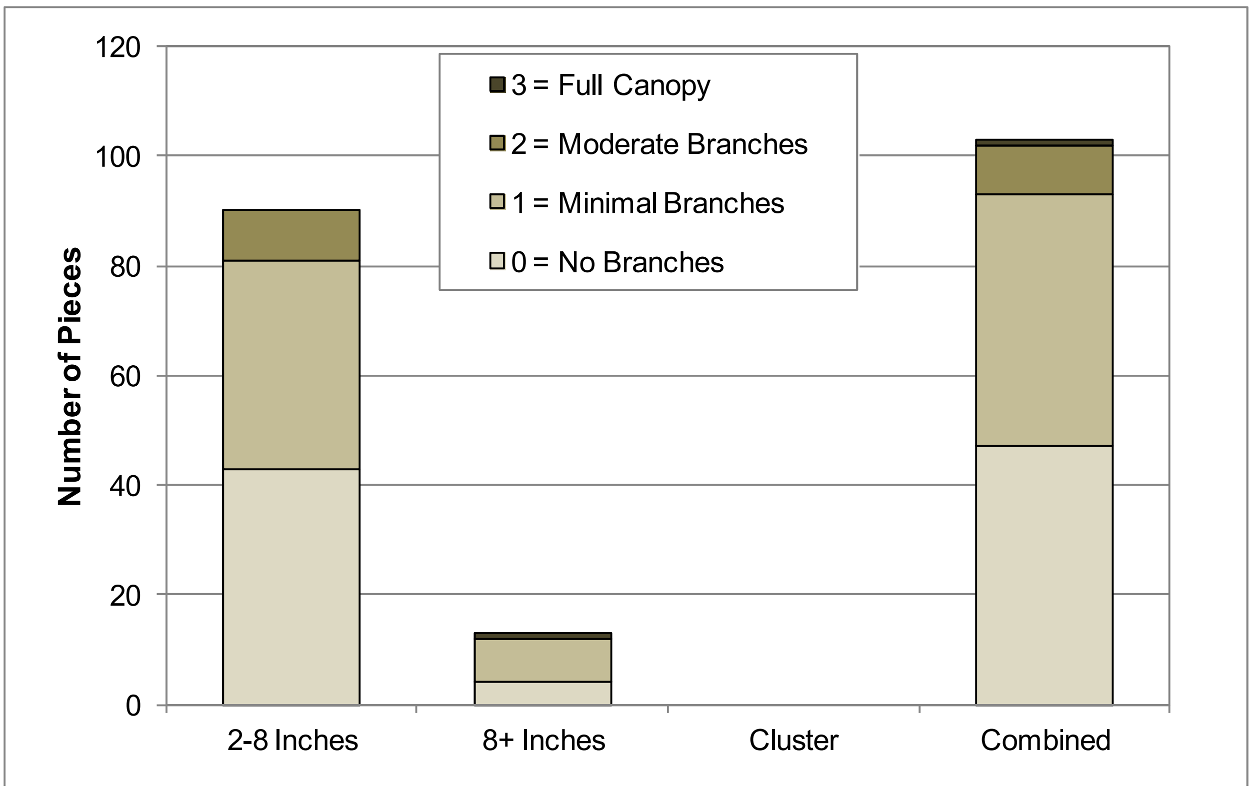



**Figure 8.9.3-2. Laurel Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Laurel Lake coarse woody habitat can be found on Laurel Lake Map 2.

## 8.9.4 Laurel Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Laurel Lake on June 22, 2011. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Laurel Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Laurel Lake on August 10, 2011 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 10 & 11 to create the aquatic plant community map (Laurel Lake Map 2). During all surveys, 33 species of native aquatic plants were located in Laurel Lake (Table 8.9.4-1). 24 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. An additional exotic plant, purple loosestrife, was found along the shoreline of Laurel Lake. Submergent aquatic plants were found growing to a depth of eight feet, which is comparable to the maximum depth of plants in the other lakes within the Three Lakes Chain of lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and fairly diverse.

Of the 158 point-intercept locations sampled within the littoral zone, approximately 71% contained aquatic vegetation. Approximately 36% of the point-intercept sampling locations where sediment data was collected at were sand, 63% consisted of a fine, organic substrate (muck) and 1% were determined to be rocky.

**Table 8.9.4-1. Aquatic plant species located in the Laurel Lake during the 2011 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2011 (Onterra) |
|---|---|---|---|---|
| Emergent | Dulichium arundinaceum | Three-way sedge | 9 | I |
| | Decodon verticillatus | Water-willow | 7 | I |
| | Eleocharis palustris | Creeping spikerush | 6 | I |
| | Iris versicolor | Northern blue flag | 5 | I |
| | Lythrum salicaria | Purple loosestrife | Exotic | I |
| | Pontederia cordata | Pickerelweed | 9 | X |
| | Sagittaria latifolia | Common arrowhead | 3 | I |
| | Scirpus cyperinus | Wool grass | 4 | I |
| | Typha spp. | Cattail spp. | 1 | I |
| | Zizania palustris | Northern wild rice | 8 | I |
| FL | Brasenia schreberi | Watershield | 7 | X |
| | Nuphar variegata | Spatterdock | 6 | X |
| | Nymphaea odorata | White water lily | 6 | X |
| FL/E | Sparganium eurycarpum | Common bur-reed | 5 | I |
| | Sparganium fluctuans | Floating-leaf bur-reed | 10 | X |
| Submergent | Chara spp. | Muskgrasses | 7 | X |
| | Ceratophyllum demersum | Coontail | 3 | X |
| | Elodea nuttallii | Slender waterweed | 7 | X |
| | Isoetes sp. | Quillwort species | N/A | X |
| | Megalodonta beckii | Water marigold | 8 | X |
| | Myriophyllum sibiricum | Northern water milfoil | 7 | X |
| | Najas flexilis | Slender naiad | 6 | X |
| | Potamogeton epihydrus | Ribbon-leaf pondweed | 8 | X |
| | Potamogeton zosteriformis | Flat-stem pondweed | 6 | X |
| | Potamogeton spirillus | Spiral-fruited pondweed | 8 | X |
| | Potamogeton vaseyi | Vasey's pondweed | 10 | X |
| | Potamogeton pusillus | Small pondweed | 7 | X |
| | Potamogeton robbinsii | Fern pondweed | 8 | X |
| | Potamogeton richardsonii | Clasping-leaf pondweed | 5 | X |
| | Potamogeton gramineus | Variable pondweed | 7 | X |
| | Utricularia vulgaris | Common bladderwort | 7 | X |
| | Vallisneria americana | Wild celery | 6 | X |
| SE | Eleocharis acicularis | Needle spikerush | 5 | X |
| FF | Spirodela polyrhiza | Greater duckweed | 5 | 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*

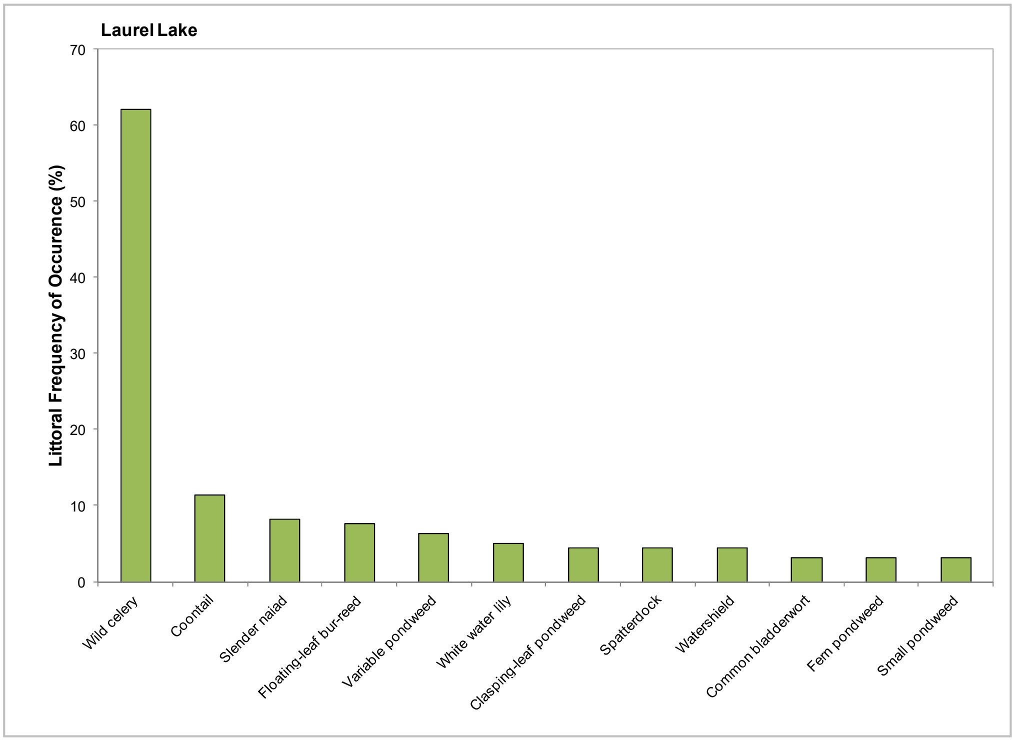



**Figure 8.9.4-1 Laurel Lake aquatic plant littoral frequency of occurrence analysis.** Chart includes species with a frequency occurrence greater than 2.0% only. Created using data from a 2011 point-intercept survey.

Figure 8.9.4-1 (above) shows that wild celery, coontail and slender naiad were the most frequently encountered plants within Laurel Lake. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Able to obtain the majority of its essential nutrients directly from the water, coontail does not produce extensive root systems, making the plant susceptible to uprooting by water-action and water movement. When this occurs, uprooted plants float and aggregate on the water's surface where they can continue to grow and form dense mats. Further, coontail is able to tolerate low-light conditions; this in addition to its ability to obtain nutrients directly from the water allow this species to thrive in productive systems. Slender naiad, as its name implies, is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only northern water milfoil was located within Laurel Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

33 species of aquatic plants (including incidentals) were found in Laurel Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Laurel Lake's plant community (0.77) lies below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake only moderate diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 wild celery was found at 62% of the sampling locations, its relative frequency of occurrence is 46%. Explained another way, if 100 plants were randomly sampled from Laurel Lake, 46 of them would be wild celery. This distribution can be observed in Figure 8.9.4-2, where together 12 species account for 90% of the population of plants within Laurel Lake, while the other 12 species account for the remaining 20%. However, wild celery clearly dominates the plan community. Nine additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.9.4-1 as incidentals.

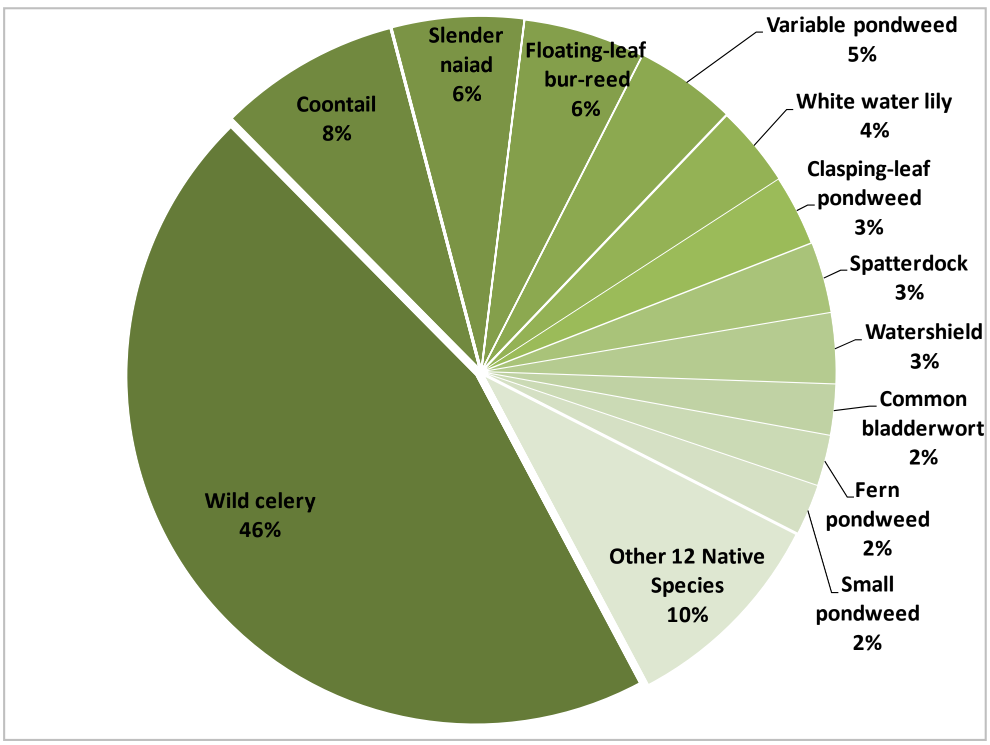



**Figure 8.9.4-2 Laurel Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2011 point-intercept survey.

Laurel Lake's average conservatism value (6.9) is higher than both the state and ecoregion median. This indicates that the plant community of Laurel Lake is indicative of a moderately undisturbed system. This is not surprising considering Laurel Lake's plant community has great diversity and high species richness. Combining Laurel Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.7 which is above the median values of the ecoregion and state.

The quality of Laurel Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2011 community map indicates that approximately 79.1 acres of the lake contains these types of plant communities (Laurel Lake Map 2, Table 8.9.4-2). Fourteen floating-leaf and emergent species were located on Laurel Lake (Table 8.9.4-1), all of which provide valuable wildlife habitat.

**Table 8.9.4-2. Laurel Lake acres of emergent and floating-leaf plant communities from the 2011 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 17.1 |
| Floating-leaf | 31.7 |
| Mixed Floating-leaf and Emergent | 30.3 |
| **Total** | 79.1 |

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

## Aquatic Invasive Species in Laurel Lake

During the 2011 community mapping survey, a single occurrence of purple loosestrife was located along the shorelines of Laurel Lake (Laurel Lake Map 2). Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by naturalized beetles, and manual hand removal – all of which have proven to be successful with continued and aggressive effort. Additional purple loosestrife monitoring during periods of control efforts would be required to ensure the eradication of the plant from the shorelines of Laurel Lake. Detailed discussion regarding this control effort will be discussed in the Implementation Plan.

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## 8.9.5 Laurel Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Laurel Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Laurel Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Laurel Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Laurel Lake's implementation plan is compiled by describing how Laurel Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

# Chain-wide Implementation Plan – Specific to Laurel Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Laurel Lake as part of this chain-wide project, it is up to Laurel Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Laurel Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## *Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes*

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** In addition to having a public access location, Laurel Lake is directly connected to the rest of the Three Lakes Chain of Lakes via Laurel and Medicine Lakes. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Laurel Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Laurel Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Laurel Lake or from Laurel Lake elsewhere. If a Laurel Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Laurel Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Laurel Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

### *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Laurel Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Laurel Lake and its stakeholders.

### *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Laurel Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, Laurel Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Laurel Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Laurel Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Laurel Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Laurel Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

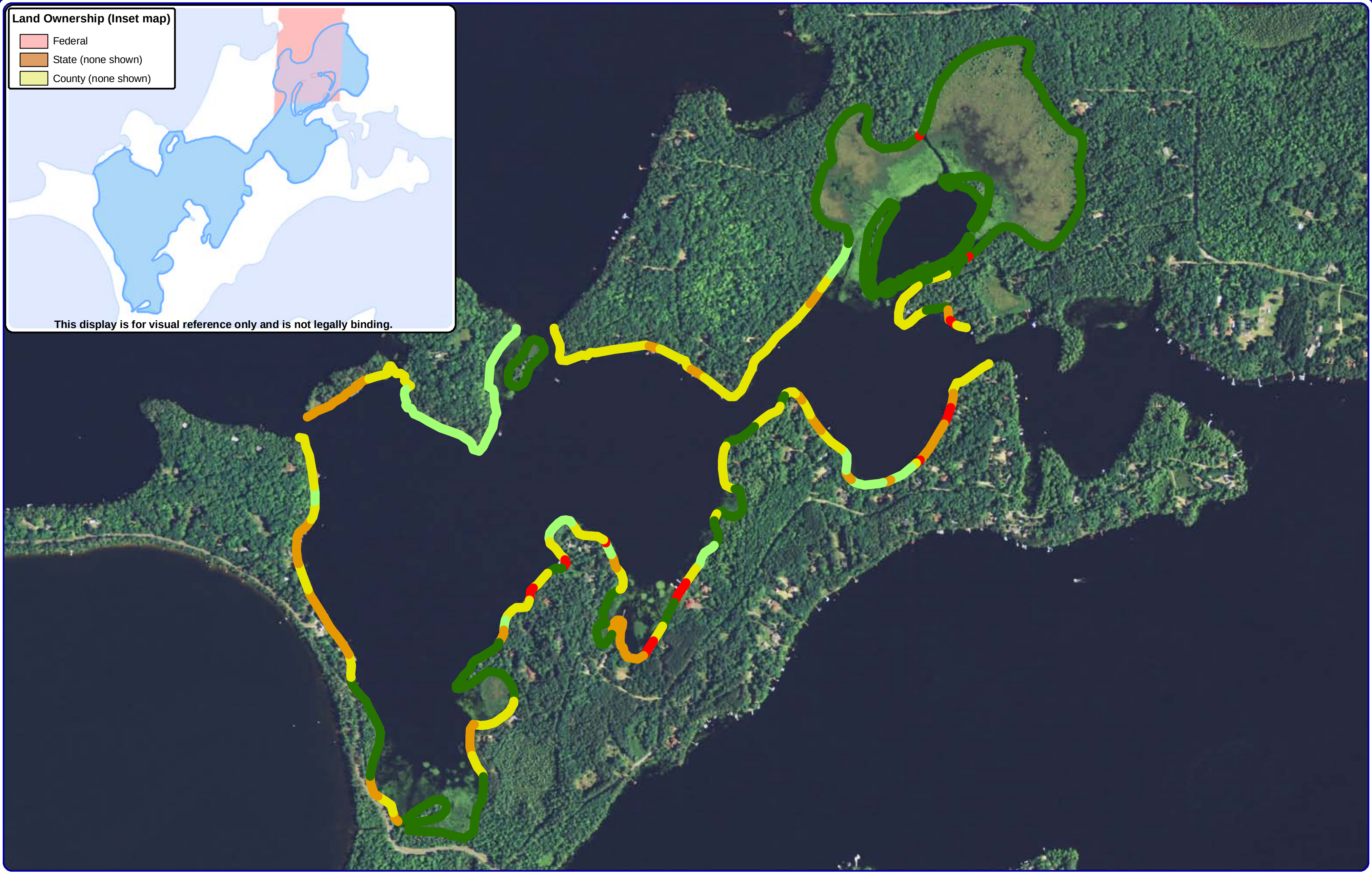
**Description:** As a part of this project, the entire Laurel Lake shoreline was categorized in terms of its development. According to the results from this survey, 14% of the shoreline is in an urbanized or developed-unnatural state, while 24% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Laurel Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Laurel Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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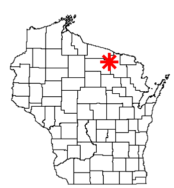
**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2011
Federal Land: USDA Forest Service
Map date: March 7, 2012
*Filename: Laurel_Map1_SA_2011.mxd*


Project Location in Wisconsin

## Legend

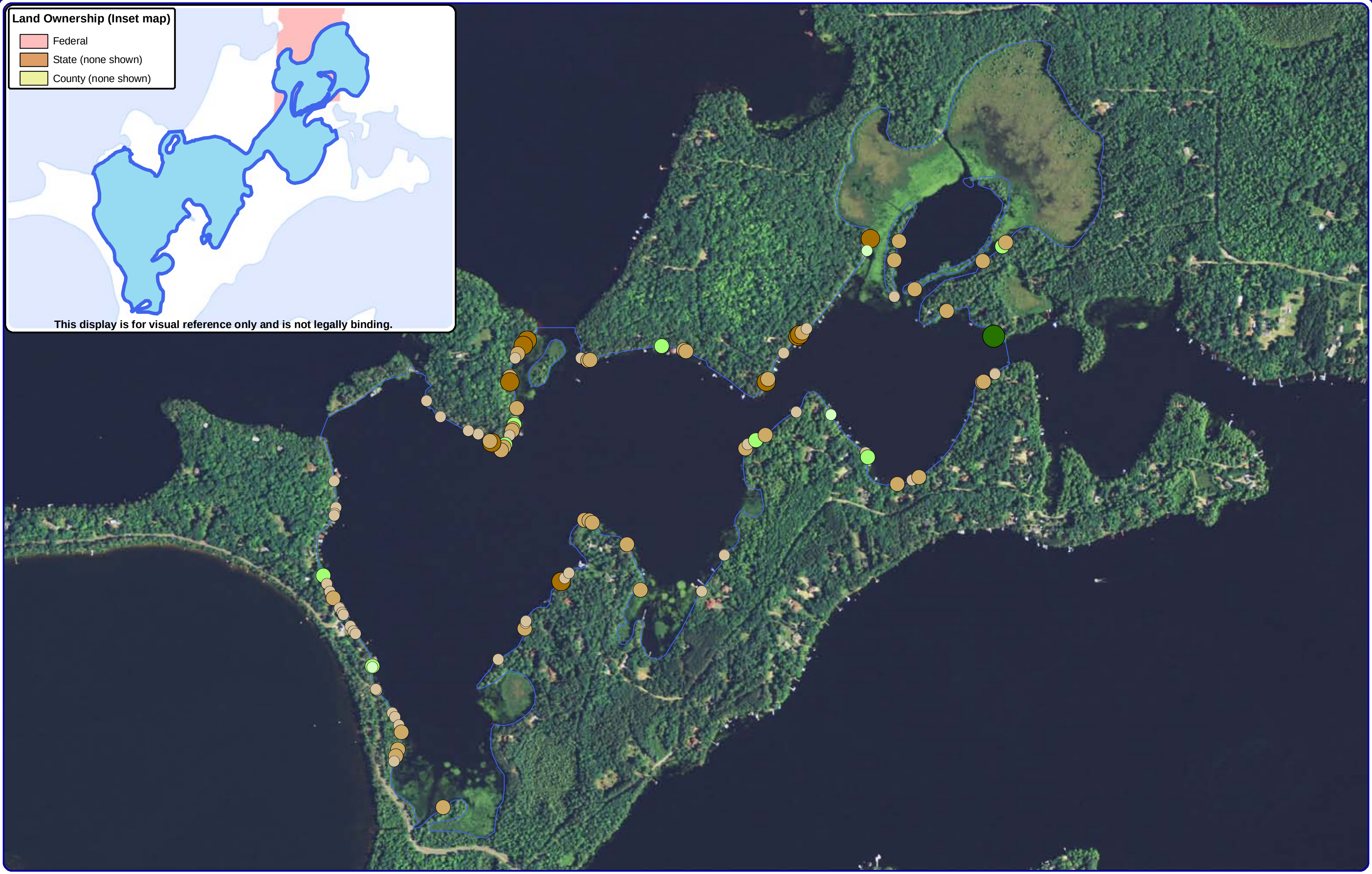
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

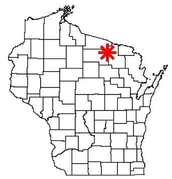
# Laurel Lake - Map 1

## Three Lakes Chain

Oneida County, Wisconsin

## Shoreland Condition




## 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 (none) | Moderate Branches |
| Full Canopy (none) | Full Canopy (none) | Full Canopy (none) |

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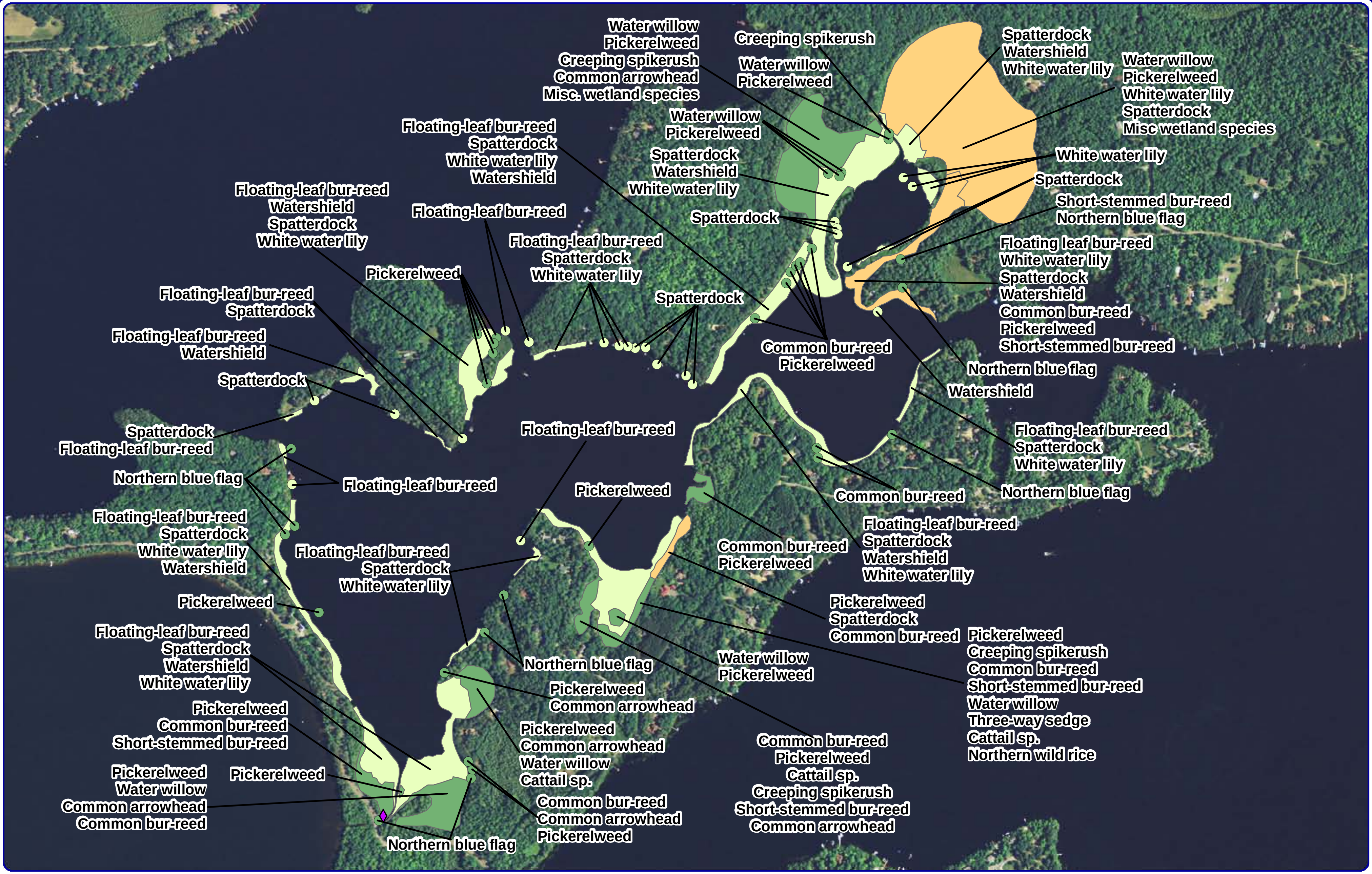
Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Federal Land: USDA Forest Service
Map date: October 17, 2014
Filename: Laurel_CWH_2014.mxd

Laurel Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin
**2014 Coarse Woody Habitat**

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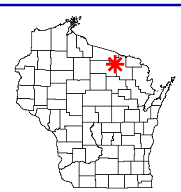
*www.onterra-eco.com*

**Sources:**
Aquatic Plants: Onterra, 2011
Orthophotography: NAIP, 2010
**Map date:** December 13, 2011
*Filename: Laurel_Comm_2011.mxd*



Project Location in Wisconsin

## Legend

**Small Plant Communities**
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple loosestrife

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

Laurel Lake - Map 3

Three Lakes Chain

Oneida County, Wisconsin

# Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on Fourmile Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

# 8.10 Fourmile Lake

## An Introduction to Fourmile Lake

Fourmile Lake, Oneida County, is a lowland drainage lake with a maximum depth of 26 feet and a surface area of 210 acres. This eutrophic lake has a large watershed when compared to the size of the lake. Fourmile Lake contains 31 native plant species, of which slender naiad was the most common plant in 2012. One exotic plant, pale yellow iris, is known to be found on the lake.

**Field Survey Notes**

*Abundant wild rice observed during aquatic plant surveys. Lake has much natural shoreline surrounding it – great wildlife habitat! Pale yellow iris spotted several times during the early season AIS survey.*

**Photo 8.10.1-1 Fourmile Lake, Oneida County**

## Lake at a Glance* – Fourmile Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 210 |
| Maximum Depth (ft) | 26 |
| Mean Depth (ft) | 12 |
| Volume (acre-feet) | 2,507 |
| Shoreline Complexity | 3.9 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 5, 2012 |
| Comprehensive Survey Date | July 17, 2012 |
| Number of Native Species | 31 (including incidentals) |
| Threatened/Special Concern Species | n/a |
| Exotic Plant Species | Pale yellow iris |
| Simpson's Diversity | 0.91 |
| Average Conservatism | 6.9 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, lowland drainage |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 68:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

### 8.10.1 Fourmile Lake Water Quality

As a part of this project, water quality data was collected from Fourmile Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake.

Though phosphorus samples collected in the mid-1980's averaged near 40 μg/L, during 2012 total phosphorus values collected from the Fourmile Lake surface averaged 27.0 μg/L, which is only slightly higher than the median values for deep, lowland drainage lakes throughout the state and also for all lakes within the Northern Lakes and Forests ecoregion (Table 8.10.3-1). Chlorophyll-*a* data is only available from 1979 and 2012. Chlorophyll-*a* concentrations (10.7 μg/L average during summer 2012) were slightly higher than comparable lakes across the state and all lakes within the ecoregion. Regardless of being slightly higher in value than comparable lakes, the 2012 total phosphorus and chlorophyll-*a* concentrations in Fourmile Lake rank as *Good* within these state-wide and ecoregional datasets.

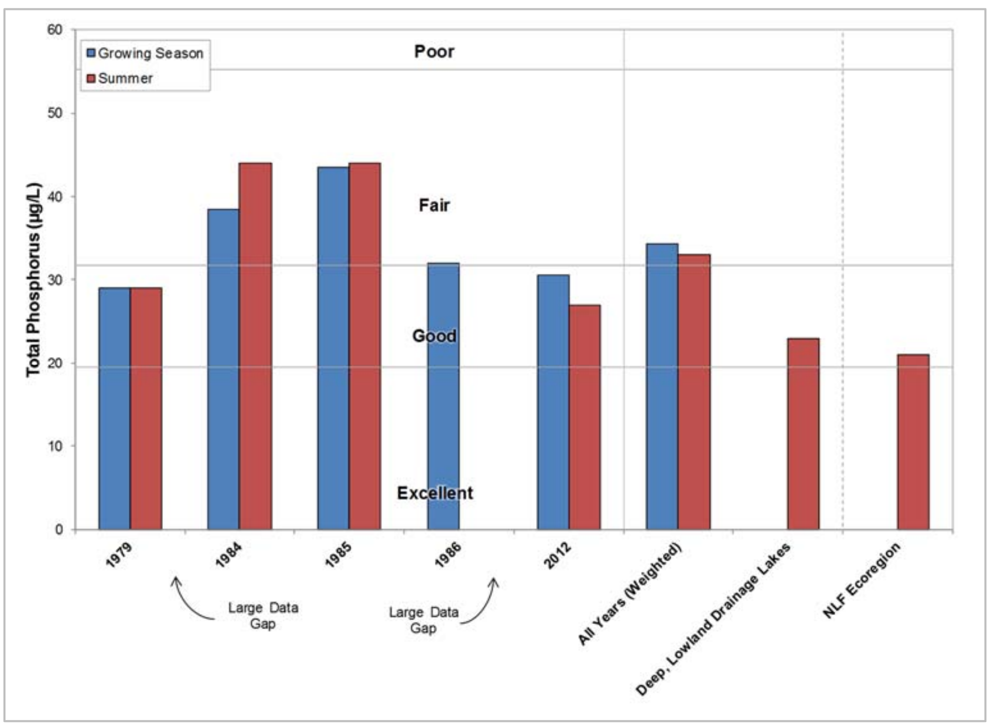



**Figure 8.10.1-1. Fourmile Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Some historical data is available for Fourmile Lake with regards to Secchi disk clarity. Data was collected in 1993-1996 through the Citizens Lake Monitoring Network (CLMN) by a Fourmile Lake volunteer. These data are comparable to what was collected by Onterra ecologists during 2012 (Figure 8.10.1-2). Weighted over the entire time period, an average summer value of roughly 3.6 ft is much lower than 8.5 ft, the median value for similar lakes across the state and 8.9, the median value for lakes within the ecoregion. This value ranks as *Fair* when comparing Fourmile lake to other deep, lowland drainage lakes.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Fourmile Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake.

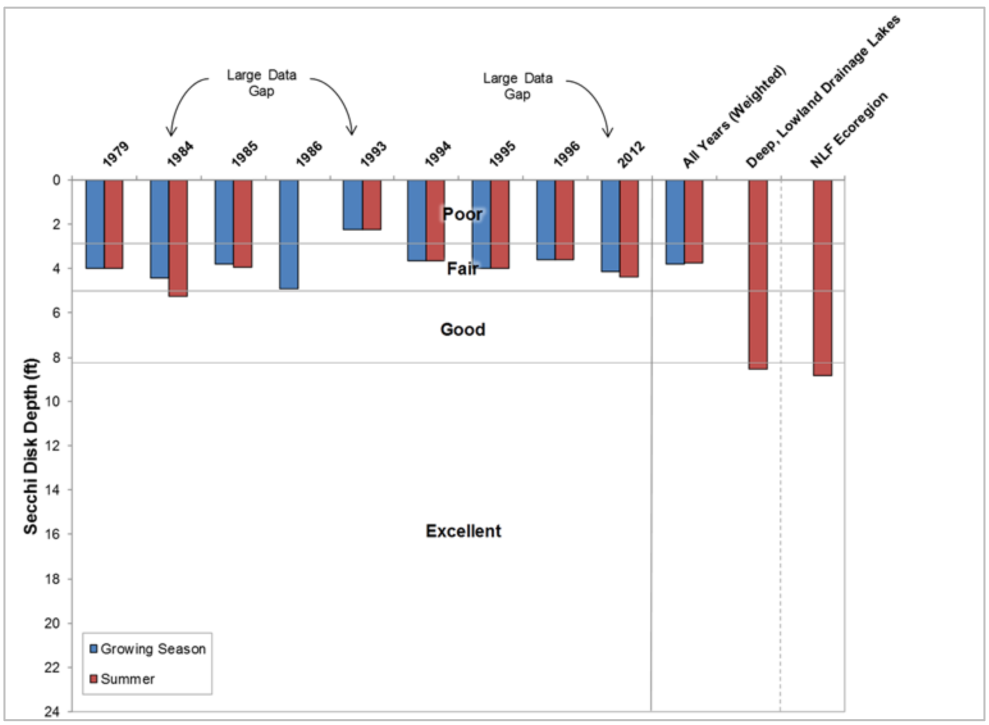



**Figure 8.10.1-2. Fourmile Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

**Fourmile Lake Trophic State**

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values fall within the eutrophic category (Figure 8.10.1-3). In general, the best values to use in judging a lake's trophic state are the biological parameters; the Secchi disk clarity value can be influenced by the color of the water as described above. Therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Fourmile Lake is in a lower eutrophic state.

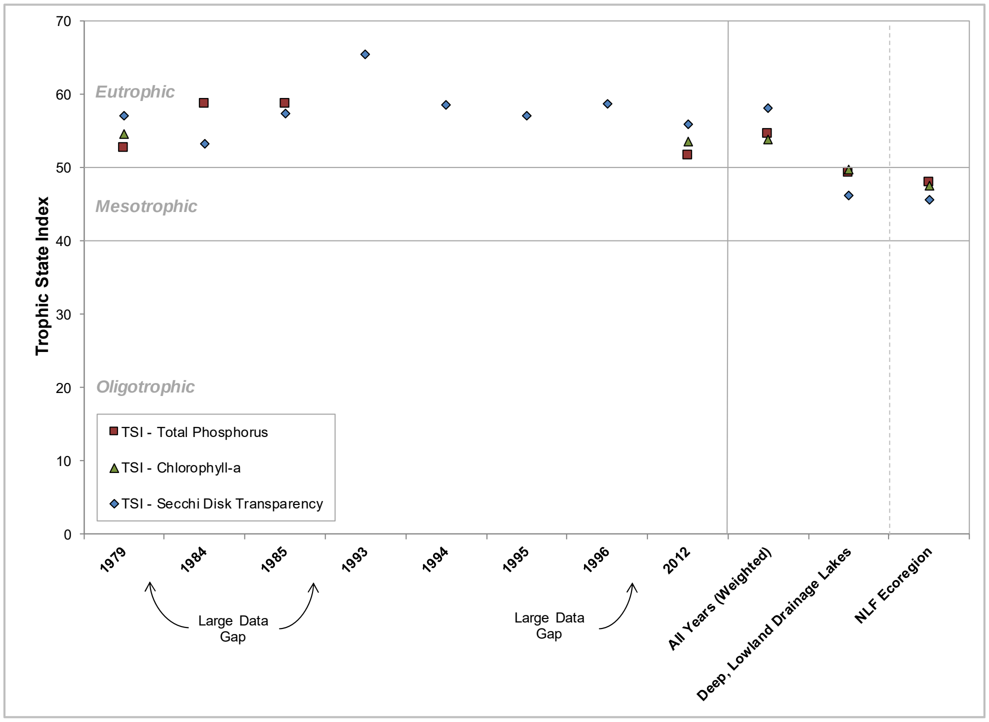



**Figure 8.10.1-3. Fourmile Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Fourmile Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Fourmile Lake by Onterra staff. Graphs of those data are displayed in Figure 8.10.1-4 for all three sampling events.

In April and October, the lake was found to be completely mixed, with dissolved oxygen and temperature readings found to be similar throughout the entire water column. During June, these parameters were higher in the epilimnion and dropped with depth. In July and August, Fourmile Lake became stratified, with a distinct warmer epilimnion and cooler hypolimnion. During these summer months, anoxic conditions were observed from 12 to 26 ft in July and 16 to 26 ft in August. Dissolved oxygen depletion may occur near the bottom of the lake as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being found in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Despite the decrease in dissolved oxygen levels during the summer months, oxygen remained sufficient in the upper 12 feet of the water column to support most aquatic life found in northern Wisconsin lakes.

Dissolved oxygen depletion may be of concern during the winter months due to the ice cover on the lake, which prohibits oxygen exchange from the air to the lake. Fortunately, dissolved oxygen was sufficient within the majority of the water column in February of 2013.

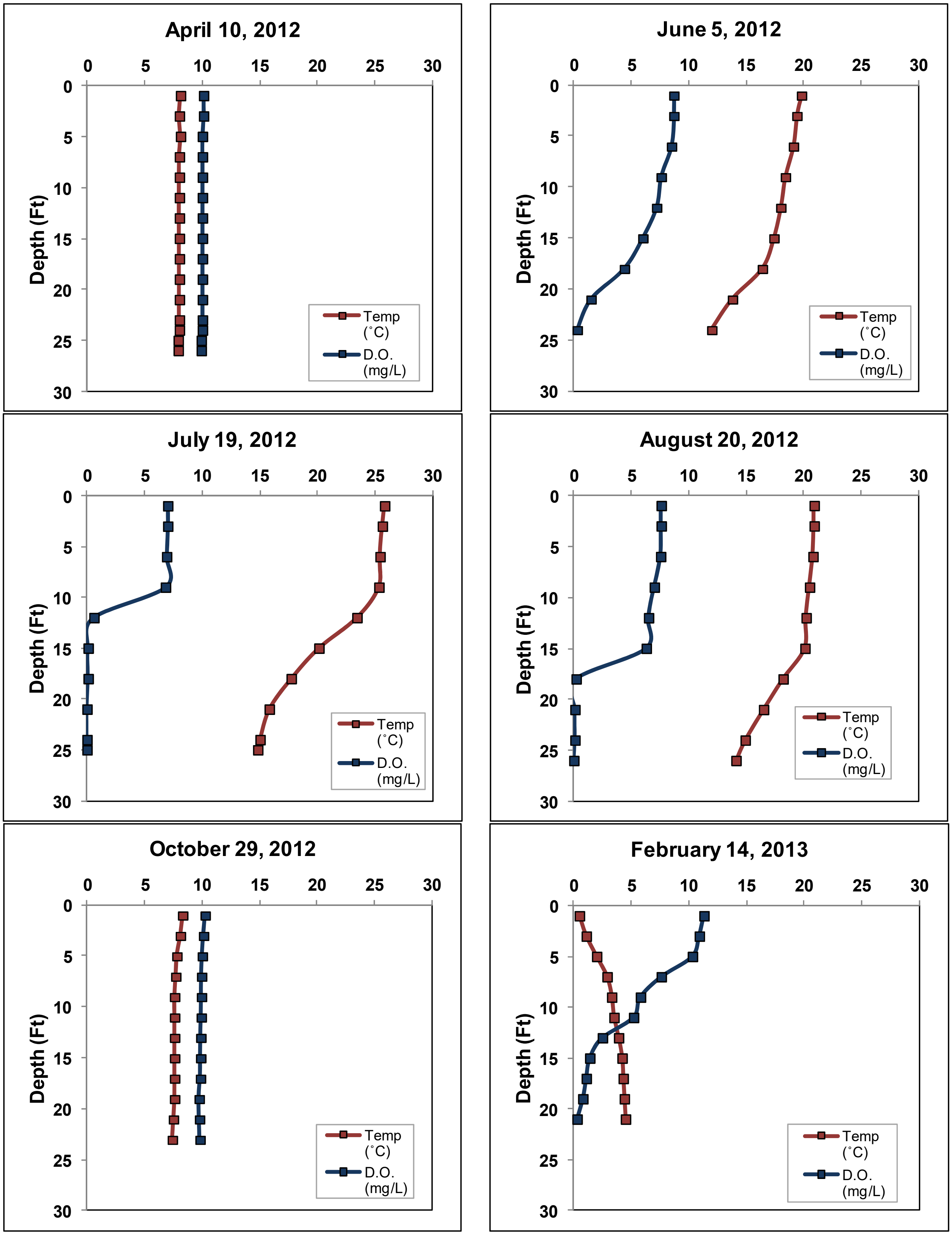



**Figure 8.10.1-4. Fourmile Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Fourmile 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 Fourmile 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Fourmile Lake's pH was measured at 7.3 in July 2012. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Fourmile Lake was measured at 24.0 (mg/L as $CaCO_3$) near the surface, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Fourmile Lake during the summer of 2010. Calcium is commonly examined because invasive and native mussels use the element to build shells and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Fourmile Lake's pH of 7.3 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Fourmile Lake was found to be 6.5 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.10.2 Fourmile Lake Watershed Assessment

Fourmile Lake's watershed is 14,558 acres in size. Compared to the lakes size of 210 acres, this makes for an incredibly large watershed to lake area ratio of 68:1.

Exact land cover calculation and modeling of nutrient input to Fourmile Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.10.3 Fourmile Lake Shoreland Condition Assessment

### Shoreland Development

As mentioned previously in the Chain-wide Watershed Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Fourmile Lake's immediate shoreline was assessed in terms of its development. Fourmile Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 3.2 miles of natural/undeveloped and developed-natural shoreline (78% of the entire shoreline) were observed during the survey (Figure 8.10.3-1). 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, roughly 0.1 miles of urbanized and developed–unnatural shoreline (3% of the total shoreline) was observed. If restoration of the Fourmile Lake shoreline 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. Fourmile Lake Map 1 displays the location of these shoreline lengths around the entire lake.

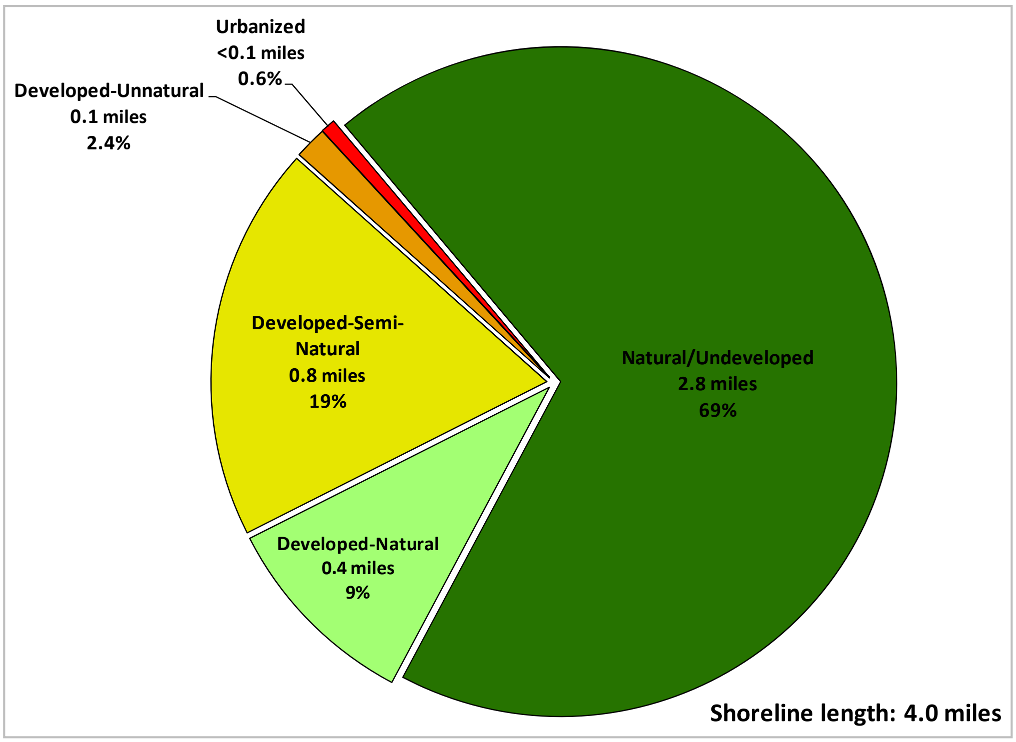



**Figure 8.10.3-1. Fourmile Lake shoreland categories and total lengths.** Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Fourmile Lake Map 1.

## Coarse Woody Habitat

Fourmile Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 98 pieces of coarse woody habitat were observed along 4.0 miles of shoreline, which gives Fourmile Lake a coarse woody habitat to shoreline mile ratio of 24:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Fourmile Lake Map 2.

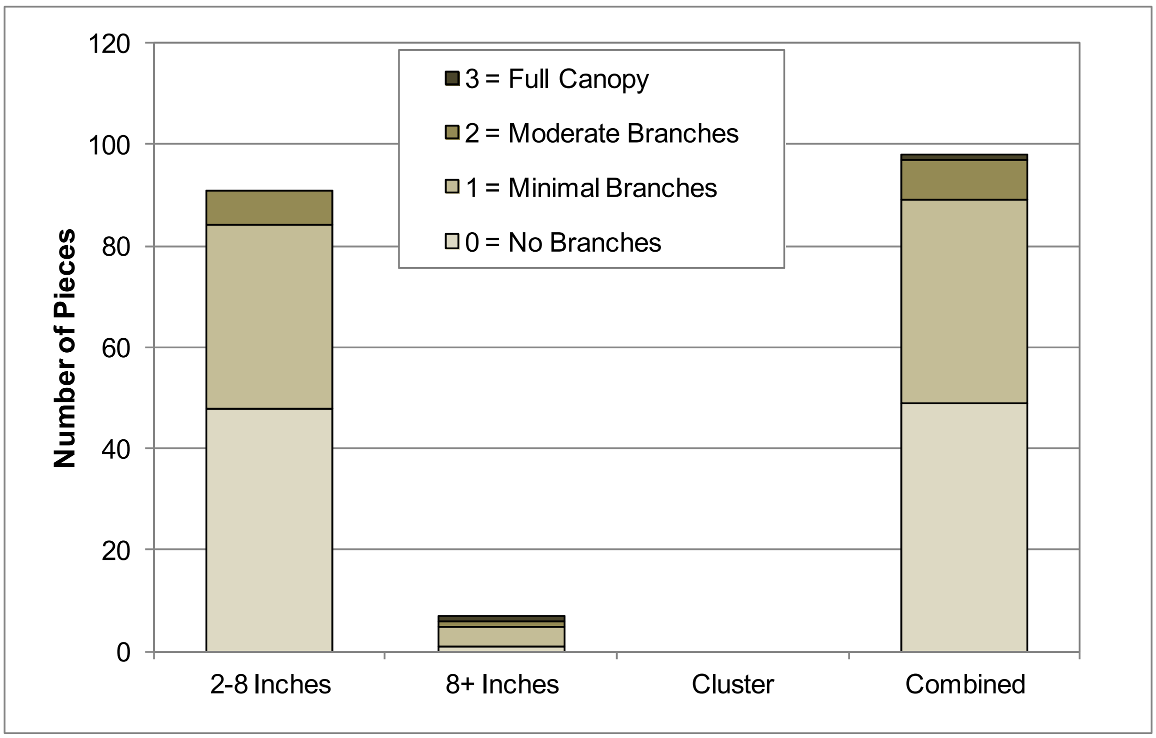



**Figure 8.10.3-2. Fourmile Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Fourmile Lake coarse woody habitat can be found on Fourmile Lake Map 2.

## 8.10.4 Fourmile Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Fourmile Lake on June 5, 2012. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants. One exotic plant, pale yellow iris, was found along the shorelines of the lake during subsequent surveys. This plant is discussed in detail at the end of this section.

The aquatic plant point-intercept survey was conducted on Fourmile Lake on July 17, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that same day to create the aquatic plant community map (Fourmile Lake Community Map). During these surveys, 31 species of native aquatic plants were located in Fourmile Lake (Table 8.10.4-1). 21 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while 10 species were found incidentally.

Aquatic plants were found growing to a depth of seven feet, which is comparable to the other lakes within the Three Lakes Chain of lakes, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 93 point-intercept locations sampled within the littoral zone, approximately 54% contained aquatic vegetation. Approximately 61% of the point-intercept sampling locations where sediment data was collected at were sand, 40% consisted of a fine, organic substrate (muck) and 13% were determined to be rocky.

**Table 8.10.4-1. Aquatic plant species located in the Fourmile Lake during the 2012 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2012 (Onterra) |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | *I* |
| | *Eleocharis palustris* | Creeping spikerush | 6 | *I* |
| | *Iris versicolor* | Northern blue flag | 5 | *I* |
| | *Pontederia cordata* | Pickerelweed | 9 | *X* |
| | *Sagittaria latifolia* | Common arrowhead | 3 | *I* |
| | *Sagittaria rigida* | Stiff arrowhead | 8 | *I* |
| | *Scirpus cyperinus* | Wool grass | 4 | *I* |
| | *Typha spp.* | Cattail spp. | 1 | *I* |
| | *Zizania palustris* | Northern wild rice | 8 | *X* |
| FL | *Brasenia schreberi* | Watershield | 7 | *I* |
| | *Nuphar x rubrodisca* | Intermediate pond-lily | 9 | *X* |
| | *Nymphaea odorata* | White water lily | 6 | *X* |
| | *Nuphar variegata* | Spatterdock | 6 | *X* |
| FL/E | *Sparganium emersum* | Short-stemmed bur-reed | 8 | *I* |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | *X* |
| Submergent | *Chara spp.* | Muskgrasses | 7 | *X* |
| | *Ceratophyllum demersum* | Coontail | 3 | *X* |
| | *Heteranthera dubia* | Water stargrass | 6 | *X* |
| | *Nitella spp.* | Stoneworts | 7 | *X* |
| | *Najas flexilis* | Slender naiad | 6 | *X* |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | *I* |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | *X* |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | *X* |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | *X* |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | *X* |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | *X* |
| | *Potamogeton gramineus* | Variable pondweed | 7 | *X* |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | *X* |
| | *Utricularia vulgaris* | Common bladderwort | 7 | *X* |
| | *Vallisneria americana* | Wild celery | 6 | *X* |
| FF | *Spirodela polyrhiza* | Greater duckweed | 5 | *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*

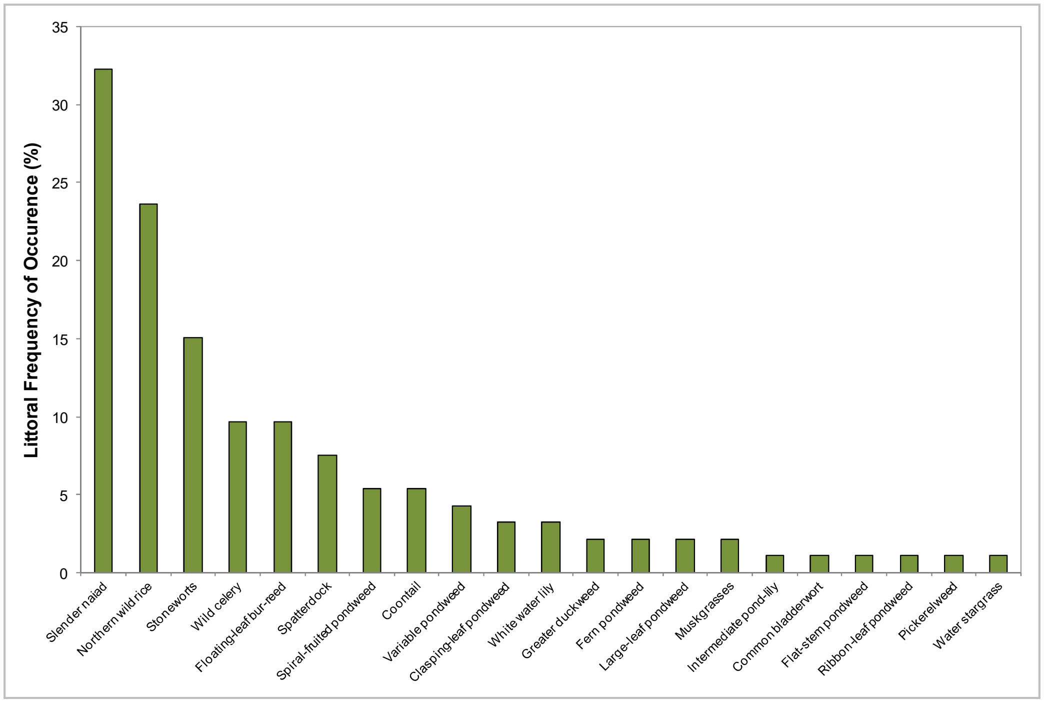



**Figure 8.10.4-1 Fourmile Lake aquatic plant littoral frequency of occurrence analysis.** Created using data from 2012 point-intercept survey.

Figure 8.10.4-1 (above) shows that slender naiad, northern wild rice and members of the stonewort grouping were the most frequently encountered plants within Fourmile Lake. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. Manoomin, as it is referred to by Ojibewa Tribal Communities, has great cultural significance as well as being an important component of Native American diets. Wild rice is also an important diet component for waterfowl, muskrats, deer, and many other species. Established wild rice communities can provide valuable nursery and brooding habitat for wetland bird and amphibian species as well as spawning habitat for various fish. Perhaps one of the most overlooked benefits of having established wild rice communities is their ability to utilize excessive nutrients, stabilize sediments, and form natural wave-breaks to protect shoreline areas. Nitella species, or stoneworts as they may be called, are actually a type of macro-algae rather than a vascular plant. Whorls of forked branches are attached to the "stems" of the plant, which are long, slender, smooth-textured algae. Because they lack roots, stoneworts remove nutrients directly from the water.

31 species of aquatic plants (including incidentals) were found in Fourmile Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Fourmile Lake's plant community (0.91) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity with respect to its aquatic plant community.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 slender naiad was found at 32% of the sampling locations, its relative frequency of occurrence is 24%. Explained another way, if 100 plants were randomly sampled from Fourmile Lake, 24 of them would be slender naiad. This distribution can be observed in Figure 8.10.4-2, where together six species account for 73% of the population of plants within Fourmile Lake, while the other 15 species account for the remaining 27%. Ten additional species were located from the lake but not from of the point-intercept survey, as indicated in Figure 8.10.4-1 as incidentals.

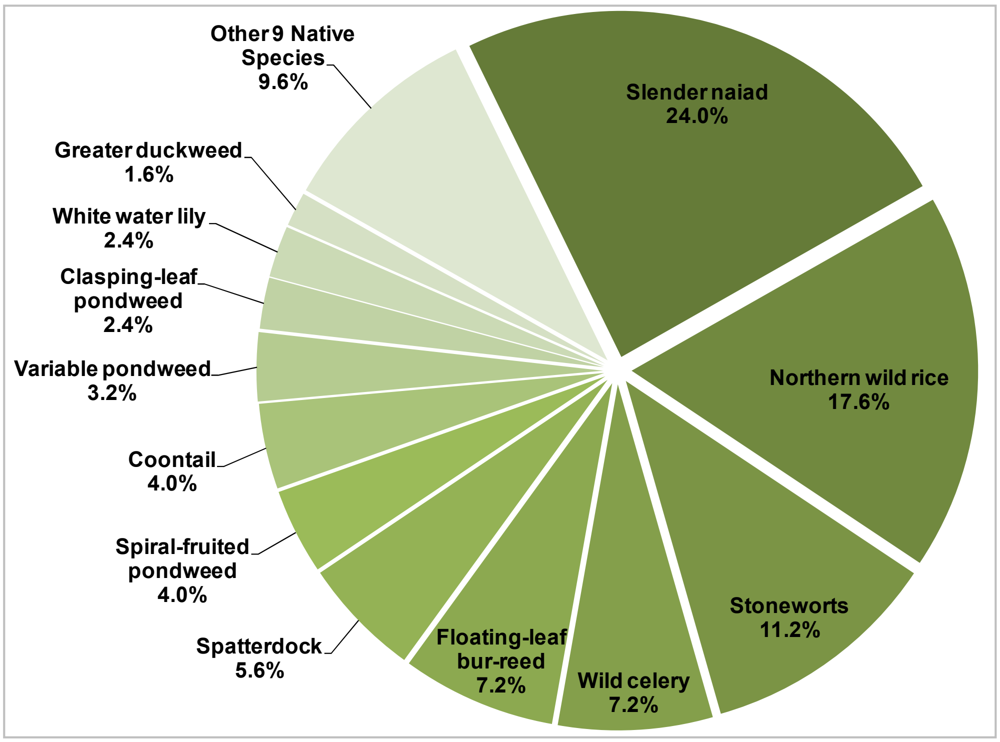



**Figure 8.10.4-2 Fourmile Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2012 point-intercept survey.

Fourmile Lake's average conservatism value (6.9) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community of Fourmile Lake is indicative of an undisturbed system. This is not surprising considering Fourmile Lake's plant community has high diversity as well as species richness. Combining Fourmile Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.4 which is well above the median values of the ecoregion (24.3) and state (22.2).

The quality of Fourmile Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 45.6 acres of the lake contains these types of plant communities (Fourmile Lake

Map 2, Table 8.10.4-2). Fifteen floating-leaf and emergent species were located on Fourmile Lake (Table 8.10.4-1), all of which provide valuable wildlife habitat.

**Table 8.10.4-2. Fourmile Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 26.4 |
| Floating-leaf | 2.1 |
| Mixed Floating-leaf and Emergent | 17.1 |
| **Total** | 45.6 |

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

## Aquatic Invasive Species in Fourmile Lake

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along some of the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale yellow iris on Fourmile Lake can be viewed on Fourmile Lake Map 2. At this time, there are a few locations where this plant is located. Visiting these locations in mid-June and hand pulling the plant, using care not to spread the reproductive seeds, is likely the best way to control this species for now. More information on this methodology is discussed within the Implementation Plan.

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### 8.10.5 Fourmile Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Fourmile Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Fourmile Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Fourmile Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Fourmile Lake's implementation plan is compiled by describing how Fourmile Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Fourmile Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Fourmile Lake as part of this chain-wide project, it is up to Fourmile Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Fourmile Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** While Fourmile Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Big Fork Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Fourmile Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Fourmile Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Fourmile Lake or from Fourmile Lake elsewhere. If a Fourmile Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Fourmile Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Fourmile Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

### Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association’s Capacity to Communicate with and Educate Lake Stakeholders

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Fourmile Lake stakeholders can assist in the implementation of this action by participating in the TLWA’s educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Fourmile Lake and its stakeholders.

### Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

**Management Action:** Enhance TLWA’s involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Fourmile Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Fourmile Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Fourmile Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Fourmile Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Fourmile Lake shoreline was categorized in terms of its development. According to the results from this survey, 3.0% of the shoreline is in an urbanized or developed-unnatural state, while 19.0% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

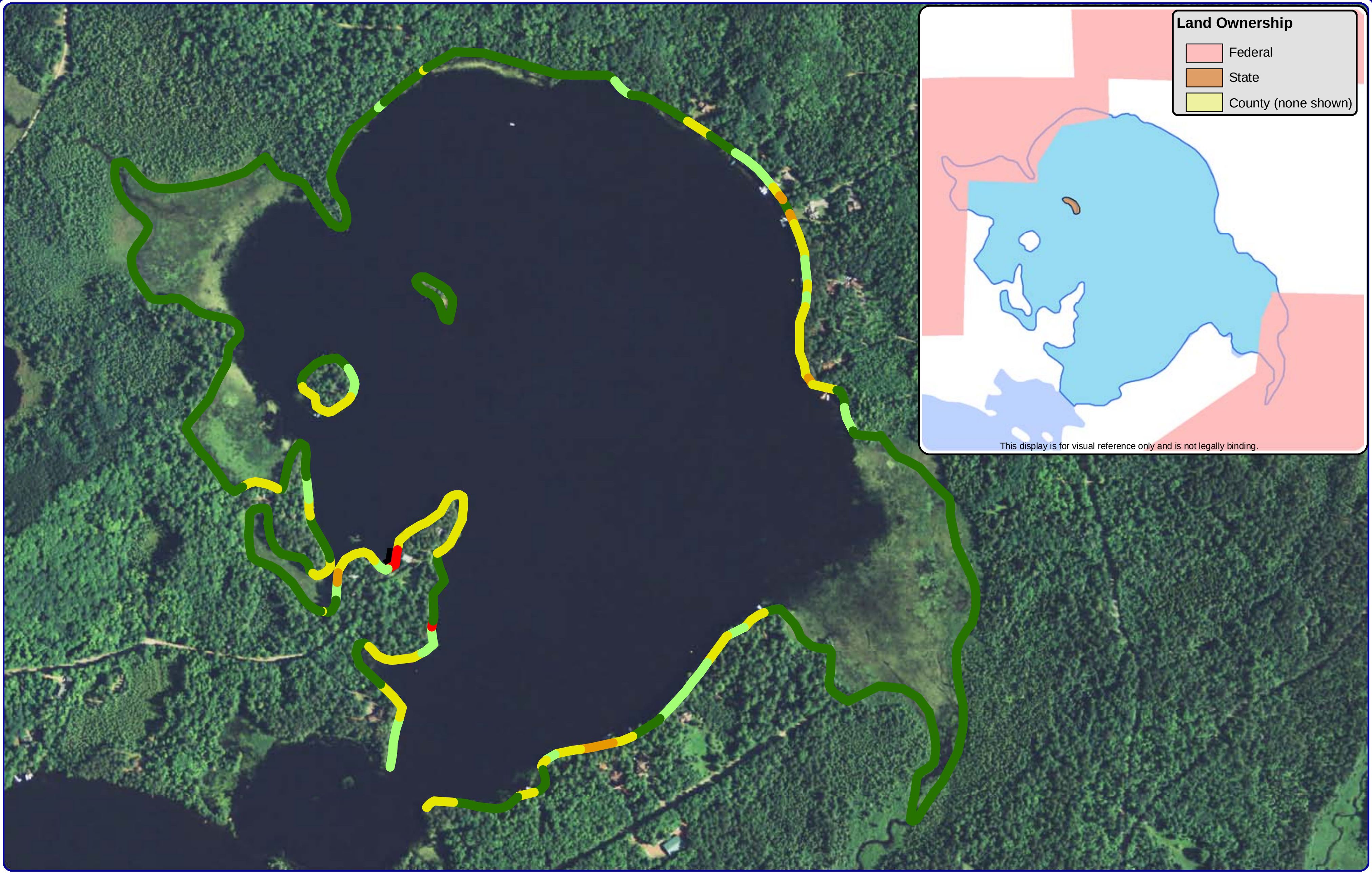
The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Fourmile Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Fourmile Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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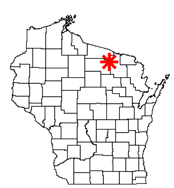
Onterra LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2012
Federal Land: USDA Forest Service
State Land: WDNR
Map date: January 3, 2013
*Filename: Fourmile_ShorelineCondition_2012.mxd*



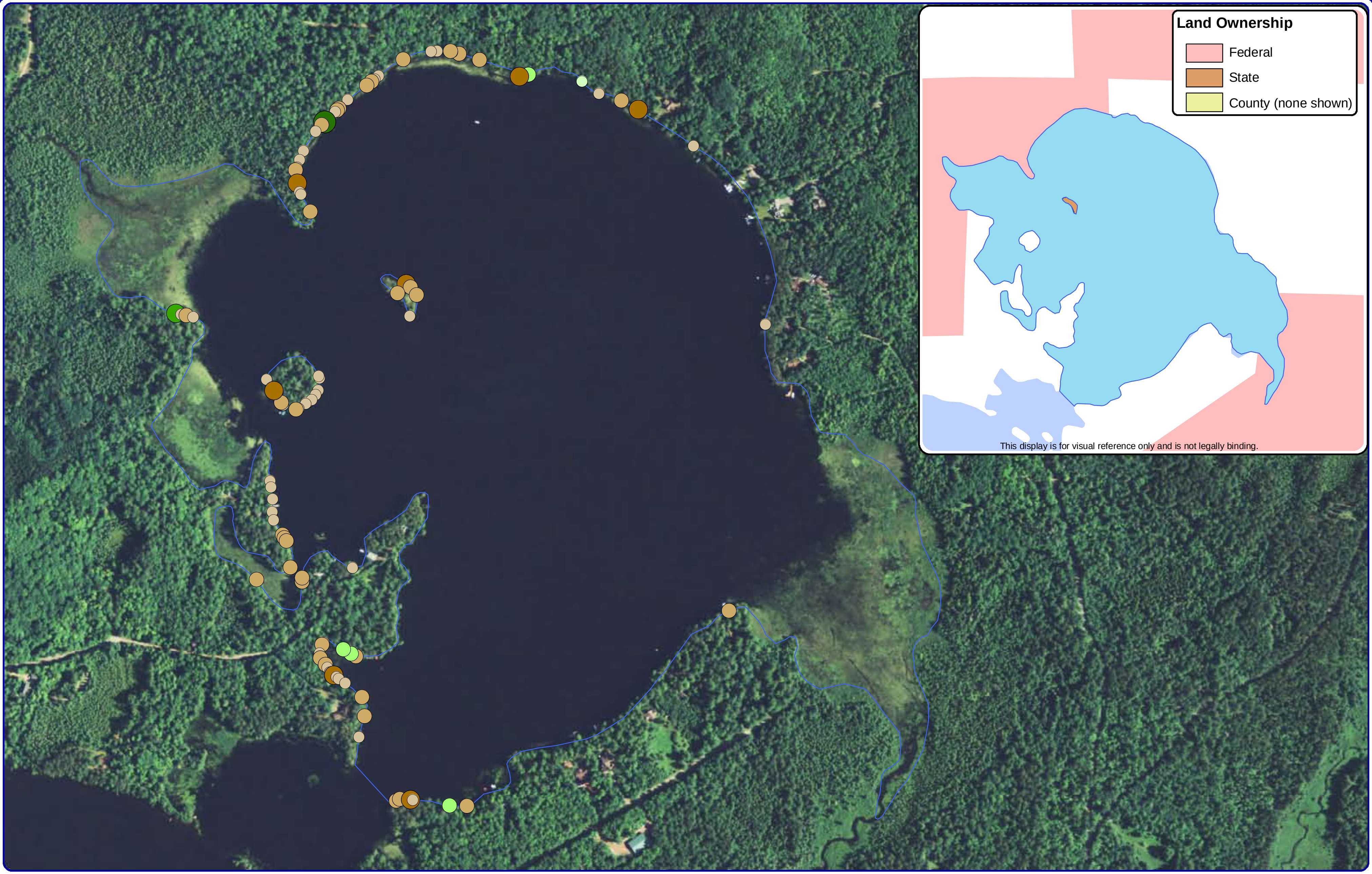
Project Location in Wisconsin

**Legend**

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

Seawall
Masonary/Metal/Wood

Fourmile Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin
**Shoreland Condition**

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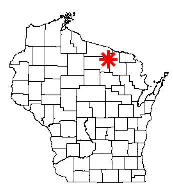
**Sources:**
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Federal Land: USDA Forest Service
State Land: WDNR
Map date: October 17, 2014
*Filename: Fourmile_CWH_2014.mxd*

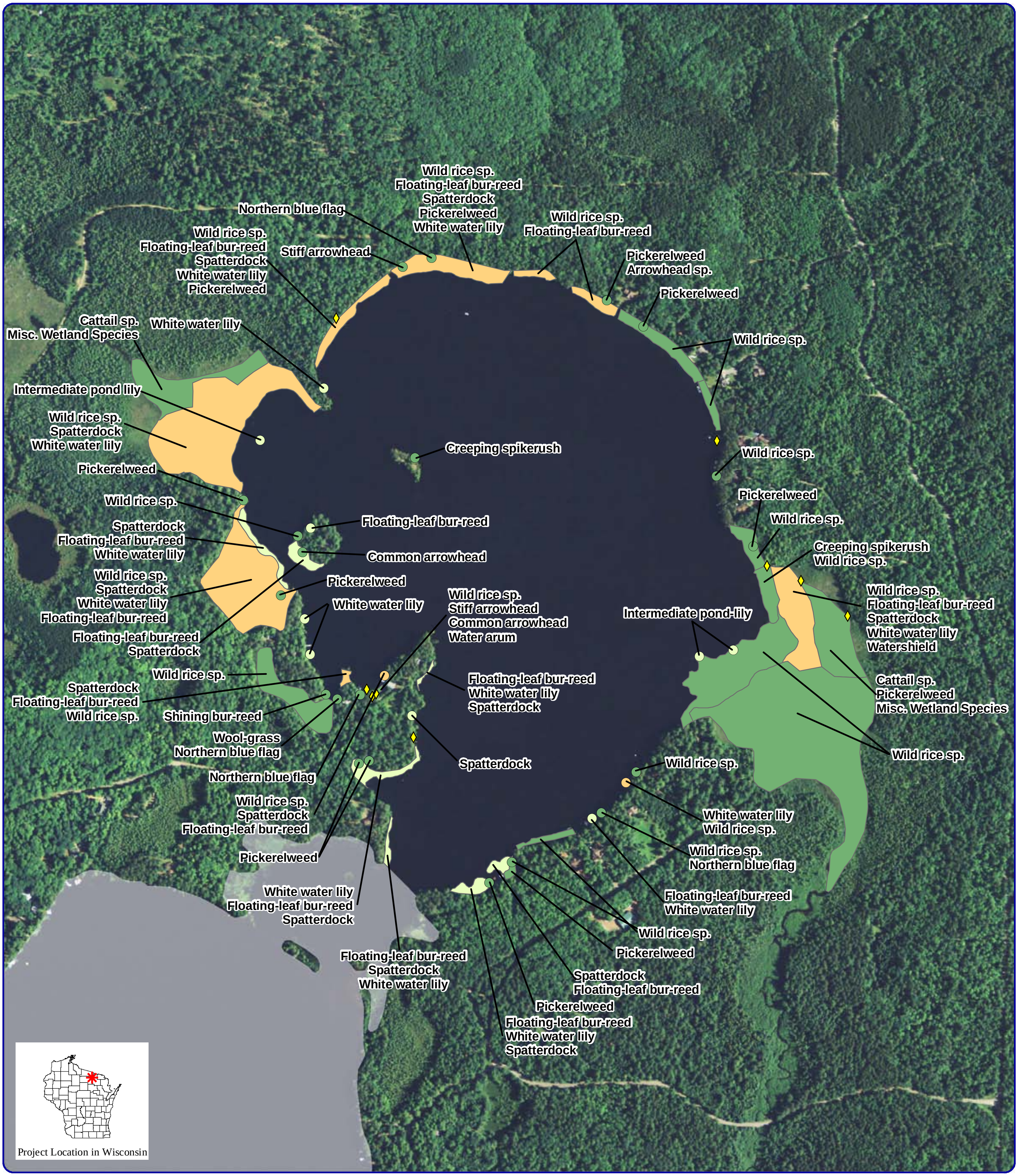

Project Location in Wisconsin

## 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 | Full Canopy (none) |

Fourmile Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin

**2014 Coarse Woody Habitat**

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

**Sources:**
Hydro: WDNR
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
**Map date:** December 7, 2012
***Filename:** Fourmile_Comm_2012.mxd*

## Legend

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

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

**Exotic Plant Communities**
- Pale Yellow Iris

Fourmile Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin

# Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on Big Fork Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

# 8.11 Big Fork Lake

## An Introduction to Big Fork Lake

Big Fork Lake, Oneida County, is a lowland drainage lake with a maximum depth of 37 feet and a surface area of 670 acres. This eutrophic lake has a large watershed when compared to the size of the lake. Big Fork Lake contains 38 native plant species, of which wild celery was the most common plant in 2012. One exotic plant, pale yellow iris, is known to be found on the lake.

**Field Survey Notes**

*A fair amount of development observed on the lake. Vasey's pondweed found in two point-intercept locations. Shoreline was dotted with much pale yellow iris during early-season AIS survey.*

**Photo 8.11.1-1 Big Fork Lake, Oneida County**

## Lake at a Glance* – Big Fork Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 670 |
| Maximum Depth (ft) | 37 |
| Mean Depth (ft) | 17.5 |
| Volume (acre-feet) | 11,690 |
| Shoreline Complexity | 2.5 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 5, 2012 |
| Comprehensive Survey Date | July 17, 2012 |
| Number of Native Species | 38 |
| Threatened/Special Concern Species | Vasey's pondweed *(Potamogeton vaseyi)* |
| Exotic Plant Species | Pale-yellow iris *(Iris pseudacorus)* |
| Simpson's Diversity | 0.84 |
| Average Conservatism | 7.2 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, lowland drainage |
| Trophic State | Eutrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 21:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.11.1 Big Fork Lake Water Quality

As a part of this project, water quality data was collected from Big Fork Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake. In addition to this project, data has been collected by the WDNR, Wisconsin Valley Improvement Company (WVIC) and Citizens Lake Monitoring Network (CLMN).

Phosphorus values collected during the mid 1970's and early 1980's rank relatively high compared to recent data (Figure 8.11.1-1). During 2012, total phosphorus values collected from the Big Fork Lake surface averaged 23.3 μg/L, which ranks as *Good* when compared to similar deep, lowland drainage lakes within the state and all lakes in the Northern Lakes and Forests ecoregion (Figure 8.11.1-1). A weighted value across all years of data is also only slightly higher than the median values for similar lakes throughout the state and also for all lakes within the ecoregion.

**Table 8.11.1-1. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional values for water quality parameters.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

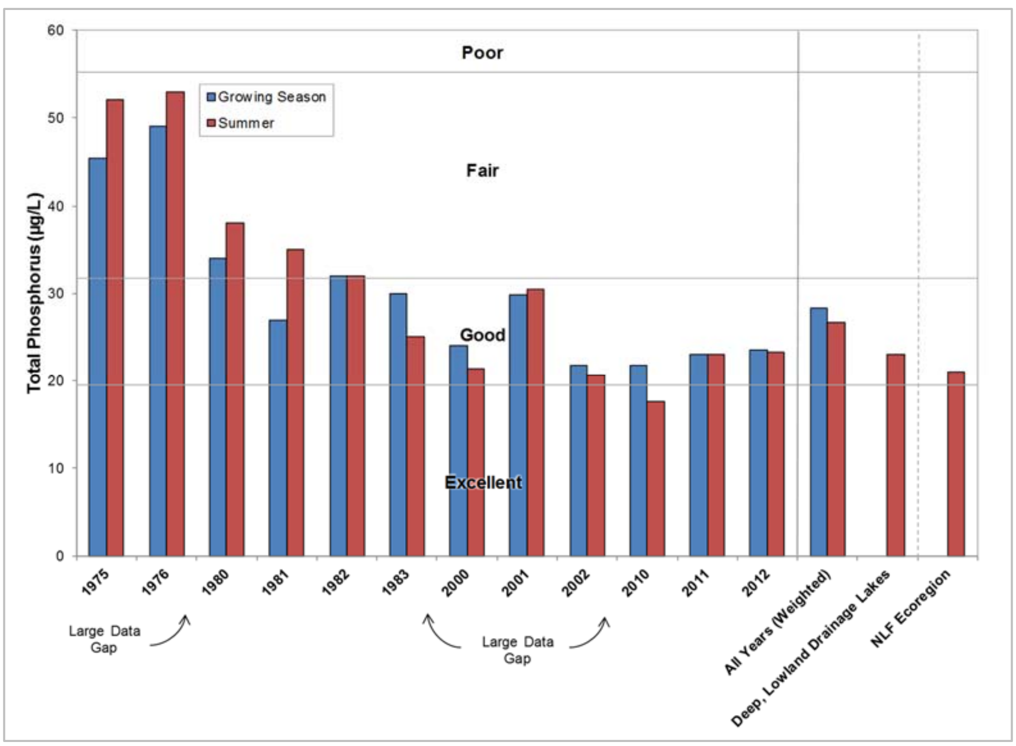


**Figure 8.11.1-1. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus values.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

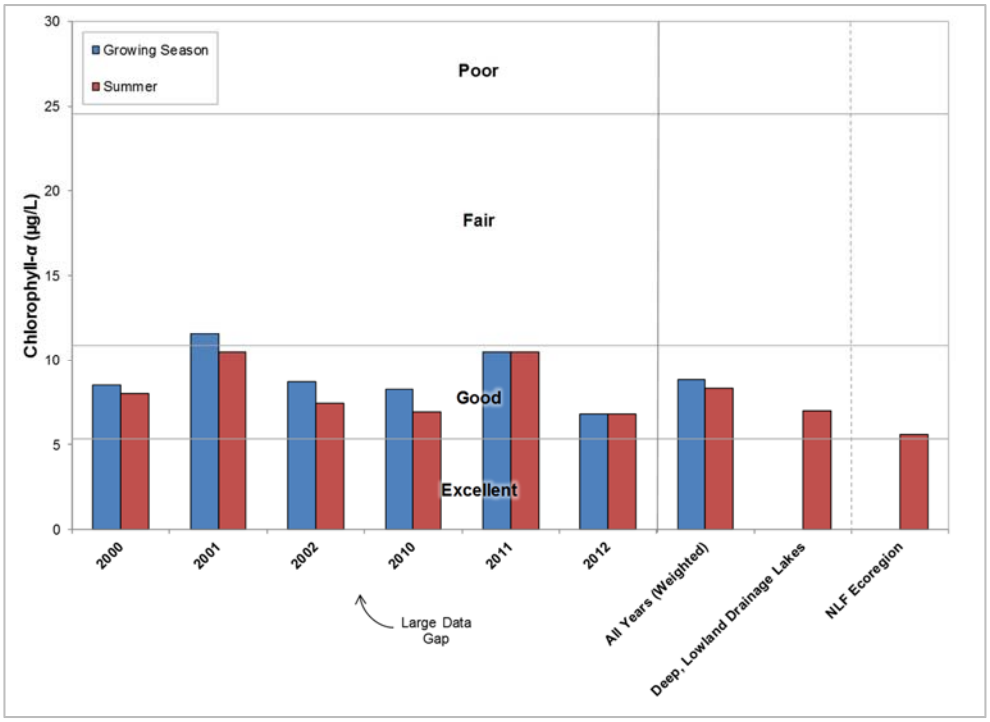


**Figure 8.11.1-2. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Average annual chlorophyll-*a* concentrations vary over the available time period; however, summer values rank as *Good* category for deep, lowland drainage lakes (Figure 8.11.1-2). A weighted average is somewhat higher than comparable lakes across the state within the ecoregion. The data indicates that algae levels within the lake are at a level that is healthy for the ecosystem and not excessive enough to cause ecological issues or recreational problems.

A larger dataset is available for Big Fork Lake with regards to Secchi disk clarity (Figure 8.11.1-3). These data largely fall within the *Good* category for deep, lowland drainage lakes across the state. However, a weighted average value across all years falls below the median value for similar lakes state-wide and all lakes in the ecoregion. Interestingly, exceptional Secchi disk clarity values were recorded during the 2010 open water season. Four measurements of this parameter (June, July, August and October) ranged between 7.5 and 12.1 feet.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In lakes such as the Three Lakes Chain, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The darker waters of Big Fork Lake contain many organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing wetland plant species. This natural staining reduces light penetration into the water column, which reduces visibility but also reduces the growing depth of aquatic vegetation within the lake. With regards to the 2010 data, it is possible that less rainfall brought fewer of these natural acids into the lake, which would result in temporarily clearer water. Other environmental anomalies may exist as well which would account for the greater water clarity in this year.

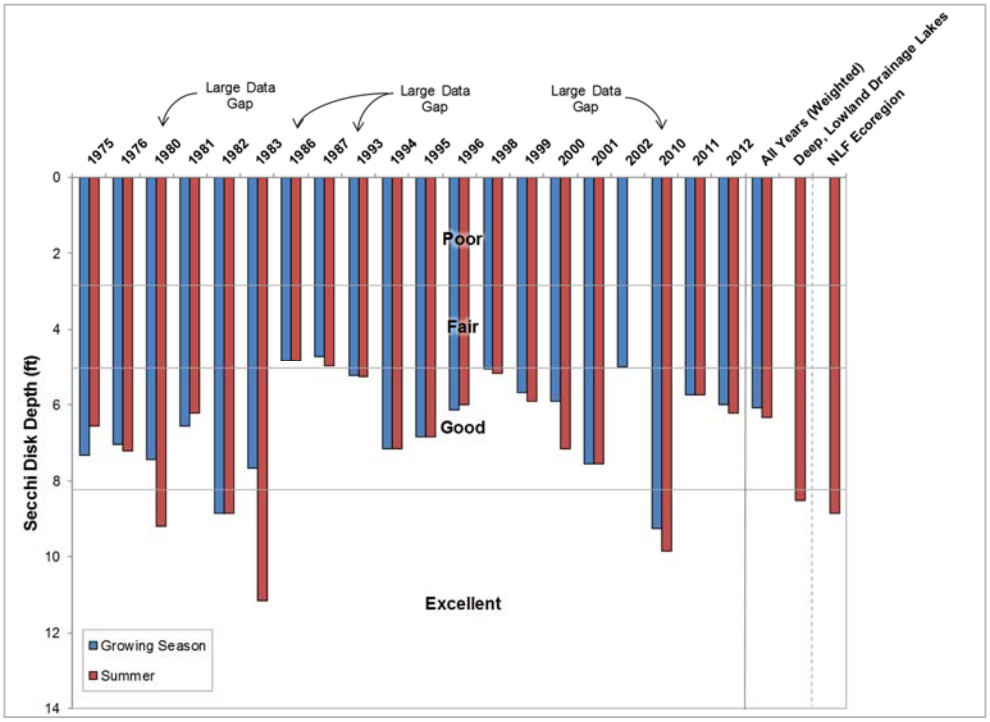


**Figure 8.11.1-3. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

## Big Fork Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.11.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Big Fork Lake is in a lower eutrophic state.

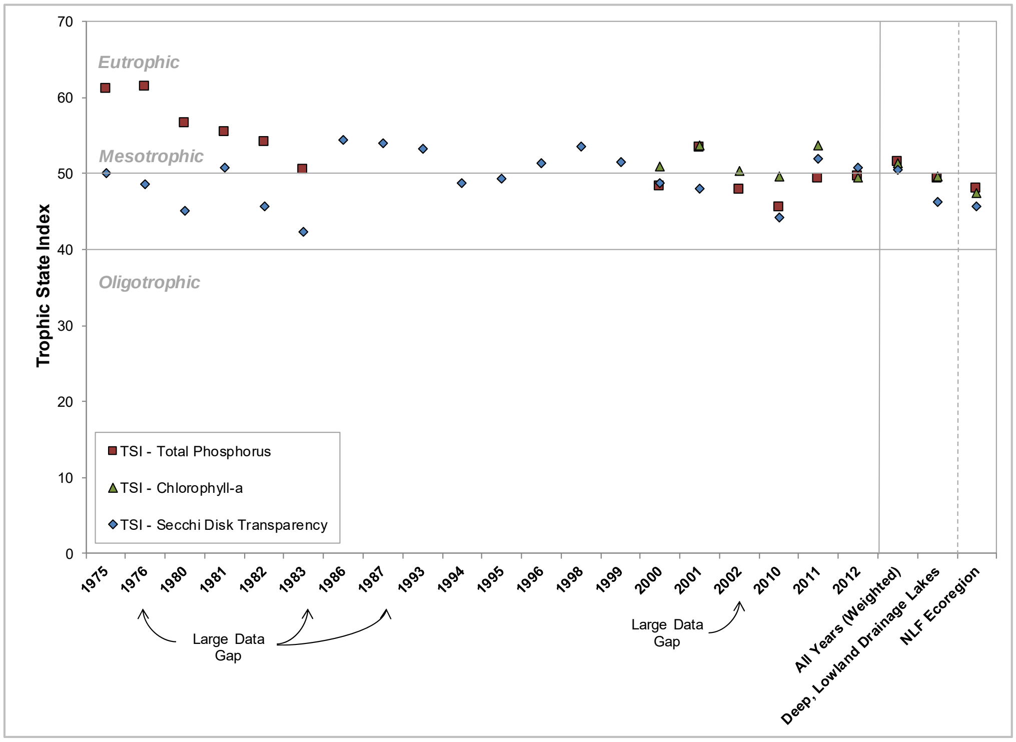


**Figure 8.11.1-4. Big Fork Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Big Fork Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Big Fork Lake by Onterra staff. Graphs of those data are displayed in Figure 8.11.1-5 for all three sampling events. In April and October, the lake was completely mixed, with dissolved oxygen and temperature readings found to be similar throughout the entire water column. During June, these parameters were higher in the epilimnion and dropped only slightly with depth. In July, Big Fork Lake became stratified, with a distinct warmer epilimnion and cooler hypolimnion. During this time, anoxic conditions were observed from 18 to 28 ft. Dissolved oxygen depletion may occur near the bottom of the lake as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being developed in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Despite the decrease in oxygen levels during the summer months, oxygen remained sufficient in the upper 18 feet of the water column to support most aquatic life found in northern Wisconsin lakes. Dissolved oxygen depletion may be of concern during the winter months due to the ice cover on the lake, which prohibits oxygen exchange from the air to the lake. Fortunately, dissolved oxygen was sufficient within the majority of the water column in February of 2013.

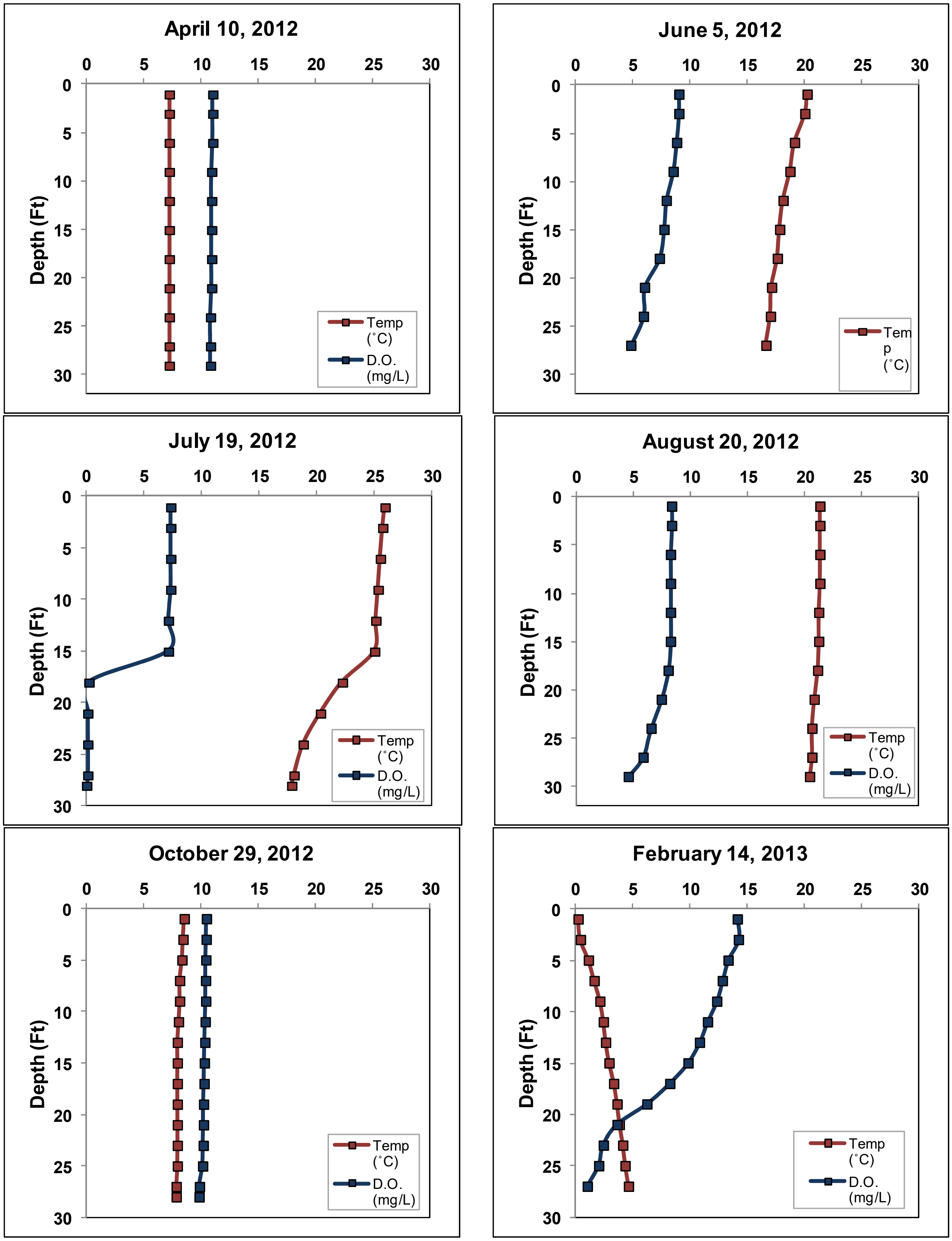


**Figure 8.11.1-5. Big Fork Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Big Fork 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 Big Fork 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Big Fork Lake's pH was measured at 7.4 in July 2012. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Big Fork Lake was measured at 39.9 (mg/L as $CaCO_3$) near the surface in July, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Big Fork Lake during the summer of 2012. Calcium is commonly examined because invasive and native mussels use the element to build shells and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Big Fork Lake's pH of 7.0-8.6 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Big Fork Lake was found to be 6.7 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.11.2 Big Fork Lake Watershed Assessment

Big Fork Lake's watershed is 14,833 acres in size. Compared to the lakes size of 670 acres, this makes for a large watershed to lake area ratio of 21:1.

Exact land cover calculation and modeling of nutrient input to Big Fork Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.11.3 Big Fork Lake Shoreland Condition Assessment

### Shoreland Development

As mentioned previously in the Chain-wide Watershed Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Big Fork Lake's immediate shoreline was assessed in terms of its development. Big Fork Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.5 miles of natural/undeveloped and developed-natural shoreline (44% of the entire shoreline) were observed during the survey (Figure 8.11.3-1). 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, roughly 1.1 miles of urbanized and developed–unnatural shoreline (17% of the total shoreline) was observed. If restoration of the Big Fork Lake shoreline 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. Big Fork Lake Map 1 displays the location of these shoreline lengths around the entire lake.

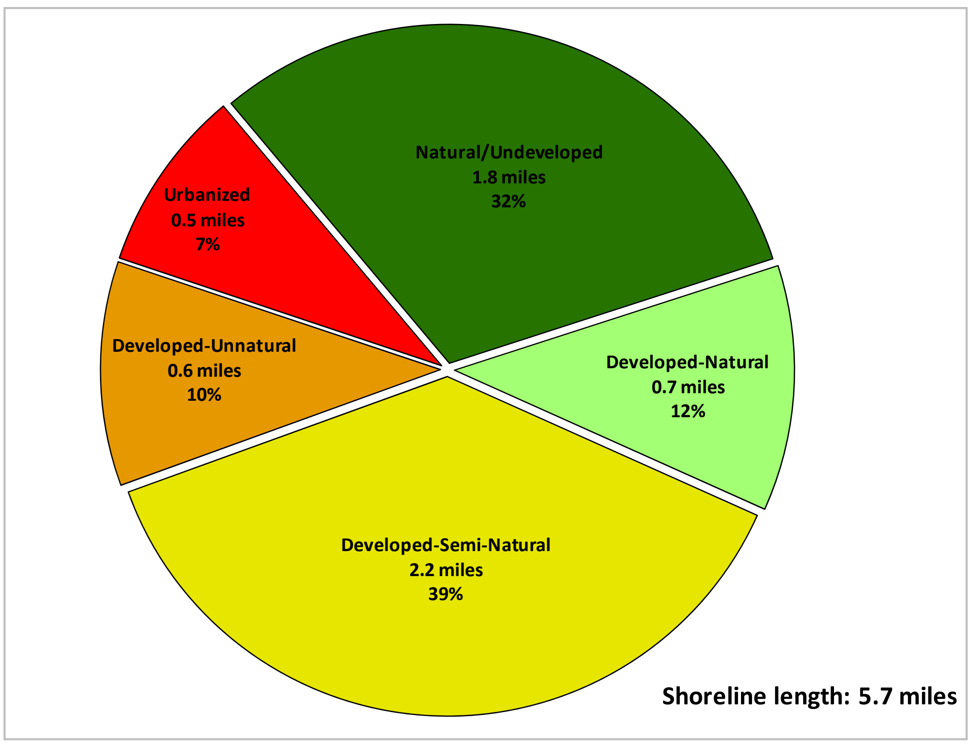


**Figure 8.11.3-1. Big Fork Lake shoreland categories and total lengths.** Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Big Fork Lake Map 1.

## Coarse Woody Habitat

Big Fork Lake was surveyed in 2014 to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, a total of 109 pieces of coarse woody habitat were observed along 5.7 miles of shoreline, which gives Big Fork Lake a coarse woody habitat to shoreline mile ratio of 19:1. Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of coarse woody habitat are displayed on Big Fork Lake Map 2.

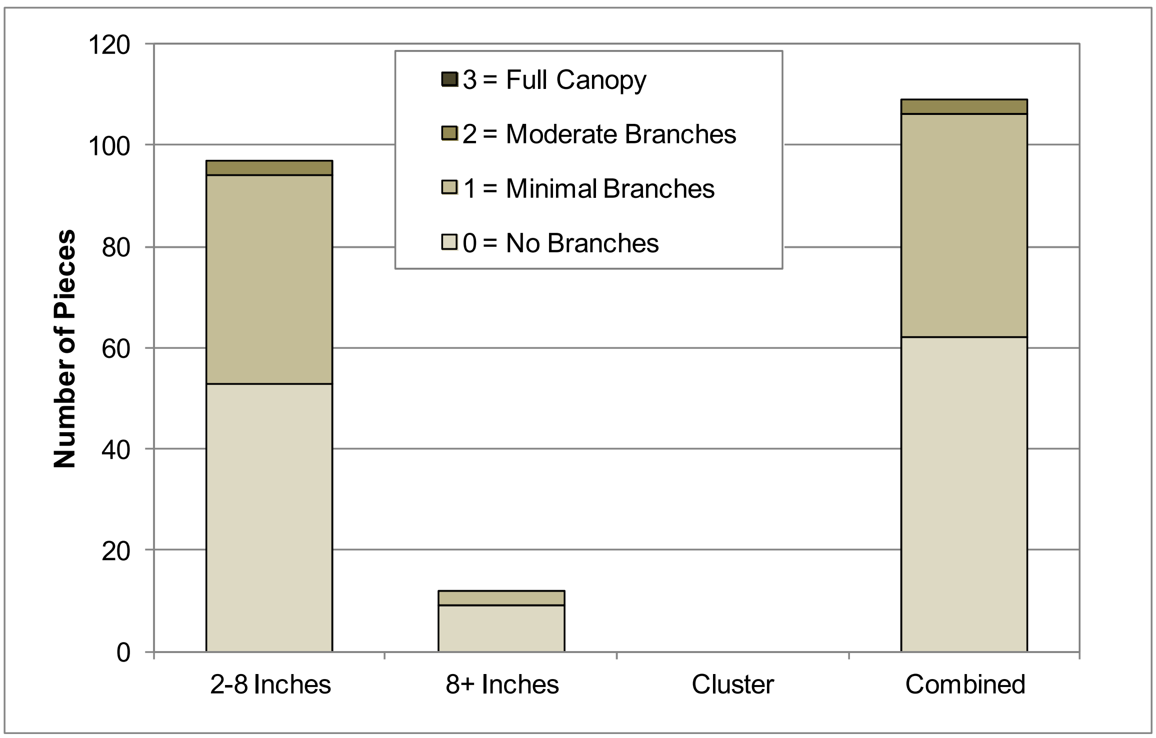


**Figure 8.11.3-2. Big Fork Lake coarse woody habitat survey results.** Based upon a Fall 2014 survey. Locations of Big Fork Lake coarse woody habitat can be found on Big Fork Lake Map 2.

### 8.11.4 Big Fork Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Big Fork Lake on June 5, 2012. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants. One exotic plant, pale yellow iris, was found along the shorelines of the lake during subsequent surveys. This plant is discussed in detail at the end of this section.

The aquatic plant point-intercept survey was conducted on Big Fork Lake on July 17, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that same day to create the aquatic plant community map (Big Fork Lake Community Map). During these surveys, 38 species of native aquatic plants were located in Big Fork Lake (Table 8.11.4-1). 23 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while 15 species were found incidentally.

Aquatic plants were found growing to a depth of ten feet, which is slightly deeper than in the other lakes within the Three Lakes Chain, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 204 point-intercept locations sampled within the littoral zone, approximately 51% contained aquatic vegetation. Approximately 77% of the point-intercept sampling locations where sediment data was collected at were sand, 10% consisted of a fine, organic substrate (muck) and 14% were determined to be rocky.

**Table 8.11.4-1. Aquatic plant species located in the Big Fork Lake during the 2012 aquatic plant surveys.**

| Life Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2012 (Onterra) |
|---|---|---|---|---|
| Emergent | *Carex vesicaria* | Blister sedge | 7 | I |
| | *Decodon verticillatus* | Water-willow | 7 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | X |
| | *Iris versicolor* | Northern blue flag | 5 | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Sagittaria rigida* | Stiff arrowhead | 8 | X |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Typha spp.* | Cattail spp. | 1 | I |
| | *Zizania palustris* | Northern wild rice | 8 | X |
| FL | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium emersum* | Short-stemmed bur-reed | 8 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| Submergent | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elatine minima* | Waterwort | 9 | X |
| | *Elodea nuttallii* | Slender waterweed | 7 | I |
| | *Heteranthera dubia* | Water stargrass | 6 | I |
| | *Isoetes spp.* | Quillwort species | 8 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | I |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Nitella spp.* | Stoneworts | 7 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton berchtoldii* | Slender pondweed | 7 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton obtusifolius* | Blunt-leaf pondweed | 9 | I |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | I |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | X |
| | *Potamogeton vaseyi* | Vasey's pondweed | 10 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | I |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | I |
| | *Utricularia vulgaris* | Common bladderwort | 7 | I |
| | *Vallisneria americana* | Wild celery | 6 | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| | *Sagittaria cristata* | Crested arrowhead | 9 | 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*

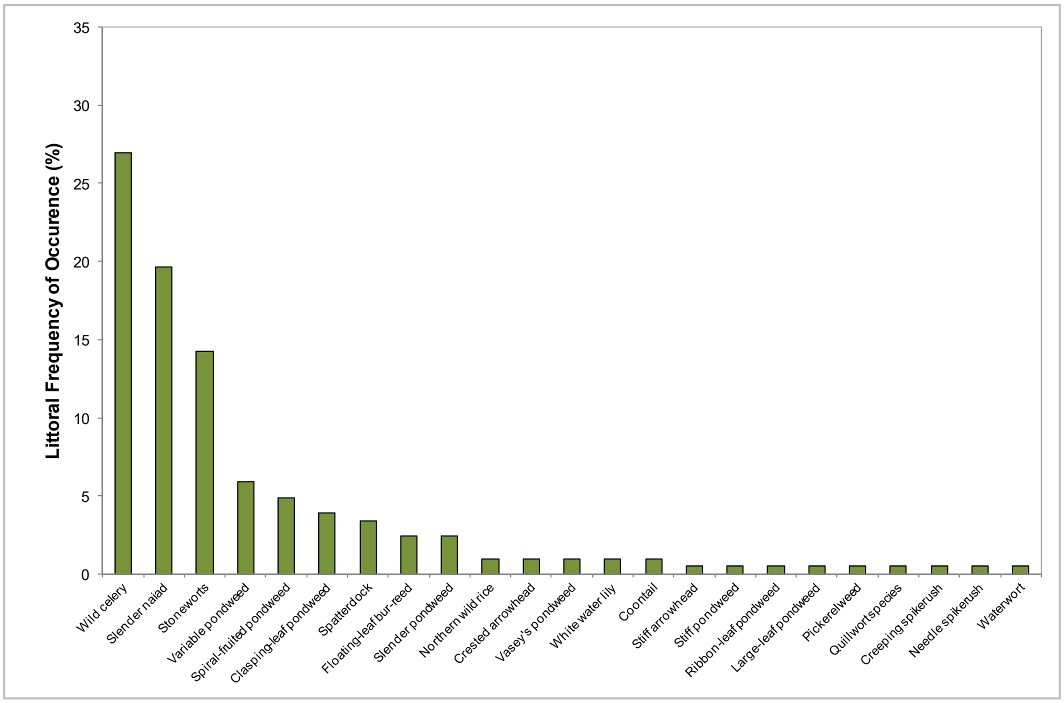


**Figure 8.11.4-1 Big Fork Lake aquatic plant littoral frequency of occurrence analysis.** Created using data from 2012 point-intercept survey.

Figure 8.11.4-1 (above) shows that wild celery, slender naiad, and members of the stonewort grouping were the most frequently encountered plants within Big Fork Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. Wild Celery has ribbon-like leaves that emerge in clusters along a creeping rhizome. The leaves have a prominant central stripe and cellophane-like consistency. The leaves are mostly submersed, with just the tips trailing on the surface of the water. Male and female flowers are produced on separate plants though they are very small (1 - 6.5 mm wide).

As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Nitella species, or stoneworts as they may be called, are actually a type of macro-algae rather than a vascular plant. Whorls of forked branches are attached to the “stems” of the plant, which are long, slender, smooth-textured algae. Because they lack roots, stoneworts remove nutrients directly from the water.

38 species of aquatic plants (including incidentals) were found in Big Fork Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Big Fork Lake’s plant community (0.84) lies slightly below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds moderate diversity with respect to its aquatic plant community. The reason for this is discussed below.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the 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 wild celery was found at 27% of the sampling locations, its relative frequency of occurrence is 29%. Explained another way, if 100 plants were randomly sampled from Big Fork Lake, 29 of them would be wild celery. This distribution can be observed in Figure 8.11.4-2, where together two species account for 50% of the population of plants within Big Fork Lake, while the remaining species account for the other half of the pie. Because of this unevenness, the diversity of the aquatic plant community is somewhat lower than the ecoregion median value. Fifteen additional species were located from the lake but not from of the point-intercept survey, as indicated in Table 8.11.4-1 as incidentals.

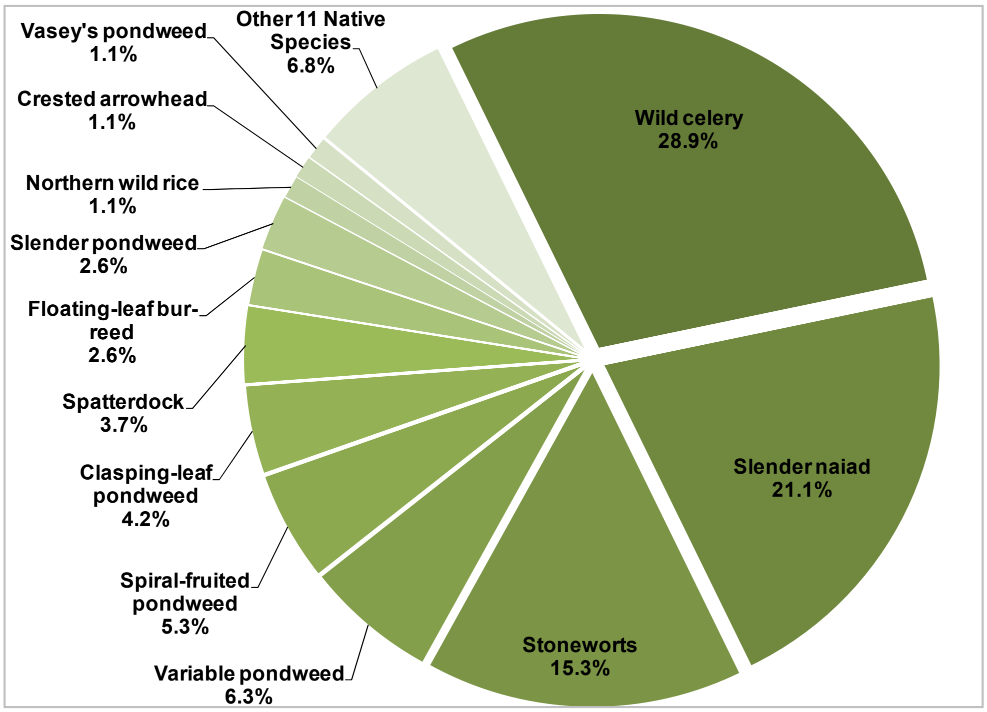


**Figure 8.11.4-2 Big Fork Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2012 point-intercept survey.

Despite the lower diversity value, Big Fork Lake’s average conservatism value (7.2) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community holds a number of species that are sensitive to environmental degradation. In other words, although there is much wild celery and slender naiad in the lake (two species that are fairly tolerant of environmental degradation), there are also several species present that are sensitive to disturbance, such as those listed on Table 8.11.4-1 that have Coefficient of Conservatism values of 8, 9 or 10 (Vasey’s pondweed, floating-leaf bur-reed, pickerelweed, blunt-leaf pondweed, quillwort species, etc.). Combining Big Fork Lake’s species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 34.6 which is above the median values of the ecoregion (24.3) and state (22.2).

The quality of Big Fork Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 9.6 acres of the lake contains these types of plant communities (Big Fork Lake Map 2, Table 8.11.4-2). Fifteen floating-leaf and emergent species were located on Big Fork Lake (Table 8.11.4-1), all of which provide valuable wildlife habitat.

**Table 8.11.4-2. Big Fork Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 2.2 |
| Floating-leaf | 3.7 |
| Mixed Floating-leaf and Emergent | 3.7 |
| **Total** | 9.6 |

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

## Aquatic Invasive Species in Big Fork Lake

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along much of the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale yellow iris on Big Fork Lake can be viewed on Big Fork Lake Map 2.

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## 8.11.5 Big Fork Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Big Fork Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Big Fork Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Big Fork Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Big Fork Lake's implementation plan is compiled by describing how Big Fork Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Big Fork Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Big Fork Lake as part of this chain-wide project, it is up to Big Fork Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Big Fork Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** While Big Fork Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Big Fork Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Big Fork Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Big Fork Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Big Fork Lake or from Big Fork Lake elsewhere. If a Big Fork Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Big Fork Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Big Fork Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Big Fork Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Big Fork Lake and its stakeholders.

## *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Big Fork Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Big Fork Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Big Fork Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Big Fork Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Big Fork Lake shoreline was categorized in terms of its development. According to the results from this survey, 17.0% of the shoreline is in an urbanized or developed-unnatural state, while 39.0% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

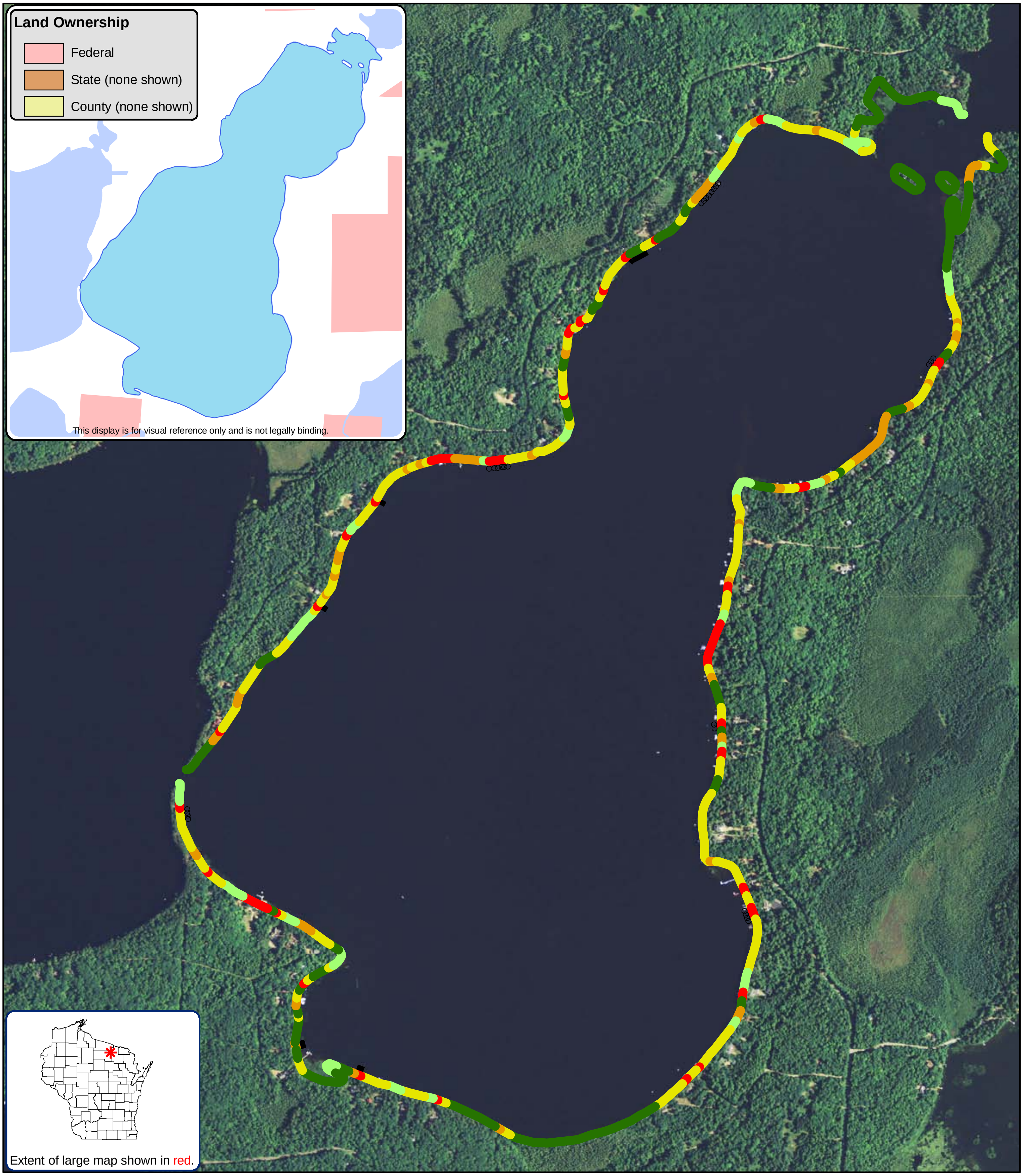
The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Big Fork Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Big Fork Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.

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Feet

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

**Sources:**
Orthophotography: NAIP, 2010
Shoreline Assessment: Onterra, 2012
Federal Land: USDA Forest Service
Map date: January 3, 2013
*Filename: BigFork_ShorelineCondition_2012.mxd*

**Legend**

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

Seawall

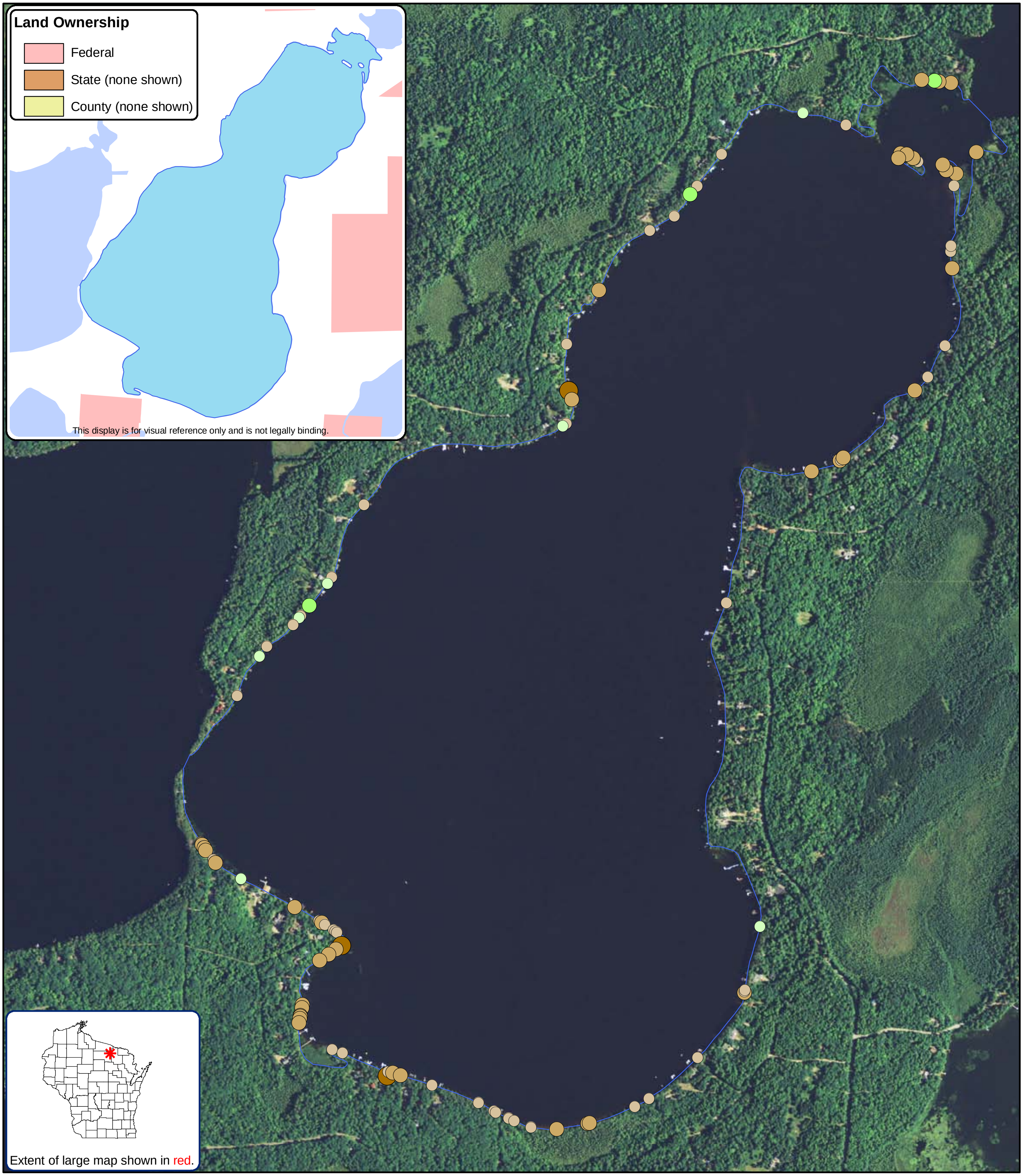
- Masonary/Wood
- Rip-Rap

Big Fork Lake - Map 1

Three Lakes Chain

Oneida County, Wisconsin

**Shoreland Condition**

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# 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 (none) | Moderate Branches (none) |
| Full Canopy (none) | Full Canopy (none) | Full Canopy (none) |


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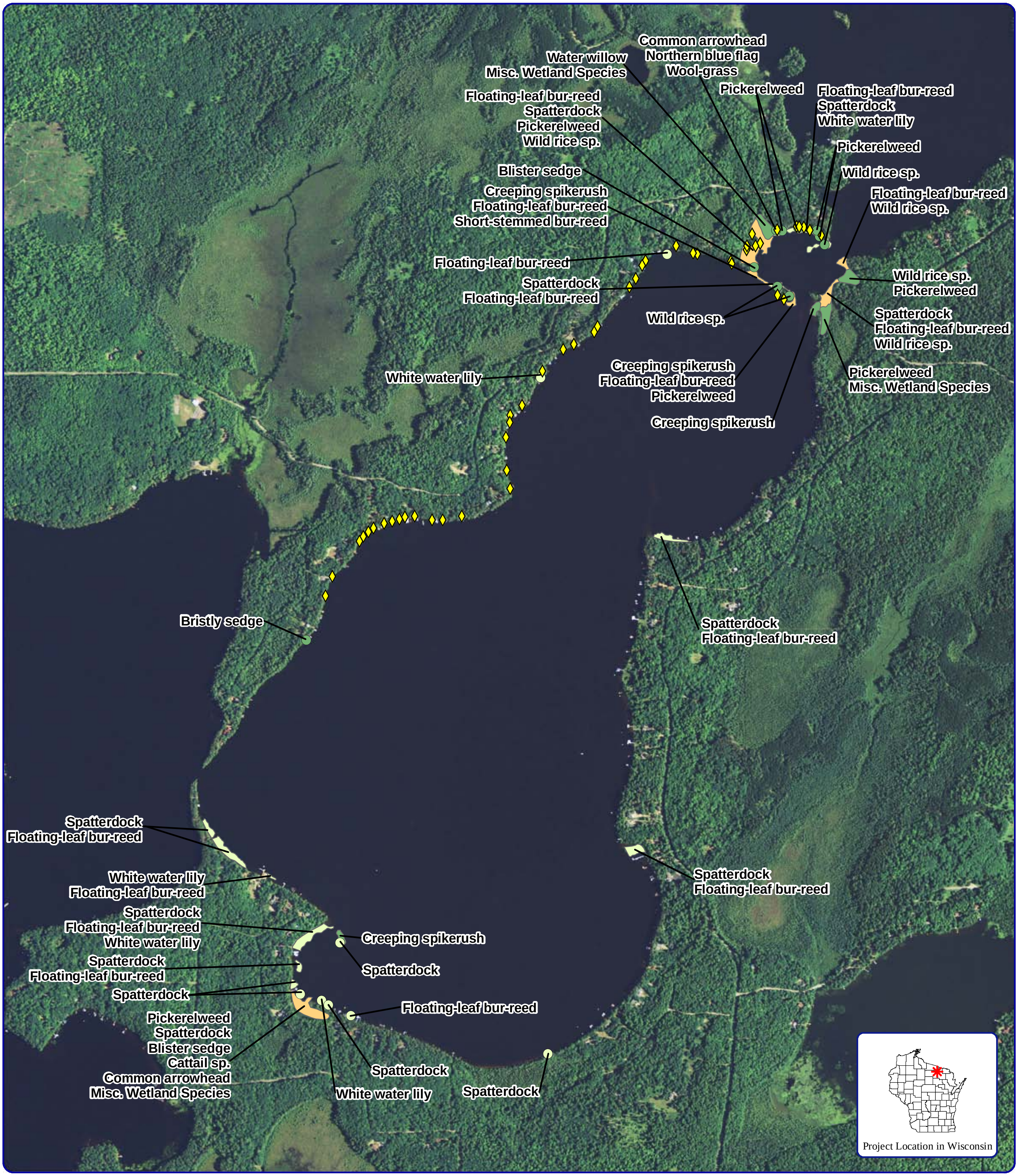
**Sources:**
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2014
Federal Land: USDA Forest Service
Map date: October 17, 2014
*Filename: BigFork_CWH_2014.mxd*

Big Fork Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin

**2014 Coarse Woody Habitat**

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*De Pere, WI 54115*
*920.338.8860*
*www.onterra-eco.com*

**Sources:**
Hydro: WDNR
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
**Map date:** November 26, 2012
***Filename:** BigFork_Comm_2012.mxd*

## Legend

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

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

**Exotic Plant Communities**
- Pale Yellow Iris

# Big Fork Lake - Map 3
## Three Lakes Chain
Oneida County, Wisconsin

# Aquatic Plant Communities

***Note: Methodology, explanation of analysis and scientific background on Moccasin Lake studies are contained within the Three Lakes Chain-wide Management Plan document.***

## 8.12 Moccasin Lake

## An Introduction to Moccasin Lake

Moccasin Lake, Oneida County, is a shallow headwater drainage lake with a maximum depth of 19 feet and a surface area of 88 acres. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Moccasin Lake contains 44 native plant species, of which fern pondweed and common waterweed are the most common. One exotic plant, pink water lily, was observed during the 2013 lake surveys.

**Field Survey Notes**

*Much of the lake shore is undeveloped with a fair amount of coarse woody habitat as well.*

*Pink water lily observed in one location of the lake.*

*Connecting waters from Moccasin to Spirit Lake were low in the late summer, but still navigable for smaller watercraft.*

**Photo 8.12.1-1 Moccasin Lake, Oneida County**

### Lake at a Glance* – Moccasin Lake

| Morphology | |
|---|---|
| Acreage | 88 |
| Maximum Depth (ft) | 19 |
| Mean Depth (ft) | 9 |
| Volume (acre-feet) | 811 |
| Shoreline Complexity | 1.7 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 25, 2013 |
| Comprehensive Survey Date | July 25, 2013 |
| Number of Native Species | 44 |
| Threatened/Special Concern Species | Vasey’s pondweed |
| Exotic Plant Species | Pale yellow iris, Pink water lily |
| Simpson's Diversity | 0.86 |
| Average Conservatism | 7.0 |
| **Water Quality** | |
| Wisconsin Lake Classification | Shallow, headwater drainage |
| Trophic State | Mesotrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 3:1 |

*These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.12.1 Moccasin Lake Water Quality

As a part of this project, water quality data was collected from Moccasin Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake. As Table 8.12.1-1 indicates, some historical data exists for these parameters. In addition to this project, data has been collected by the WDNR, WVIC and Citizens Lake Monitoring Network (CLMN).

During 2013, summer total phosphorus values collected from the Moccasin Lake surface averaged 12.0 µg/L, which ranks as *Excellent* when compared to similar shallow, headwater drainage lakes within the state and all lakes in the Northern Lakes and Forests ecoregion (Figure 8.12.1-1). A growing season average, which includes data from spring (May) and fall (October) turnover periods is slightly higher at 17.0 µg/L, but still *Excellent* for this lake type and location within the state. Historical data for the lake includes samples collected in 1979, 1984 and 1985.

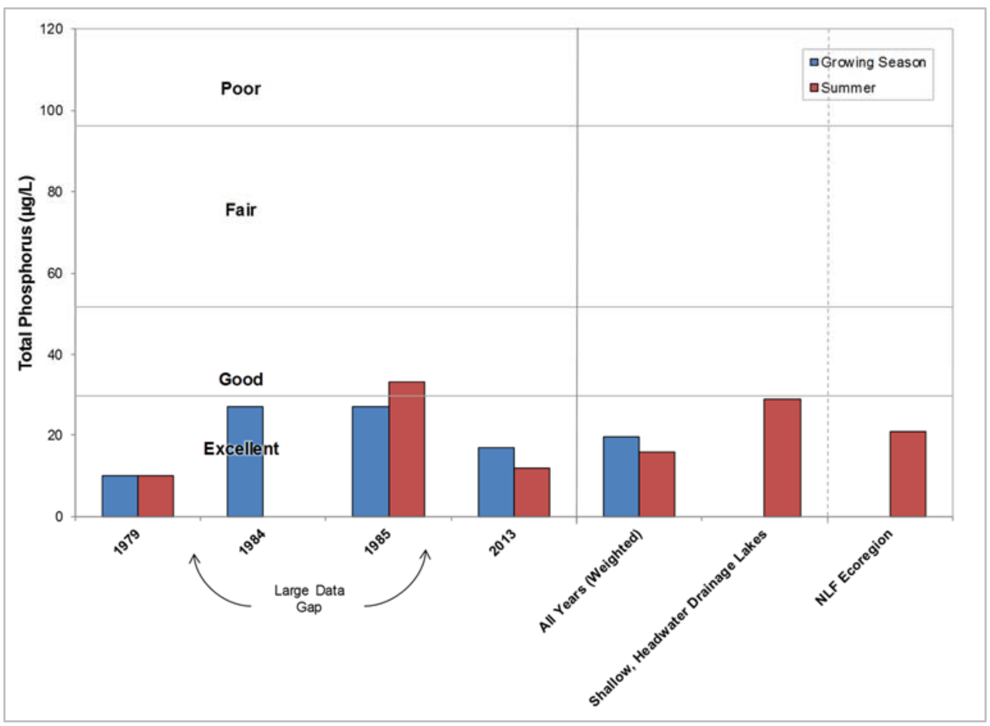



**Figure 8.12.1-1. Moccasin Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Chlorophyll-*a* has only been measured in two years on Moccasin Lake (1979 and 2013). 2013 growing season and summer concentrations were low and rank as *Excellent* for shallow, headwater drainage lakes and all lakes statewide. A direct indicator of algae, these results indicate that a low amount of free-floating algae exists within the lake. This parameter does not however give an indication of other kinds of algae, such as those species bound to plants or substrate (i.e. periphyton or filamentous algae).

Through citizen monitoring that took place in the late 1980's and early 1990's, a larger dataset is available for Moccasin Lake with regards to Secchi disk clarity (Figure 8.12.1-2). These data largely fall within the *Excellent* category for shallow, headwater drainage lakes across the state. A weighted average value across all years lies above the median value for similar lakes state-wide and all lakes in the ecoregion. Several large data gaps exist within the dataset, so trends occurring through 2013 are not able to be determined as it is difficult to say what occurred with Moccasin Lake's water quality from 1992 through 2013.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In other lakes within Three Lakes Chain, a natural staining of the water plays a major role in light penetration, and thus water clarity. Moccasin Lake, being a headwater lake, has a much smaller watershed and no direct inlet to draw water from. Therefore, it is less stained than other lakes within the chain. Algal production is likely the greatest factor that can influence water clarity within Moccasin Lake.

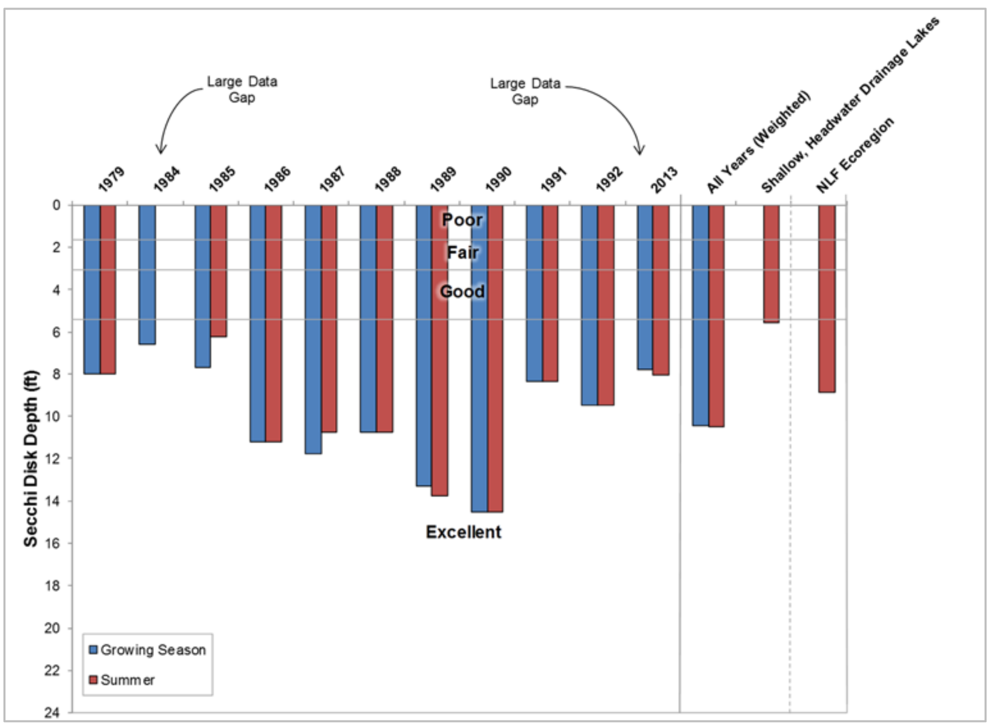



**Figure 8.12.1-2. Moccasin Lake, state-wide shallow, headwater drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

**Moccasin Lake Trophic State**

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.12.1-3). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Moccasin Lake is in a mesotrophic/lower oligotrophic state.

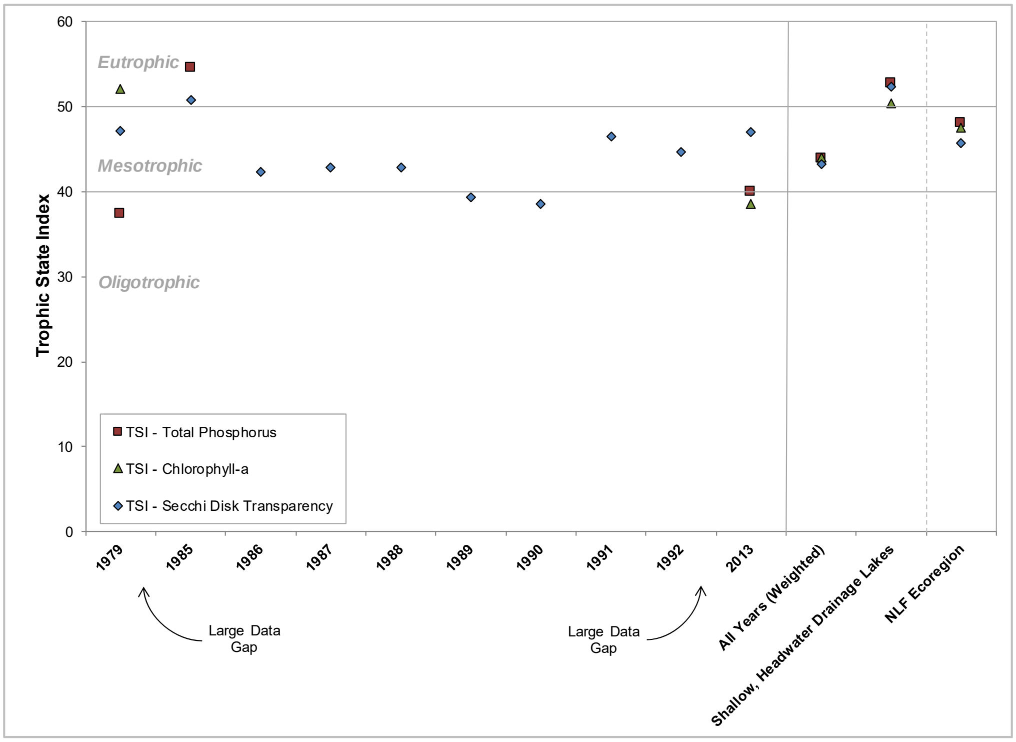



**Figure 8.12.1-3. Moccasin Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Moccasin Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Moccasin Lake by Onterra staff. Graphs of those data are displayed in Figure 8.12.1-4 for all three sampling events. In April and October, the lake was completely mixed, with dissolved oxygen and temperature readings found to be similar throughout the entire water column. During June, these parameters were higher in the epilimnion and dropped with depth – an indication that the lake was setting up thermal zones (stratifying). In July, Moccasin Lake displayed some characteristics of slight mixing throughout part of the water column. This may happen in relatively shallow lakes when winds are strong enough to mix the water column. Some stratification began to reappear in August, with complete mixing occurring in October.

During stratification, it is possible for oxygen concentrations to reduce within the lower portions of the lake. Dissolved oxygen depletion occurs as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being developed in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Dissolved oxygen depletion may be of concern during the winter months due to the ice cover on the lake, which prohibits oxygen exchange from the air to the lake. In February of 2014, oxygen depletion had occurred from a depth of roughly seven feet to the bottom. With ice cover lasting well through March and April of 2014, it is quite possible that additional oxygen depletion occurred. During these times, fish may move to areas of open water, such as near the Spirit Lake-Moccasin Lake connecting waterway or natural spring areas, to seek oxygen. It is unknown if winter fish kill, a sign of high oxygen depletion, has occurred on Moccasin Lake.

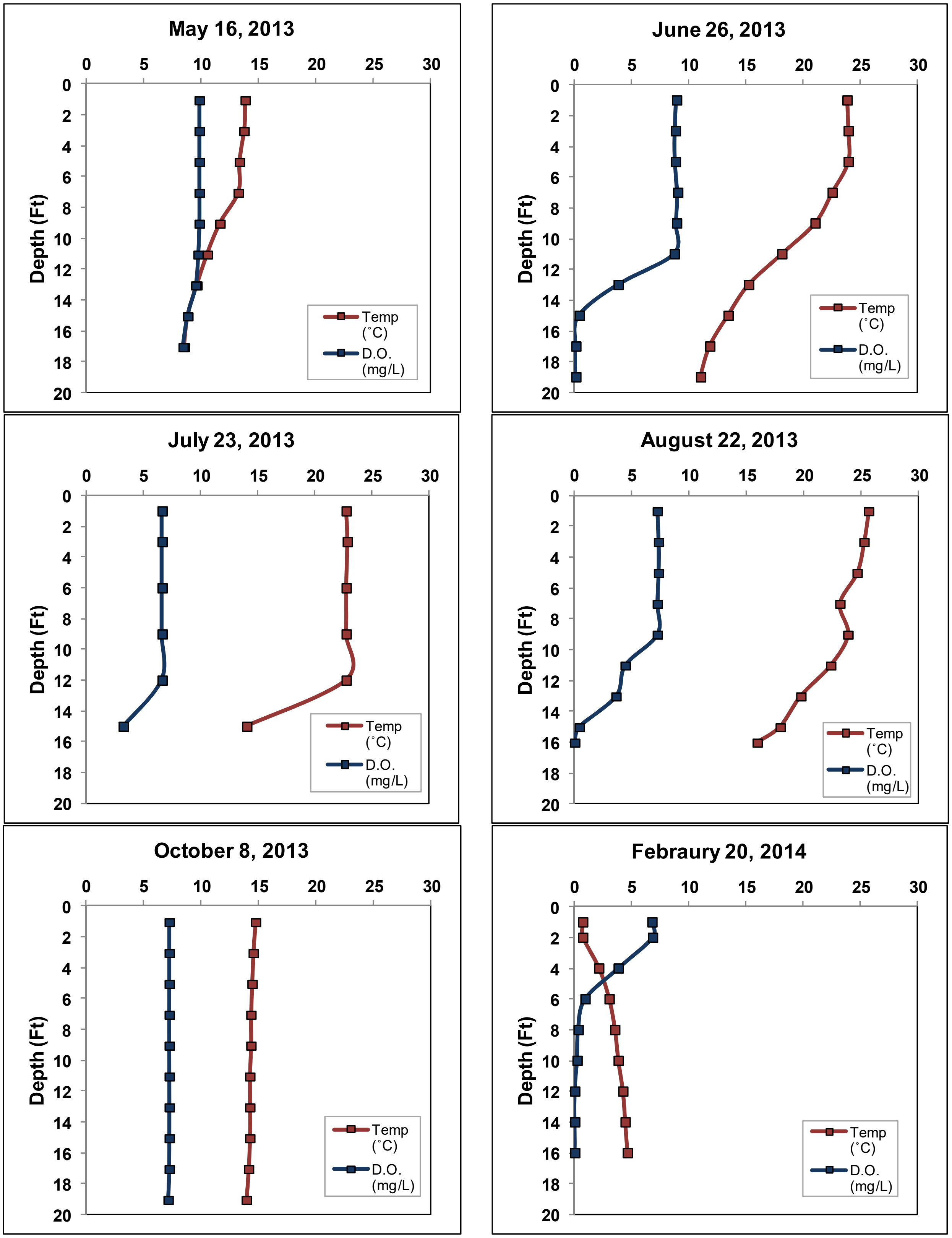



**Figure 8.12.1-4. Moccasin Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Moccasin 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 Moccasin 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Moccasin Lake's surface pH was measured at 7.6 in July 2013. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Moccasin Lake was measured at 37.0 (mg/L as $CaCO_3$) near the surface in July 2013, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Moccasin Lake during the summer of 2013. Calcium is commonly examined because invasive and native mussels use the element to build shells and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Moccasin Lake's pH of 7.6 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Moccasin Lake was found to be 9.4 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.12.2 Moccasin Lake Watershed Assessment

Moccasin Lake's watershed is 377 acres in size. Compared to the lakes size of 88 acres, this makes for a small watershed to lake area ratio of 3:1.

Exact land cover calculation and modeling of nutrient input to Moccasin Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.12.3 Moccasin Lake Shoreland Condition Assessment

### Shoreland Development

As mentioned previously in the Chain-wide Watershed Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In the fall of 2013, Moccasin Lake's immediate shoreline was assessed in terms of its development. Moccasin Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.3 miles of natural/undeveloped and developed-natural shoreline (75% of the entire shoreline) were observed during the survey (Figure 8.12.3-1). 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, less than 0.3 miles of urbanized and developed–unnatural shoreline (14% of the total shoreline) was observed. If restoration of the Moccasin Lake shoreline 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. Moccasin Lake Map 1 displays the location of these shoreline lengths around the entire lake.

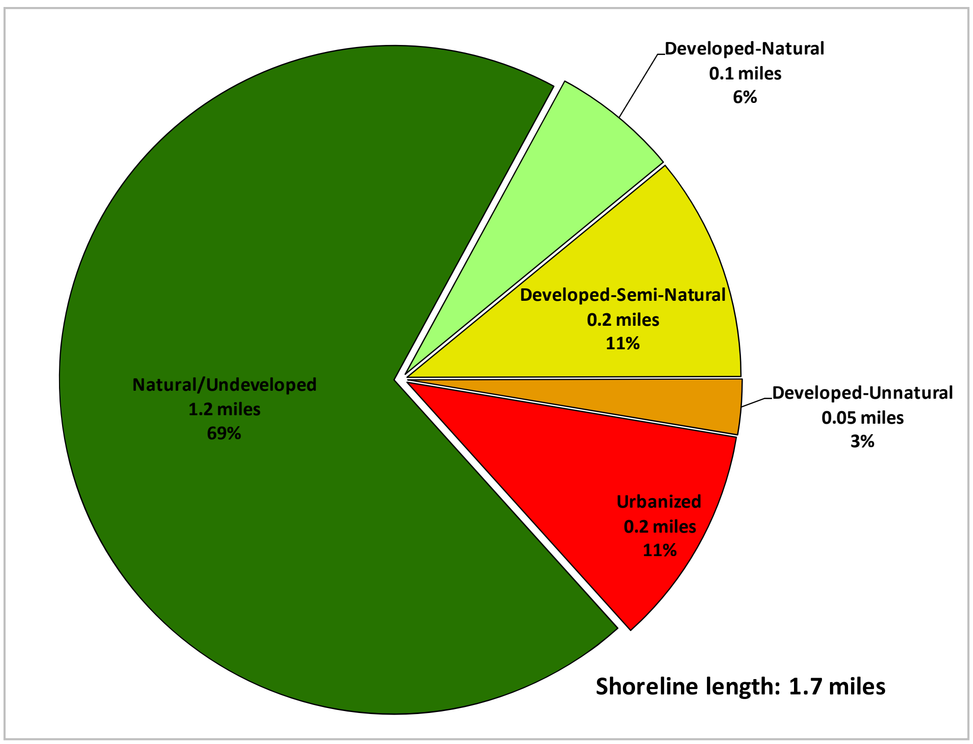



**Figure 8.12.3-1. Moccasin Lake shoreland categories and total lengths.** Based upon a fall 2013 survey. Locations of these categorized shorelands can be found on Moccasin Lake Map 1.

## Coarse Woody Habitat

Moccasin Lake was 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 and 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, 83 total pieces of coarse woody habitat were observed along 1.7 miles of shoreline, which gives Moccasin Lake a coarse woody habitat to shoreline mile ratio of 48:1 (Figure 8.12.3-2). Locations of coarse woody habitat are displayed on Moccasin Lake Map 2.

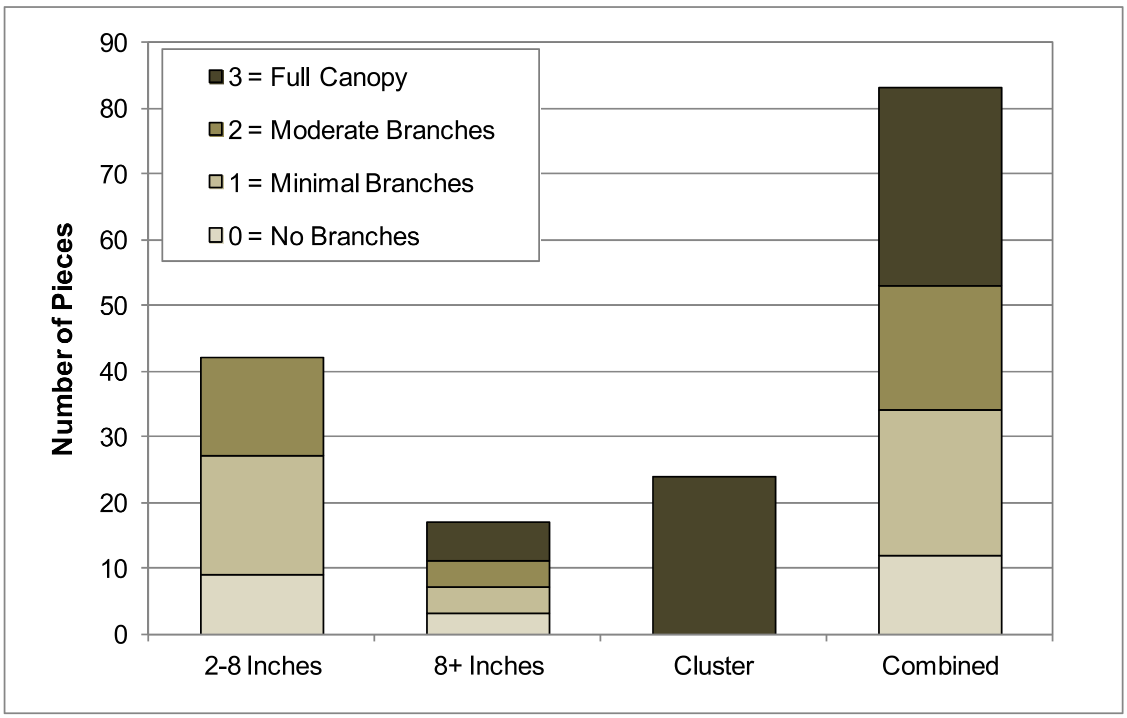



**Figure 8.12.3-2. Moccasin Lake coarse woody habitat survey results.** Based upon a Fall 2013 survey. Locations of Moccasin Lake coarse woody habitat can be found on Moccasin Lake Map 2.

## 8.12.4 Moccasin Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Moccasin Lake on June 25, 2013. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants.

The aquatic plant point-intercept survey was conducted on Moccasin Lake on July 25, 2014 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that same day to create the aquatic plant community map (Moccasin Lake Map 3). During these surveys, 44 species of native aquatic plants were located in Moccasin Lake (Table 8.12.4-1). 36 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while eight native species were found incidentally. Two additional plants, pale yellow iris (*Iris pseudocorus*) and pink water lily (*Nymphaea odorata f. rosea*) are considered non-native species and will be discussed further at the end of this section.

Aquatic plants were found growing to a depth of fourteen feet, which is slightly deeper than in the other lakes within the Three Lakes Chain, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 207 point-intercept locations sampled within the littoral zone, approximately 88% contained aquatic vegetation. Approximately 11% of the point-intercept sampling locations where sediment data was collected at were sand, 89% consisted of a fine, organic substrate (muck) and no locations were determined to be rocky.

**Table 8.12.4-1. Aquatic plant species located in the Moccasin Lake during the 2013 aquatic plant surveys.**

| Growth Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2013 (Onterra) |
|---|---|---|---|---|
| Emergent | *Carex lasiocarpa* | Woolly-fruit sedge | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | I |
| | *Glyceria canadensis* | Rattlesnake grass | 7 | I |
| | *Iris pseudocorus* | Pale yellow iris | Exotic | I |
| | *Juncus effusus* | Soft rush | 4 | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Schoenoplectus pungens* | Three-square rush | 5 | I |
| | *Schoenoplectus subterminalis* | Water bulrush | 9 | X |
| | *Typha spp.* | Cattail spp. | 1 | I |
| FL | *Brasenia schreberi* | Watershield | 7 | X |
| | *Nymphaea odorata f. rosea* | Pink water lily | Exotic | I |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | X |
| | *Sparganium natans* | Little bur-reed | 9 | X |
| Submergent | *Chara spp.* | Muskgrasses | 7 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Eriocaulon aquaticum* | Pipewort | 9 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Heteranthera dubia* | Water stargrass | 6 | X |
| | *Isoetes sp.* | Quillwort species | N/A | X |
| | *Lobelia dortmanna* | Water lobelia | 10 | X |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Myriophyllum tenellum* | Dwarf water milfoil | 10 | X |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | X |
| | *Potamogeton vaseyi* | Vasey's pondweed | 10 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Sagitaria sp. (rosette)* | Arrowhead rosette | N/A | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Utricularia minor* | Small bladderwort | 10 | X |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| | *Juncus pelocarpus* | Brown-fruited rush | 8 | X |
| FF | *Spirodela polyrhiza* | Greater duckweed | 5 | 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*

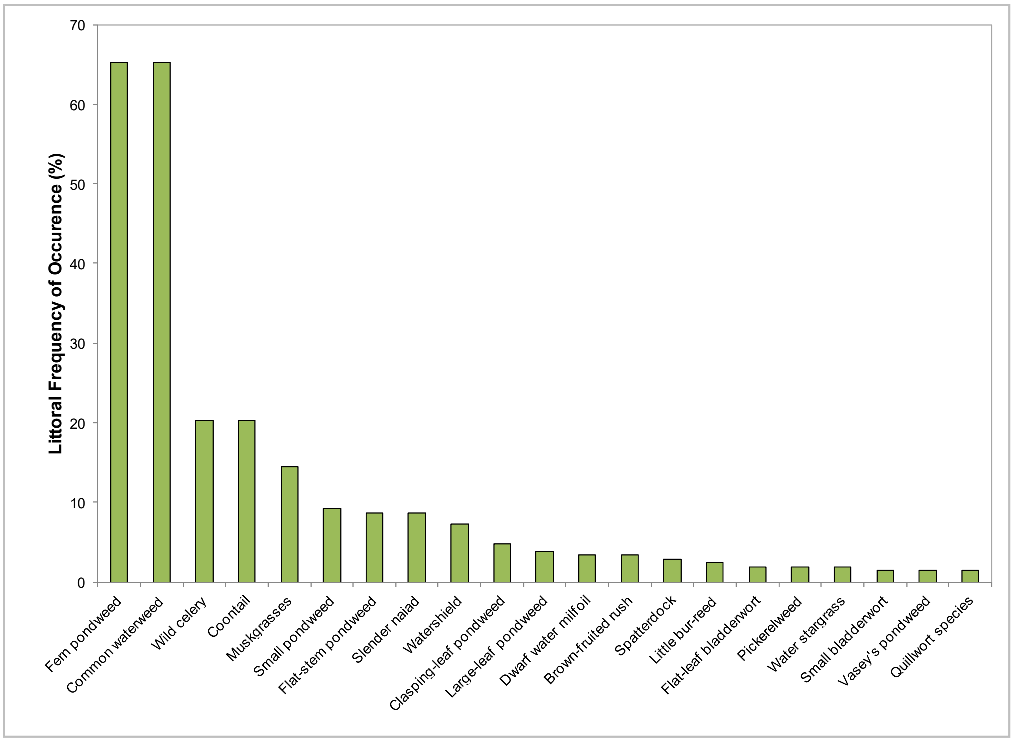



**Figure 8.12.4-1 Moccasin Lake aquatic plant littoral frequency of occurrence analysis.** Created using data from 2013 point-intercept survey. Only plants with frequency greater than 1.0% are displayed.

Figure 8.12.4-1 (above) shows that fern pondweed, common waterweed, and wild celery were the most frequently encountered plants within Moccasin Lake. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Common waterweed is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and their locations can be largely a product of water movement. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates.

44 species of aquatic plants (including incidentals) were found in Moccasin Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Moccasin Lake's plant community (0.86) is equal to the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds good diversity with respect to its aquatic plant community. The reason for this is discussed below.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section (Chain-wide plan, page 50), the 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 fern pondweed was found at 65% of the sampling locations, its relative frequency of occurrence is 25%. Explained another way, if 100 plants were randomly sampled from Moccasin Lake, 25 of them would be fern pondweed. This distribution can be observed in Figure 8.12.4-2, where together two species account for 50% of the population of plants within Moccasin Lake, while the remaining species account for the other half of the pie. If the top two species accounted for less of the relative frequency total, the diversity value would likely be larger. Nine additional native species were located from the lake but not from of the point-intercept survey, as indicated in Table 8.12.4-1 as incidentals.

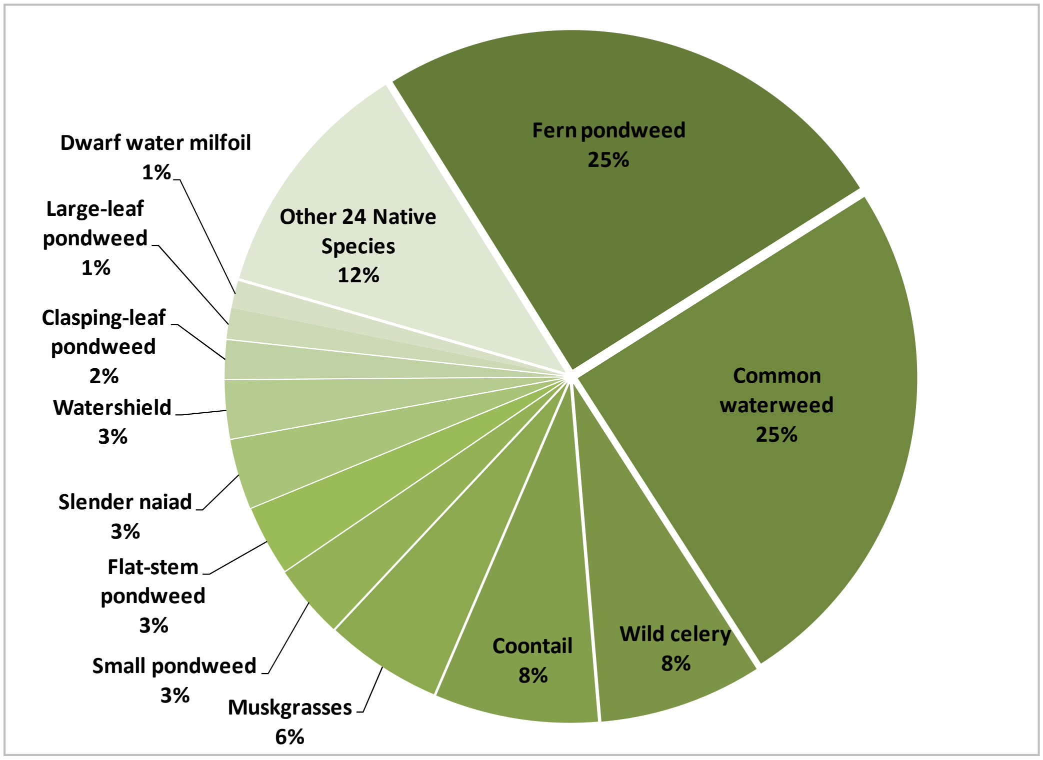



**Figure 8.12.4-2 Moccasin Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2013 point-intercept survey.

Moccasin Lake's average conservatism value (7.3) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community holds a number of species that are sensitive to environmental degradation. In other words, although there is much fern pondweed and common waterweed in the lake (two species that are fairly tolerant of environmental degradation), there are also several species present that are sensitive to disturbance, such as those listed on Table 8.12.4-1 that have Coefficient of Conservatism values of 8, 9 or 10 (water lobelia, dwarf water milfoil, floating-leaf bur-reed, flat-leaf bladderwort, etc.). Combining Moccasin Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 43.8 which is above the median values of the ecoregion (24.3) and state (22.2).

The quality of Moccasin Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2013 community map indicates that approximately 14.2 acres of the lake contains these types of plant communities (Moccasin Lake Map 2, Table 8.12.4-2). Sixteen floating-leaf and emergent species were located on Moccasin Lake (Table 8.12.4-1), all of which provide valuable wildlife habitat.

**Table 8.12.4-2. Moccasin Lake acres of emergent and floating-leaf plant communities from the 2013 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 2.7 |
| Floating-leaf | 10.5 |
| Mixed Floating-leaf and Emergent | 1.0 |
| **Total** | 14.2 |

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

## *Aquatic Plants of Concern*

### Water lily (pink)

During the 2013 point-intercept survey, Onterra ecologists came upon an occurrence of a non-native floating-leaf plant - *Nymphaea odorata var. rosea*, or what is commonly called a pink water lily. This is a floating-leaf species closely related to white water lily; it is a sub-species that is commonly found planted within small ornamental ponds or aquariums. It is popular in this arena due to the bright pink/rose colored flower it produces. This colony was found to exist in only a single location. Currently, this variety of lily is considered non-native, though not necessarily invasive as it is not thought to exhibit the aggressive, rapidly expanding qualities that invasive plants such as Eurasian water milfoil and curly-leaf pondweed display. Nevertheless, it is recommended that this non-native plant be manually removed from the lake and not given the chance to expand. Details regarding the management of this water lily are discussed within the Implementation Plan.

**Photograph 3.4-1. *Nymphaea odorata var. rosea,* Moccasin Lake.**

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along the shoreline areas in a few locations during the early-season aquatic invasive species survey.

### 8.12.5 Moccasin Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Moccasin Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Moccasin Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Moccasin Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Moccasin Lake's implementation plan is compiled by describing how Moccasin Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Moccasin Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Moccasin Lake as part of this chain-wide project, it is up to Moccasin Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Moccasin Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** While Moccasin Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Spirit Lake and Laurel Lake, though this connection is small. Regardless, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Moccasin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Moccasin Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Moccasin Lake or from Moccasin Lake elsewhere. If a Moccasin Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Moccasin Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Moccasin Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Moccasin Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Moccasin Lake and its stakeholders.

## Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Moccasin Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Moccasin Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Moccasin Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Moccasin Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Moccasin Lake shoreline was categorized in terms of its development. According to the results from this survey, 14.0% of the shoreline is in an urbanized or developed-unnatural state, while 75.0% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

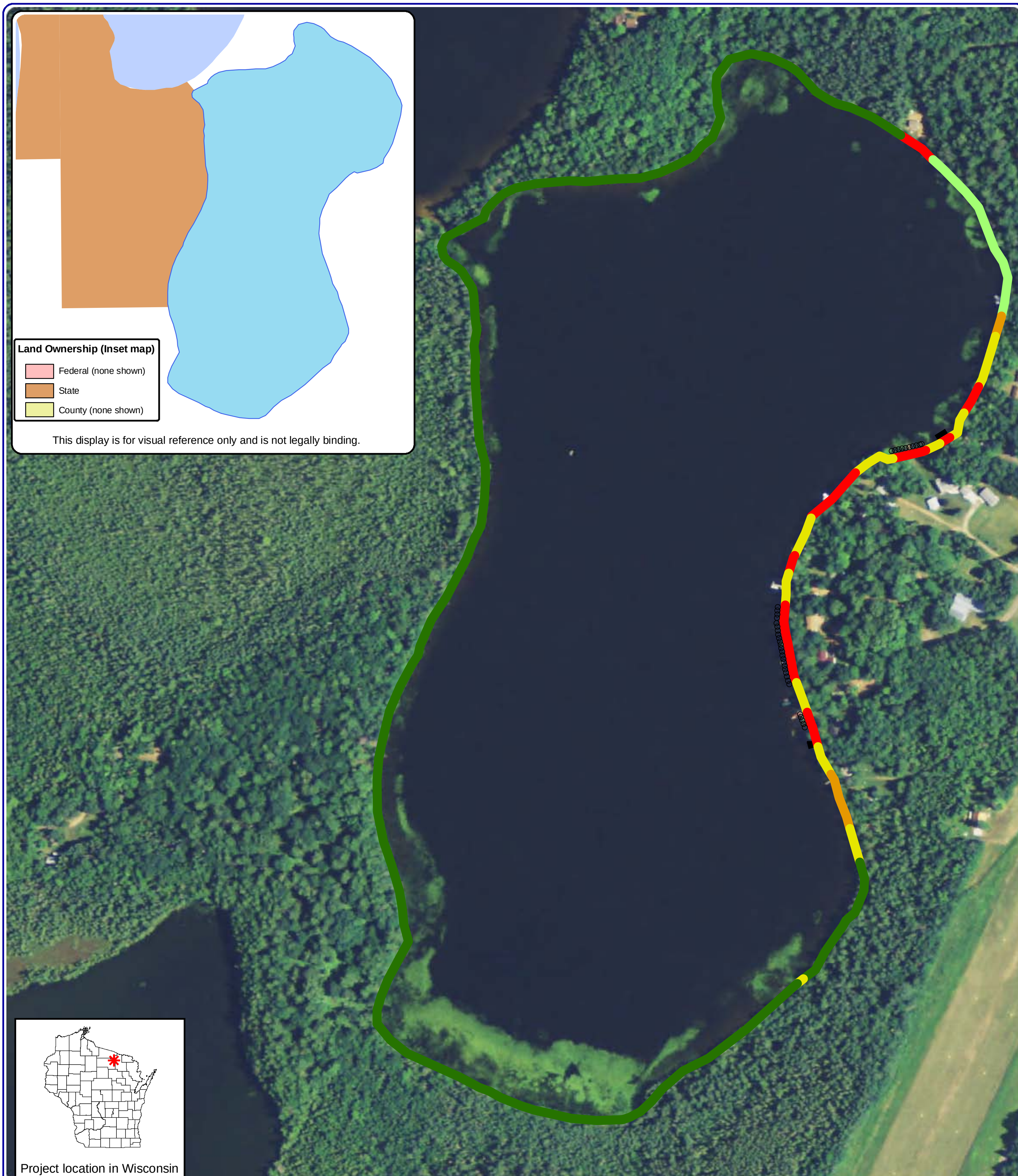
The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## *Chain-wide Management Goal 6: Improve Fishery Resource and Fishing*

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Moccasin Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Moccasin Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.




N
W E
S
400
Feet

**Legend**

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

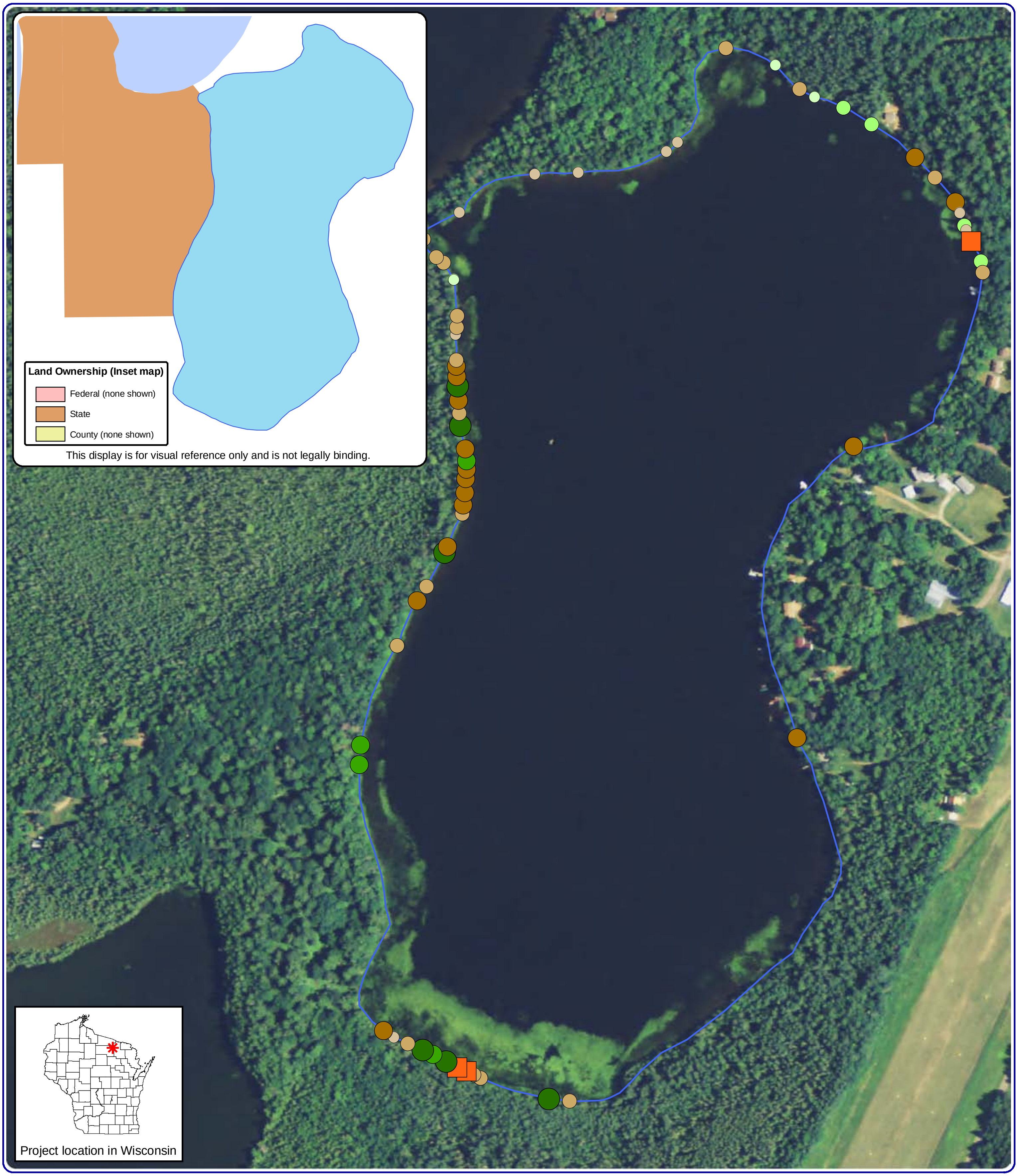
Seawall
- Wood
- Rip-Rap

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

Sources:
Orthophotography: NAIP, 2013
SCA Survey: Onterra, 2013
Map date: December 2, 2013
Filename: Moccasin_SCA_2013.mxd

# Moccasin Lake - Map 1
## Three Lakes Chain
Oneida County, Wisconsin

## Shoreland Condition Assessment




400
Feet

## Legend

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

# Moccasin Lake - Map 2
## Three Lakes Chain
Oneida County, Wisconsin

# Coarse Woody Habitat


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


Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2013

Map date: December 30, 2013
Filename: Moccasin_CWH_2013.mxd


N W E S

400

Feet

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

**Sources:**
Hydro: WDNR
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2013
**Map date:** November 13, 2013
*Filename: Moccasin_Comm_2013.mxd*

## Legend

| Exotic Communities | Small Plant Communities | Large Plant Communities |
|---|---|---|
| | Emergent | Emergent |
| Pink water lily | Floating-leaf | Floating-leaf |
| | Mixed Floating-leaf & Emergent | Mixed Floating-leaf & Emergent |

Moccasin Lake - Map 3

Three Lakes Chain

Oneida County, Wisconsin

**Aquatic Plant Communities**

**Note: Methodology, explanation of analysis and scientific background on Spirit Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.13 Spirit Lake

## An Introduction to Spirit Lake

Spirit Lake, Oneida County, is a deep, headwater drainage lake with a maximum depth of 39 feet and a surface area of 355 acres. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Roughly 37% of the shoreline borders State Highway 32 as it crosses the Three Lakes Chain in Oneida County. Spirit Lake contains 62 native plant species, of which common waterweed was the most common plant. Reed canary grass and pale yellow iris are two non-native plant species observed in the 2013 surveys.

**Field Survey Notes**

*Incredible diversity of native aquatic plants species found during the comprehensive plant surveys. A large amount of the shoreline is undeveloped.*

**Photo 8.13.1-1 Spirit Lake, Oneida County**

### Lake at a Glance* – Spirit Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 355 |
| Maximum Depth (ft) | 41 |
| Mean Depth (ft) | 14 |
| Volume (acre-feet) | 5,086 |
| Shoreline Complexity | 2.4 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 25, 2013 |
| Comprehensive Survey Date | July 24-25, 2013 |
| Number of Native Species | 62 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | Reed canary grass, Pale-yellow iris |
| Simpson's Diversity | 0.92 |
| Average Conservatism | 7.2 |
| **Water Quality** | |
| Wisconsin Lake Classification | Deep, headwater drainage |
| Trophic State | Mesotrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 4:1 |

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.13.1 Spirit Lake Water Quality

As a part of this project, water quality data was collected from Spirit Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake. In addition to this project, data has been collected by the WDNR, WVIC and the Citizens Lake Monitoring Network (CLMN).

During 2013, summer total phosphorus values collected from the Spirit Lake surface averaged 9.7 μg/L, which ranks as *Excellent* when compared to similar deep, headwater drainage lakes within the state and all lakes in the Northern Lakes and Forests ecoregion (Figure 8.13.1-1). A weighted value across all years of data is also only slightly higher than the median values for similar lakes throughout the state and also for all lakes within the ecoregion. A growing season average, which includes data from spring (May) and fall (October) turnover periods is higher at 13.8 μg/L, but still *Excellent* for this lake type and location within the state. Additional water quality data was collected in 1979, 1984 and 1985 in Spirit Lake.

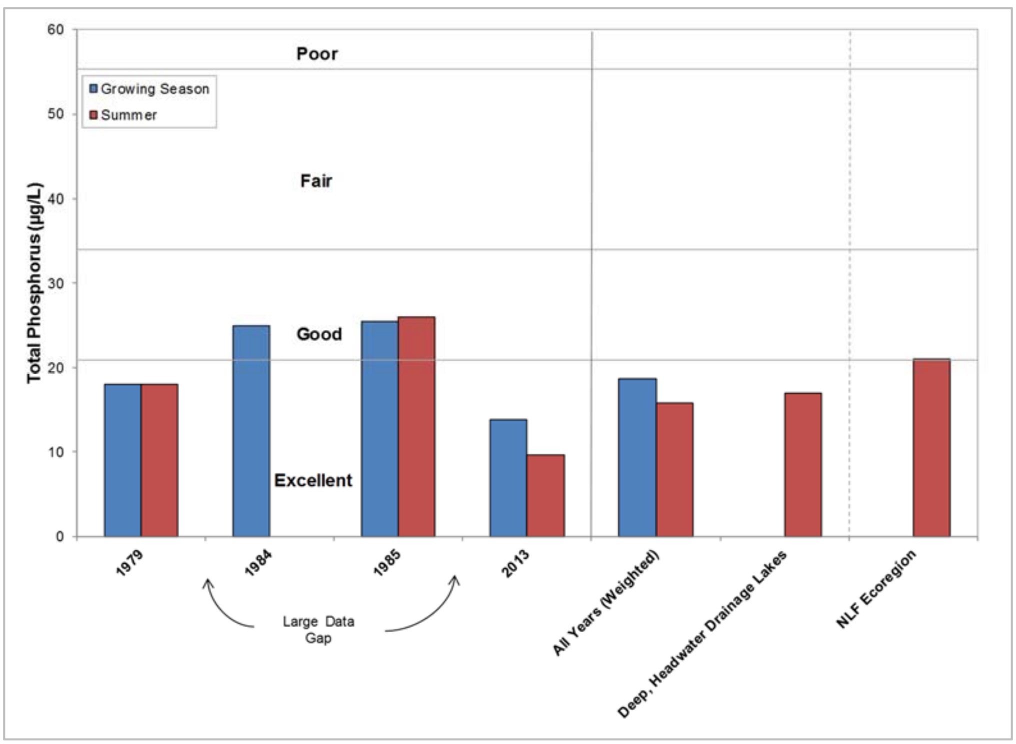



**Figure 8.13.1-1. Spirit Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus values.** Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Chlorophyll-*a*, similar to total phosphorus, has only been measured in two years on Spirit Lake (1979 and 2013). 2013 growing season and summer concentrations were low and rank as *Excellent* for deep, headwater drainage lakes and all lakes statewide. A direct indicator of algae, these results indicate that a low amount of free-floating algae exists within the lake. This parameter does not however give an indication of other kinds of algae, such as those species bound to plants or substrate (i.e. periphyton or filamentous algae).

Through citizen monitoring that took place in the late 1980's and early 1990's, a larger dataset is available for Spirit Lake with regards to Secchi disk clarity (Figure 8.13.1-2). These data largely fall within the *Excellent* category for deep, headwater drainage lakes across the state. A weighted average value across all years lies above the median value for similar lakes state-wide and all lakes in the ecoregion. Several large data gaps exist within the dataset, so trends occurring through present time are not able to be determined as it is difficult to say what occurred with Spirit Lake's water quality from 1993 through 2012.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In other lakes within Three Lakes Chain, a natural staining of the water plays a major role in light penetration, and thus water clarity. Spirit Lake, being a headwater lake, has a much smaller watershed. Therefore, it is less stained than other lakes within the chain. Algal production is likely the greatest factor that can influence water clarity within Spirit Lake.

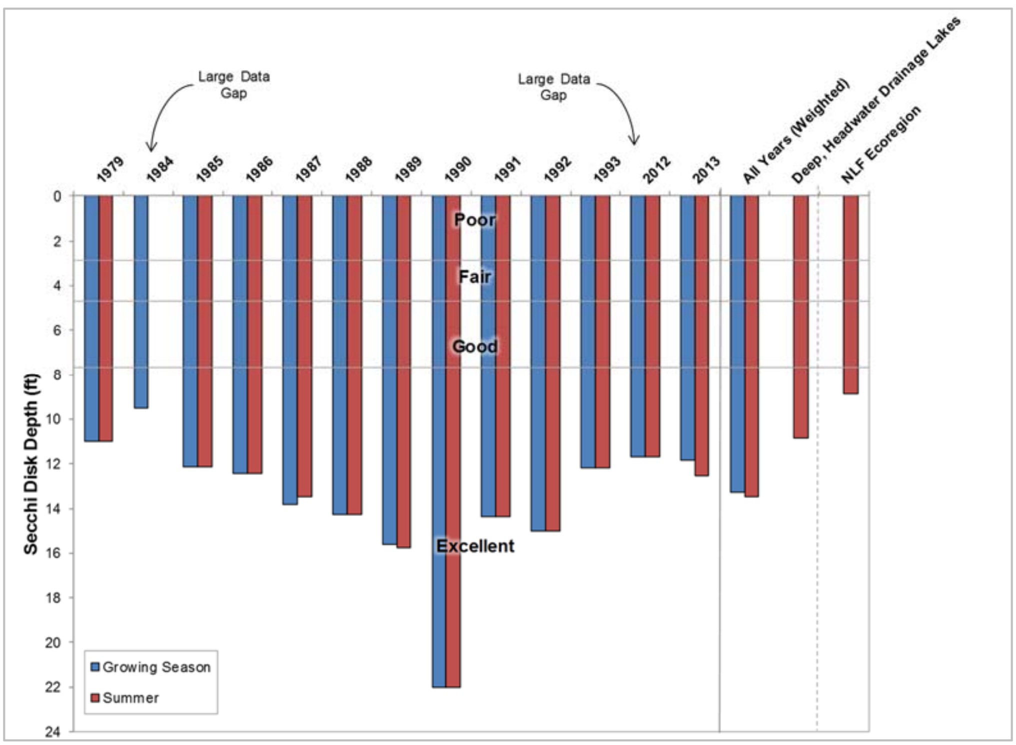



**Figure 8.13.1-2. Spirit Lake, state-wide deep, headwater drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

## Spirit Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper oligotrophic to mesotrophic (Figure 8.13.1-3). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Spirit Lake is in a mesotrophic state.

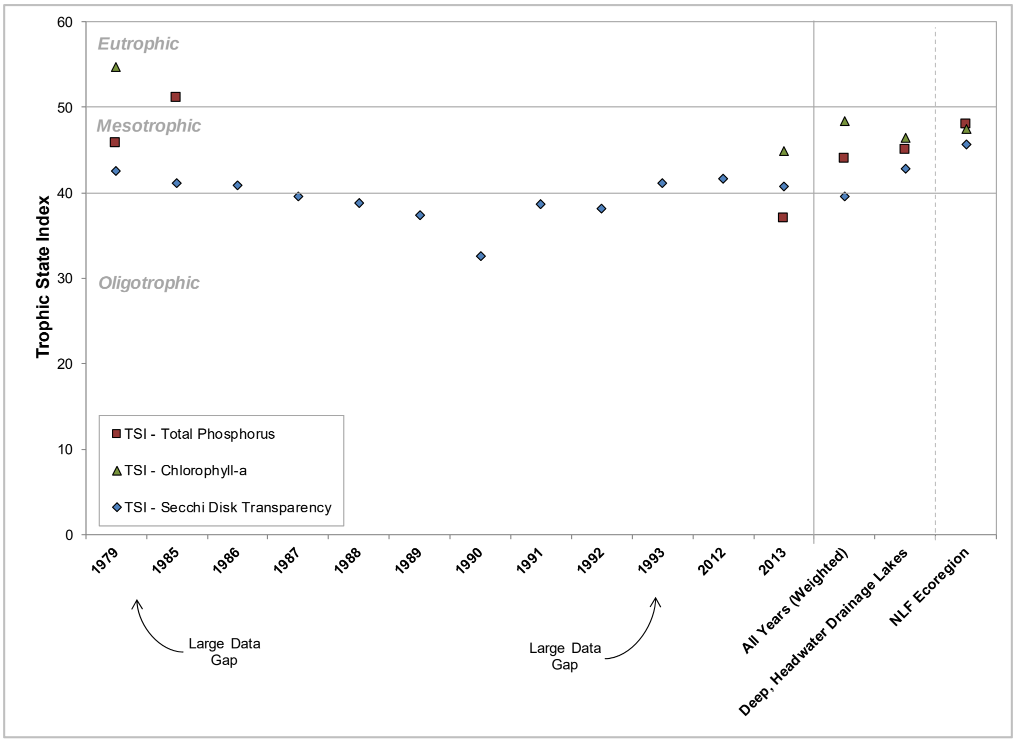



**Figure 8.13.1-3. Spirit Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

## Dissolved Oxygen and Temperature in Spirit Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Spirit Lake by Onterra staff. Graphs of those data are displayed in Figure 8.13.1-4 for all three sampling events. During the summer months, a strong stratification occurs in Spirit Lake, with warmer, well oxygenated waters being found in the upper portion of the water column and colder water being found deeper in the lake. During this time, anoxic conditions were observed from 23-25 ft towards the bottom. Dissolved oxygen depletion may occur near the bottom of the lake as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being developed in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Despite the decrease in oxygen levels during the summer months, oxygen remained sufficient in the upper 20 feet of the water column to support most aquatic life found in northern Wisconsin lakes. During the winter, the coldest water is found just under the ice in Spirit Lake, while the slightly warmer and also denser water can be found towards the bottom. Winter oxygen levels were found to be ample during February of 2014.

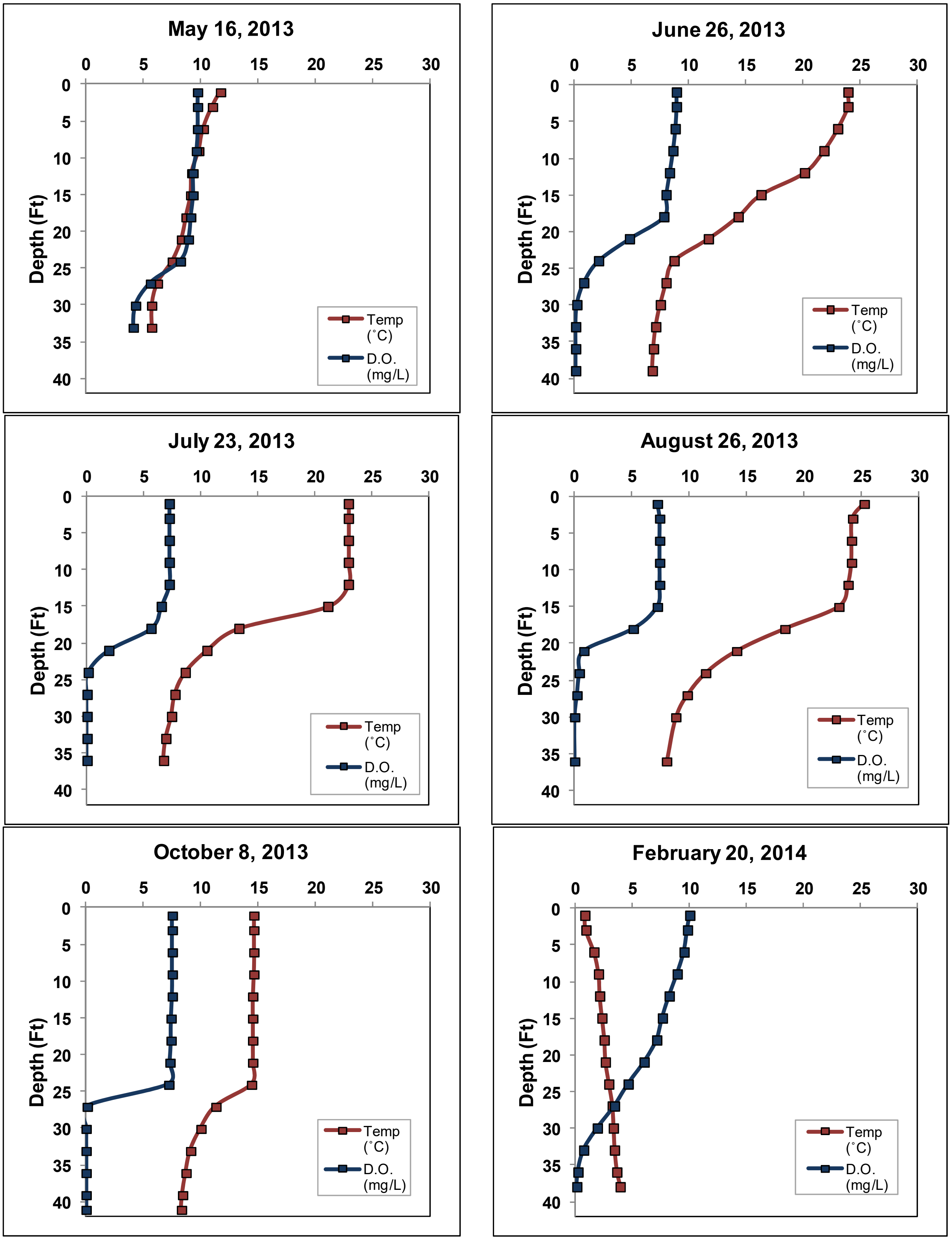



**Figure 8.13.1-4. Spirit Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Spirit 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 Spirit 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Spirit Lake's pH was measured at 7.7 in July 2013. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Spirit Lake was measured at 35.5 (mg/L as $CaCO_3$) near the surface in July, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Spirit Lake during the summer of 2013. Calcium is commonly examined because invasive and native mussels use the element to build shells and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Spirit Lake's pH of 7.7 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Spirit Lake was found to be 10.2 mg/L, falling below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.13.2 Spirit Lake Watershed Assessment

Spirit Lake's watershed is 1,334 acres in size. Compared to the lakes size of 355 acres, this makes for a relatively small watershed to lake area ratio of 4:1. Spirit Lake, as well as Moccasin Lake, were likely minimally connected to the remaining Three Lakes Chain lakes prior to installation of the Burnt Rollways Dam, which raised water levels. The connection that exists between Spirit Lake and Laurel Lake now is through a large culvert, of which is mostly non-navigable to watercraft.

Exact land cover calculation and modeling of nutrient input to Spirit Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.13.3 Spirit Lake Shoreland Condition Assessment

### Shoreland Development

As mentioned previously in the Chain-wide Watershed Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In the fall of 2013, Spirit Lake's immediate shoreline was assessed in terms of its development. Spirit Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.4 miles of natural/undeveloped and developed-natural shoreline (58% of the entire shoreline) were observed during the survey (Figure 8.13.3-1). 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, 0.3 miles of urbanized and developed–unnatural shoreline (8% of the total shoreline) was observed. If restoration of the Spirit Lake shoreline 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. Spirit Lake Map 1 displays the location of these shoreline lengths around the entire lake.

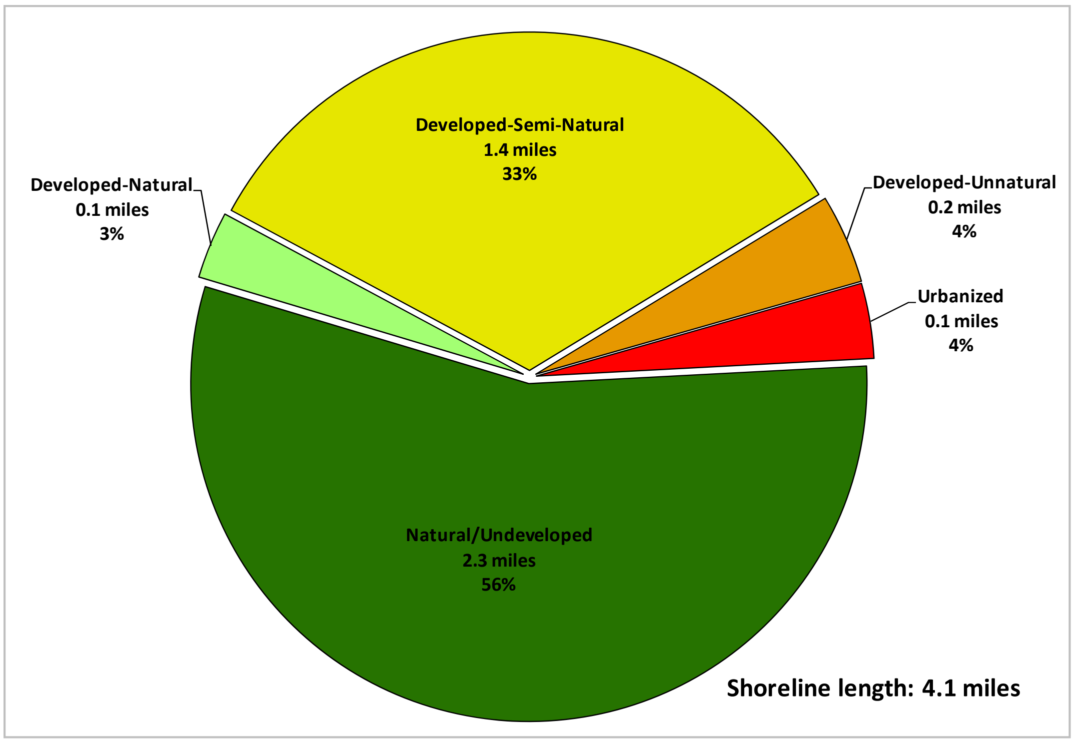



**Figure 8.13.3-1. Spirit Lake shoreland categories and total lengths.** Based upon a fall 2013 survey. Locations of these categorized shorelands can be found on Spirit Lake Map 1.

During project planning meetings, discussions were held regarding the proximity of State Highway 32 to Spirit Lake. Impervious surfaces such as roadways have the potential to congregate and transport pollutants such as nutrients, hydrocarbons, road salt, etc. into an aquatic ecosystem. While these threats may be present in varying degrees, the best way to prevent these pollutants from reaching the lake is through buffering the lake shoreline with natural vegetation. More discussion on this can be found within the Spirit Lake Implementation Plan.

## Coarse Woody Habitat

Spirit Lake was 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 and 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, 67 total pieces of coarse woody habitat were observed along 4.1 miles of shoreline, which gives Spirit Lake a coarse woody habitat to shoreline mile ratio of 16:1 (Figure 8.13.3-2). Locations of coarse woody habitat are displayed on Spirit Lake Map 2.

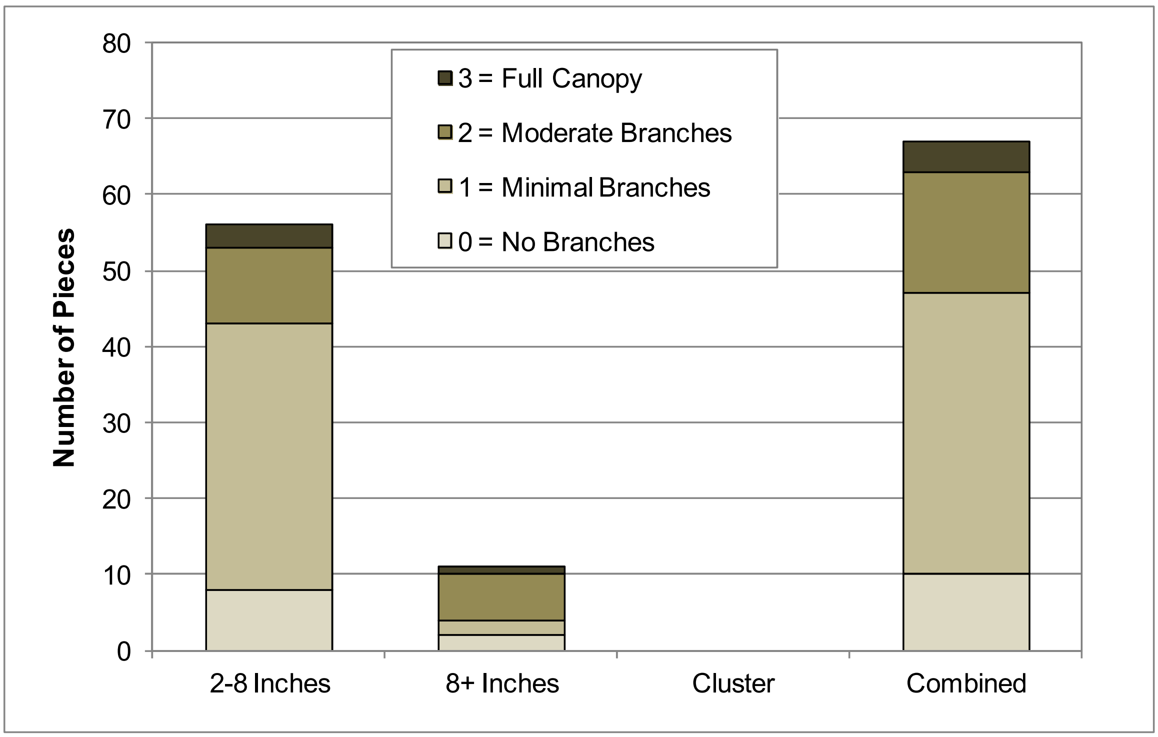



**Figure 8.13.3-2. Spirit Lake coarse woody habitat survey results.** Based upon a Fall 2013 survey. Locations of Spirit Lake coarse woody habitat can be found on Spirit Lake Map 2.

## 8.13.4 Spirit Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Spirit Lake on June 25, 2013. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants. One exotic plant, pale yellow iris, was found along the shorelines of the lake during subsequent surveys. This plant is discussed in detail at the end of this section.

The aquatic plant point-intercept survey was conducted on Spirit Lake on July 24, 2013 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that next day to create the aquatic plant community map (Spirit Lake Community Map). During these surveys, 60 species of native aquatic plants were located in Spirit Lake (Table 8.13.4-1). 44 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while 16 species were found incidentally.

Aquatic plants were found growing to a depth of 21 feet, which is much deeper than in the other lakes within the Three Lakes Chain, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 473 point-intercept locations sampled within the littoral zone, approximately 87% contained aquatic vegetation. Approximately 44% of the point-intercept sampling locations where sediment data was collected at were sand, 56% consisted of a fine, organic substrate (muck) and no locations were determined to be rocky.

**Table 8.13.4-1. Aquatic plant species located in the Spirit Lake during the 2013 aquatic plant surveys.**

| Growth Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2013 (Onterra) |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | I |
| | *Carex comosa* | Bristly sedge | 5 | I |
| | *Carex vesicaria* | Blister sedge | 7 | I |
| | *Carex lasiocarpa* | Woolly-fruit sedge | 9 | I |
| | *Carex utriculata* | Common yellow lake sedge | 7 | I |
| | *Decodon verticillatus* | Water-willow | 7 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | X |
| | *Glyceria canadensis* | Rattlesnake grass | 7 | I |
| | *Iris pseudacorus* | Pale yellow iris | Exotic | I |
| | *Juncus effusus* | Soft rush | 4 | I |
| | *Phalaris arundinacea* | Reed canary grass | Exotic | I |
| | *Pontederia cordata* | Pickerelweed | 9 | X |
| | *Scirpus cyperinus* | Wool grass | 4 | I |
| | *Schoenoplectus subterminalis* | Water bulrush | 9 | I |
| | *Sagittaria latifolia* | Common arrowhead | 3 | I |
| | *Sparganium sp.* | Bur-reed species | N/A | X |
| | *Schoenoplectus acutus* | Hardstem bulrush | 5 | X |
| | *Typha spp.* | Cattail spp. | 1 | X |
| FL | *Brasenia schreberi* | Watershield | 7 | X |
| | *Nymphaea odorata* | White water lily | 6 | X |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium natans* | Small bur-reed | 9 | I |
| | *Sparganium americanum* | Eastern bur-reed | 8 | I |
| | *Sparganium emersum* | Short-stemmed bur-reed | 8 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | I |
| Submergent | *Ceratophyllum echinatum* | Spiny hornwort | 10 | X |
| | *Chara spp.* | Muskgrasses | 7 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Eriocaulon aquaticum* | Pipewort | 9 | X |
| | *Elatine minima* | Waterwort | 9 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Heteranthera dubia* | Water stargrass | 6 | X |
| | *Isoetes sp.* | Quillwort species | N/A | X |
| | *Lobelia dortmanna* | Water lobelia | 10 | X |
| | *Myriophyllum verticillatum* | Whorled water milfoil | 8 | X |
| | *Myriophyllum alterniflorum* | Alternate-flowered water milfoil | 10 | X |
| | *Myriophyllum tenellum* | Dwarf water milfoil | 10 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Nitella sp.* | Stoneworts | 7 | X |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | X |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | X |
| | *Potamogeton foliosus* | Leafy pondweed | 6 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton vaseyi* | Vasey's pondweed | 10 | X |
| | *Potamogeton berchtoldii* | Small pondweed | 7 | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Ranunculus flammula* | Creeping spearwort | 9 | I |
| | *Utricularia minor* | Small bladderwort | 10 | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | X |
| | *Utricularia intermedia* | Flat-leaf bladderwort | 9 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| | *Juncus pelocarpus* | Brown-fruited rush | 8 | 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*

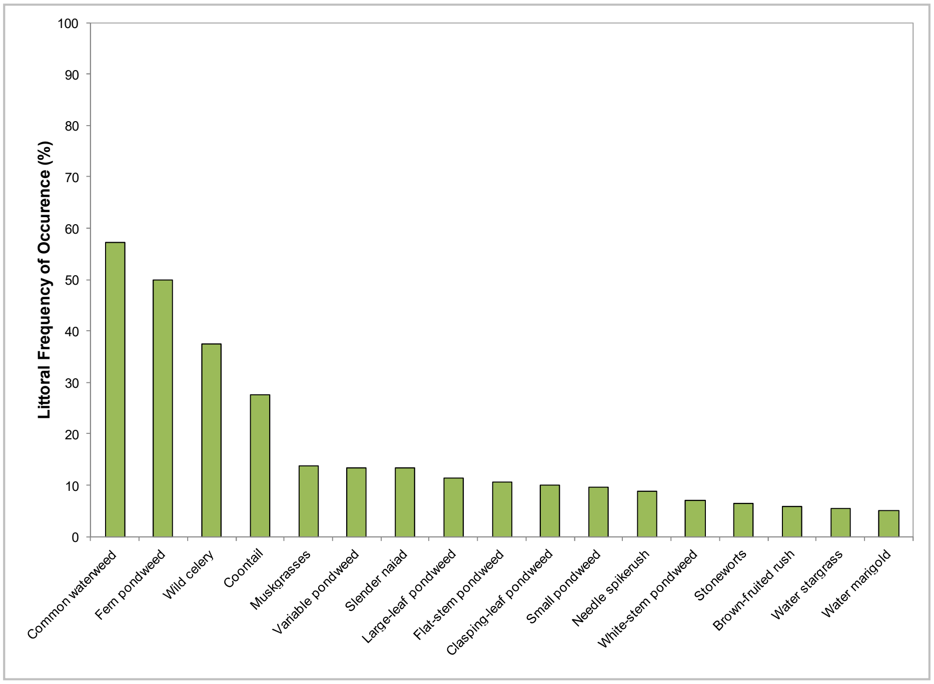



**Figure 8.13.4-1 Spirit Lake aquatic plant littoral frequency of occurrence analysis.** Created using data from 2013 point-intercept survey. Due to the number of species, only those with 5% frequency or greater are displayed on this graph.

Figure 8.13.4-1 (above) shows that common waterweed, fern pondweed and wild celery were the most frequently encountered plants within Spirit Lake. Common waterweed is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and their locations can be largely a product of water movement. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates.

60 species of native aquatic plants (including incidentals) were found in Spirit Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Spirit Lake's plant community (0.92) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds great diversity with respect to its aquatic plant community. The reason for this is discussed below.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section (Chain-wide plan, page 50), the 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 common waterweed was found at 57% of the sampling locations, its relative frequency of occurrence is 17%. Explained another way, if 100 plants were randomly sampled from Spirit Lake, 17 of them would be wild celery. This distribution can be observed in Figure 8.13.4-2, where together four species account for roughly 50% of the population of plants within Spirit Lake, while the remaining species account for the other half of the pie. Because of this distribution in frequency, the diversity of the aquatic plant community is higher than the ecoregion median value. Sixteen additional species were located from the lake but not from of the point-intercept survey, as indicated in Table 8.13.4-1 as incidentals.

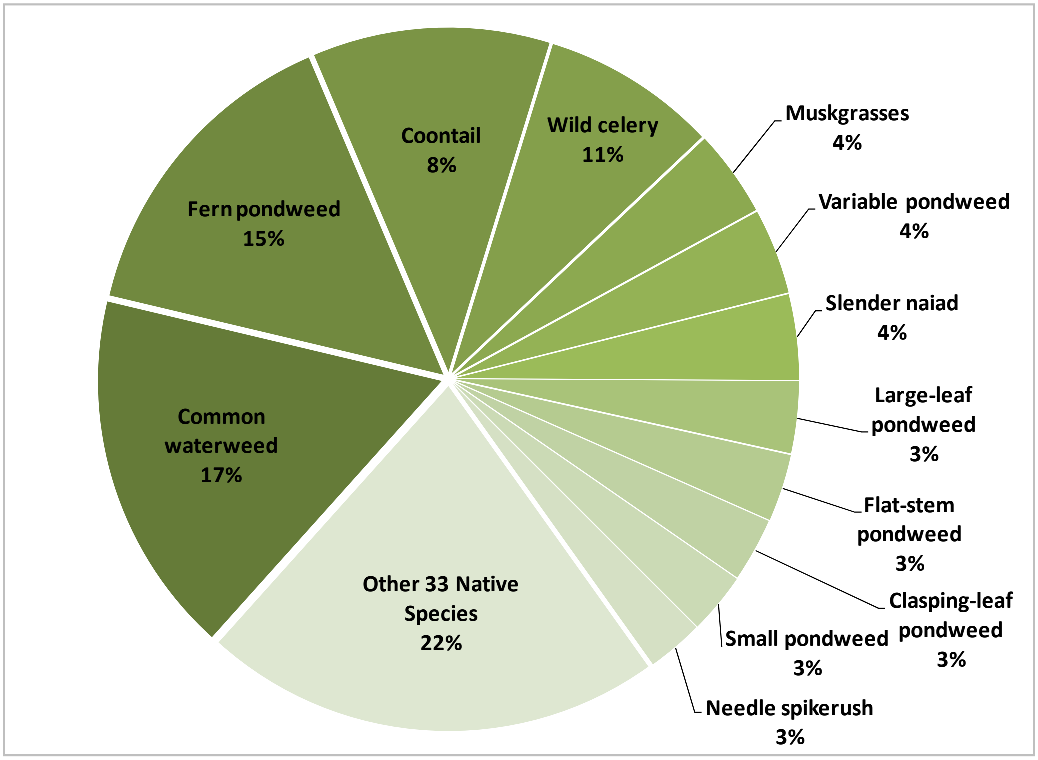



**Figure 8.13.4-2 Spirit Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2013 point-intercept survey.

Spirit Lake's average conservatism value (7.1) is higher than both the state (6.0) and ecoregion (6.7) median. This indicates that the plant community holds a number of species that are sensitive to environmental degradation. In other words, although there is much common waterweed and fern pondweed in the lake (two species that are fairly tolerant of environmental degradation), there are also several species present that are sensitive to disturbance, such as those listed on Table 8.13.4-1 that have Coefficient of Conservatism values of 8, 9 or 10 (spiny hornwort, floating-leaf bur-reed, water lobelia, Vasey's pondweed, etc.). Combining Spirit Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 47.6 which is above the median values of the ecoregion (24.3) and state (22.2).

The quality of Spirit Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2013 community map indicates that approximately 28.6 acres of the lake contains these types of plant communities (Spirit Lake Map 3, Table 8.13.4-2). Twenty-five floating-leaf and emergent species were located on Spirit Lake (Table 8.13.4-1), all of which provide valuable wildlife habitat.

**Table 8.13.4-2. Spirit Lake acres of emergent and floating-leaf plant communities from the 2013 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 13.1 |
| Floating-leaf | 2.9 |
| Mixed Floating-leaf and Emergent | 12.7 |
| **Total** | 28.7 |

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

## Aquatic Invasive Species in Spirit Lake

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along much of the northern shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale yellow iris on Spirit Lake can be viewed on Spirit Lake Map 3.

.

## 8.13.5 Spirit Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Spirit Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Spirit Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Spirit Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Spirit Lake's implementation plan is compiled by describing how Spirit Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

## Chain-wide Implementation Plan – Specific to Spirit Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Spirit Lake as part of this chain-wide project, it is up to Spirit Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Spirit Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## *Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes*

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** While Spirit Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Laurel Lake, though this connection is quite small. Regardless, The threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Spirit Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Spirit Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Spirit Lake or from Spirit Lake elsewhere. If a Spirit Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Spirit Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Spirit Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Spirit Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Spirit Lake and its stakeholders.

## Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Spirit Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Spirit Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Spirit Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Spirit Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Spirit Lake shoreline was categorized in terms of its development. According to the results from this survey, 8.0% of the shoreline is in an urbanized or developed-unnatural state, while 59.0% of the shoreline is currently in a mostlynatural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

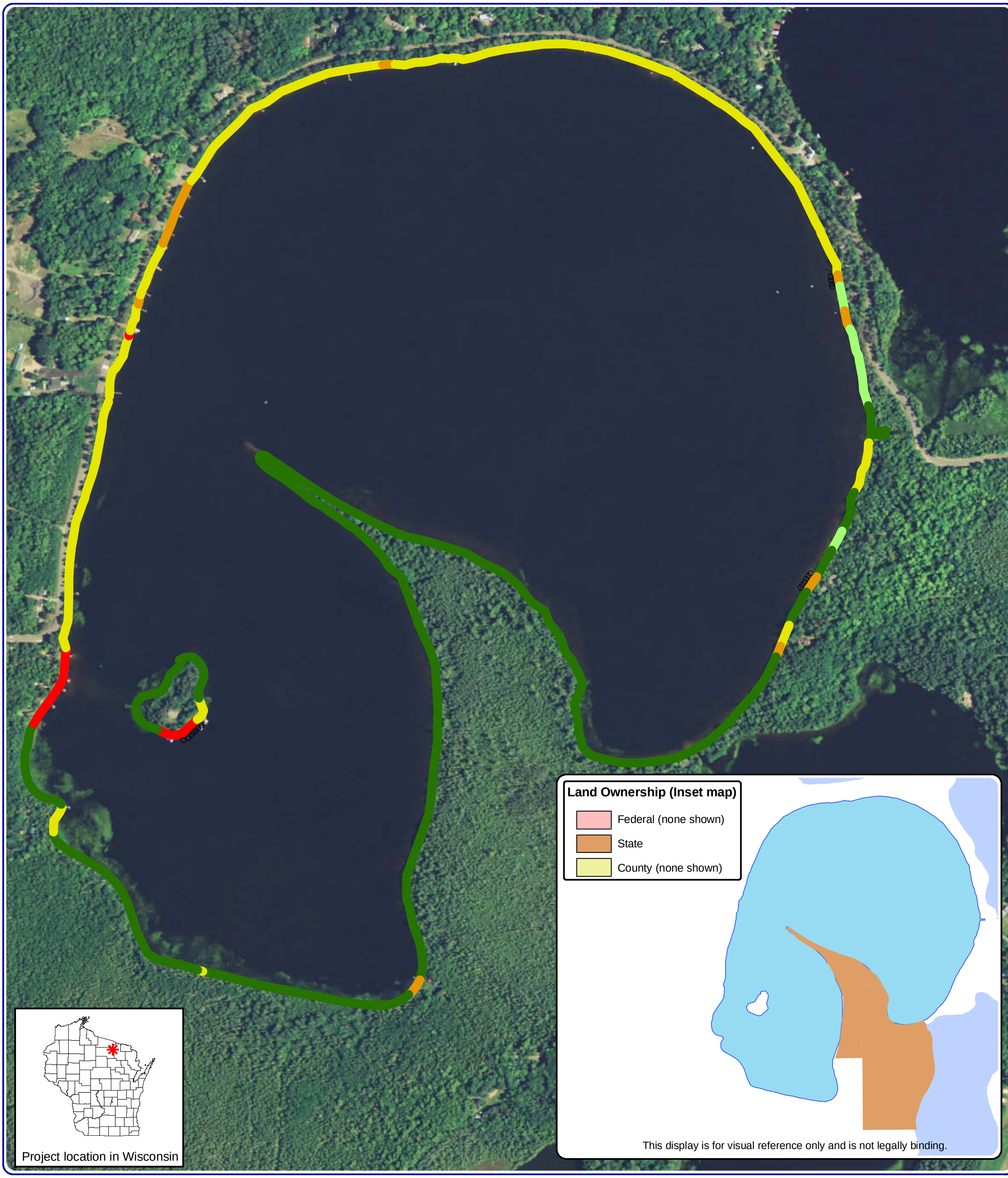
Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

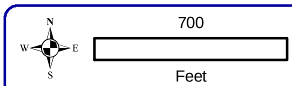
During the Phase IV planning meeting, Spirit Lake property owners expressed concern along the shoreline that borders State Hwy 32. Their concerns stemmed from fluctuating water levels on the Three Lakes Chain lakes as well as runoff from the impervious surface of the highway. These property owners were advised to contact the appropriate parties (Wisconsin Valley Improvement Company for shoreland erosion and Oneida County Highway Department for roadside erosion) listed in the Chainwide Implementation Plan to share their concerns. Identifying areas of erosion or excessive runoff is important as immediate mediation can often prevent further and larger problems.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Spirit Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Spirit Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.




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

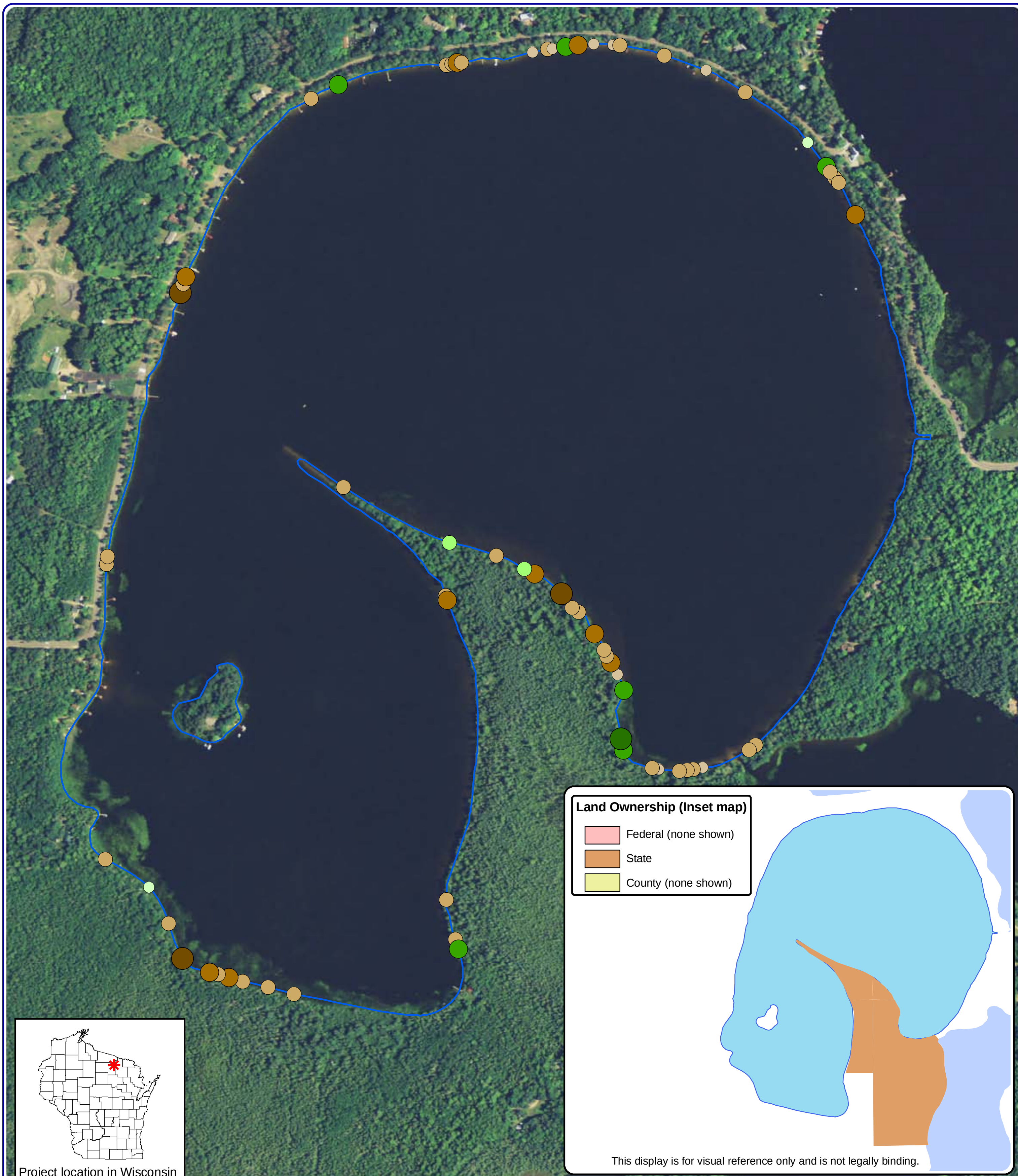
Sources:
Orthophotography: NAIP, 2013
SCA Survey: Onterra, 2013
Map date: December 2, 2013
Filename: Spirit_SCA_2013.mxd

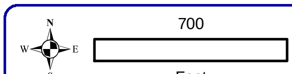
**Legend**

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized
- Seawall
- Rip-Rap

Spirit Lake - Map 1
Three Lakes Chain
Oneida County, Wisconsin

**Shoreland Condition Assessment**

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www.onterra-eco.com

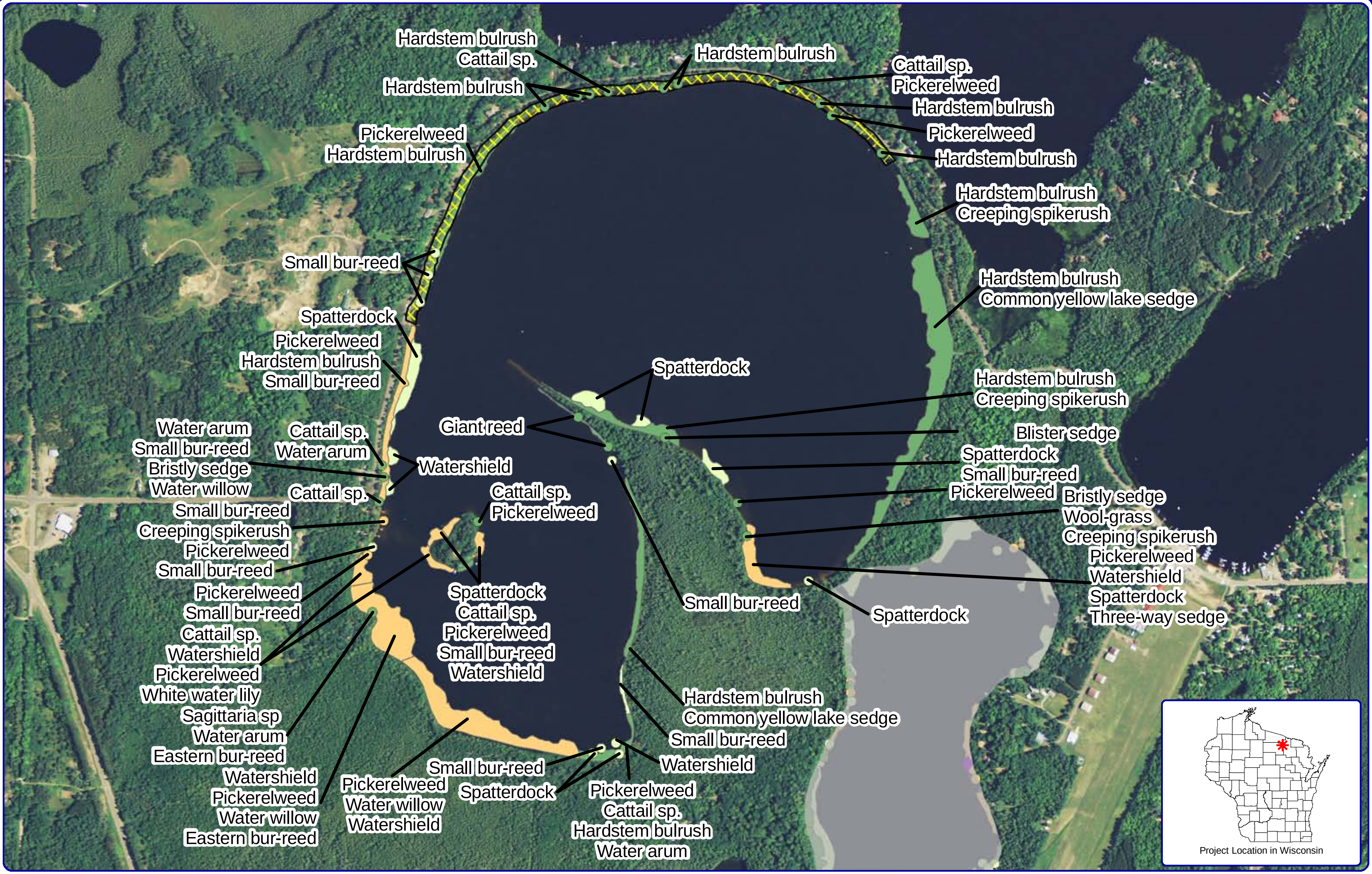
Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2013
Map date: December 30, 2013
Filename: Spirit_CWH_2013.mxd

**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 | Full Canopy (none) |

# Spirit Lake - Map 2
## Three Lakes Chain
Oneida County, Wisconsin

## Coarse Woody Habitat




N W E S

1,000

Feet

## Legend

**Exotic Communities**

Highly Scattered Pale Yellow Iris Community

**Small Plant Communities**

Emergent

Floating-leaf

Mixed Floating-leaf & Emergent

**Large Plant Communities**

Emergent

Floating-leaf

Mixed Floating-leaf & Emergent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**Sources:**
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2010
**Map date:** November 13, 2013
*Filename: Maple_Comm_2013.mxd*

Spirit Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin

# Aquatic Plant Communities

**Note: Methodology, explanation of analysis and scientific background on Spirit Lake studies are contained within the Three Lakes Chain-wide Management Plan document.**

## 8.14 Maple Lake

## An Introduction to Maple Lake

Maple Lake, Oneida County, is a shallow, headwater drainage lake with a maximum depth of 15 feet and a surface area of 131 acres. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Maple Lake contains 42 native plant species, of which southern naiad was the most common plant.

**Field Survey Notes**

*Much of the lake holds native plants, including many pondweed species. No aquatic invasive species found during 2013 surveys.*

**Photo 8.14.1-1 Maple Lake, Oneida County**

### Lake at a Glance* – Maple Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 131 |
| Maximum Depth (ft) | 15 |
| Mean Depth (ft) | 9 |
| Volume (acre-feet) | 1,149 |
| Shoreline Complexity | 1.9 |
| **Vegetation** | |
| Curly-leaf Survey Date | June 25, 2013 |
| Comprehensive Survey Date | July 24-25, 2013 |
| Number of Native Species | 42 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | - |
| Simpson's Diversity | 0.95 |
| Average Conservatism | 6.7 |
| **Water Quality** | |
| Wisconsin Lake Classification | Shallow, headwater drainage |
| Trophic State | Mesotrophic |
| Limiting Nutrient | Phosphorus |
| Watershed to Lake Area Ratio | 3:1 |

*These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

## 8.14.1 Maple Lake Water Quality

As a part of this project, water quality data was collected from Maple Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. The WDNR online water quality database SWIMS was accessed as well to search for historical data that may have been collected on the lake. In addition to this project, data has been collected by the WDNR and the Citizens Lake Monitoring Network (CLMN).

A fair amount of volunteer-collected data exists for Maple Lake, spanning 1991-2004. This data is useful because it gives lake managers a perspective of what conditions were in the past, compared to the data collected through this planning project (2013). Unfortunately, it is difficult to determine how conditions fluctuated (if they did at all) between 2004 and 2013. Volunteer-based monitoring cannot be emphasized enough; these efforts provide consistent, reliable data on which a comparable database may be built. Monitoring should be continued in order to understand trends in the water quality of Maple Lake for years to come.

During the years in which data has been collected, summer average total phosphorus concentrations have fluctuated a bit, ranging between 7.7 and 23.8 μg/L (Figure 8.14.1-1). These average values rank within the TSI category of *Excellent*. A weighted value across all years is less than the median for shallow, headwater drainage lakes in the state of Wisconsin. As with the total phosphorus values, average chlorophyll-*a* concentrations also rank in the *Excellent* category, and a weighted average is also less than the median concentration for similar lakes across the state (Figure 8.14.1-2). As with phosphorus, some fluctuation can be observed within this dataset.

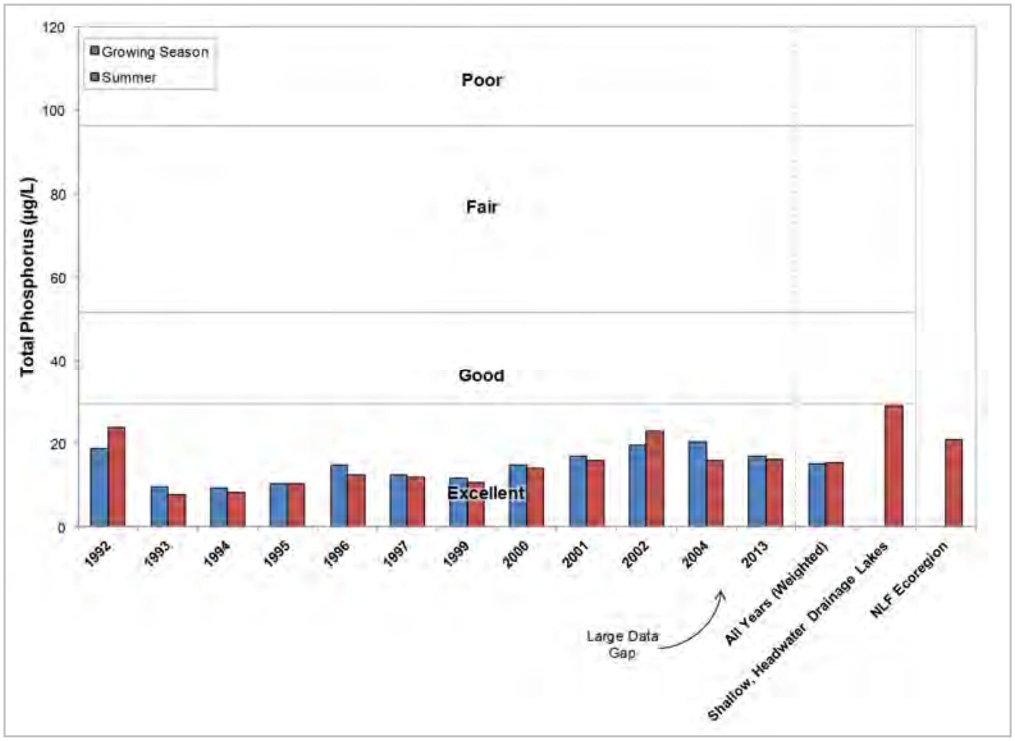


**Figure 8.14.1-1. Maple Lake, state-wide shallow, headwater drainage lakes, and regional total phosphorus concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

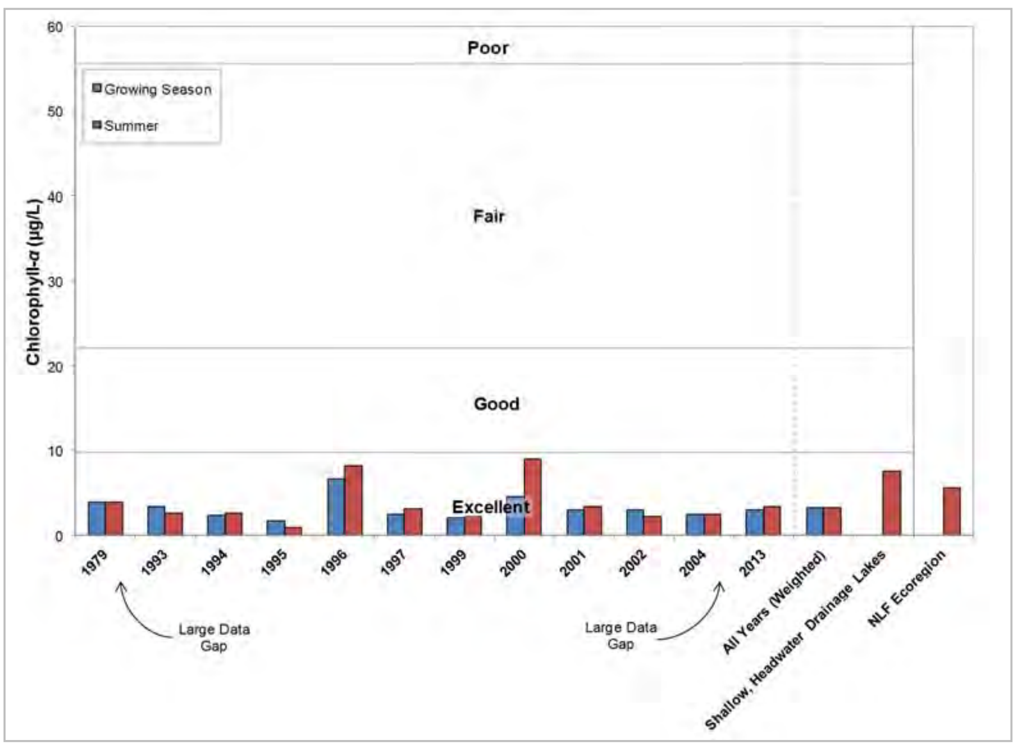


**Figure 8.14.1-2. Maple Lake, state-wide shallow, headwater drainage lakes, and regional chlorophyll-*a* concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

Measurements of Secchi disk clarity span a similar timeframe as the other two primary water quality parameters and show a little annual variance as well (Figure 8.14.1-3). All summer averages fall within the *Excellent* category, and a weighted average across all years is greater than the median for shallow, headwater drainage lakes statewide.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In other lakes within Three Lakes Chain, a natural staining of the water plays a major role in light penetration, and thus water clarity. Maple Lake, being a headwater lake, has a much smaller watershed. Therefore, it is less stained than other lakes within the chain. Algal production is likely the greatest factor that can influence water clarity within Maple Lake.

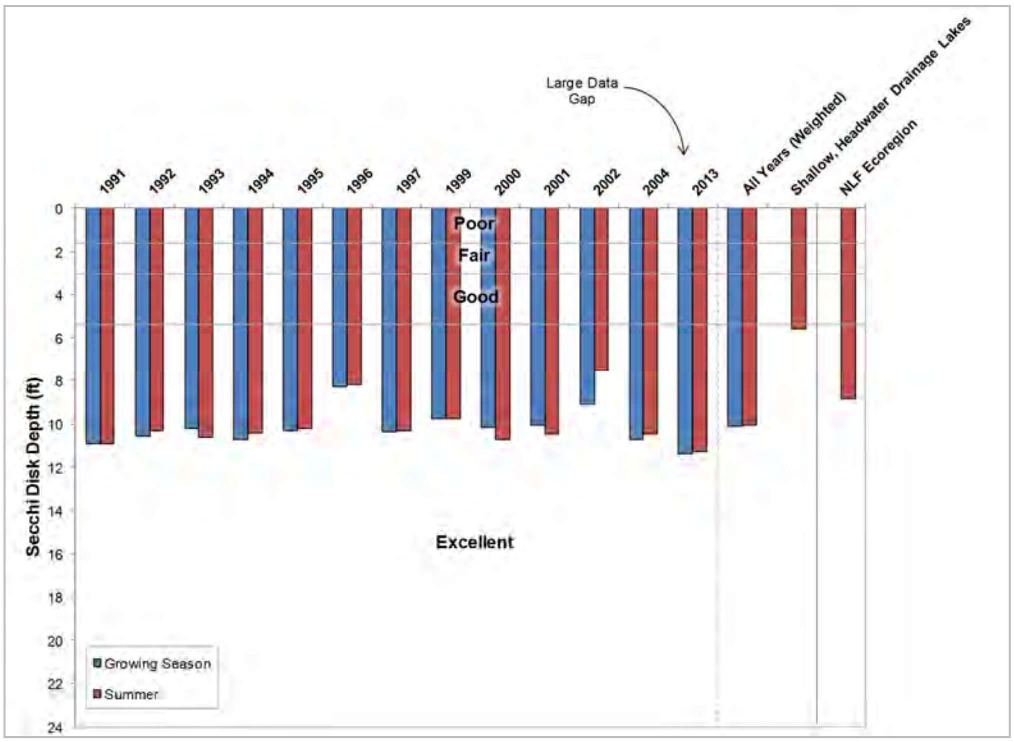


**Figure 8.14.1-3. Maple Lake, state-wide shallow, headwater drainage lakes, and regional Secchi disk clarity values.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

**Maple Lake Trophic State**

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to oligotrophic (Figure 8.14.1-4). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Maple Lake is in an upper mesotrophic state. As the phosphorus, chlorophyll-*a* and Secchi values all fall within a category of *Excellent*, one might wonder why the TSI rating is not oligotrophic instead of mesotrophic. Even though a lake is categorized as mesotrophic or eutrophic does not mean it does not have excellent phosphorus or chlorophyll-*a* values – the values are relative for the lake's classification, in this case a shallow, headwater drainage lake.

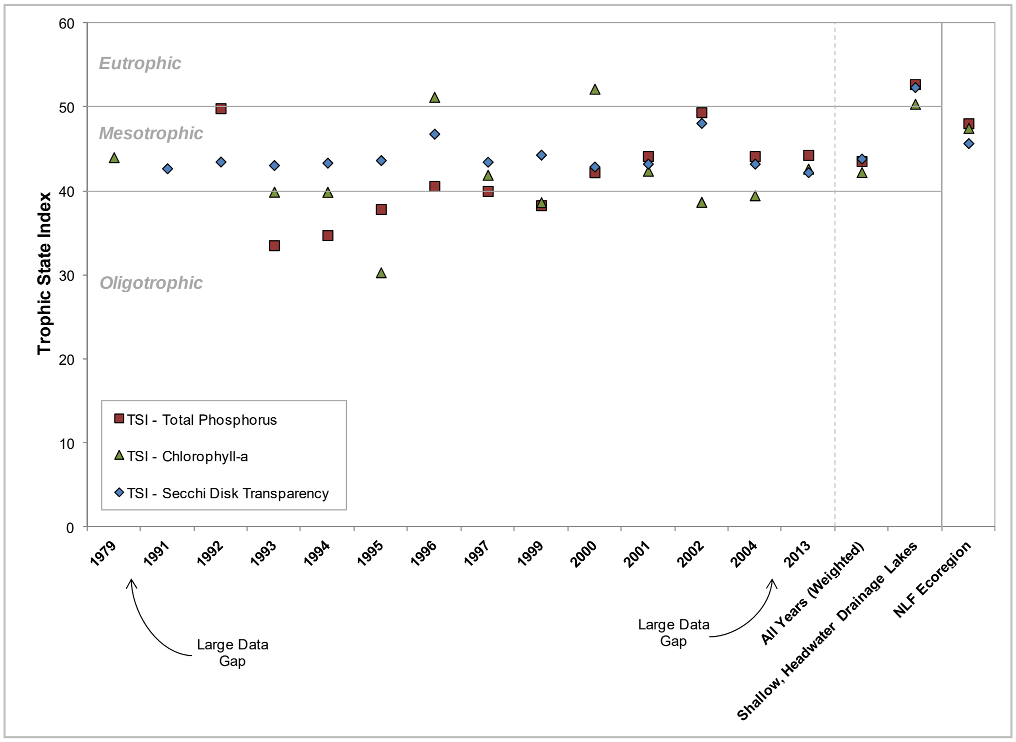


**Figure 8.14.1-4. Maple Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values.** Values calculated with summer month surface sample data using WDNR 2013.

**Dissolved Oxygen and Temperature in Maple Lake**

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Maple Lake by Onterra staff. Graphs of those data are displayed in Figure 8.14.1-5 for all three sampling events. Shallow lakes such as Maple Lake tend to remain completely mixed throughout the year, with dissolved oxygen and temperature readings found to be similar throughout the entire water column. In deeper lakes, stratification may occur, where a distinct warmer epilimnion and cooler hypolimnion develops.

Dissolved oxygen depletion may occur near the bottom of the lake as bacteria breakdown organic matter from decomposing plants, fish, algae, etc. With the stratified layers being developed in the lake, it is difficult for oxygen replenishment of the hypolimnion to occur from the epilimnion. Non-stratified lakes, such as Maple Lake, often do not have significant oxygen depletion during the summer months. During the winter, however, dissolved oxygen depletion may be of concern due to the ice cover on the lake, which prohibits oxygen exchange from the air to the lake. In February of 2014 dissolved oxygen was found to deplete at 10 feet of depth and below, leaving oxygen at 4-5 mg/L in the upper water column. Some biologists believe that sport fish can usually handle low dissolved oxygen levels under the ice. Fish may sustain levels as low as 1.0 mg/L for 2-3 weeks. Anecdotal reports of a mid 1990’s winter fish kill were shared with Onterra staff during this project. Maple Lake holds a good biomass of aquatic plants, and is relatively shallow, so mass oxygen depletion during the winter is very possible. Some fisheries biologists believe that a partial fish kill every few years is good for a fish community as it removes stunted individuals. If a winter fish kill is ever suspected in Maple Lake, the regional fisheries biologist should be contacted for verification and follow-up studies.

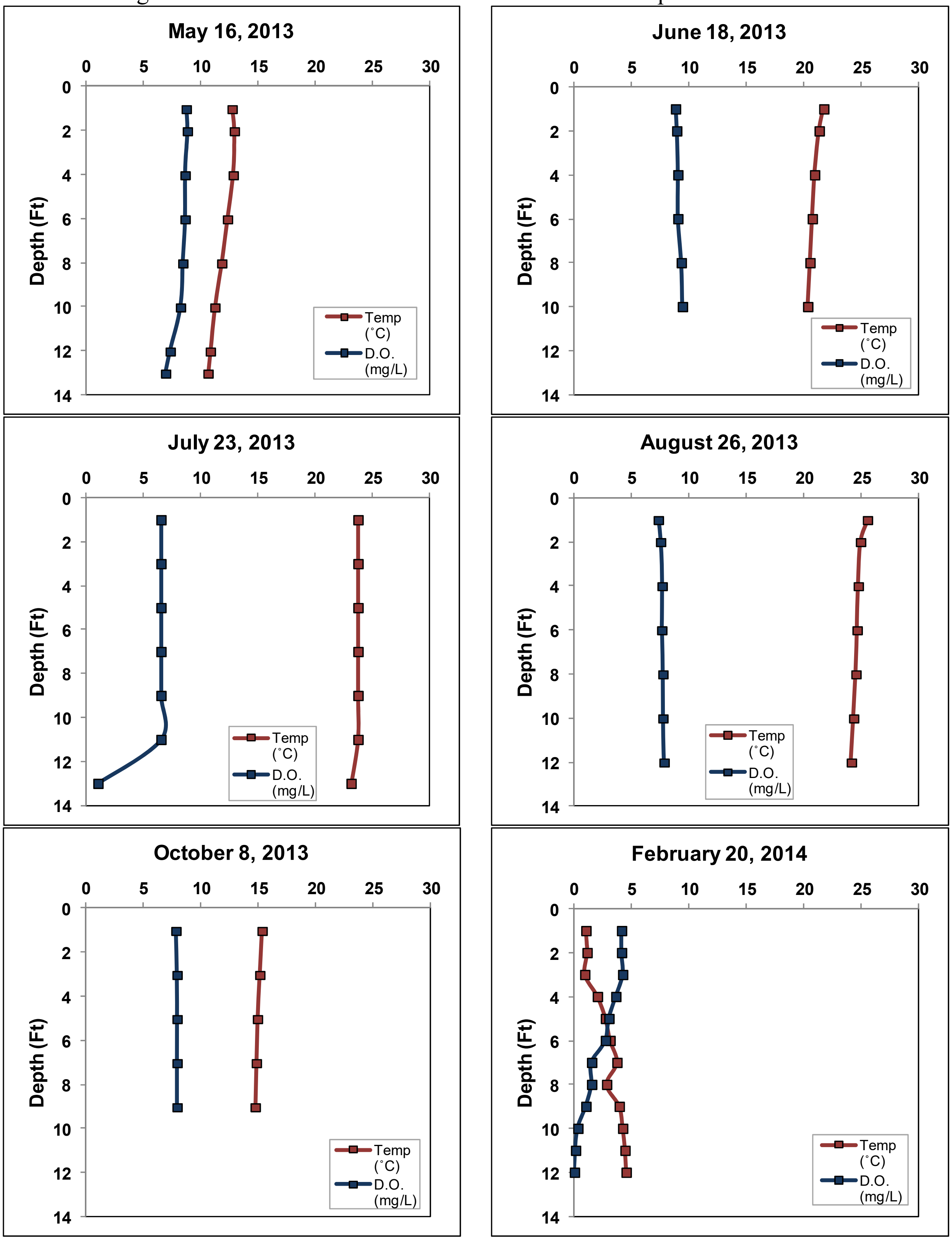


**Figure 8.14.1-5. Maple Lake dissolved oxygen and temperature profiles.**

## Additional Water Quality Data Collected at Maple 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 Maple 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.

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is thus an index of the lake's acidity. Maple Lake's pH was measured at 7.6 in July 2013. This value is near neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound ($HCO_3^-$) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Maple Lake was measured at 38.8 (mg/L as $CaCO_3$) near the surface in July, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Maple Lake during the summer of 2013. Calcium is commonly examined because invasive and native mussels use the element to build shells and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Maple Lake's pH of 7.6 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Maple Lake was found to be 15.2 mg/L, falling within the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval zebra mussels) were found within these samples.

## 8.14.2 Maple Lake Watershed Assessment

Maple Lake's watershed is 589 acres in size. Compared to the lakes size of 131 acres, this makes for a large watershed to lake area ratio of 3:1.

Exact land cover calculation and modeling of nutrient input to Maple Lake will be completed towards the end of this project (in 2016-2017). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

## 8.14.3 Maple Lake Shoreland Condition Assessment

### Shoreland Development

As mentioned previously in the Chain-wide Watershed Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In the fall of 2013, Maple Lake's immediate shoreline was assessed in terms of its development. Maple Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.9 miles of natural/undeveloped and developed-natural shoreline (45% of the entire shoreline) were observed during the survey (Figure 8.14.3-1). 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, 0.3 miles of urbanized and developed–unnatural shoreline (13% of the total shoreline) was observed. If restoration of the Maple Lake shoreline 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. Maple Lake Map 1 displays the location of these shoreline lengths around the entire lake.

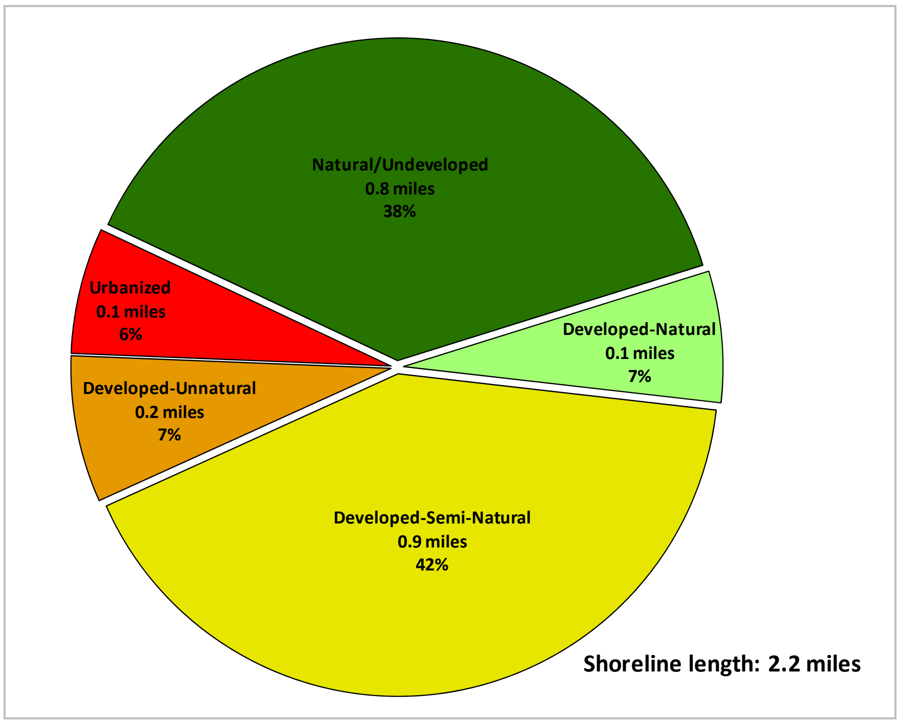


**Figure 8.14.3-1. Maple Lake shoreland categories and total lengths.** Based upon a fall 2013 survey. Locations of these categorized shorelands can be found on the Maple Lake Map 1.

## Coarse Woody Habitat

Maple Lake was 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 and 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, 57 total pieces of coarse woody habitat were observed along 2.2 miles of shoreline, which gives Maple Lake a coarse woody habitat to shoreline mile ratio of 26:1 (Figure 8.14.3-2). Locations of coarse woody habitat are displayed on the Maple Lake Map 2.

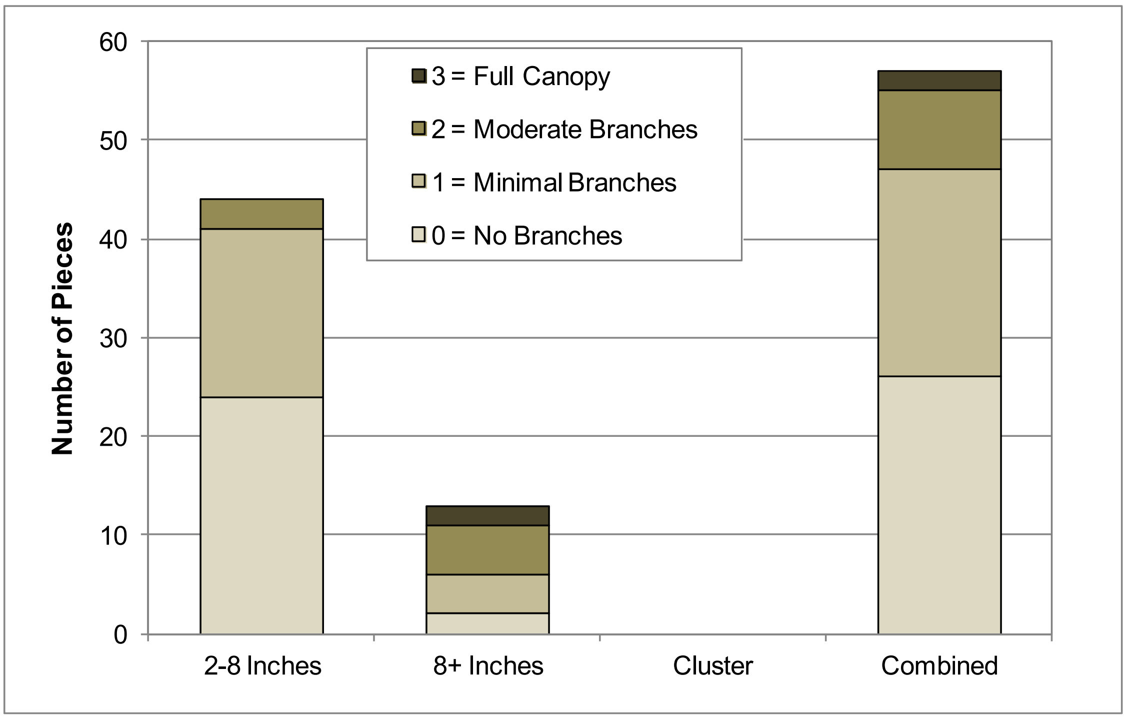


**Figure 8.14.3-2. Maple Lake coarse woody habitat survey results.** Based upon a Fall 2013 survey. Locations of Maple Lake coarse woody habitat can be found on Maple Lake Map 2.

## 8.14.4 Maple Lake Aquatic Vegetation

An early-season aquatic invasive species survey was conducted on Maple Lake on June 25, 2013. This meander-based survey is done at this time to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of the year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This survey did not locate any occurrences of these exotic plants.

The aquatic plant point-intercept survey was conducted on Maple Lake on July 24, 2013 by Onterra. The floating-leaf and emergent plant community mapping survey was completed that next day to create the aquatic plant community map (Maple Lake Map 3). During these surveys, 42 species of native aquatic plants were located in Maple Lake (Table 8.14.4-1). 33 of these species were sampled during the point-intercept survey and are used in the analysis that follows, while nine species were found incidentally.

Aquatic plants were found growing to a depth of fourteen feet, which is slightly deeper than in the other lakes within the Three Lakes Chain, where darkly stained water prohibits aquatic plant growth over six-seven feet of water in most of the lakes. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy and quite diverse. Of the 261 point-intercept locations sampled within the littoral zone, approximately 99% contained aquatic vegetation. Approximately 10% of the point-intercept sampling locations where sediment data was collected at were sand, 88% consisted of a fine, organic substrate (muck) and 2% were determined to be rocky.

**Table 8.14.4-1. Aquatic plant species located in the Maple Lake during the 2013 aquatic plant surveys.**

| Growth Form | Scientific Name | Common Name | Coefficient of Conservatism (c) | 2013 (Onterra) |
|---|---|---|---|---|
| Emergent | *Calla palustris* | Water arum | 9 | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | I |
| | *Eleocharis palustris* | Creeping spikerush | 6 | I |
| | *Pontederia cordata* | Pickerelweed | 9 | I |
| | *Sparganium sp.* | Bur-reed species | N/A | X |
| | *Typha spp.* | Cattail spp. | 1 | X |
| FL | *Brasenia schreberi* | Watershield | 7 | X |
| | *Nymphaea odorata* | White water lily | 6 | I |
| | *Nuphar variegata* | Spatterdock | 6 | X |
| FL/E | *Sparganium natans* | Small bur-reed | 9 | I |
| | *Sparganium fluctuans* | Floating-leaf bur-reed | 10 | I |
| | *Sparganium angustifolium* | Narrow-leaf bur-reed | 9 | I |
| Submergent | *Chara spp.* | Muskgrasses | 7 | X |
| | *Ceratophyllum demersum* | Coontail | 3 | X |
| | *Elatine minima* | Waterwort | 9 | X |
| | *Elodea canadensis* | Common waterweed | 3 | X |
| | *Heteranthera dubia* | Water stargrass | 6 | X |
| | *Isoetes sp.* | Quillwort species | N/A | X |
| | *Lobelia dortmanna* | Water lobelia | 10 | X |
| | *Megalodonta beckii* | Water marigold | 8 | X |
| | *Myriophyllum sibiricum* | Northern water milfoil | 7 | X |
| | *Nitella sp.* | Stoneworts | 7 | X |
| | *Najas flexilis* | Slender naiad | 6 | X |
| | *Najas guadalupensis* | Southern naiad | 7 | X |
| | *Potamogeton epihydrus* | Ribbon-leaf pondweed | 8 | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X |
| | *Potamogeton vaseyi* | Vasey's pondweed | 10 | X |
| | *Potamogeton pusillus* | Small pondweed | 7 | X |
| | *Potamogeton strictifolius* | Stiff pondweed | 8 | X |
| | *Potamogeton berchtoldii* | Narrow-leaved small pondweed | 7 | X |
| | *Potamogeton robbinsii* | Fern pondweed | 8 | X |
| | *Potamogeton gramineus* | Variable pondweed | 7 | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | X |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X |
| | *Potamogeton richardsonii* | Clasping-leaf pondweed | 5 | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X |
| | *Vallisneria americana* | Wild celery | 6 | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X |
| | *Juncus pelocarpus* | Brown-fruited rush | 8 | X |
| | *Sagittaria graminea* | Grass-leaved arrowhead | 9 | I |
| | *Sagittaria cristata* | Crested arrowhead | 9 | X |
| FF | *Lemna minor* | Lesser duckweed | 5 | *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*

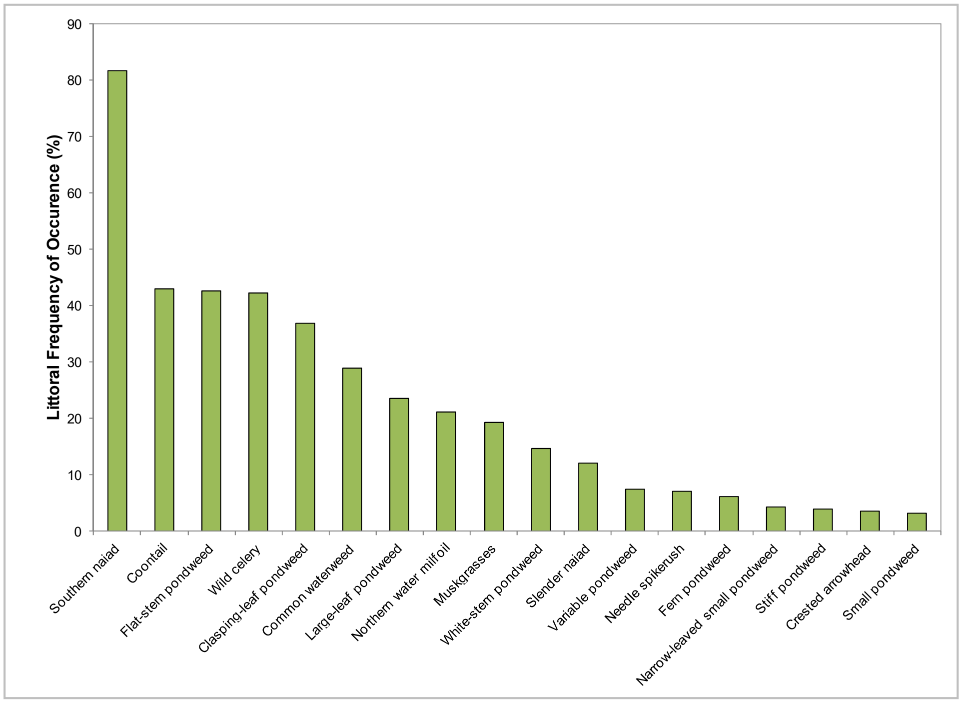


**Figure 8.14.4-1 Maple Lake aquatic plant littoral frequency of occurrence analysis.** Created using data from 2013 point-intercept survey.

Figure 8.14.4-1 (above) shows that southern naiad, coontail and flat-stem pondweed were the most frequently encountered plants within Maple Lake. Southern naiad is a slender, low-growing species with narrow, short greenish-brown leaves. This submerged plant provides habitat for small aquatic organisms and is a food source of waterfowl. Coontail is largely un-rooted (although do sometimes possess structures that function similar to roots or become partially buried in the sediment) and their locations can be largely a product of water movement. Flat-stem pondweed, as its name implies, is a freely branched plant with strongly flattened stems and long, stiff leaves. Flat-stem pondweed lacks floating leaves, a feature many plants in the *Potamogeton* genus have. This plant can be a locally important food source to many aquatic and terrestrial organisms.

42 species of aquatic plants (including incidentals) were found in Maple Lake and because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Maple Lake's plant community (0.95) lies above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds great diversity with respect to its aquatic plant community. The reason for this is discussed below.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section (Chain-wide plan, page 50), the 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 southern naiad was found at 82% of the sampling locations, its relative frequency of occurrence is 20%. Explained another way, if 100 plants were randomly sampled from Maple Lake, 20 of them would be southern naiad. This distribution can be observed in Figure 8.14.4-2, where no one species dominates the aquatic plant community to a great extent. Because of this even distribution, the diversity of the aquatic plant community is higher than the ecoregion median value. Nine additional species were located from the lake but not from of the point-intercept survey, as indicated in Table 8.14.4-1 as incidentals.

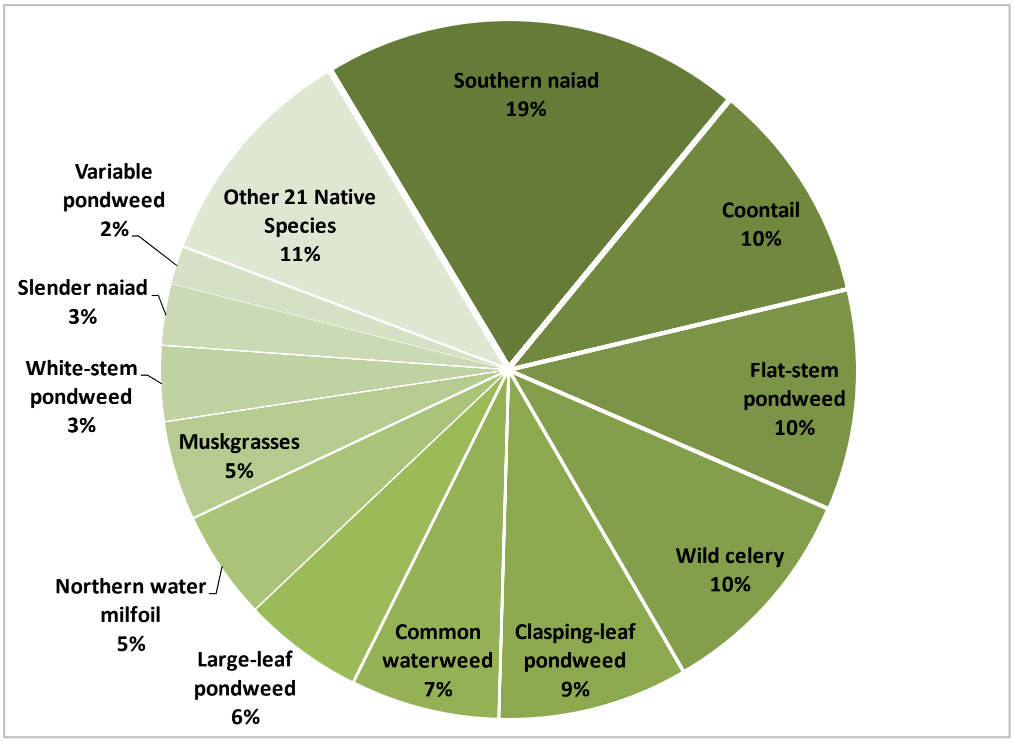


**Figure 8.14.4-2 Maple Lake aquatic plant relative frequency of occurrence analysis.** Created using data from 2012 point-intercept survey.

Maple Lake's average conservatism value (6.7) is higher than both the state (6.0) and equal to the ecoregion (6.7) median. This indicates that the plant community holds a number of species that are sensitive to environmental degradation, but also some species that may be tolerant. Table 8.14.4-1 lists the Coefficient of Conservatism values for each of the species found in Maple Lake. Species that have an 8, 9 or 10 are considered to be of higher quality, while species of a lesser value are of lesser quality to an aquatic ecosystem. Species of a variety of Conservatism values are represented in this table. Combining Maple Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 38.7 which is above the median values of the ecoregion (24.3) and state (22.2).

The quality of Maple Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2013 community map indicates that approximately 4.4 acres of the lake contains these types of plant communities (Maple Lake Map 3, Table 8.14.4-2). Nine floating-leaf and emergent species were located on Maple Lake (Table 8.14.4-1), all of which provide valuable wildlife habitat.

**Table 8.14.4-2. Maple Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.**

| Plant Community | Acres |
|---|---|
| Emergent | 0.9 |
| Floating-leaf | 0.8 |
| Mixed Floating-leaf and Emergent | 2.7 |
| **Total** | 4.4 |

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

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## 8.14.5 Maple Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Maple Lake stakeholders, the TLWA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Maple Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Three Lakes Chain of Lakes are geographically similar, they are definitely ecologically diverse. The latter is detailed throughout this report. This diversity leads to the need for diverse plans aimed at managing the lakes. Some of the project lakes have more complicated management needs than others, but in general most of the lakes', including Maple Lake's, needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition; therefore, Maple Lake's implementation plan is compiled by describing how Maple Lake stakeholders should proceed in implementing applicable portions of the Chain-wide implementation plan for their lake.

# Chain-wide Implementation Plan – Specific to Maple Lake

### *Chain-wide Management Goal 1: Continue to Understand, Protect and Enhance the Ecology of the Three Lakes Chain of Lakes Through Stakeholder Stewardship and Science-based Studies*

**Management Action:** Continue the development of comprehensive management plans for the Three Lakes Chain waterbodies.

**Timeframe:** In progress.

**Facilitator:** Board of Directors.

**Grant:** Lake Management Protection Grant (Diagnostic/Feasibility Studies).

**Description:** Though studies have been completed on Maple Lake as part of this chain-wide project, it is up to Maple Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the TLWA and recommendations in this management plan. Additionally, efforts may be extended to other lakes within the chain.

In addition to current monitoring and protection, Maple Lake may wish to revisit their lake management plan in 5-10 years. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

**Action Steps:**

1. Work with TLWA and qualified consultant to plan continued monitoring and survey efforts.

## Chain-wide Management Goal 2: Continue to Control Eurasian Water Milfoil and Prevent Other Aquatic Invasive Species Infestations on the Three Lakes Chain of Lakes

**Management Action:** Continue Clean Boats Clean Waters watercraft inspections at Three Lakes Chain of Lakes public access locations.

**Description:** While Maple Lake does not have a public access point, it is directly connected to the rest of the Three lakes Chain via Maple Lake. Because of this, the threat of introduction of aquatic invasive species exists from property owners as well as from transient boaters throughout the chain. Therefore, both parties must be educated on the threat of aquatic invasive species.

Maple Lake stakeholders can assist in the implementation of this action by participating in the TLWA's chain-wide CBCW initiatives. These would include volunteering in CBCW watercraft inspections throughout the entire chain, or participation in any one of the TLWA's educational initiatives. On Maple Lake, education is crucial as each property owner needs to be aware of boat cleansing techniques and how they must be careful not to transport plants or animals to Maple Lake or from Maple Lake elsewhere. If a Maple Lake property owner chooses to provide access to multiple other residents, they may elect to work with the TLWA to create signage which would be placed at this location to warn boaters about the threat of aquatic invasive species.

**Management Action:** Coordinate monitoring for aquatic invasive species through continuation of Adopt-A-Shoreline program.

**Description:** Maple Lake stakeholders may monitor their lake for the presence of aquatic invasive species. The TLWA's Education committee, as well as Oneida County Aquatic Invasive Species Coordinator Michelle Saduskas, can train volunteers not only on aquatic invasive species identification but also on methods to monitor the lake for these species. Having more "eyes on the water" increases the odds of spotting early pioneer colonies of aquatic invasive species should they become introduced. Maple Lake riparian property owners, in coordination with the TLWA, may elect to have professional surveys conducted, perhaps with a management plan update or on a contract basis, in the future at a pre-determined interval.

## *Chain-wide Management Goal 3: Increase the Three Lakes Waterfront Association's Capacity to Communicate with and Educate Lake Stakeholders*

**Management Action:** Support an Education Committee to promote safe boating, water quality, public safety and quality of life on the Three Lakes Chain of Lakes.

**Description:** Maple Lake stakeholders can assist in the implementation of this action by participating in the TLWA's educational initiatives. Participation may include presentation of educational topics, volunteering at local and regional events, participating in committees, or simply notifying the lakes committee of concerns involving Maple Lake and its stakeholders.

## *Chain-wide Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders*

**Management Action:** Enhance TLWA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Three Lakes Chain of Lakes.

**Description:** While the TLWA is primarily responsible for facilitating partnerships with many defined management units, Maple Lake property owners may participate in this management goal by keeping the lines of communication open with the TLWA Board of Directors, as well as members from other Three Lakes Chain lakes. This may be done through volunteering in TLWA sponsored events, attending the annual meeting, etc.

## Chain-wide Management Goal 5: Maintain Current Water Quality Conditions

**Management Action:** Monitor water quality through WDNR Citizens Lake Monitoring Network.

**Description:** Currently, no volunteer water quality collection is occurring on Maple Lake. The first step to maintaining water quality conditions on the lake is to enroll in the CLMN. Following enrollment into the program, Secchi disk clarity data will be collected during the open water season. Following collection, these data will automatically be entered into SWIMS, an internet warehouse of water quality data for Wisconsin waterbodies. This information can be accessed in future years so that comparisons can be made to historical data and changes in lake water quality can be scientifically and accurately identified. After one year of enrollment within the basic CLMN program, Maple Lake will become eligible to enroll in the CLMN's Advanced Monitoring program. Efforts should be coordinated through the TLWA Board of Directors.

**Management Action:** Preserve and protect natural shoreland zones along Three Lakes Chain of Lakes.

**Description:** This management action ties in very much with the action under Management Goal 3, which is to support an Education Committee. The Education Committee's purpose (with regards to shoreland properties) is to assemble applicable shoreland protection knowledge and materials and distribute this to riparian property owners on the Three Lakes Chain. Maple Lake stakeholders may assist in this management action by attending educational events held by the TLWA and distributing the TLWA's materials to riparian property owners.

**Management Action:** Investigate restoration of urbanized shoreland areas on the Three Lakes Chain of Lakes.

**Description:** As a part of this project, the entire Maple Lake shoreline was categorized in terms of its development. According to the results from this survey, 17.0% of the shoreline is in an urbanized or developed-unnatural state, while 39.0% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

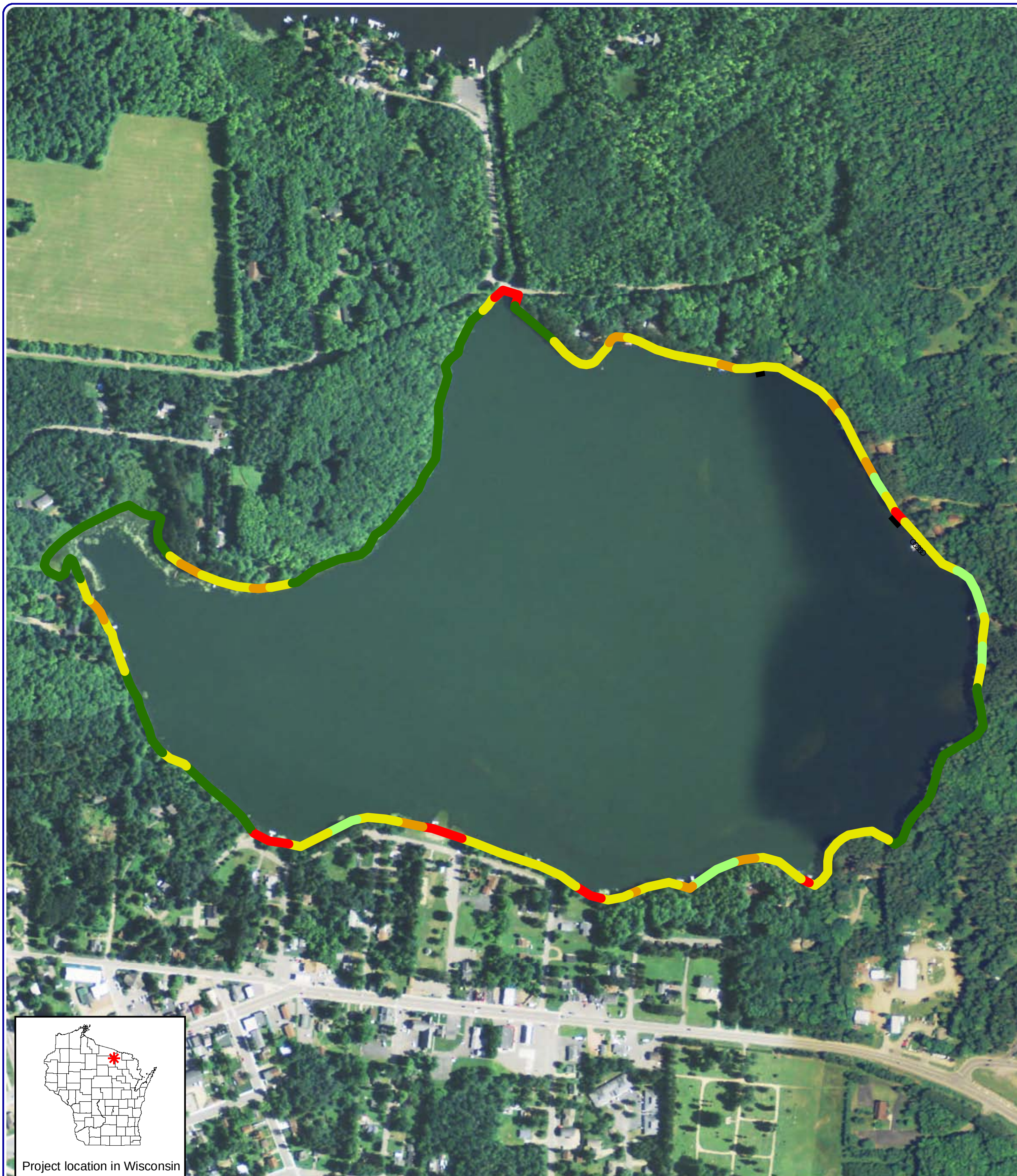
The TLWA will appoint a Shoreland Representative(s) to oversee shoreland restoration activities on the Three Lakes Chain of Lakes. This person will serve as a contact for property owners who are interested in pursuing shoreland restoration on their property.

Interested property owners may contact the TLWA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

## Chain-wide Management Goal 6: Improve Fishery Resource and Fishing

**Management Action:** Work with fisheries managers to enhance and understand the fishery on the Three Lakes Chain of Lakes.

**Description:** A representative of the TLWA Board of Directors will be contacting WDNR biologists once a year (or more if deemed appropriate) for recent information pertaining to the fishery of the Three Lakes Chain of Lakes. This information will be published either on the TLWA's website or within periodic newsletters. If Maple Lake stakeholders have specific questions/concerns about the walleye population or the overall fishery of Maple Lake, a representative will contact the TLWA board with these comments, who will forward them on to WDNR fisheries biologists.




550
Feet

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

**Sources:**
Orthophotography: NAIP, 2013
SCA Survey: Onterra, 2013
Map date: December 2, 2013
*Filename: Maple_SCA_2013.mxd*

**Legend**

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

Seawall
Masonary/Wood
Rip-Rap

# Maple Lake - Map 1
# Three Lakes Chain
Oneida County, Wisconsin

## Shoreland Condition Assessment


550

Feet

# Legend

| 2-8 Inch Pieces | 8+ Inch Pieces | Cluster of Pieces |
|---|---|---|
| No Branches | No Branches | No Branches (none) |
| Minimal Branches | Minimal Branches | Minimal Branches (none) |
| Moderate Branches | Moderate Branches | Moderate Branches (none) |
| Full Canopy (none) | Full Canopy | Full Canopy (none) |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www.onterra-eco.com


Sources:
Orthophotography: NAIP, 2013
CWH Survey: Onterra, 2013

Map date: December 30, 2013
Filename: Maple_CWH_2013.mxd

Maple Lake - Map 2
Three Lakes Chain
Oneida County, Wisconsin

**Coarse Woody Habitat**

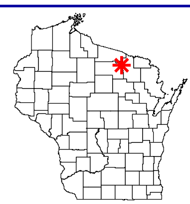

N
W E
S

500

Feet

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

**Sources:**
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2010
**Map date:** November 13, 2013
*Filename: Maple_Comm_2013.mxd*



Project Location in Wisconsin

## Legend

| **Small Plant Communities** | **Large Plant Communities** |
|---|---|
| Emergent | Emergent |
| Floating-leaf | Floating-leaf |
| Mixed Floating-leaf & Emergent | Mixed Floating-leaf & Emergent |

Maple Lake - Map 3
Three Lakes Chain
Oneida County, Wisconsin

**Aquatic Plant Communities**