# Twin Lakes

Marquette County, Wisconsin

# Comprehensive Management Plan

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## Acknowledgements

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

### Twin Lakes Planning Committee

Michelle Crombie  Gretchen Miller  Bob Simonson  Angie Halverson  Ken Klemm  Jeff Williams  Catherine & Glenn Wallberg  Rebecca Fallow  Dick & Joan Pelletier  Cameron Crombie  Abigail Crombie  Kevin St Angel

#### Organization

Twin Lakes Conservancy, Inc

#### Wisconsin Dept. of Natural Resources

Ted Johnson

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# 1.0 INTRODUCTION

Twin Lakes in Marquette County, Wisconsin, is comprised of two distinct but hydrologically connected basins; East Twin Lake and West Twin Lake (Map 1). Twin Lakes are seepage lakes that have experienced dramatic fluctuations in water levels in recent years as a function of the high amounts of recent local precipitation. A maximum water depth of approximately 35 feet was measured during 2020 in West Twin and 14 feet in East Twin. The lakes combined comprise approximately 42 acres measured during a period of high water levels observed in 2020. Twin Lakes watershed encompasses an area of approximately 390 acres. Twin Lakes harbor a lower-than-expected population of native aquatic plants, with two non-native species, Eurasian watermilfoil and curly-leaf pondweed, also present in the lakes. The presence of common carp in the lake has negative implications to the lake's water quality and aquatic vegetation.

**Field Survey Notes**

*Very high water levels in 2020 resulted in the presence of many dead standing trees and shrubs around the margins of the lake.*

*Large stretches of undeveloped shoreline contribute to the scenic beauty of the lake.*

**Photograph 1.0-1. Twin Lakes, Marquette County**

## Lakes at a Glance – Twin Lakes

| | West Twin Lake | East Twin Lake |
|---|---|---|
| **Morphology** | | |
| Surface Area (acres) (2020) | 20.9 | 21.1 |
| Maximum Depth (feet) (2020) | 35 | 14 |
| Watershed Area (acres) | 390 | |
| Perimeter (miles) | 0.99 | 0.94 |
| **Vegetation** | | |
| Number of Native Species (2019) | 9 | |
| Exotic Plant Species | EWM, CLP | EWM, CLP |
| Simpson's Diversity (2019) | 0.50 | 0.68 |
| Average Conservatism (2019) | 6.0 | 5.5 |
| **Water Quality** | | |
| Trophic State | Mesotrophic | Meso-eutrophic |
| Limiting Nutrient | Phosphorus | |
| Water Acidity (pH) | 8.6 | |
| Sensitivity to Acid Rain | Not sensitive | |

The Twin Lakes Conservancy, Inc (TLC) is the local non-profit organization formed in 2001 that oversees the protection and management of Twin Lakes. The TLC is run by volunteers, and financially supported by the families that own property on the lakes. The TLC is a member of the Wisconsin Association of Lakes and Marquette County Association of Lakes.

# 2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee and the completion of a stakeholder survey.

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

## General Public Meetings

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

### *Kick-off Meeting*

In June 2020, a recorded project kick-off meeting was distributed to introduce the project to the general public. The meeting was announced through hosting on Onterra's YouTube website and shared by TLC board members. The video includes presentation given by Todd Hanke, an aquatic ecologist with Onterra. Mr. Hanke's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved.

### *Project Wrap-up Meeting*

A virtual project wrap-up meeting is anticipated to occur in December 2023. Any interested persons are encouraged to attend. During the meeting, Onterra staff will provide an overview of the project and the conclusions drawn from the results of the studies that took place. The TLC's management goals and actions that were developed for this project will be reviewed. Participants will also have an opportunity to ask questions about the lake and the management plan that was created.

## Committee Level Meetings

### *Planning Committee Meeting I*

On June 8, 2021, Onterra staff met virtually with 14 volunteer members from around Twin Lakes comprising the Planning Committee for this project. During this approximate 3-hour meeting, Onterra presented the results of the studies that have taken place and answered questions about

Twin lakes. Following the meeting, committee members were tasked with reviewing the stakeholder survey results and compiling challenges they see facing the lake and the groups' ability to manage it.

### *Planning Committee Meeting II*

On July 13, 2021, Onterra staff met once again through a virtual platform with nine members serving on the Planning Committee for this project. During this approximately 2.5-hour meeting, discussions revolved around meeting the challenges facing Twin Lakes and developing a framework of management goals meant to meet these challenges. Specific actions were considered and facilitators were selected to oversee the completion of the action steps that were developed.

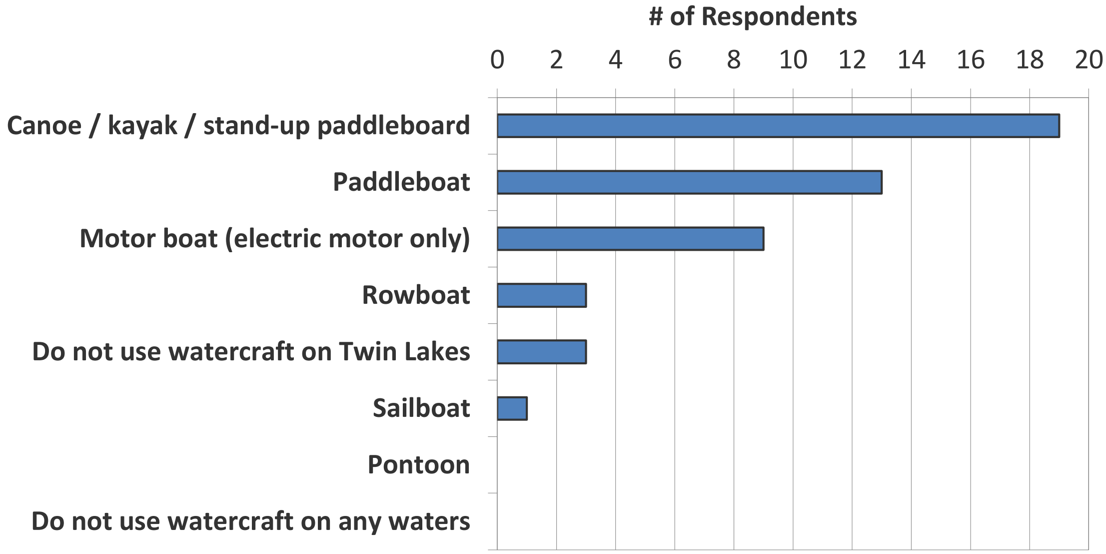
## Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to Twin Lakes Conservancy Inc members and riparian property owners around the Twin Lakes. The survey was designed by Onterra staff and the Twin Lakes Conservancy Inc planning committee and reviewed by a WDNR social scientist. During November of 2020, the seven-page, 30-question survey was posted online through Survey Monkey for survey-takers to answer electronically. If requested, a hard copy was sent with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a Twin Lakes Conservancy Inc volunteer for analysis. Sixty-one percent (30 out of 49) of the surveys were returned. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people who use and care for the Twin Lakes. Fifty percent of respondents indicated that their property on the lake is a vacation home, while 33% of properties are a part-time residence, and 13% are full-time residence properties. Fifty percent of respondents have owned their property for from 11 to 25 years, and 23% 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 either a canoe/kayak, stand-up paddleboard, paddleboat or a combination of these vessels on the Twin Lakes (Question 12). Electric motor boats were also a popular option. On a relatively small waterbody such as the Twin Lakes, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. A concern of stakeholders noted throughout the stakeholder survey (see Question 16 and survey comments – Appendix B) was water quality degradation and aquatic invasive species introduction within the Twin Lakes.

*Question 12: What types of watercraft do you currently use on Twin Lakes?*




*Question 15: Rank up to three activities that are important reasons for owning your property on Twin Lakes.*

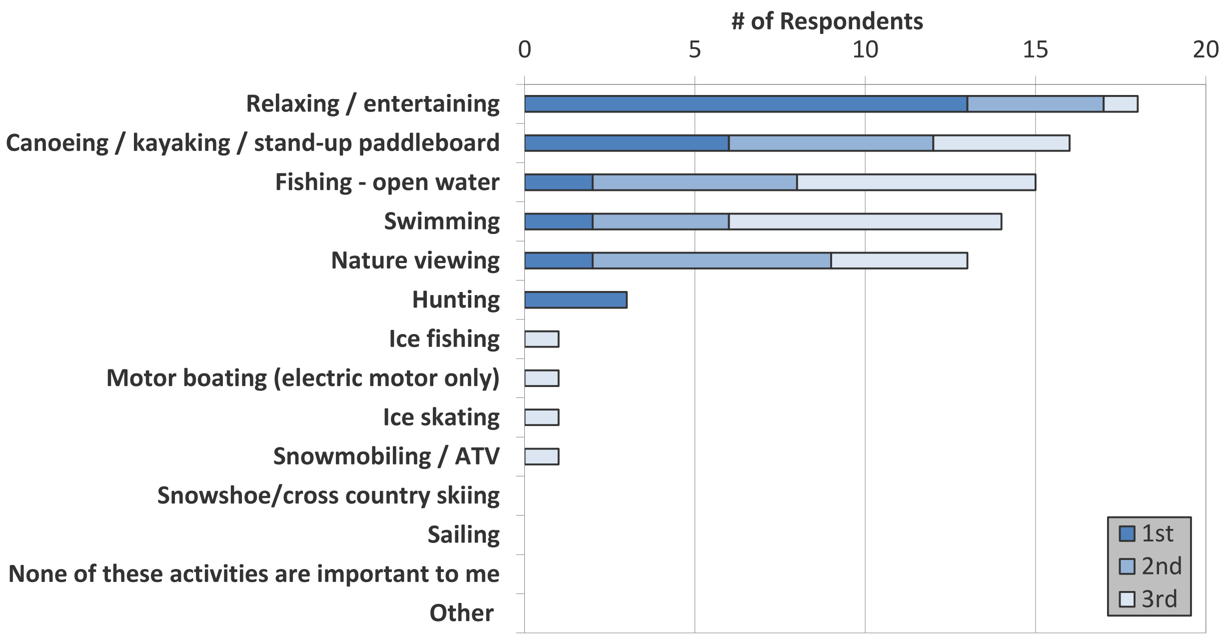



**Figure 2.0-1. Select survey responses from the Twin Lakes Stakeholder Survey.** Additional questions and response charts may be found in Appendix B.

*Question 16: Please rank your top three concerns regarding Twin Lakes.*

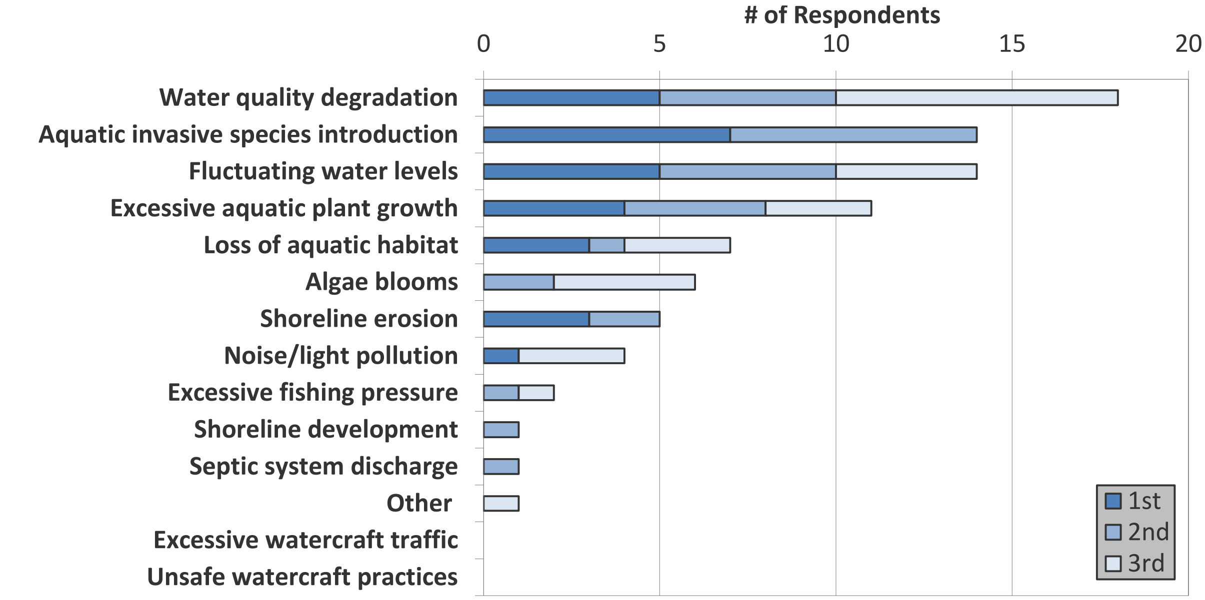



**Figure 2.0-2. Select survey responses from the Twin Lakes Stakeholder Survey, continued.** Additional questions and response charts may be found in Appendix B.

## Management Plan Review and Adoption Process

On November 8, 2021, a draft of the Implementation Plan was sent to the Planning Committee for review. The Committee submitted comments on December 30, 2021 after which Onterra made edits and updates to the draft. A second draft of the Implementation Plan was issued to the Committee on January 6, 2022. The Planning Committee provided final comments and approved of the Implementation Plan on January 24, 2022.

The Official First Draft of the Management Plan was compiled in late-January 2022 and distributed to WDNR, County, TLC, and other local project partners for official review. Comments were received from the local WDNR lakes biologist – Ted Johnson and WDNR fisheries biologist Adam Nickel.

Supplemental meetings took place on 12-15-22 to discuss the WDNR 2022 fisheries study and on 9-11-23 to discuss the results of the summer 2023 aquatic plant point-intercept survey. Revisions were made the draft version of this management plan to include text analysis and reporting of these studies. Further, the TLC made edits to the Implementation Plan section of this document including the addition of a fisheries related goal.

# 3.0 RESULTS & DISCUSSION

## 3.1 Lake Water Quality

### *Water Quality Data Analysis and Interpretation*

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

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analyses 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 Twin Lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the same ecoregion (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Twin 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 quadrants (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, Nelson and Everett 1994) (Dinius 2007) (Smith, Cragg and Croker 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. Oligotrophic lakes have the lowest amounts of nutrients and biological productivity, and are generally characterized by having high water clarity and a lower abundance of aquatic plants. Mesotrophic lakes have moderate levels of nutrients and biological productivity and generally support more abundant aquatic plant growth. Eutrophic lakes have higher levels of nutrients and biological productivity, and generally have a high abundance of aquatic plants.

Most lakes will naturally progress through these states and under natural conditions (i.e. not influenced by the activities of humans) but this process can take tens of thousands of years. Unfortunately, human development of watersheds and the direct discharge of nutrient-rich effluent has accelerated this natural aging process in many Wisconsin lakes, and this is termed cultural eutrophication. The excessive input of nutrients through cultural eutrophication has resulted in some lakes becoming hypereutrophic. Hypereutrophic lakes have the highest levels of nutrients and biological productivity. These lakes are typically dominated by algae, have very poor water clarity, and little if any aquatic plant growth.

It is important to note that both natural factors and human activity can affect a lake's trophic state, and that some lakes can be naturally eutrophic. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

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

## Limiting Nutrient

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

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

## Temperature and Dissolved Oxygen Profiles

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

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

**Lake stratification** occurs when temperature and density gradients are developed with depth in a lake. During stratification, the lake can be broken into three layers: The ***epilimnion*** is the surface layer with the lowest density and has the warmest water in the summer months and the coolest water in the winter months. The ***hypolimnion*** is the bottom layer the highest density and has the coolest water in the summer months and the warmest water in the winter months. The ***metalimnion***, often called the thermocline, is the layer between the epilimnion and hypolimnion where temperature changes most rapidly with depth.

## Internal Nutrient Loading

In general, lakes tend to act as phosphorus sinks, meaning they tend accumulate phosphorus over time and export less phosphorus than the amount that is loaded to the lake from its watershed. In most lakes, there is a net movement of phosphorus from the water to bottom sediments where it accumulates over time. The retention of this phosphorus within bottom sediments depends on a number of physical, chemical, and biological factors (Wetzel, 2001). If this phosphorus remains bound within bottom sediments, it is largely unavailable for biological use. However, under certain conditions, this phosphorus can be released from bottom sediments into the overlying water where it may become biologically available. This release of phosphorus (and other nutrients) from bottom sediments into the overlying water is termed *internal nutrient loading*. While phosphorus can be released from bottom sediments under a few varying conditions, it occurs most often when the sediment-water interface becomes devoid of oxygen, or anoxic.

When water at the sediment-water interface contains oxygen, phosphorus largely remains bound to ferric iron within the sediment. When the water at the sediment-water interface becomes anoxic, or devoid of oxygen, ferric iron is reduced to ferrous iron and the bond between iron and phosphorus is broken. Under these conditions, iron and phosphorus are now soluble in water and are released from the sediments into the overlying water (Pettersson, 1998). Anoxia at the sediment-water interface typically first develops following thermal stratification, or the formation of distinct layers of water based on temperature and density.

As surface waters warm in late-spring/early summer, it becomes less dense and floats atop the colder, denser layer of water below. The large density gradient between the upper, warm layer of water (*epilimnion*) and lower, cold layer of water (*hypolimnion*) prevents these layers from mixing together and eliminates atmospheric diffusion of oxygen into bottom waters. If there is a high rate of biological decomposition of organic matter in the bottom sediments, anoxic conditions within the hypolimnion can develop as oxygen is consumed and is not replaced through mixing. The loss of oxygen then results in the release of phosphorus from bottom sediments into the hypolimnion.

The development of an anoxic hypolimnion and subsequent release of phosphorus from bottom sediments occurs in many lakes in Wisconsin. However, in deeper, dimictic lakes which remain stratified during the summer, internal nutrient loading is often not problematic as the majority of the phosphorus released from bottom sediments is confined within the hypolimnion where it is largely inaccessible to phytoplankton at the surface. Dimictic lakes are those which remain stratified throughout the summer (and winter) and experience only two complete mixing events (turnover) per year, one in spring and one in fall. In dimictic lakes, phosphorus released from bottom sediments into the hypolimnion during stratification only becomes available to phytoplankton in surface waters during the spring and fall mixing events. While these spring and fall mixing events can stimulate diatom and golden-brown phytoplankton blooms, these mixing events generally to not stimulate cyanobacterial (blue-green algae) blooms because water temperatures are cooler.

Internal nutrient loading can become problematic in lakes when sediment-released phosphorus becomes accessible to phytoplankton during the summer months when surface temperatures are at their warmest. Sediment-released phosphorus can be mobilized to surface waters during the summer in polymictic lakes, or lakes which have the capacity to experience multiple stratification and mixing events over the course of the growing season. Some polymictic lakes tend to straddle the boundary between deep and shallow lakes, and have the capacity to break stratification in summer when sufficient wind energy is generated. Consequently, phosphorus which has accumulated in the anoxic hypolimnion during periods of stratification is mobilized to the surface during partial or full mixing events where it then can spur nuisance phytoplankton blooms at the surface.

Phosphorus from bottom waters can also be mobilized to the surface in polymictic lakes through entrainment, or the continual deepening of the epilimnion and erosion of the metalimnion below (Wetzel, 2001). Wind-driven water generates turbulence across the thermal barrier between the epilimnion and the metalimnion and the metalimnion is eroded, mixing sediment-released nutrients into the epilimnion above. Both periodic mixing and entrainment act as “nutrient pumps” in polymictic lakes, delivering sediment-released nutrients in bottom waters to surface waters (Orihel, et al., 2015). While a continuum exists between dimictic and polymictic lakes, the Osgood Index (Osgood, 1988) is used to determine the probability that a lake will remain stratified during the summer. This probability is estimated using the ratio of the lake's mean depth to its surface area. Lakes with an Osgood Index of less than 4.0 are deemed polymictic.

## Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR, Wisconsin 2018 Consolidated Assessment and Listing Methodology [WisCALM] 2018) 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 Twin Lakes will be compared to lakes in the state with similar physical characteristics.

The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1). First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, and hydrology. An equation developed by Lathrop and Lillie (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.

Using these criteria, East Twin Lake is classified as a *shallow seepage lake* while West Twin Lake is classified as a *deep seepage lake*.

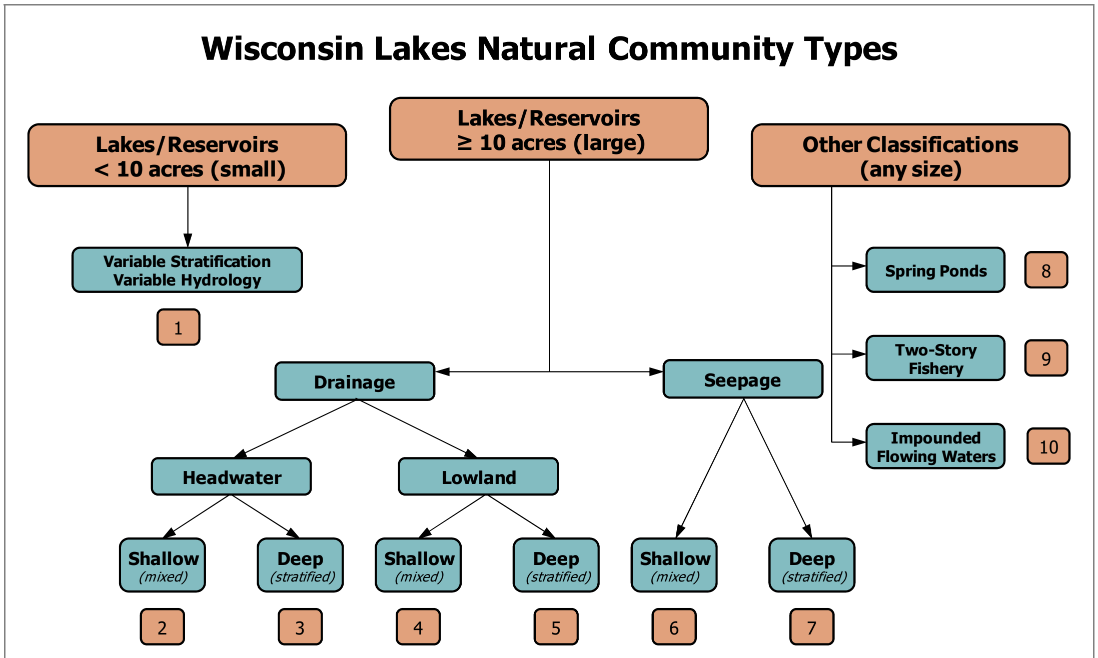



**Figure 3.1-1. Wisconsin Lake Natural Communities.** Adapted from WDNR 2017. East Twin Lake is classified as a shallow (mixed) seepage lake (class 6), while West Twin Lake is classified as a deep (stratified) seepage lake (class 7).

(Garrison et al. 2008) developed statewide 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 Twin Lakes are located within the North Central Hardwood Forests ecoregion.

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

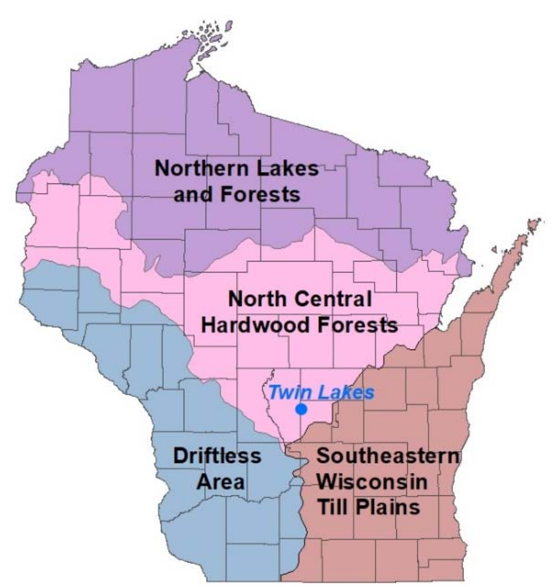



**Figure 3.1-2. Location of Twin Lakes within the ecoregions of Wisconsin.** After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historical, current, and average data from Twin Lakes are displayed in the subsequent section. *Growing season* refers to data collected at any time between April and October, while *summer* refers to data collected in June, July, or August. 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.

The data presented in the following section include data collected by TLC volunteers through the WDNR Citizens Lake Monitoring Network, data collected from a previous lake management planning project, and data collected by Onterra ecologists in 2020/2021 as part of this lake management planning project. All data presented in this section were collected at the deep hole sampling locations within both East and West Twin lakes (Figure 3.1-3).

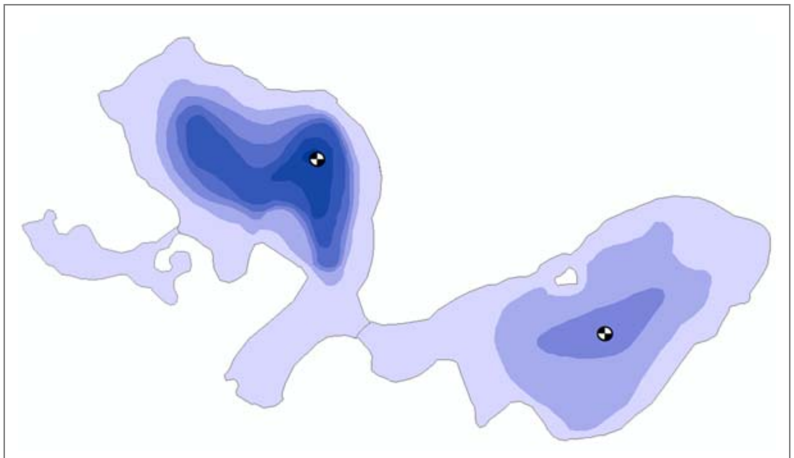


**Figure 3.1-3. Twin Lakes water quality sampling locations.**

## *Twin Lakes Water Quality Analysis*

### Total Phosphorus

Using 2020 mid-summer nitrogen and phosphorus concentrations, nitrogen:phosphorus ratios of 110:1 and 117:1 were calculated for East Twin Lake and West Twin Lake, respectively. These ratios indicate that both lakes are phosphorus limited, as are most of Wisconsin's lakes. In general, this means that phosphorus is the primary nutrient regulating algal growth within the lake, and increases in phosphorus will likely result in increased algal production and lower water clarity. Conservation of Twin Lake's water quality means limiting anthropogenic sources of phosphorus to the lake (i.e., shoreland development and runoff).

Near-surface total phosphorus (TP) data from East Twin and West Twin lakes are available from 2002-2004 and 2020 (Figure 3.1-4 – top frame). The weighted summer average TP concentration from East Twin Lake over this time period is 32.6 µg/L, indicating the lake's TP concentrations are *good* for Wisconsin's shallow mixed seepage lakes. The average summer TP concentration in 2020 of 18.2 µg/L was lower than the long-term average. Overall, East Twin Lake's weighted TP concentrations are higher than the median concentrations for Wisconsin's shallow seepage lakes (18.0 µg/L) but lower when compared to all lakes within the NCHF ecoregion (52.0 µg/L).

Near-surface total phosphorus data from West Twin Lake are available from the same time period (Figure 3.1-4-bottom frame). The weighted summer average TP concentration over this time period is 21.3 µg/L, indicating the lake's TP concentrations are *good* for Wisconsin's deep seepage lakes. The average summer TP concentration in 2020 of 19.7 µg/L was slightly lower than the long-term average. Overall, West Twin Lake's weighted TP concentrations are higher than the median concentrations for Wisconsin's deep seepage lakes (15.0 µg/L) but lower when compared to all lakes within the NCHF ecoregion (52.0 µg/L).

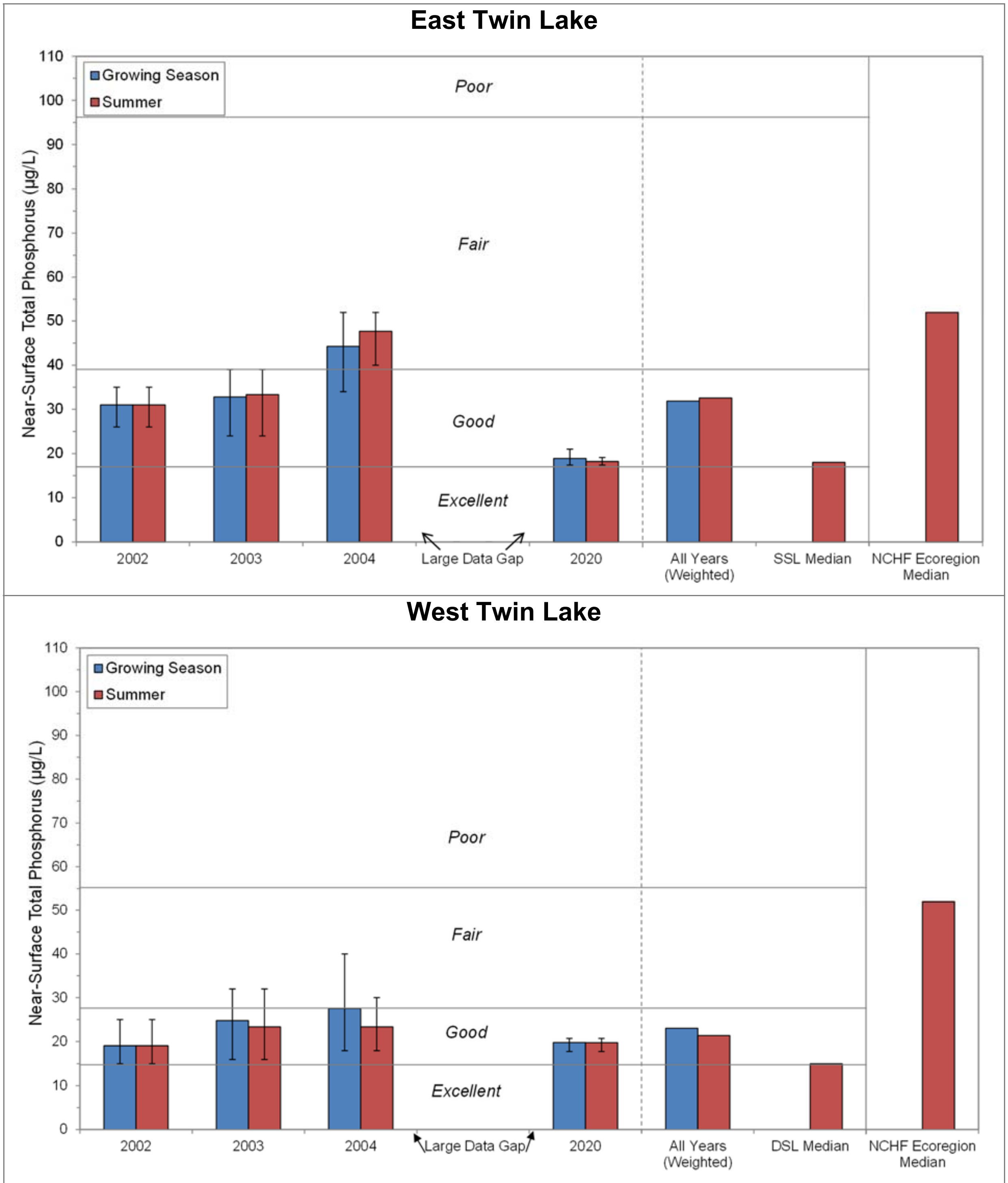



**Figure 3.1-4. East Twin Lake (Top) and West Twin Lake (Bottom) average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for statewide shallow and deep seepage lakes (SSL & DSL) and North Central Hardwood Forests (NCHF) ecoregion lakes.** Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.


Onterra LLC
*Lake Management Planning*

To determine if internal nutrient loading occurs and has a detectable effect on the Twin Lake's water quality, phosphorus concentrations over the course of the growing season were examined. In dimictic lakes that experience internal nutrient loading, near-surface concentrations will often be highest in the fall following fall turnover when the phosphorus-rich bottom waters are mixed throughout the water column. In shallower lakes that experience internal loading and periodic mixing throughout the growing season, near-surface phosphorus concentrations will often increase over the course of the growing season as sediment-released phosphorus is periodically mobilized to the surface. In addition, near-bottom phosphorus concentrations are also measured during periods of stratification to determine if significant levels of phosphorus are accumulating in bottom waters. Near bottom samples were not collected from East Twin Lake during this project due to the relatively shallow nature of this lake and the expectation that the lake would be mixed throughout the water column.

Finally, watershed modeling was used to determine if measured phosphorus concentrations were similar to those predicted based on watershed size, land cover, and precipitation. If predicted phosphorus concentrations are significantly lower than those measured, this indicates that source(s) of phosphorus are entering the lake that were not accounted for in the model. This unaccounted source of phosphorus is often attributable to the internal loading of phosphorus.

Figure 3.1-5 displays the total phosphorus concentrations from near surface and near bottom samples collected from the deep hole sampling location in West Twin Lake. These data show consistently higher phosphorus concentrations in the near bottom samples compared to near surface in nearly every analysis. This can be attributed to release of phosphorus from the sediment in the lake during periods of anoxia. In the fall, when waters mix throughout the water column, a slight increase in near-surface phosphorus concentrations is observed compared to levels measured during other times of the year.

This is common in many dimictic systems and is a process by which phosphorus is recycled from bottom waters to the surface. This process can become problematic when hypolimnetic phosphorus gets mobilized to surface waters during the summer months, spurring algal blooms. In June, July, and August 2020, near surface phosphorus concentrations were between 17.8-20.7 µg/L compared to 33.9 µg/L in November 2020 while the lake had mixed. Although this indicates some amount of phosphorus loading in West Twin Lake, the amount is not believed to be a significant factor impacting the water quality in the lake.

The near-bottom phosphorus levels were highest in samples collected during 2004. The levels measured in 2020 were similar to those measured in 2002-2003 and lower than levels measured in 2004 (Figure 3.1-5). It is not known why near-bottom TP concentrations were higher in 2004, but may be due to differences in water levels and/or the length of time the hypolimnion was devoid of oxygen.

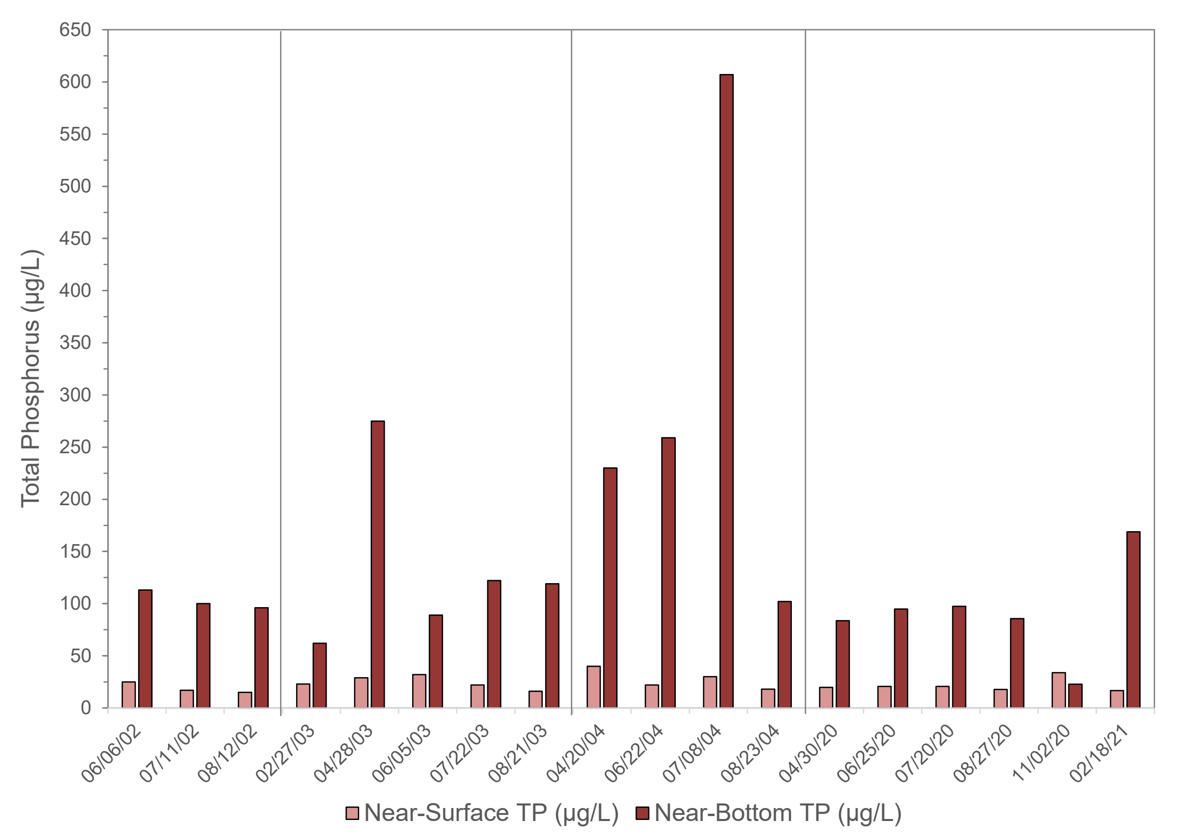



**Figure 3.1-5. West Twin Lake near-surface and near bottom total phosphorus concentrations.**

## Total Nitrogen

Nitrogen is second to phosphorus in terms of its importance in regulating the growth of phytoplankton, and in some Wisconsin lakes, nitrogen is the nutrient that is in shortest supply and thus limits the growth of phytoplankton. As discussed previously, the productivity of Twin Lakes is limited by phosphorous so an excess of nitrogen would not increase the productivity of the lakes.

There are numerous sources and numerous different forms of nitrogen which are delivered to Wisconsin's lakes. Nitrogen enters waterbodies through precipitation, fixation from the atmosphere by cyanobacteria, surface inflow including fertilizers and animal wastes from agricultural areas, groundwater, and sewage treatment plants or septic systems (Wetzel 2001) Unlike phosphorus, nitrogen does not occur naturally within soil minerals. The majority of the earth's nitrogen occurs within the atmosphere and is unavailable to most organisms. A bio-available form of nitrogen is created by organism that have the ability to convert atmospheric nitrogen into a usable form.

Total nitrogen was measured on three occasions in East Twin and West Twin lakes in 2020-2021 including April 2020, July 2020, and February 2021 (Table 3.1-1). Total nitrogen was also measured on one earlier occasion in West Twin Lake in April 2003. Samples analyzed in 2020-2021 showed highly elevated levels of nitrogen in both East Twin and West Twin lakes with concentrations between 2,000 and 4,500 µg/L. To put these values into perspective, a study of many of Wisconsin's lakes in the late 1970's to early 1980's had a mean nitrogen concentration of 860 µg/L, a median concentration of 730 µg/L, and 71% of lakes fell within a range between

300 µg/L to 1000 µg/L (Lillie and Mason 1983). This indicates that nitrogen values in Twin Lakes are higher when compared to the majority of lakes in Wisconsin. Elevated nitrogen levels in a lake are typically an indication of pollution originating from agricultural sources in the watershed. Being seepage lakes, it is likely that this is a sign of nitrate pollution originating from agriculture and entering the lakes via groundwater. Groundwater flows have been studied in parts of Marquette and Adams counties in the past. These studies have shown groundwater generally flows from northwest to southeast in the vicinity of Twin Lakes. Sources of nitrogen are present in agricultural lands that contribute to the groundwater that feeds into Twin Lakes. Local septic systems may also contribute to the increased nitrogen levels in the lakes; however, this was not specifically measured during this project. If septic systems were contributing to nutrients, we might expect higher phosphorus levels as well, which was not indicated in the available data.

**Table 3.1-1. Total Nitrogen Concentrations in Twin Lakes from 2003-2021.**

| Total Nitrogen (µg/L) | | |
|---|---|---|
| | West Twin | East Twin |
| 04/28/03 | 1200 | - |
| 04/30/20 | 4060 | 3320 |
| 07/20/20 | 2430 | 2000 |
| 02/18/21 | 4500 | 3280 |

## Chlorophyll

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from East and West Twin Lake for the same time period as TP, from 2002-2004 and 2020. In East Twin Lake, the weighted summer average chlorophyll-*a* concentration over this period is 9.8 µg/L, indicating the lake's chlorophyll-*a* concentrations are overall *good* for Wisconsin's shallow seepage lakes (Figure 3.1-6 – top frame). The weighted average falls above median concentrations for statewide shallow seepage lakes and below the median from the NCHF ecoregion. Summer 2020 chlorophyll-*a* concentrations were slightly below the weighted average at 9.2 µg/L.

The weighted summer average chlorophyll-*a* concentration from West Twin Lake over this period is 6.8 µg/L, indicating the lake's chlorophyll-*a* concentrations are overall *good* for Wisconsin's deep seepage lakes (Figure 3.1-6- bottom frame). The weighted average falls above median concentrations for statewide deep seepage lakes and below the median from the NCHF ecoregion. Summer 2020 chlorophyll-*a* concentrations were slightly below the weighted average at 6.5 µg/L. Chlorophyll-*a* concentrations in both lakes are at expected levels based on the measured concentrations of phosphorus.

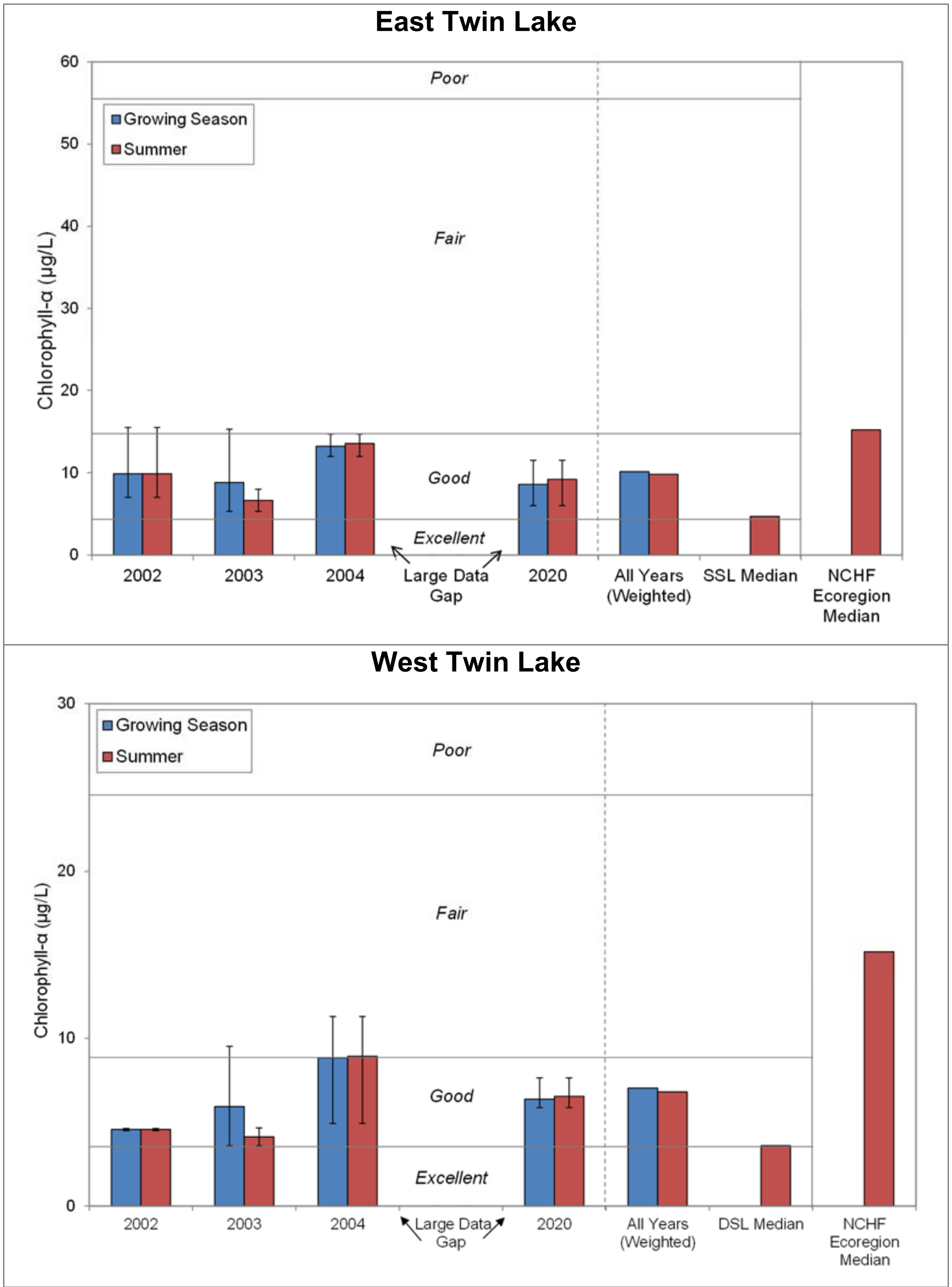



**Figure 3.1-6. East Twin Lake (top frame) and West Twin Lake (bottom frame) average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for statewide shallow and deep seepage lakes (SSL & DSL) and North Central Hardwood Forests (NCHF) ecoregion lakes.** Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

## Water Clarity

Water clarity monitoring using Secchi disk depths has been conducted at East Twin Lake's deep hole sampling location in 2008, 2009, 2011, and 2020 (Figure 3.1-7- top frame). Secchi disk readings were recorded by CLMN volunteers during additional years as well; however, in many cases the Secchi disk hit bottom in which case the data are not used in this analysis. Average summer Secchi disk depths have ranged from 3.5 feet in 2008 to 5.2 feet in 2009. The weighted summer average Secchi disk depth over this time period is 4.0 feet, indicating East Twin Lake's water clarity is considered *fair* for Wisconsin's shallow seepage lakes. Summer Secchi disk depths in 2020 were 4.2 feet. On average, East Twin Lake's Secchi disk depths are much lower than median depths for other shallow seepage lakes in Wisconsin and below lakes within the NCHF ecoregion.

Water clarity monitoring has been conducted at West Twin Lake's deep hole sampling location in 2001, 2002, and 2020 (Figure 3.1-7 – bottom frame). The weighted summer average Secchi disk depth over this time period is 5.3 feet, indicating West Twin Lake's water clarity is considered *fair* for Wisconsin's deep seepage lakes. Summer Secchi disk depths in 2020 were 4.8 feet. On average, West Twin Lake's Secchi disk depths are much lower than median depths for other deep seepage lakes in Wisconsin and similar to lakes within the NCHF ecoregion.

Water clarity in both East Twin and West Twin lakes is lower than expected based on the measured chlorophyll-*a* concentrations. This indicates that another factor(s) in addition to algae is influencing the water clarity in these lakes. The two most important factors affecting water clarity in Wisconsin's lakes are algal abundance and water color, or true color. True color is a measure of water clarity once all particulates (i.e., algae, sediments, etc.) have been filtered out and only dissolved compounds remain. Dissolved organic matter (DOM) causes the water in lakes, particularly in northern Wisconsin, to be brown in color, or stained. This DOM originates from decaying plant matter in forests and wetlands in the lake's watershed.

Studies have been showing that DOM has been increasing in lakes across North America as the result of increases in precipitation and increases in extreme precipitation events (LakeLine 2020). Higher rates of precipitation cause increases in DOM in a couple of ways: first, higher precipitation saturates soils which creates anoxic conditions which increases the production of DOM, and second, higher precipitation increases the amount of water and DOM flowing into the lake. True color was measured in samples collected from Twin Lakes during 2020 and indicate that the water contains low concentrations of DOM, and is considered to be *clear* as opposed to *tea-colored* (Figure 3.1-8). This indicates that DOM has minimal influence on water clarity in Twin Lakes.

Total suspended solids, a measure of suspended particulates in the water (algae and sediment), were elevated in both lakes in 2020. This indicates that in addition to algae, there a higher level of abiotic particulates (sediment) suspended in the water. Given the Twin Lakes do not have a tributary which could carry-in sediments and are not large enough to experience wind-driven sediment resuspension, it is believed the higher levels of suspended particulates are the result of the introduced common carp (*Cyperinus carpio*) population. The feeding and foraging behavior of common carp disturb and resuspend bottom sediments, increasing suspended solids and decreasing water clarity. This is more evident in East Twin Lake which is shallower, allowing bottom sediments to be resuspended to surface waters more readily. East Twin Lake has lower water clarity when compared to West Twin Lake.

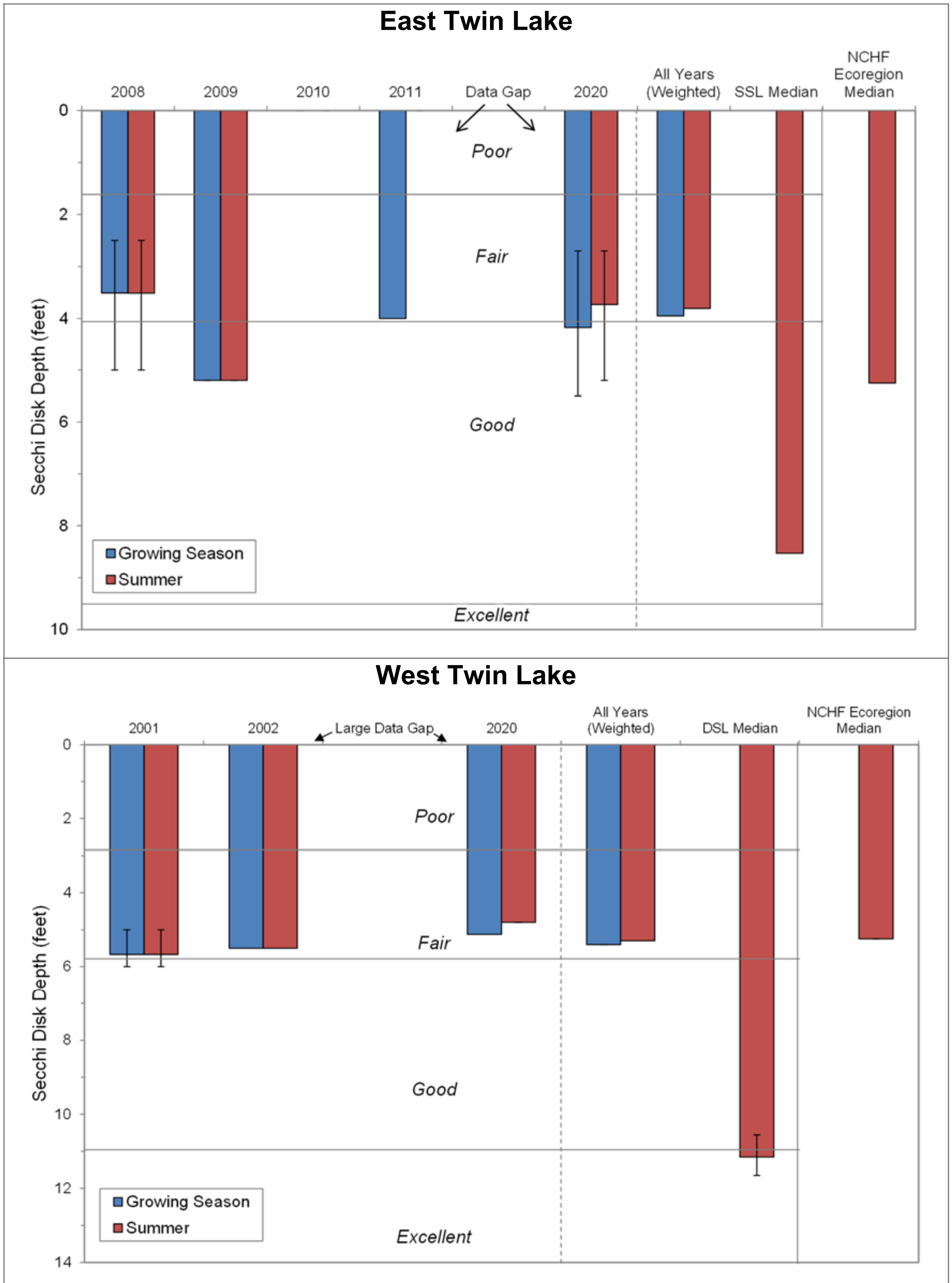



**Figure 3.1-7. East Twin Lake (top frame) and West Twin Lake (bottom frame) average annual Secchi disk depth measured at the deep hole sampling location and median Secchi disk depth for state-wide shallow and deep seepage lakes (SSL & DSL) and North Central Hardwood Forests (NCHF) ecoregion lakes.** Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

## Twin Lakes Trophic State

The Trophic State Index (TSI) values for East and West Twin lakes were calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with historical data (Figure 3.1-9). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors other than algae.

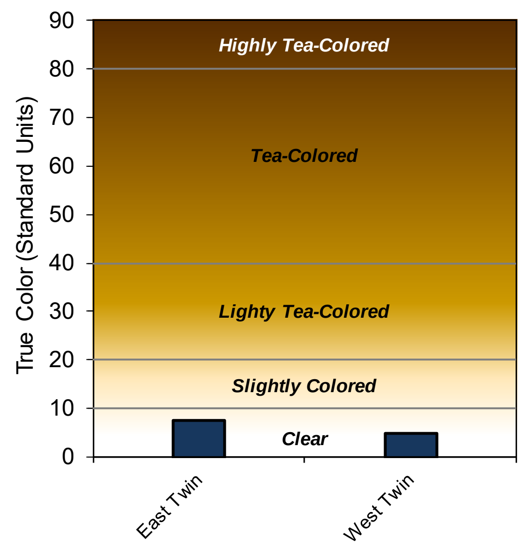



**Figure 3.1-8. East and West Twin Lake true color.**

East Twin Lake's recorded TSI values for phosphorus were in the eutrophic category in 2002-2004 and fell in the mesotrophic category in 2020. The weighted TSI values indicate that East Twin Lake falls on the threshold between mesotrophic and eutrophic lakes, and therefore can be classified as meso-eutrophic. The higher TSI value for Secchi disk transparency is another indication that abiotic particulates in addition to algae are influencing water clarity. This productivity level is somewhat higher when compared to the majority of other shallow seepage lakes in Wisconsin and is similar to the productivity of lakes in the NCHF ecoregion.

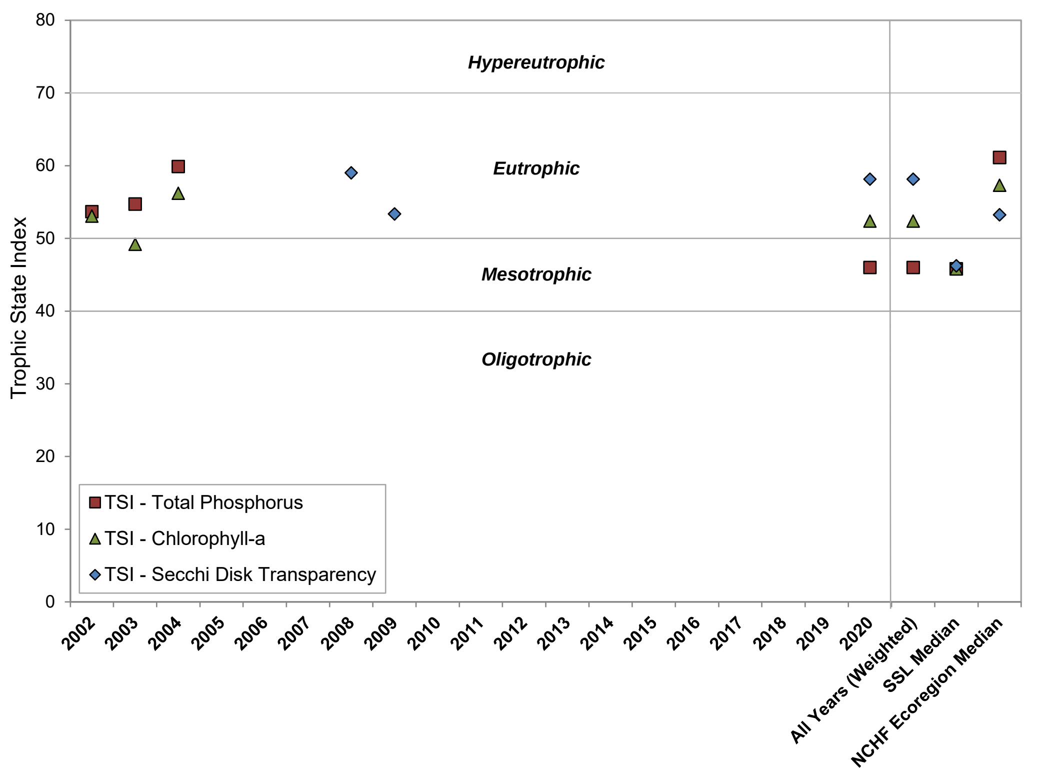



**Figure 3.1-9. East Twin Lake, statewide shallow seepage lakes, and regional Trophic State Index values.** Values calculated with summer month surface sample data using WDNR PUB-WT-193.

West Twin Lake's weighted TSI values for phosphorus and chlorophyll indicate the lake is currently in a mesotrophic state (Figure 3.1-10). Like in East Twin Lake, the TSI value for Secchi disk depth is higher than that of chlorophyll-*a*, indicating the influence of abiotic particulates on the lake's water clarity. This productivity level is similar to the majority of other shallow seepage lakes in Wisconsin which tend to also be mesotrophic and is less productive compared to lakes in the NCHF ecoregion which tend to be eutrophic.

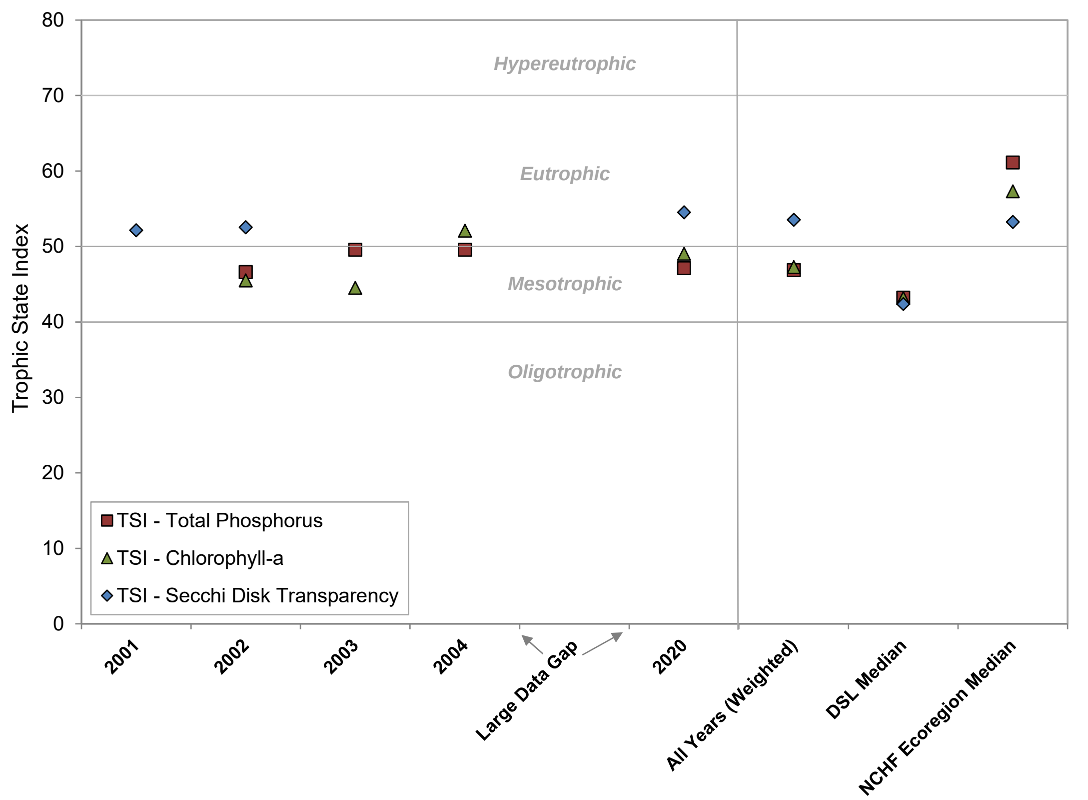



**Figure 3.1-10. West Twin Lake, statewide deep seepage lakes, and regional Trophic State Index values.** Values calculated with summer month surface sample data using WDNR PUB-WT-193.

## Dissolved Oxygen and Temperature in Twin Lakes

Dissolved oxygen and temperature were measured during the growing season of 2020 by Onterra. A profile was also collected through the ice by Onterra in February of 2021. Profiles depicting these data from East Twin Lake are displayed in Figure 3.1-11. As discussed previously, East Twin Lake is shallow mixed, or polymictic lake, meaning that the lake does not thermally stratify during the summer. East Twin Lake is shallow enough where wind and water movement are sufficient during the summer to mix the entire water column of the lake. Dissolved oxygen levels were consistent through the majority of the water column during 2020 and often decreased as the probe approached the sediment-water interface at the bottom of the lake. It is common for dissolved oxygen levels to be low near the bottom of the water column as oxygen is consumed by the decomposition of organic matter.

In February 2021, East Twin Lake was found to support sufficient levels of dissolved oxygen under the ice throughout most of the water column. This indicates that winter fish kills are not a concern on East Twin Lake. As expected, the temperature profile shows East Twin Lake inversely stratifies during the winter, with the coldest water being found just under the ice and the warmest water found near the bottom.

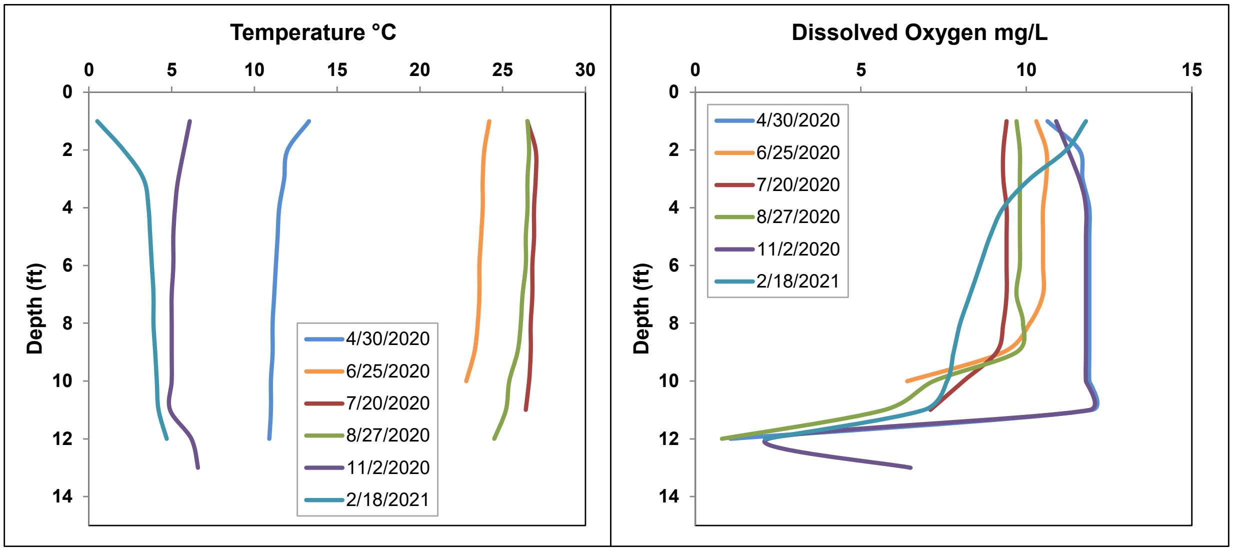



**Figure 3.1-11. East Twin Lake 2020 growing season and winter 2021 temperature and dissolved oxygen profiles.** Collected by Onterra ecologists from the deep hole sampling location.

In contrast to East Twin Lake, West Twin Lake is dimictic, meaning that the lake remains stratified during the summer (also inversely stratified in winter) and completely mixes, or turns over, once in spring and again in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. West Twin Lake is deep enough where wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer causes oxygen levels to decline over the course of the summer.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake. In February 2021, West Twin Lake was found to support sufficient levels of dissolved oxygen under the ice throughout the upper 20+ feet of the water column. This indicates that winter fish kills are not a concern on West Twin Lake.

During the summer, West Twin Lake exhibits a metalimnetic oxygen maximum. This is demonstrated by the increase in dissolved oxygen concentrations at approximately 10-15' depth in the water column measured during June, July, and August (Figure 3.1-12, right frame). This high level of oxygen in the middle of the water column is the result of planktonic algal production in the metalimnion where oxygen production from photosynthesis exceeds respiration. Although chlorophyll-*a* was not analyzed in the metalimnion it is likely these concentrations would be higher than in the surface waters.

Nutrient levels are higher in the metalimnion because they tend to be higher in the deeper waters where there is no algal uptake and phosphorus in the organic form is broken down into a form that can be utilized by algae. This phosphorus found in the deep water slowly moves upward and is available to algae growing in the metalimnion. As described earlier, algae grow at this depth because there is sufficient light for photosynthesis and nutrient levels are often higher than in the epilimnion. The metalimnetic oxygen maximum indicates that the lake has good water clarity since enough light must reach these deeper depths in order for photosynthesis to occur. If nutrient levels increase sufficiently, the increased algal growth in the surface waters would provide adequate light from reaching the metalimnion for algal growth.

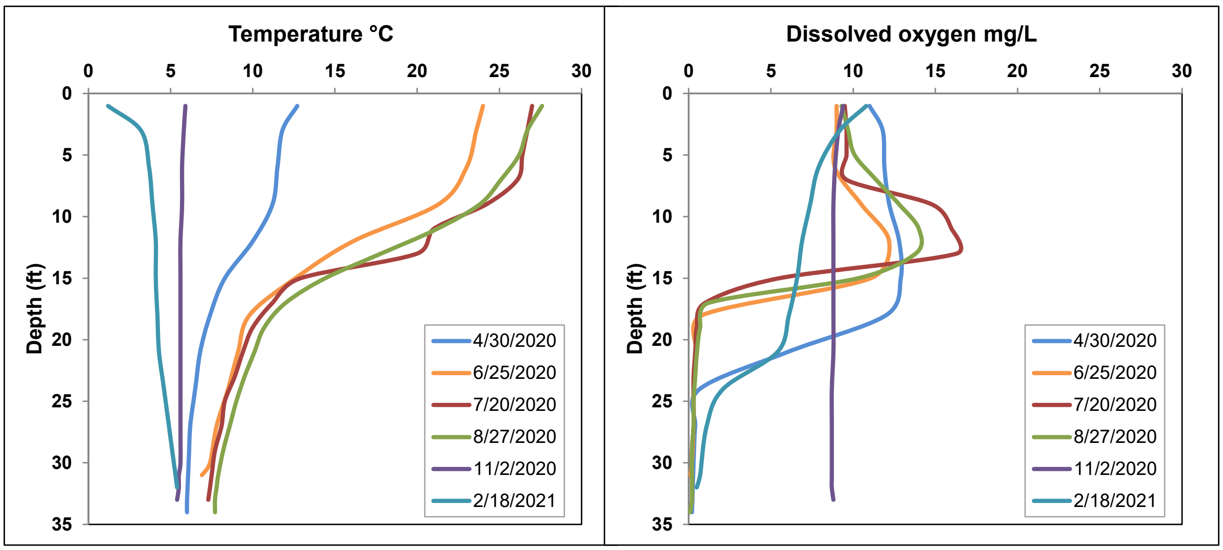



**Figure 3.1-12. West Twin Lake 2020 growing season and winter 2021 temperature and dissolved oxygen profiles.** Collected by Onterra ecologists from the deep hole sampling location.

## Additional Water Quality Data Collected at East and West Twin Lakes

The previous sections were largely centered on parameters related to 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 East Twin Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions ($H^+$) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions ($OH^-$), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic, meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in

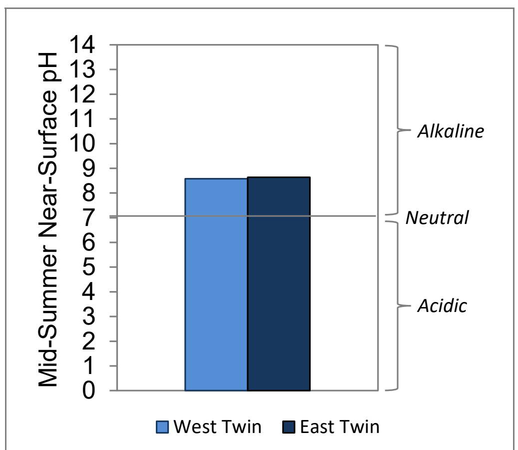



**Figure 3.1-13. East and West Twin Lake mid-summer near-surface pH.**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some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw & Nimphius, 1985). The mid-summer pH of the water in both East and West Twin Lake was found to be alkaline with a value of 8.6 which is indicative of a marl lake (Figure 3.1-13).

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 ($(CaMgCO_3)_2$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity was measured at 158.0 (mg/L as $CaCO_3$) in East Twin Lake and 161.5 in West Twin Lake, indicating that the lakes have a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain (Figure 3.1-14).

Similar to alkalinity is water hardness. While alkalinity is a measure of a lake's capacity to resist acidic changes in pH, water hardness is the combined concentration of dissolved calcium and magnesium in the water. Lakes in Wisconsin range from soft water lakes with little to no dissolved minerals to very hard water lakes with high concentrations of dissolved minerals. Alkalinity and associated water hardness are the most important factors driving aquatic plant community composition. Water hardness was 192 mg/L in East Twin Lake, and was 198.5 mg/L in West Twin Lake indicating both lakes are considered hardwater lakes.

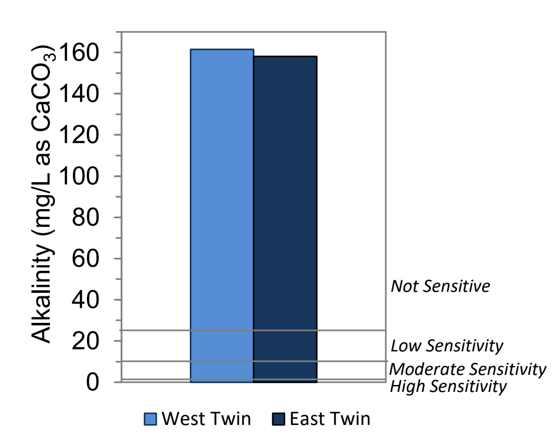


**Figure 3.1-14. East and West Twin lakes' alkalinity value and sensitivity to acid rain.**

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so the Twin Lake's pH falls inside 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 was found to be 38.8 mg/L in East Twin Lake and 40.1 mg/L in West Twin

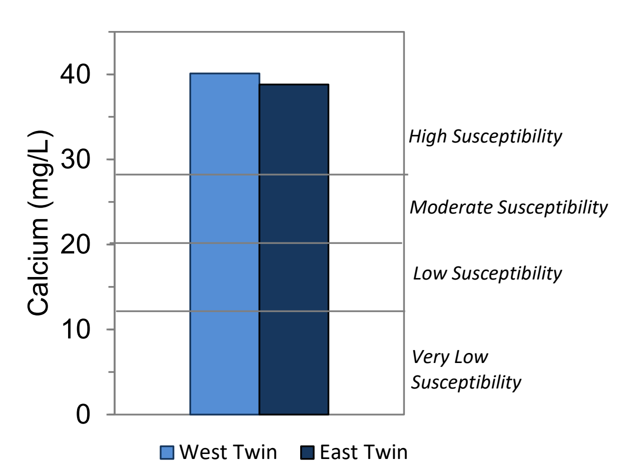


**Figure 3.1-15. East and West Twin Lakes' near-surface calcium concentrations and zebra mussel susceptibility.**

Lake, both falling in the optimal range for zebra mussels (Figure 3.1-15).

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

### *Stakeholder Survey Responses to Twin Lakes Water Quality*

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The following figures display the responses of members of Twin Lakes stakeholders to questions regarding water quality and how it has changed over their years visiting the lakes.

When asked how to describe Twin Lake's current water quality, seven respondents indicated the current water quality was *fair*, 20 indicated it was *good*, and one indicated it was *excellent* (Figure 3.1-16). No respondents indicated the lake's current water quality was *poor* or *very poor*. Respondents were also asked how they believe Twin Lake's water quality has changed since they first visited the lake. The majority of respondents, 14, indicated that the lake's water quality has remained the same, ten respondents indicated the water quality has somewhat improved or greatly improved, while five respondents indicated it has either somewhat degraded, or severely degraded (Figure 3.1-17).

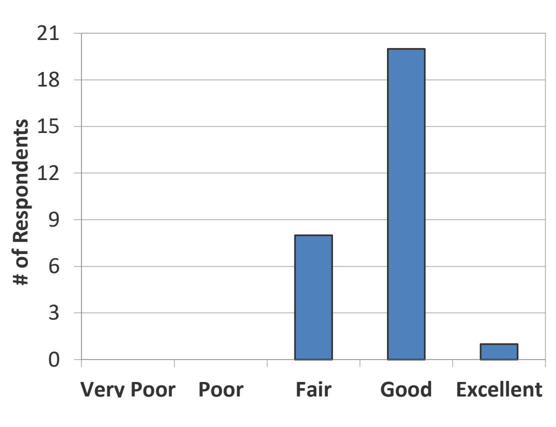


**Figure 3.1-16. Stakeholder survey response Question #17.** How would you describe the current overall water quality of Twin Lakes?

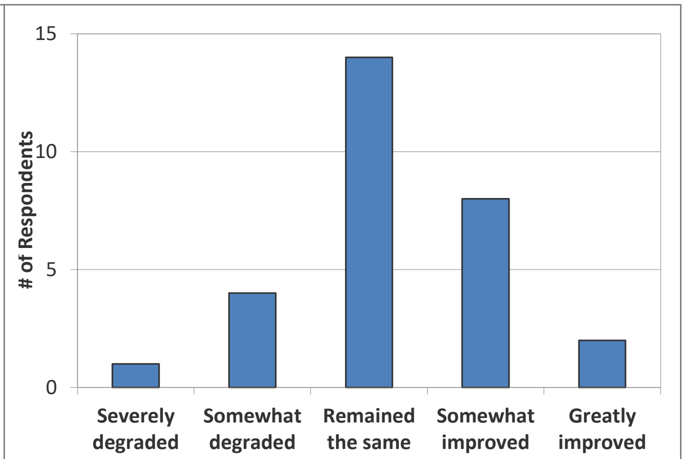


**Figure 3.1-17. Stakeholder survey response Question #18.** How has the overall water quality changed in Twin Lakes since you first visited the lake?

Water quality degradation was the number one ranked response when asked to rank the top concerns regarding Twin Lakes (Figure 3.1-18). When asked what is the single most important aspect when considering water quality, 51.7% of the respondents said water clarity, followed by 34.5% who said aquatic plant growth (Figure 3.1-19).

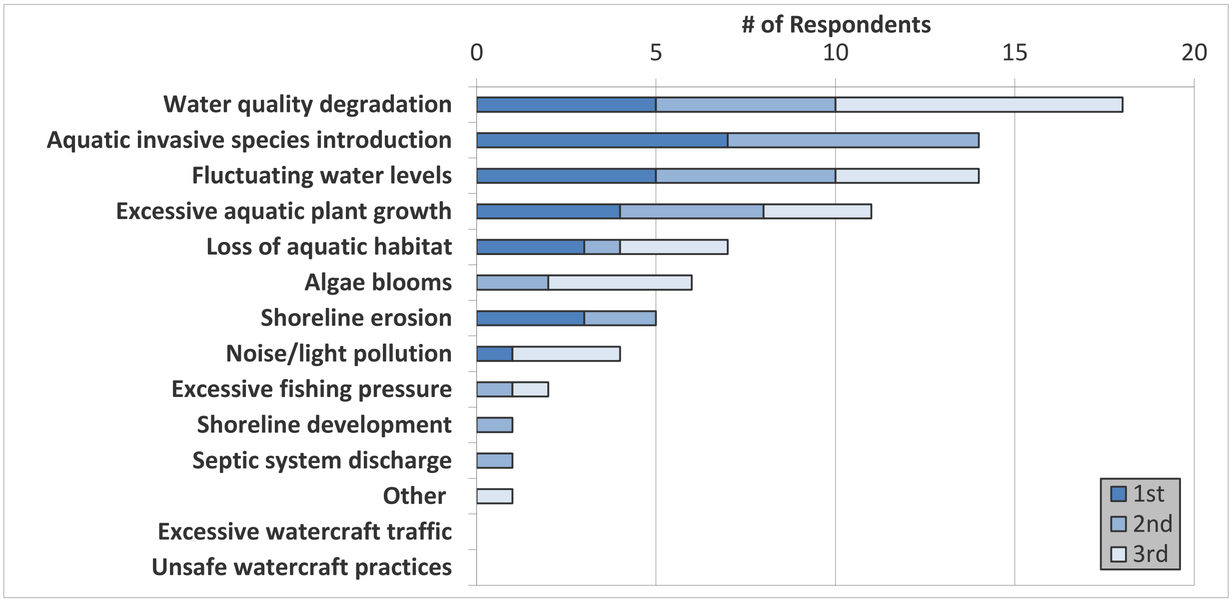


**Figure 3.1-18. Stakeholder survey response Question 16.** For the list below, rank your top three concerns regarding Twin Lakes, with 1st being your top concern.

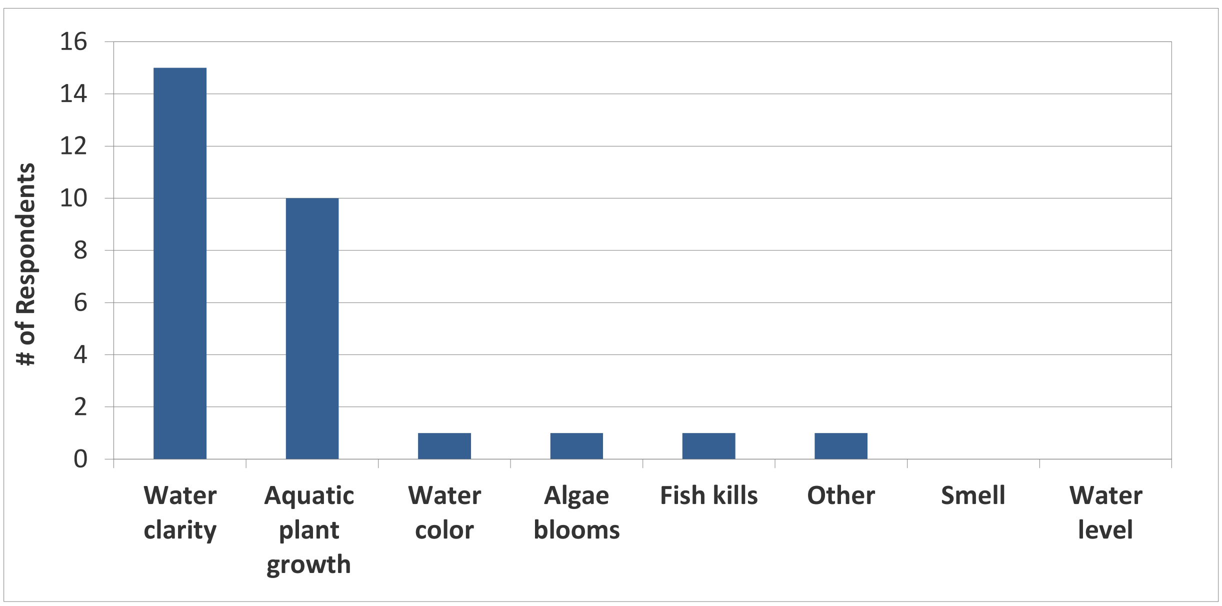


**Figure 3.1-19. Stakeholder survey response Question 19.** Which of the following would you say is the single most important aspect when considering water quality?

## 3.2 Watershed Assessment

### *Watershed Modeling*

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

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

In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems, the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grass or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g. reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

> 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.

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

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

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

### *Twin Lakes Watershed Assessment*

The surface watershed for the Twin Lakes system encompasses approximately 390 acres in Marquette County (Figure 3.2-1 and Map 2). The lake's groundwater watershed is likely significantly larger, extending to the northwest. There are no tributaries flowing into or out of the Twin Lakes.

Wisconsin Lakes Modeling Suite (WiLMS) estimated that the Twin Lakes have a relatively long water residence time of 2.5 years, meaning on average it takes 2.5 years for water in these lakes to be completely replaced. The 2016 land cover data indicate that the watershed is comprised of upland forests (68%), row crops (16%), row crops, (11%), the lakes' surface (11%), pasture/grasslands (4%), rural residential areas (1%), and wetlands (<1%) (Figures 3.2-2 and 3.2-3).

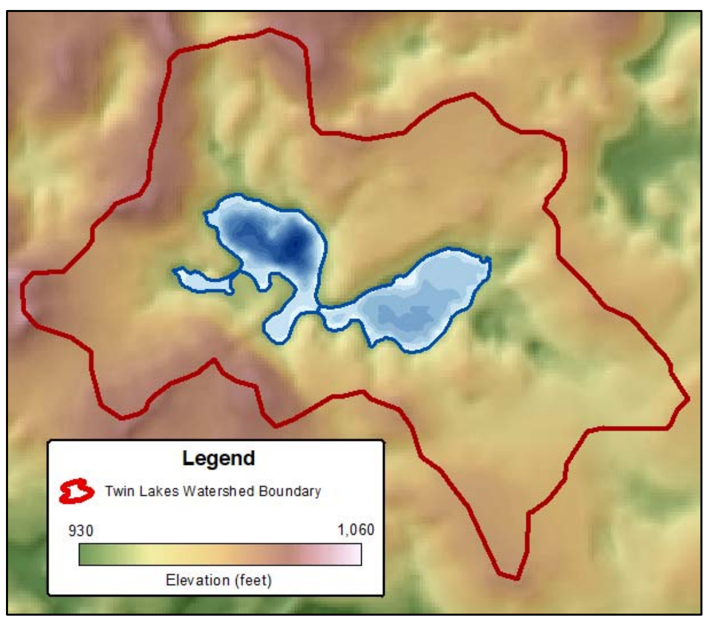


**Figure 3.2-1. Twin Lakes watershed and land elevation.**

Given the differences in morphology and water quality of East and West Twin lakes, each lake was modeled separately to assess the phosphorus contribution from the watershed. Using the land cover types and their acreages within each lake's subwatershed (Figure 3.2-2), WiLMS was utilized to estimate the annual potential phosphorus load delivered to each lake. In addition, data obtained from a stakeholder survey distributed in 2020 was also used to estimate the potential phosphorus loading to each lake from riparian septic systems. The model estimated that approximately 24 pounds of phosphorus are loaded to West Twin Lake on an annual basis from its watershed (Figure 3.2-4). Based on this estimated annual loading of phosphorus, WiLMS predicted that the in-lake average growing season total phosphorus concentrations should be 21.0 µg/L. The average measured growing season total phosphorus concentration in West Twin Lake is 23.0 µg/L. WiLMS estimated that 56% of the annual phosphorus load in West Twin Lake originates from forested areas, 19% from row crops, 16% from atmospheric deposition, and 9% from pasture/grass areas (Figure 3.2-4).

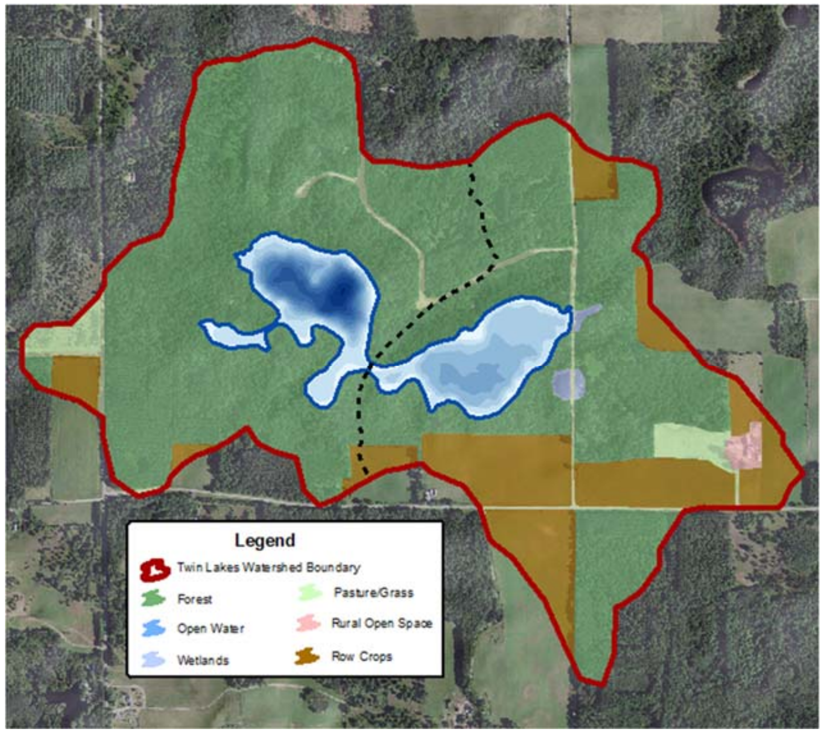


**Figure 3.2-2. Twin Lakes watershed and land cover types.** Based upon National Land Cover Database (USGS 2019). Note: dashed line is dividing the two watersheds for analysis.

WiLMS estimated that East Twin Lake receives an estimated 67 pounds of phosphorus from its watershed on an annual basis (Figure 3.2-4). Based on this estimated phosphorus load, WiLMS predicted an in-lake average growing season total phosphorus concentration of 63.0 µg/L. The average measured growing season total phosphorus concentration in East Twin Lake was 31.9 µg/L, 50% lower than predicted. In fact, measured concentrations of phosphorus align with concentrations that were predicted by the model if 100% of the agricultural areas in East Twin Lake's watershed were converted to forest. The over-prediction of phosphorus loading is an indication that even though these agricultural areas are within the lake's watershed and in close proximity to the lake, phosphorus from these areas is likely not reaching the lake through runoff. If runoff is originating from these fields, it is intercepted first by a small wetland immediately adjacent to East Twin Lake. Based on measured phosphorus concentrations in East Twin Lake, it is estimated that the annual phosphorus load is approximately 32 pounds per year. However, these areas may be contributors of nitrogen to East Twin Lake as nitrogen is more mobile in groundwater than phosphorus.

Regarding septic systems, it is important to note that a failing septic system may not necessarily be impacting the lake if it is located in an area where groundwater is leaving the lake, while a properly functioning septic system may impact the lake if groundwater is passing through it and into the lake. The septic estimates for Twin Lakes did not take into account the location of the septic systems and flow of groundwater into and out of these lakes. While it is important that riparians with septic systems conduct routine maintenance and inspections, this analysis indicates that septic systems around these lakes are likely not having a detectable impact on water quality at this time.

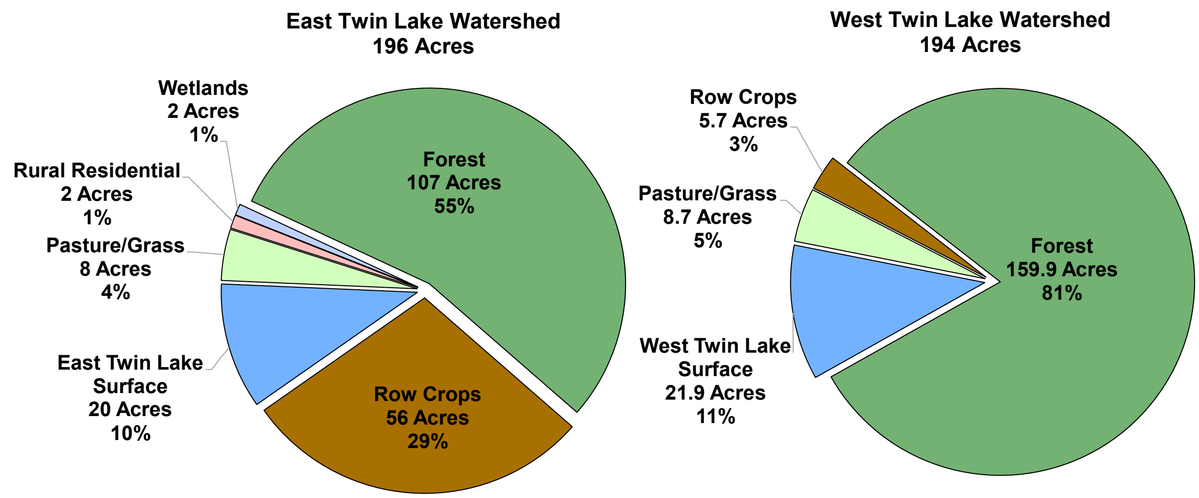


**Figure 3.2-3. Proportion of land cover types within Twin Lakes' watersheds.** Based upon National Land Cover Database (USGS 2019).

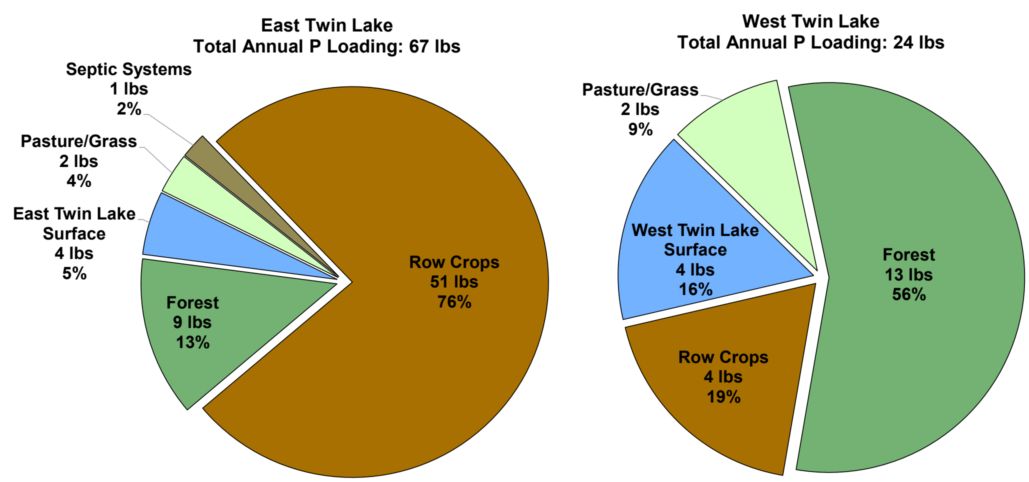


**Figure 3.2-4. Twin Lakes estimated annual phosphorus loading.** Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates. Please note that estimates for East Twin Lake are approximately 50% higher, and actual loading is likely 32 pounds per year.

## 3.3 Shoreland Condition

### *Lake Shoreland Zone and its Importance*

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

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

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

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

### Shoreland Zone Regulations

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

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

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Revised in February of 2010, and again in October of 2014, the finalized NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below.

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

- Impervious surface standards: In general, the amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit, up to 30% for residential land use. Exceptions to this limit do exist if a county has designated highly-developed areas, so it is recommended to consult county-specific zoning regulations for this standard.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet. Other specifications must be met as well, and local zoning regulations should be referenced.

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

### Wisconsin Act 31

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

## Shoreland Research

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

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

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

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

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

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

With development of a lake's shoreland zone, much of the coarse woody habitat that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions due to logging practices. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities such as 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 nation's lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with* *poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

### Native Species Enhancement

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

**Photograph 3.3-2. Example of a biolog restoration site.**

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

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

## Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.3-1).

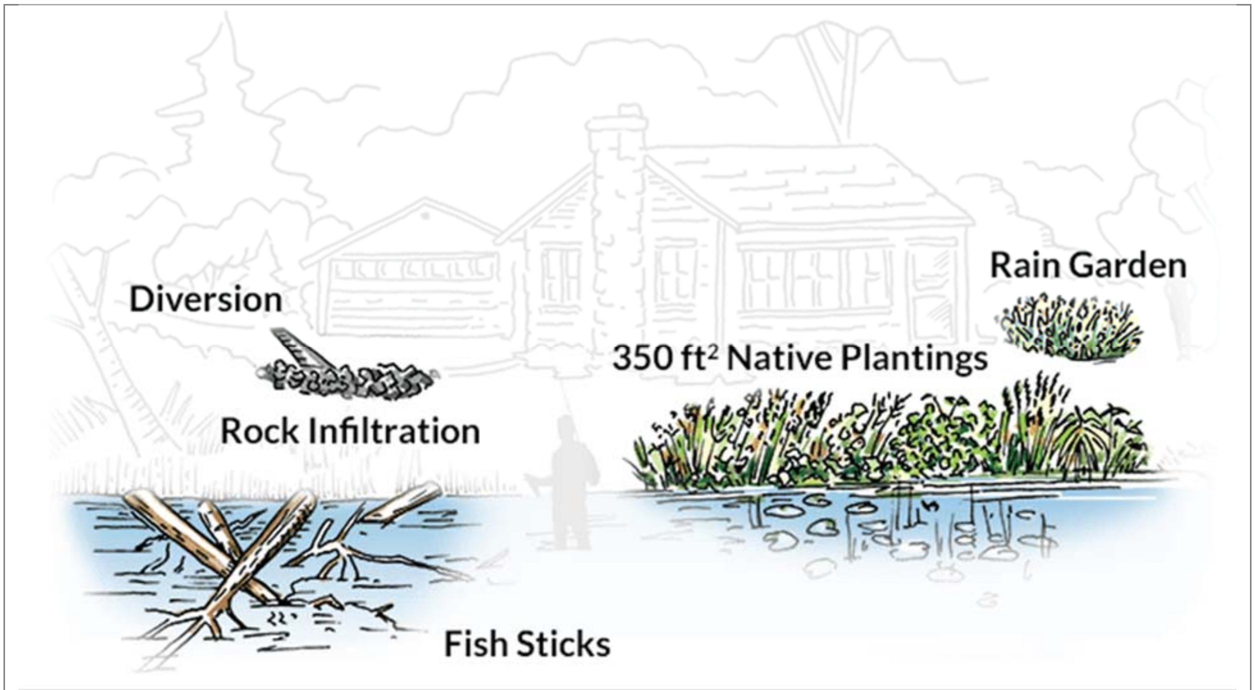


**Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices.** Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- Rain Gardens: This upland best practice consists of a landscaped and vegetated shallow depression aimed at capturing water runoff and allowing it to infiltrate into the soil.
- Rock Infiltration: This upland best practice is an excavated pit or trench, filled with rock, that encourages water to infiltrate into the soil. These practices are strategically placed at along a roof line or the downward sloping area of a driveway.
- Diversion: This best practice can occur in the transition or upland zone. These practices use berms, trenches, and/or treated lumber to redirect water that would otherwise move downhill into a lake. Water diversions may direct water into a Rock Infiltration or Rain Garden to provide the greatest reductions in runoff volumes.
- Native Plantings: This best practice aims to installing native plants within at least 350 square-foot shoreland transition area. This will slow runoff water and provide valuable habitat. One native planting per property per year is eligible.
- Fish Sticks: These in-lake best practices (not eligible for rivers) are woody habitat structures that provide feeding, breeding, and nesting areas for wildlife. Fish sticks consist of multiple whole trees grouped together and anchored to the shore. Trees are not felled from the shoreline, as existing trees are valuable in place, but brought from a short distance or dragged across the ice. In order for this practice to be eligible, an existing vegetated buffer or pledge to install one is required.

The Healthy Lakes and Rivers Grant Program allows partial cost coverage for implementing best practices. Competitive grants are available to eligible applicants such as lake associations and lake districts. The program allows a 75% state cost share up to $1,000 per practice. Multiple practices can be included per grant application, with a $25,000 maximum award per year. Eligible projects need to be on shoreland properties within 1,000 feet of a lake or 300 feet from a river. The landowner must sign a Conservation Commitment pledge to leave the practice in place and provide continued maintenance for 10 years. More information on this program can be found here:

https://healthylakeswi.com/

It is important to note that this grant program is intentionally designed for relatively simple, low-cost, and shovel-ready projects, limiting 10% of the grant award for technical assistance. Larger and more complex projects, especially those that require engineering design components may seek alternative funding sources potentially through the County. Small-Scale Lake Planning Grants can provide up to $3,000 to help build a Healthy Lakes and Rivers project. Eligible expenses in this grant program are surveys, planning, and design.

## *Twin Lakes Shoreland Zone Condition*

### Shoreland Development

The entire shoreline of Twin Lakes was surveyed in the summer of 2020. A draft WDNR Lake Shoreland & Shallows Habitat Monitoring Field Protocol (WDNR, Lake Shoreland & Shallows Habitat Monitoring Field Protocol 2020) was utilized to evaluate the shoreland zone on a parcel-by-parcel basis beginning at the estimated high-water level mark and extending inland 35 feet. The immediate shoreline was surveyed and classified based upon its potential to negatively impact the system due to development and other human impacts. Within the shoreland zone, the natural vegetation (canopy cover, shrub/herbaceous) was given an estimate of the percentage of the plot which is dominated by each category. Human disturbances (impervious surface, manicured lawn, agriculture, number of buildings, boats on shore, piers, boat lifts, sea wall length and other similar categories) were also recorded by number of occurrence or percentage during the survey.

These data have been provided to the WDNR where they have been uploaded onto a web-based viewing platform through the WDNR's Lakes and AIS Mapping Tool application (Lakes_AIS_Viewer).

For this management plan, the percent canopy cover, percent shrub/herbaceous, percent manicured lawn and percent impervious surfaces are primarily focused upon to assess the shoreline for development and determine a need for restoration. In general, developed shorelands impact a lake ecosystem in a negative manner, while definite benefits occur from shorelands that are left in their natural state or a near-natural state.


**Photograph 3.3-3. Example of canopy, shrub and herbaceous layers.**

Canopy cover was defined as an area which is shaded by trees that are at least 16 feet tall (Photograph 3.3-3). Ninety three percent (1.7 miles) of Twin Lake's shoreline contains a canopy that covers between 81-100% of the parcel (Figure 3.3-2, Map 3). All parcels around the lake contained at least 61-80% canopy cover.

Shrub and herbaceous layers are small trees and plants without woody stems less than 16 feet tall (Photograph 3.3-3). Seventy-six percent (1.4 miles) of Twin Lake's shoreline contains a shrub/herbaceous layer that covers between 81-100% of the parcel (Figure 3.3-2, Map 4).

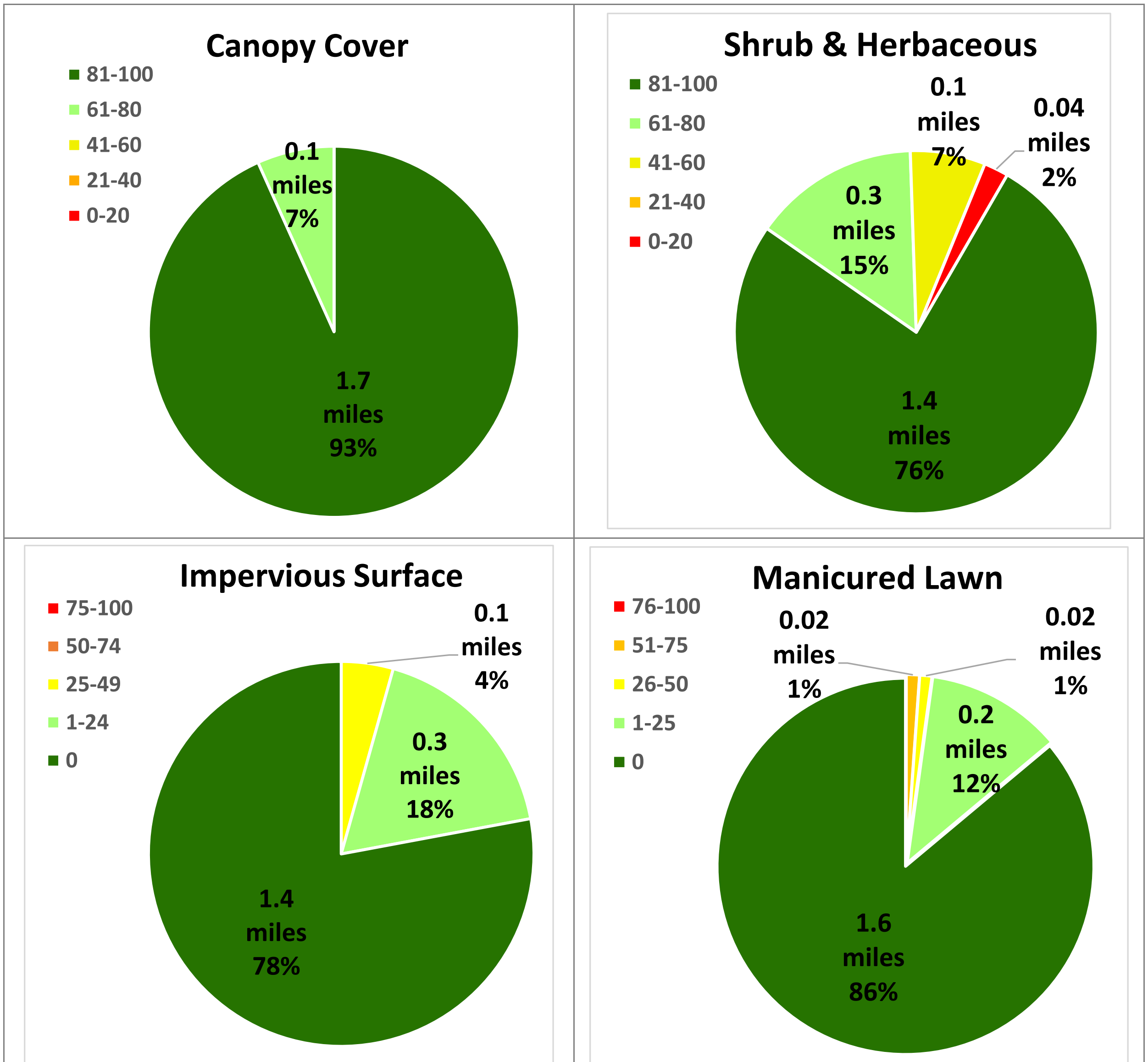


**Figure 3.3-2. Twin Lake's 2020 shoreland parcel canopy cover, shrub-herbaceous cover, manicured lawn, and impervious surface.** Data from Onterra 2020 Survey.

A manicured lawn is defined as grass that is mowed short and is direct evidence of urbanization. Having a manicured lawn poses a risk as runoff will carry pollutants, such as lawn fertilizers, into the lake. Ninety-eight percent of Twin Lakes shoreline had less than 25% manicured lawns on the parcels (Figure 3.3-2, Map 5).

Impervious surface is an area that releases all or a majority of the precipitation that falls onto it (e.g. rooftops, concrete, stairs, boulders and boats flipped over on shore). About 1.7 miles or 96% of Twin Lake's shoreline contains 0% or between 1-24% impervious surfaces (Figure 3.3-2, Map 6). No parcels were identified to contain greater that 50% impervious surface.

Sections of Twin Lake's shoreline which contain a manicured lawn and a small percentage of canopy, shrub and herbaceous cover are potential candidates for shoreline restorations.

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

## Coarse Woody Habitat

As part of the shoreland condition assessment, Twin Lake was also surveyed to determine the extent of its coarse woody habitat. Survey methodology was consistent with the WDNR Shoreland and Shallows Habitat Monitoring Field Protocol (WDNR 2016). All wood greater than 4 inches in diameter, at least 5 feet long and located between the high-water level (HWL) mark and 2-foot contour line was marked with a GPS waypoint. The coarse woody habitat was then given a complexity ranking (no branches, a few branches and tree trunk has a full crown), marked if the wood touched shore and whether the wood was mostly submerged in water. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 55 total pieces of coarse woody habitat were observed along 0.93 miles of shoreline of East Twin Lake, and 45 pieces along 0.99 miles of shoreline in West Twin Lake (Figure 3.3-3 – left frame), Map 7). The ratio of coarse woody habitat pieces to mile of shoreline is 59:1 for East Twin Lake and 45:1 for West Twin Lake. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Twin Lakes and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 128 lakes throughout Wisconsin since 2012, with the majority occurring in the Northern Lakes and Forests ecoregion. The number of coarse woody habitat pieces per shoreline mile in both East and West Twin Lake falls well above the 75th percentile of these 128 lakes (Figure 3.3-3 – right frame). Compared to the eight other lakes that have been surveyed within the same ecoregion as Twin Lakes (North Central Hardwood Forests), both East and West Twin Lakes had a higher ratio of CWH pieces per mile of shoreline.

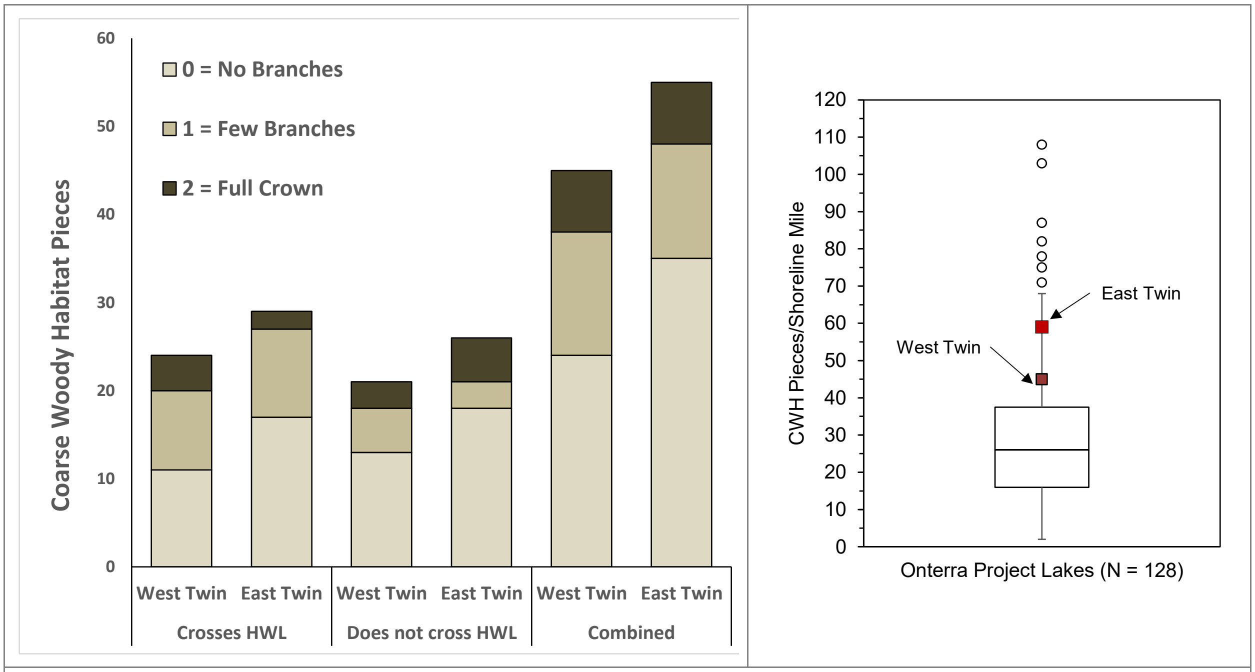


**Figure 3.3-3. East and West Twin Lake's coarse woody habitat survey results.** Based upon a summer 2020 survey. Locations of the Twin Lake's coarse woody habitat can be found on Map 7.

During the coarse woody habitat survey, Onterra ecologists collected additional data in an effort to document and quantify the woody habitat consisting solely of flooded standing trees and shrubs including a variety of either deciduous or coniferous species (Photo 3.3-4). These occurrences were not accounted for in the WDNR survey protocol, but were instead assessed with area-based mapping methods using the onboard GPS technology. Map 7 displays the areas mapped with this methodology and indicates that substantial area totaling approximately 4.6 acres is comprised of this unique habitat at the time of the survey. Of the 4.6 acres of flooded trees and shrubs, approximately 3.1 acres were described as *dense* and 1.5 acres as *sparse*. Many of these flooded trees and shrubs had lost their foliage or appeared to be dead or dying due to a sustained period of high water levels.

**Photograph 3.3-4. Examples of standing flooded trees and shrubs along much of Twin Lake's shoreline during a 2020 coarse woody habitat assessment survey.**

# 3.4 Aquatic Plants

## *Introduction*

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

**Photograph 3.4-1. Example of emergent and floating-leaf communities.**

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

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

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

## Aquatic Plant Management and Protection

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

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

### Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within those 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 (Hand-Harvesting & DASH)

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.

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

Manual removal or hand-harvesting of aquatic invasive species has gained favor in recent years as an alternative to herbicide control programs. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

### Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,500 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,500 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

| *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 to correspond with fish spawning.<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.

Permeable benthic barriers (aka benthic mats) can be effective to control unwanted aquatic plants in small scale situations. Benthic barriers applied over aquatic plants like EWM will starve the plants of light and ultimately suppress or kill them. Benthic barriers are often criticized for being nonselective and negatively impacting beneficial native plants. They also serve as a barrier to beneficial aquatic organisms that need to burrow into or emerge from the sediment. Benthic barriers would be fatal to these processes. The WDNR precludes the use of benthic barriers for large-scale applications, but would allow them in small-scale situations near a riparian's use corridor (i.e., pier, beach, swim platform, etc.). As a plant inhibitor, installation of benthic barriers would need a permit under NR 109 and as a structure on the bed of public water; benthic barriers would need a permit under Chapter 30.12. Please note that the Chapter 30 permit likely allows "coverage" on the NR 109 permit, so two permits would not be required.

Since the use of benthic barriers is not typically permitted in Wisconsin, the WDNR may require a thorough evaluation including non-target plants and invertebrates as a condition of the permit.

### 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 watermilfoil 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 and reed canary grass.<br>• Permitting process may require an environmental assessment that may take months to prepare.<br>• Non-selective. |

## Mechanical Harvesting


**Photograph 3.4-3. Mechanical harvester.**

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

**Cost**

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $100,000 and $200,000. Larger harvesters or stainless-steel models range between $200,000 and $300,000. Shore conveyors cost approximately $30,000 and trailers range from $15,000 to $40,000. Used equipment may be available at lower costs, but increased maintenance would be associated. 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, Haller and (eds) 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.

**Table 3.4-1. Common herbicides used for aquatic plant management.**

| | 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; invasive watermilfoil control when mixed with auxin herbicides |
| | | Diquat | Inhibits photosynthesis & destroys cell membranes | Nusiance species including duckweeds, targeted AIS control when exposure times are low |
| | | Flumioxazin | Inhibits photosynthesis & destroys cell membranes | Nusiance species, targeted AIS control when exposure times are low |
| Systemic | Auxin Mimics | 2,4-D | auxin mimic, plant growth regulator | Submersed species, largely for invasive watermilfoil |
| | | Triclopyr | auxin mimic, plant growth regulator | Submersed species, largely for invasive watermilfoil |
| | | Florpyrauxifen -benzyl | arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr | Submersed species, largely for invasive watermilfoil |
| | In Water Use Only | Fluridone | Inhibits plant specific enzyme, new growth bleached | Submersed species, largely for invasive watermilfoil |
| | Enzyme Specific (ALS) | Penoxsulam | Inhibits plant-specific enzyme (ALS), new growth stunted | Emergent species with 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 watermilfoil.<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 fish kills 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 watermilfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian watermilfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

**Cost**

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1,000 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 watermilfoil density. |

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

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

**Cost**

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Extremely inexpensive control method.<br>• Once released, considerably less effort than other control methods are required.<br>• Augmenting populations may 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 emergent 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 Twin 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.

### Point-intercept Aquatic Plant Survey

The point-intercept method as described by Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was conducted by the WDNR in 2019. A point spacing (resolution) of 25 meters was used in East Twin Lake resulting in 116 sampling points and a 20-meter point spacing in West Twin Lake resulting in 151 sampling locations being evenly distributed across the lake (Map 1). This project was initially designed to utilize the 2019 point-intercept data within the analysis; however, over the course of the project, the survey was replicated during 2023. The aquatic plant analysis below includes a comparison analysis of the 2019 and 2023 point-intercept surveys. At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 15 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 15 feet. Depth information was collected using graduated marks on the pole of the rake (at depths < 15 ft) or using an onboard sonar unit (at depths > 15 feet). When a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately "feel" the bottom with this sampling device.

The methodology of the point-intercept survey is not comparable to past aquatic plant inventories that have taken place in Twin Lakes that included collecting data along transects within the lake. Aquatic plants were studied during 2002 as a part of Twin Lakes first management planning effort. Reporting associated with the 2002 plant survey lists nine species present in the lake, with EWM being the most dominant species (Aron & Associates 2003).

**Species List**

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Twin Lakes. The list also contains the growth-form of each plant found (e.g., submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

**Frequency of Occurrence**

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Twin Lakes; plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

**Floristic Quality Assessment**

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

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

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Twin Lakes to be compared to other lakes within the region and state.

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

**Species Diversity**

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Twin Lakes is compared to data collected by Onterra and the WDNR Science Services on lakes withn the North Central Hardwood Forests ecoregion and on lakes throughout Wisconsin.

### Emergent and Floating-Leaf Community Mapping

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

## *Twin Lakes Aquatic Plant Survey Results*

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

A study by (Watras et al. 2013) found that water levels in seepage lakes and aquifers across the Great Lakes region have seen climatically-driven water level fluctuations that occur approximately every 13 years. These changes are associated with increases and decreases in precipitation associated with changes in atmospheric circulation patterns. Seasonal and longer-term water level fluctuations are natural in Wisconsin's lakes and play an essential ecological role (e.g., maintaining emergent plant communities). Water level fluctuations are most pronounced in seepage lakes like Twin Lakes where water levels are largely determined by precipitation and groundwater.

The impact that the rising water levels may impose on the aquatic plant communities in Twin Lakes are difficult to determine. Certainly, some species are well adapted to fluctuating water levels, whereas other species may struggle to adapt and survive in deeper waters. The littoral zone in Twin Lakes has changed in recent years as areas that were previously near the deepest limits of plant growth in the past may now be too deep for aquatic plants to obtain sufficient light to persist. Additionally, exposed lakebed that were present around parts of Twin Lakes during periods of low lake levels, are now underwater again, resulting in new littoral areas for plants to establish. Pioneer species, which can include invasive plants such as EWM, are often at an advantage in establishing newly available habitat (i.e., empty niches) in lakes.

An Early-Season Aquatic Invasive Species (ESAIS) Survey was completed on Twin Lakes on June 25, 2020. The goal of this survey was to identify and assess any new or existing occurrences of invasive plant species in the lake, with a particular focus on species that are most likely to be observed at this time of year: curly-leaf pondweed and pale-yellow iris. During this survey, Onterra ecologists observed occurrences of curly-leaf pondweed and Eurasian watermilfoil. Pale yellow iris, a large and showy non-native species often found on lake shorelines, was not observed during the survey.

The whole-lake point-intercept survey was conducted on Twin Lakes on August 6 and 9, 2019 by the WDNR and was replicated on June 27, 2023 by Golden Sands RC&D. The emergent and floating-leaf community mapping survey was completed on August 27, 2020 by Onterra ecologists. During the 2019-2023 plant surveys, a total of 14 aquatic plant species were located in Twin Lakes or along the immediate shoreline (Table 3.4-2). The two non-native, invasive aquatic plant species, Eurasian watermilfoil and curly-leaf pondweed, are discussed in the subsequent Non-Native Aquatic Plants Section. As is discussed in the Water Quality section (Section 3.1), the water quality in East and West Twin lakes differs, and these lakes are not connected during periods of low water levels. For these reasons, the point-intercept survey aquatic plant data is analyzed separately for each lake in the following analysis.

All of the aquatic plant species that have been located in Twin Lakes in 2019-2020 or 2023 are listed on Table 3.4-2. Several of these species were located incidentally, meaning they were observed while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are rare within the plant community.

**Table 3.4-2. Aquatic plant species located on Twin Lakes during aquatic plant surveys.**

| Growth Form | Scientific Name | Common Name | Status in Wisconsin | Coefficient of Conservatism |
|---|---|---|---|---|
| E | *Juncus balticus* | Arctic rush | Native | N/A |
| | *Spartina pectinata* | Prairie cordgrass | Native | N/A |
| | *Schoenoplectus acutus* | Hardstem bulrush | Native | 5 |
| | *Typha latifolia* | Broad-leaved cattail | Native | 1 |
| Submergent | *Chara spp.* | Muskgrasses | Native | 7 |
| | *Myriophyllum spicatum* | Eurasian watermilfoil | Non-Native - Invasive | N/A |
| | *Potamogeton crispus* | Curly-leaf pondweed | Non-Native - Invasive | N/A |
| | *Potamogeton foliosus* | Leafy pondweed | Native | 6 |
| | *Potamogeton gramineus* | Variable-leaf pondweed | Native | 7 |
| | *Potamogeton illinoensis* | Illinois pondweed | Native | 6 |
| | *Potamogeton Illinoensis x P. natans hybrid* | Hybrid pondweed sp. | Native | N/A |
| | *Stuckenia pectinata* | Sago pondweed | Native | 3 |
| FL | *Nuphar variagata* | Spatterdock | Native | 6 |
| | *Persicaria amphibium* | Water smartweed | Native | 5 |

*E = Emergent; FL = Floating-leaf*

Data from the 2019 point-intercept survey indicate that approximately 58% of the sampling locations located within the littoral zone of West Twin Lake contained soft organic sediment, 42% contained sand, and 0% contained rock (Figure 3.4-1). In East Twin Lake, 77% of the littoral sampling locations were comprised of soft organic sediment, 22% contained sand, and 1% were rock. In general, lakes with variations in substrate types often support more aquatic plant species given the different habitat types available. However, as is discussed further, Twin Lakes supports a depauperate aquatic plant community.

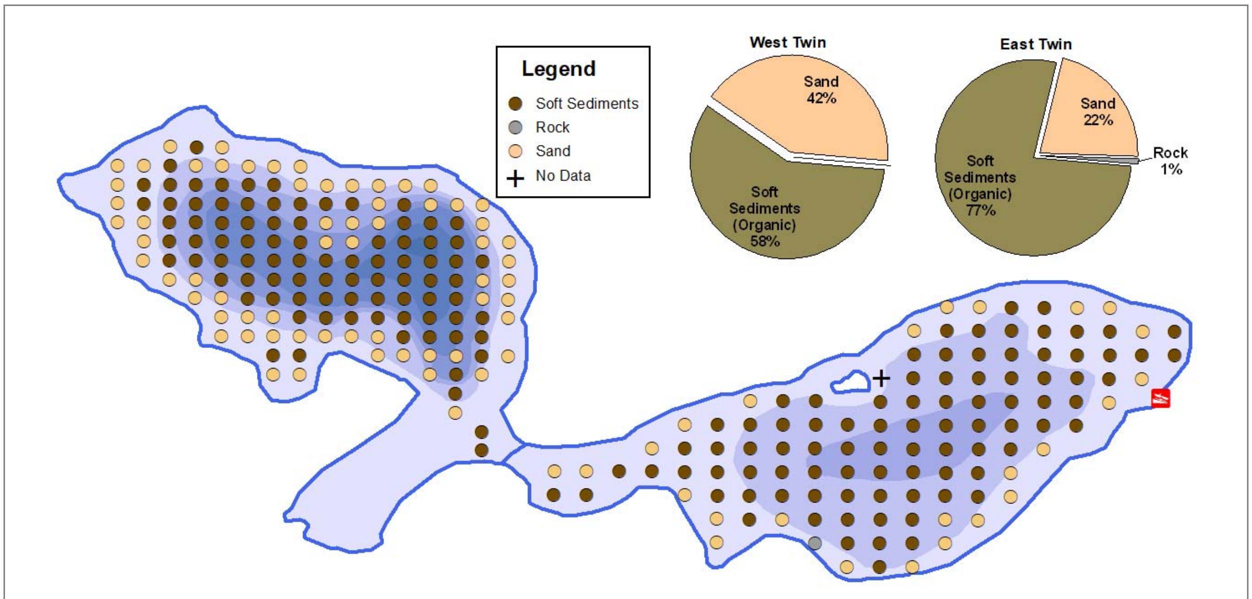


**Figure 3.4-1. Twin Lakes proportion of substrate types within littoral areas.** Created using data from WDNR 2019 point-intercept survey.

The maximum depth of plant growth is largely going to be determined by water clarity. Aquatic plants were found growing to a maximum depth of 10.0 feet in East Twin Lake and 7.0 feet in West Twin Lake in 2019. The maximum depth of plants declined between the 2019 and 2023


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surveys, with a max depth of plants of 6.0 in East Twin and 4.5 feet in West Twin. The lake water level was also considerably lower in 2023 compared to 2019 which may contribute to the differing maximum depth of plant growth between the two surveys. Of the 81 point-intercept sampling locations that fell within East Twin Lake's littoral zone (≤ 10 feet) in 2019, 38.3% contained aquatic vegetation compared to 34.6% in the 2023 survey (Figure 3.4-2 - top). In West Twin Lake, aquatic plants were present at just 12 sampling points or 28.6% of the 42 sampling locations that were within the littoral zone in 2019 compared to only five sampling locations with vegetation present in 2023 (Figure 3.4-2- bottom).

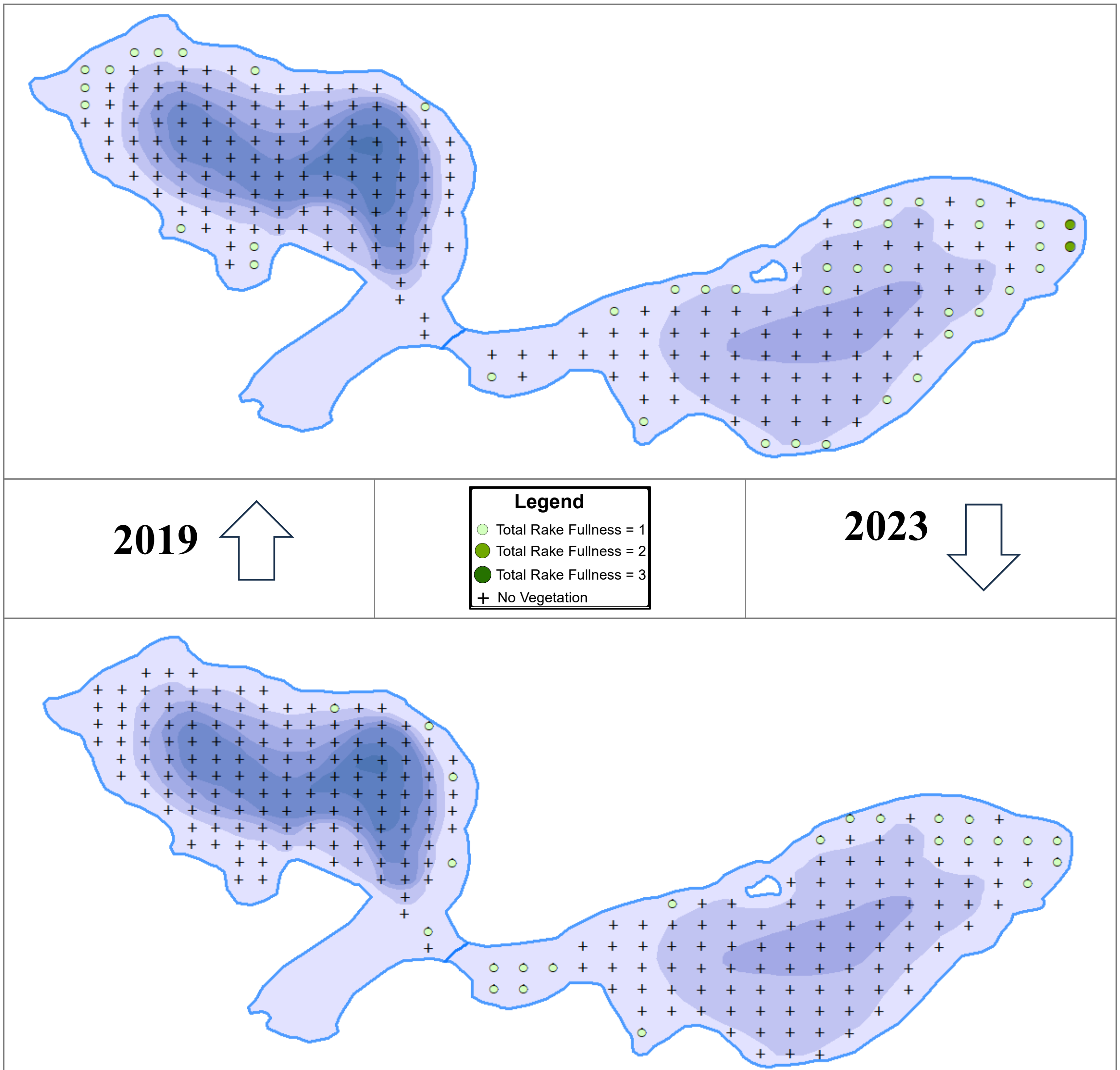



**Figure 3.4-2. Twin Lakes aquatic vegetation total rake fullness ratings (TRF).** Created using data from 2019 and 2023 point-intercept surveys.

Aquatic plant total rake fullness (TRF) data, a measure of plant abundance, showed that all but two of the littoral sampling locations in 2019 containing vegetation had a TRF rating of 1, and just two locations had a TRF rating of 2. No sampling locations in either lake had a TRF rating of 3

(Figure 3.4-2). These TRF ratings indicate that where vegetation is present in Twin Lakes, its biomass is low. The 2023 survey found similar TRF ratings with all 19 vegetated sites given a TRF rating of 1 with no sampling locations receiving a TRF or 2 or 3. This shows that aquatic plant biomass remained low in 2023 with no indication of an increased biomass since 2019.

In East Twin Lake, EWM had a littoral frequency of occurrence of 19.8% in 2019 compared to 29.1% in 2023 (Figure 3.4-3). Although the occurrence was higher in the 2023 survey, the change in occurrence was not statistically valid, and the higher percentage in 2023 is a result of a shallower maximum depth of plant growth which results in fewer littoral sampling locations in 2023. The total number of sampling locations that EWM was present on the survey rake from the 2019 and 2023 surveys was 16 during each survey. Muskgrasses were the most frequently encountered native aquatic plant species in the 2019 survey with an occurrence of 16.0%. The occurrence of muskgrasses was reduced to 0% in 2023 which represents a statistically valid decrease in occurrence from the 2019 survey. Variable-leaf pondweed exhibited an occurrence of 9.9% in 2019 and decreased to 1.8% in 2023. Sago pondweed (1.2%) and hardstem bulrush (1.2%) were also recorded on the survey rake during the 2019 point-intercept survey with only hardstem bulrush also recorded during the 2013 survey. Illinois pondweed was not sampled in the 2019 survey but exhibited an occurrence of 3.6% in 2023.

Just two aquatic plant species were sampled on the rake in West Twin Lake, variable-leaf pondweed (*Potamogeton gramineus*, 16.7%) and hardstem bulrush (*Schoenoplectus acutus*, 14.3%) (Figure 3.4-3). Eurasian watermilfoil (6.3%), spatterdock (3.1%), variable-leaf pondweed (1.8%), hardstem bulrush (3.1%), and muskgrasses (3.1%) were recorded in the 2023 survey. Onterra also documented the presence of CLP and a pondweed determined to be a hybrid between Illinois pondweed and floating-leaf pondweed, during surveys completed during 2020 in West Twin Lake.

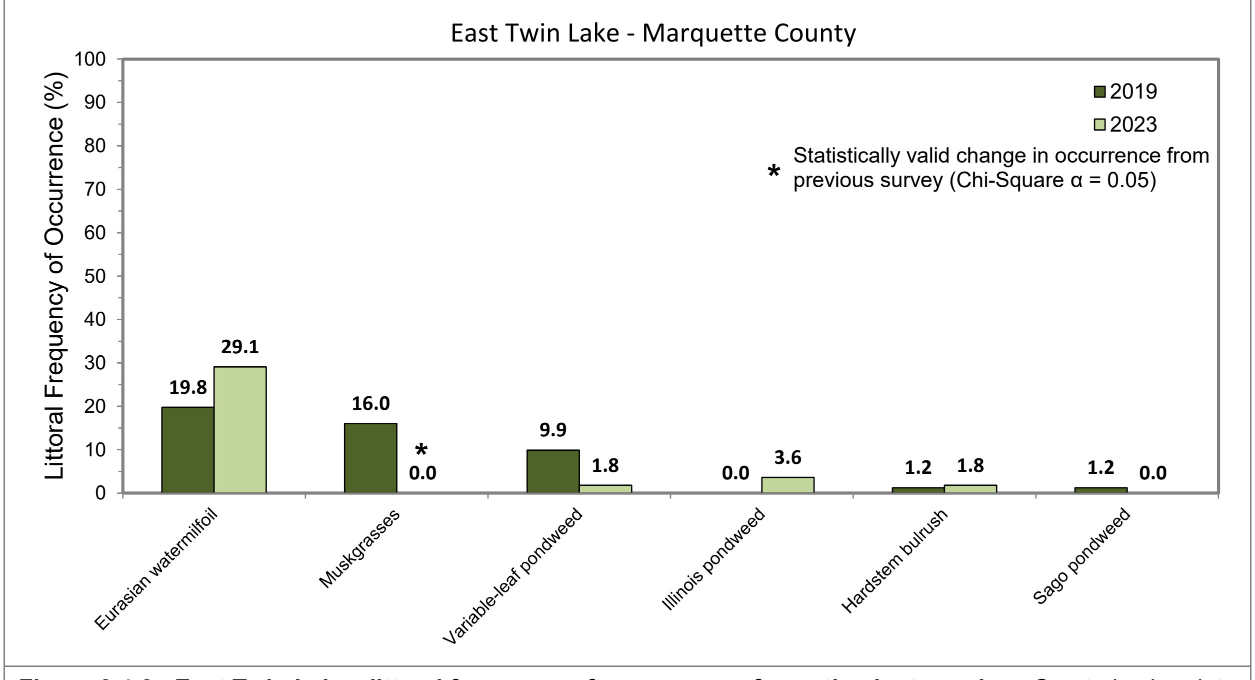



**Figure 3.4-3. East Twin Lakes littoral frequency of occurrence of aquatic plant species.** Created using data from 2019 and 2023 whole-lake point-intercept surveys.

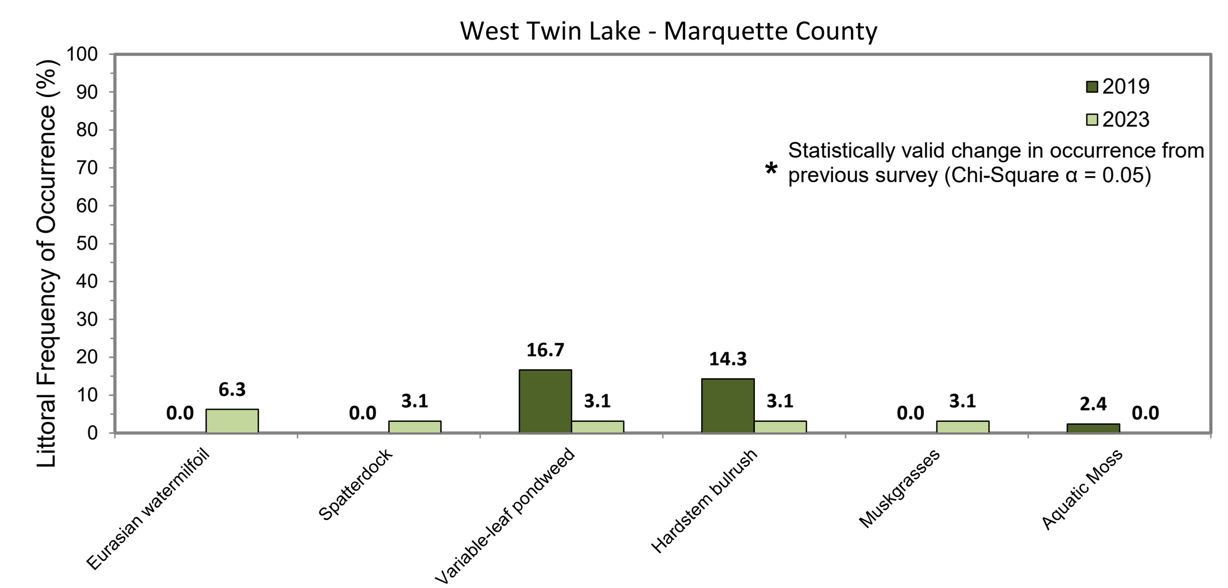



**Figure 3.4-4. West Twin Lakes littoral frequency of occurrence of aquatic plant species.** Created using data from 2019 and 2023 whole-lake point-intercept surveys.

**Photograph 3.4-4. Muskgrasses (Chara spp.)** Photo credit Onterra.

Muskgrasses are a genus of macroalgae represented by seven species in Wisconsin (Photograph 3.4-1). Lakes rich in calcium are often termed *marl lakes*, and in general have lower aquatic productivity and diversity (Cole and Weihe 2016). Muskgrasses have been found to more competitive against vascular plants (e.g., pondweeds, watermilfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002), (Wetzel 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. They are grey to green colored and grow in large clumps in shallow to deep water. When growing in hard, mineral rich water, muskgrasses sometimes become coated with lime, giving them a rough, "gritty" feel. They are easily identified by their strong skunk-like or garlic odor. As well as providing a food source for waterfowl, muskgrasses often serves as a sanctuary for small fish and other aquatic organisms. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

Variable-leaf pondweed is known to exhibit highly variable leaf growth characteristics, often-times even within an individual plant or different plants in the same lake. This species is often present in lakes with hard-water habitats where muskgrasses are also common. This species can provide valuable habitat for fishes in a lake, particularly when large and heavily branched plants are present. Sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity.

**Photograph 3.4-5. Variable-leaf pondweed (left) and sago pondweed (right).** Photo credit Onterra.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species or non-native species. For example, while eight aquatic plant species were located in West Twin Lake during the 2023 point-intercept survey, only four were native species encountered on the rake during the point-intercept survey. Figures 3.4-5 and 3.4-6 shows that the native species richness for East and West Twin Lakes is far below the North Central Hardwood Forests Ecoregion and Wisconsin State medians.

Combining East and West Twin Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in an exceptionally low values of 8.5 (2019) and 12.6 (2023) in West Twin and 11.0 (2019) and 10.4 (2023) in East Twin (equation shown below); well below the median values for the ecoregion and state (Figures 3.4-5 and 3.4-6), and further illustrating the poor condition of Twin Lake's plant community.

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

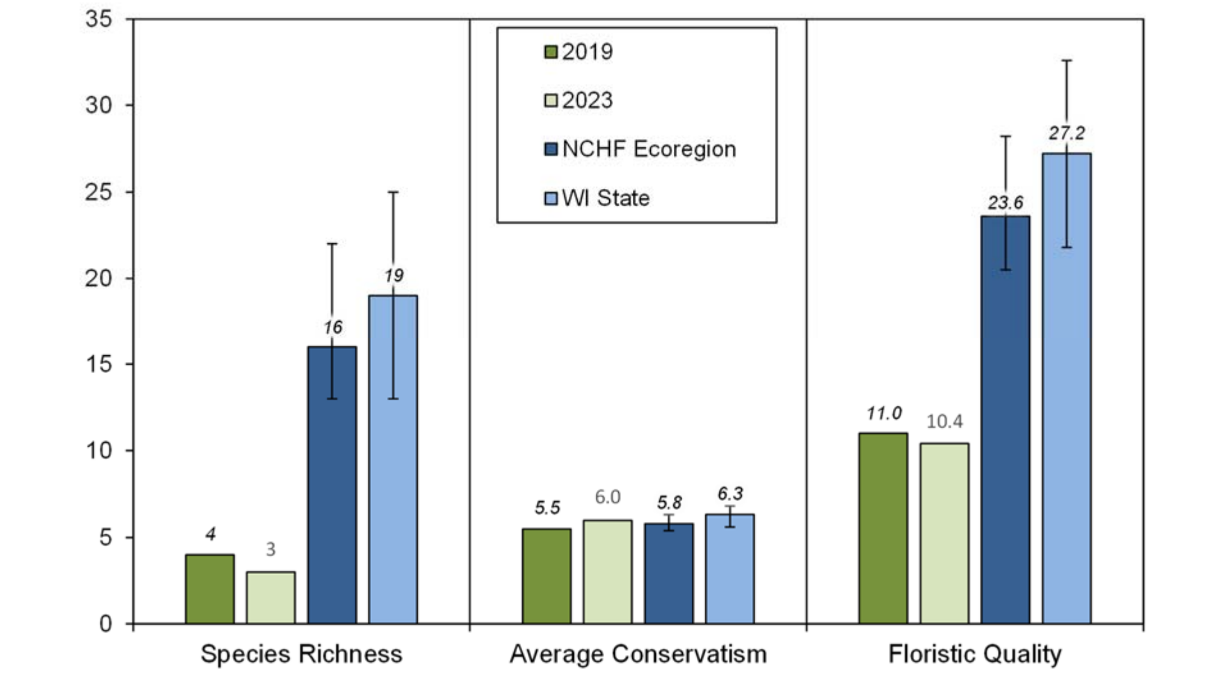



**Figure 3.4-5. East Twin Lake Floristic Quality Assessment.** Created using data from 2019 and 2023 Point-Intercept surveys. Analysis following (Nichols 1999) where NCHF = North Central Hardwood Forests Ecoregion.

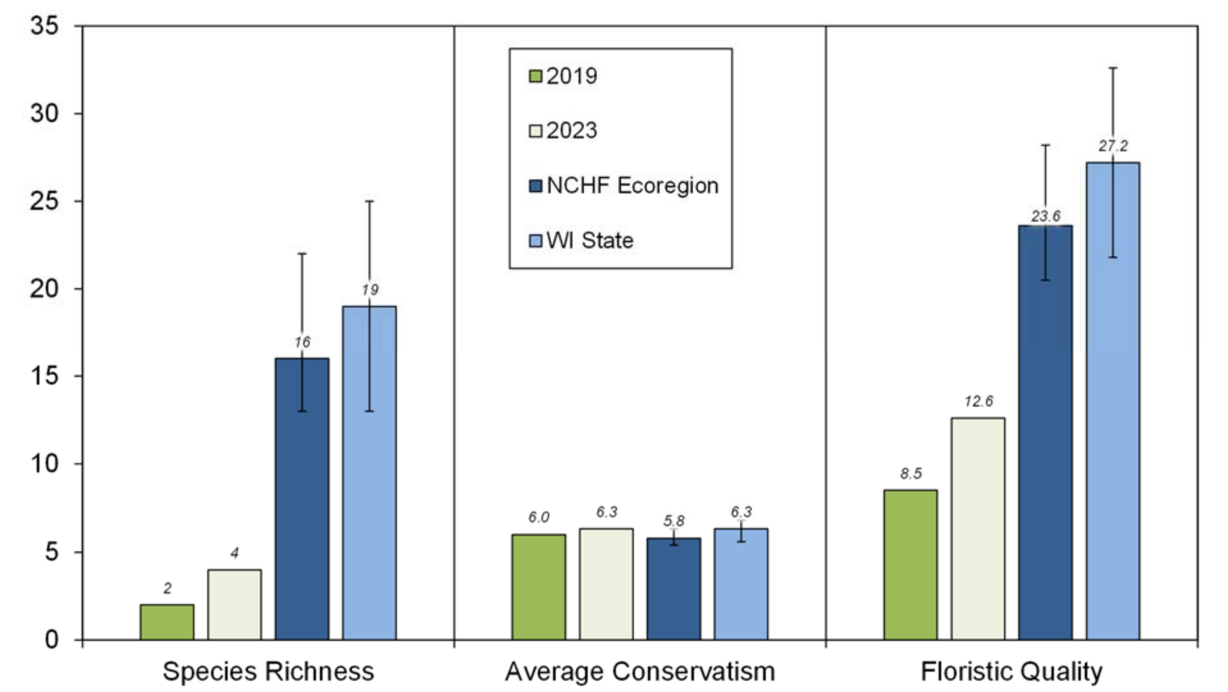



**Figure 3.4-6. West Twin Lake Floristic Quality Assessment.** Created using data from 2019 and 2023 Point-Intercept surveys. Analysis following (Nichols 1999) where NCHF = North Central Hardwood Forests Ecoregion.

It is believed that lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Twin Lake's diversity value ranks.

Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 85 lakes within the NCHF ecoregion. Using the data collected from the point-intercept surveys, East and West Twin Lake's aquatic plant community were found to have low species diversity with a Simpson's Diversity Index value of 0.68 in East Twin and 0.50 in West Twin in 2019 (Figure 3.4-7). The values remained below the lower quartile level in the 2023 data with West Twin at 0.78 and East Twin at 0.35. The lowest of these values are considered outliers within this dataset indicating the unusually low values.

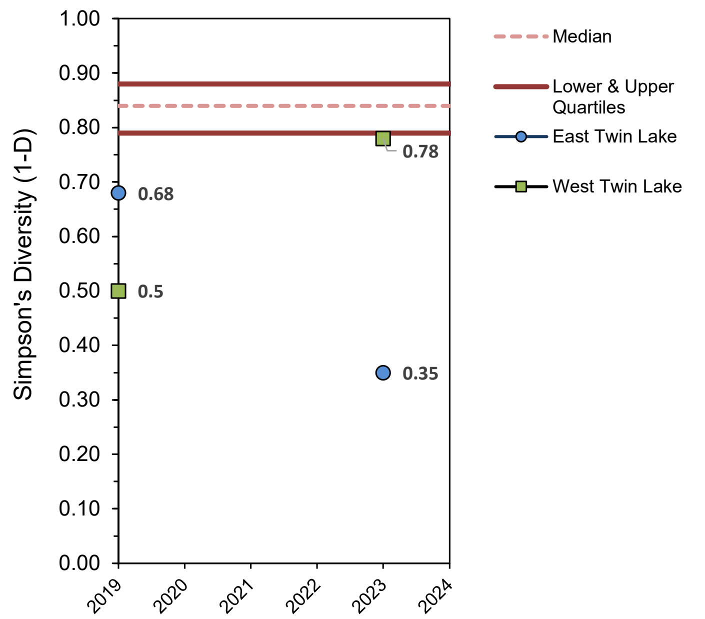



**Figure 3.4-7. Twin Lake species diversity index.** Created using data from 2019 and 2023 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

Twin Lakes harbors a population of the non-native common carp (*Cyprinus carpio*). Numerous studies have documented the deleterious effects these fish have on lake ecosystems. Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber and Brown 2011). Following the introduction of common carp to a waterbody, studies have documented declines in submersed aquatic vegetation and increases in total phosphorus and suspended solids from their feeding and spawning behavior (Bajer and Sorensen 2015).

On Twin Lakes, carp were likely contributors in the loss of vegetation in much of the lake and inhibit the proliferation of newly established vegetation by uprooting and disturbing the sediment. The carp population likely impacted the water quality in a negative way as well through frequent sediment disruptions and re-suspending sediment into the water column resulting in a reduction in water clarity and thus a reduction in aquatic plant growth. Soft sediments like those found in many parts of Twin Lakes can take hours to days to settle again once disturbed making this suspension particularly detrimental to water clarity.

## Floating-leaf and Emergent Community Mapping Survey

In 2020, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf marsh communities in Twin Lakes (Map 8). Emergent marshes are a wetland community type dominated by species such as cattails, bulrushes, spikerushes among others, and are plants that have leaves and flowers emersed out of the water. Floating-leaved marshes are communities dominated by species that have leaves which float on the water's surface, such as white water lily and spatterdock. Emergent marshes are typically found in shallower water than floating-leaved marshes, but they do intergrade with one another. These wetland community types are important to overall lake health as they provide structural habitat for spawning and refuge and sources of food. In addition, they stabilize bottom sediments and reduce shoreland erosion. These communities are often particularly important during periods of low water levels when structural habitat provided by fallen trees become unavailable above the receding water line.

During the 2020 community mapping survey, 2.6 acres of emergent communities were mapped around Twin Lakes consisting largely of hardstem bulrush (Photo 3.4-2, right frame). Field survey notes recorded during the survey indicated that many of the bulrush communities were relatively sparse in terms of plant density. Approximately 3.1 acres of floating-leaf communities were identified during the survey of which water smartweed comprised the majority of occurrences (Photo 3.4-2, left frame). Water smartweed is easily identified by its bright pink flowers that appear during mid-summer. Water smartweed is well adapted to growing in areas of fluctuating water depths and can sometimes be found growing terrestrially on the shores surrounding a lake. Small floating-leaf plant communities of spatterdock were identified in West Twin Lake. In total, 6.6 acres of emergent and floating-leaf aquatic plant communities were mapped around Twin Lakes (Table 3.4-3).

**Photograph 3.4-6. Water smartweed (left) and hardstem bulrush (right) mapped in Twin Lakes during the 2020 community mapping survey.** Photo credit Onterra.

The community map created in 2020 represents a 'snapshot' of the important plant communities in Twin Lakes, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the lake. This is important because these communities are often negatively affected by recreational use and shoreland development.

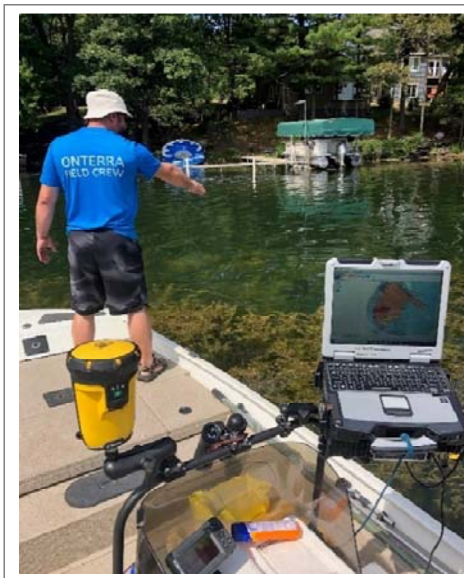
**Table 3.4-3. Twin Lakes floating-leaf and emergent plant community types.** Created from August 2020 community mapping survey.

| Plant Community | Acres |
|---|---|
| Emergent | 2.6 |
| Floating-leaf | 3.1 |
| Mixed Emergent & Floating-leaf | 0.9 |
| **Total** | **6.6** |

## *Non-native Plants in Twin Lakes*

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 exotic species, curly-leaf pondweed and Eurasian watermilfoil are the primary targets of this extra attention. Due to its odd life-cycle, a special survey is conducted early in the growing season to account for and map curly-leaf pondweed occurrences within the lake. Although Eurasian watermilfoil starts to grow earlier than our native plants, it reaches its peak biomass later in summer, so it is inventoried during mid- to late summer.

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake. During the AIS mapping surveys, the entire littoral area of each lake was surveyed through visual observations from the boat (Photo 3.4-7). Field crews supplemented the visual survey by deploying a submersible camera along with periodically taking rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.




**Photograph 3.4-7. AIS mapping survey on a Waushara County Lake.** Photo credit Onterra.

## Curly-leaf Pondweed

**Photograph 3.4-8. Curly-leaf pondweed.**
Photo credit; Onterra

Curly-leaf pondweed is a European exotic that has an unconventional lifecycle (Photograph 3.4-8). The plants begin rapidly growing almost immediately after, if not before, ice-out and by early-summer they reach their peak growth. As they are growing, each plant produces numerous turions (asexual reproductive structures) which break away from the plant and settle to the bottom following the plant's senescence (die off) in early summer. The deposited turions lie dormant until autumn when a portion of them sprout to produce small winter foliage, and they remain in this state until spring foliage is produced. The portion of turions that do not sprout can remain dormant for at least 5 years (likely longer) and still sprout (Johnson, Jones and Newman 2012).

The advanced growth in spring gives the plant a significant head start over native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition (James et al. 2002). However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced each year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally, a control strategy for an established CLP population includes multiple years of controlling the same area to deplete the existing turion bank within the sediment. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.

Curly-leaf pondweed has been present in the Twin Lakes for some time with records of its presence dating back to at least 2002. Curly-leaf pondweed occurrences were targeted with small herbicide spot treatments using the active ingredient of endothall in 2006, 2009, 2010, and 2012 (Table 3.4-4). On June 25, 2020, an Early-Season AIS Survey was completed by Onterra on Twin Lakes that focused upon locating and mapping CLP. The survey yielded sparse CLP in the lake including one single plant and one clump of plants near the northern shores of East Twin Lake and six single or few plant occurrences on the western end of West Twin Lake (Map 9). At the population levels documented in 2020, CLP is not causing any detectable ecological impacts within Twin Lakes.

## Eurasian watermilfoil

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. Eurasian watermilfoil was verified in both East and West Twin Lakes in 1999 although was likely present in the lake for some time prior to verification. Onterra staff collected a milfoil sample from Twin Lakes during 2021 and sent a dried specimen to Montana State University where genetic analysis confirmed the specimen to be pure-strain Eurasian watermilfoil as opposed to Hybrid watermilfoil. Hybrid watermilfoil is a cross between Eurasian watermilfoil and northern watermilfoil and is known to be present in many lakes in the same region as Twin Lakes. Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants: 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes are not that simplistic. The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake.

Since initial detection, the EWM population has been managed within Twin Lakes through hand harvesting efforts and herbicide spot-treatments (Table 3.4-4). The lake has been impacted by nuisance EWM growth in past years which prompted the initial herbicide management efforts in 2004. Herbicide treatments targeting EWM have occurred during 2004, 2005, 2009, 2010, and 2012 all utilizing the 2,4-D herbicide. Endothall treatments have occurred in 2006, 2009, 2010, and 2012 to target CLP. A review of past EWM mapping efforts indicates concentrations of EWM historically along the shores of East Twin Lake and in the channel area between the two lake basins. The most recent active management to occur on Twin Lakes was through targeted hand harvesting of EWM during 2018.

**Table 3.4-4. AIS Management History for Twin Lakes from 2004 – present.** Table created from records provided by TLC.

| Year | AIS Management | Target Species | Acres Treated | Chemical |
|---|---|---|---|---|
| 2004 | Herbicide Treatment | EWM | 4.65 | 2,4-D |
| 2005 | Herbicide Treatment | EWM | 2.71 | 2,4-D |
| 2006 | Herbicide Treatment | CLP | 1.54 | endothall |
| 2009 | Herbicide Treatment | EWM & CLP | 1.3 (2,4-D) + .3 endothall | 2,4-D & endothall |
| 2010 | Herbicide Treatment | EWM & CLP | 1.3 (2,4-D) + .33 endothall | 2,4-D & endothall |
| 2012 | Herbicide Treatment | EWM & CLP | ? | 2,4-D & endothall |
| 2018 | Hand Harvesting | EWM | | |

### *Late-Summer EWM Mapping Survey*

Onterra ecologists mapped the EWM population in Twin Lakes during a September 29, 2020 visit to the lake. The survey results are displayed on Map 10 and indicate that EWM is present in low to moderate densities around many areas of Twin Lakes. The largest concentration of EWM, including an area mapped as dominant density, was located along the northern shoreline of East Twin Lake including along 2nd Avenue. The EWM population in West Twin Lake was characterized by relatively low-density occurrences including highly scattered and scattered density colonies and many isolated individual singles or few plants occurrences. The channel area between the two basins harbored a modest EWM population consisting of single or few plants occurrences. No areas of EWM were causing significant nuisance conditions that would interfere with recreational use of the lake at the time of the survey.

During the summer of 2022, local TLC AIS monitors reported that the EWM population had expanded since the September 2020 survey. The TLC wished to have the most up-to-date census of the EWM population for use in finalizing their AIS management goals. Therefore, the EWM population was professionally mapped again during a September 29, 2022 survey. This survey found that EWM had increased in density since 2020, in particular in a few locations within East Twin Lake (Map 11). EWM colonies ranging from scattered to surface matted in density were identified near the constriction leading to West Twin Lake, north of a small island on the northern end of East Twin Lake, as well as along the eastern-most end of the lake along 2nd avenue. These denser colonies have the potential to interfere with recreational use of the area for activities such as boating or swimming. The EWM population was slightly increased in West Twin Lake compared to 2020 as well; however, was largely comprised of point-based occurrences mapped as either singles, clumps, or small plant colonies. It is likely that somewhat decreased water levels since 2020 may have favored EWM growth during 2022.

## *Stakeholder Survey Responses to Aquatic Vegetation within Twin Lakes*

As discussed in section 2.0, the stakeholder survey asked many questions pertaining to perception of the lakes and how they may have changed over the years. Figures 3.4-8 and 3.4-9 display the responses of members of Twin Lakes stakeholders to questions regarding aquatic plants, and aquatic invasive plant management. Question #23 from the stakeholder survey polled respondents support for various AIS management techniques (Figure 3.4-8). Support for each of the options listed varied amongst the respondents; however, in general, respondents were not supportive of a *do not manage plants* option.

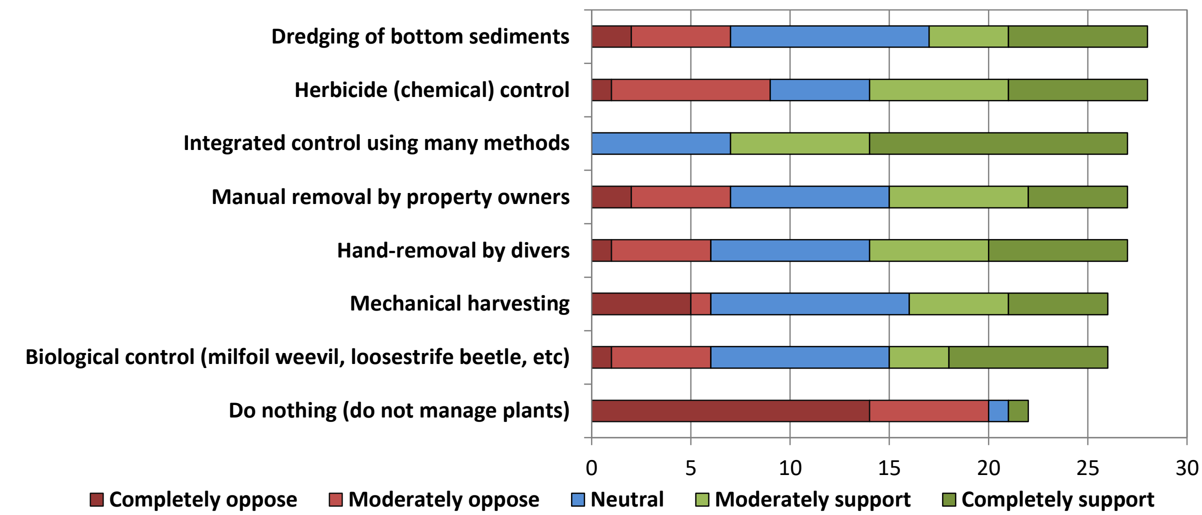



**Figure 3.4-8. Stakeholder survey response Question #23.** What is your level of support for the responsible use of the following aquatic invasive plant management techniques on Twin Lakes?

Since EWM and CLP have been managed in the past in Twin Lakes, question #24 in the stakeholder survey asked respondents about any concerns they may have in managing EWM with herbicide or hand harvesting control techniques (Figure 3.4-9). The main concerns respondents had with aquatic herbicides were potential impacts to non-target species of plants or animals including fish or insect species, uncertainty of future impacts, and potential impacts to human health. The main concerns respondents had for a hand harvesting strategy were ineffectiveness of the technique, and potential costs being too high.

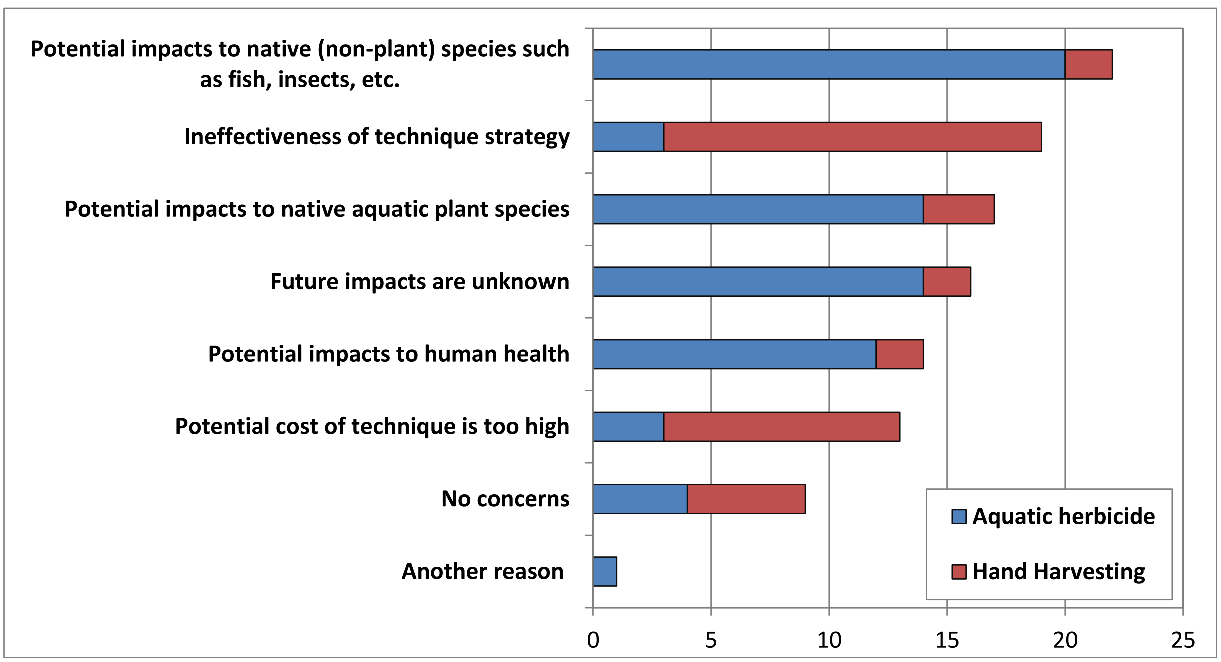



**Figure 3.4-9. Stakeholder survey response Question #24.** What concerns, if any, do you have for the future use of aquatic herbicides and hand-harvesting to manage Eurasian watermilfoil in Twin Lakes?

## 3.5 Aquatic Invasive Species in Twin Lakes

As is discussed in section 2.0 Stakeholder Participation, the lakes' stakeholders were asked about aquatic invasive species (AIS) and their presence in Twin Lakes within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are three AIS present (Table 3.5-1).

**Table 3.5-1. AIS present within Twin Lakes**

| Type | Common name | Scientific name | Location within the report |
|---|---|---|---|
| Plants | Eurasian watermilfoil | *Myriophyllum spicatum* | Section 3.4 – Aquatic Plants |
| | Curly-leaf pondweed | *Potamogeton crispus* | Section 3.4 – Aquatic Plants |
| Fish | Common carp | *Cyprinus carpio* | Section 3.1 – Water Quality & Below |

Figure 3.5-1 displays the aquatic invasive species that Twin Lakes stakeholder survey respondents believe are the lakes. Only the species present in Twin Lakes are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species that are present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

### Common Carp

Since the introduction of common carp (*Cyprinus carpio*), an invasive species which originates from Eurasia, to waterbodies in the United States and other countries around the world, numerous studies have documented the deleterious effects these fish have on lake ecosystems. Common carp can survive in a wide range of waterbody conditions, but they reach their greatest densities in shallow, eutrophic systems. Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber and Brown 2011).

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

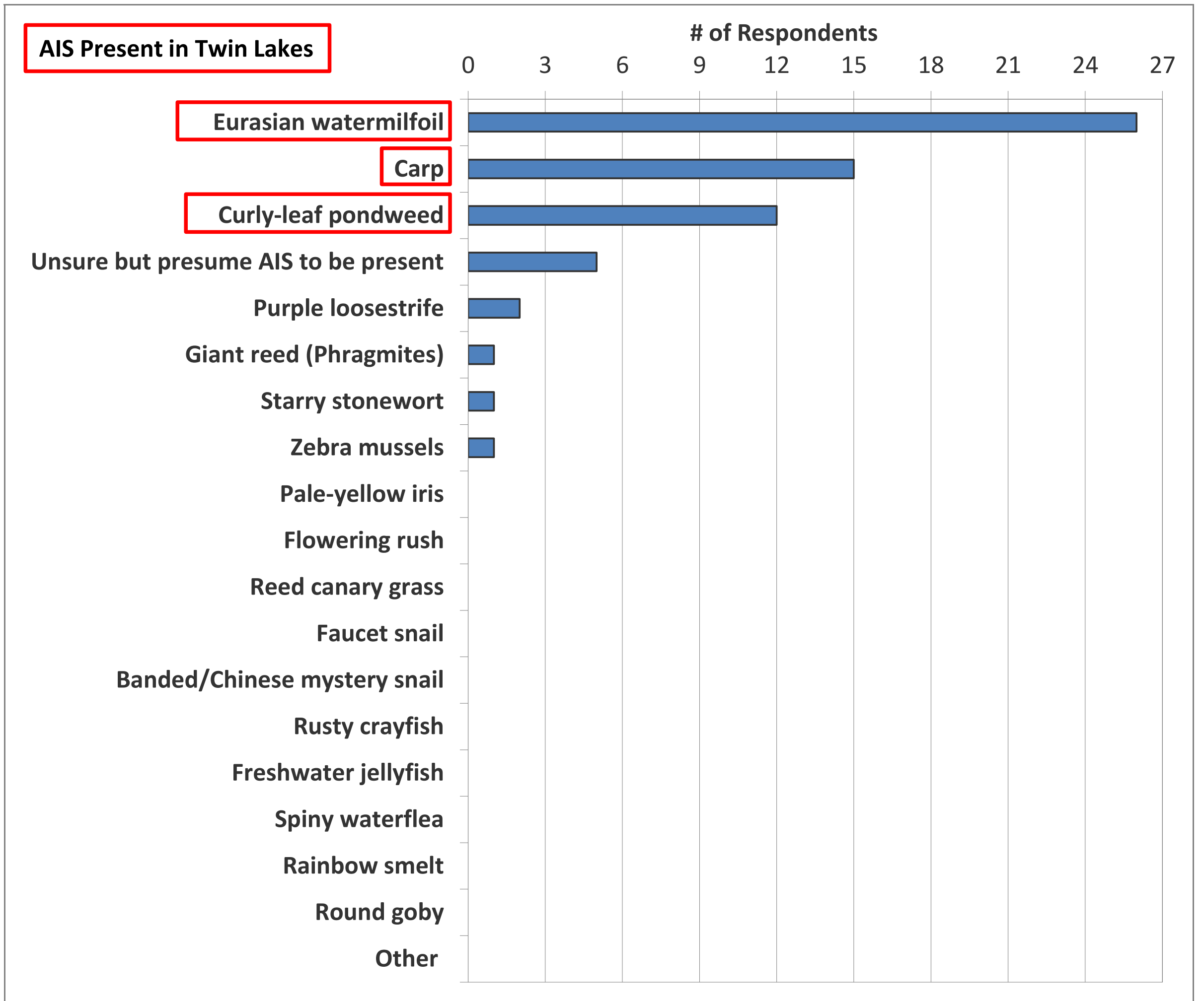



**Figure 3.5-1. Stakeholder survey response Question #22.** Which aquatic invasive species do you believe are in Twin Lakes?

## 3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing the Twin Lakes. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) and personal communications with DNR Fisheries Biologist Scott Bunde (WDNR 2021).

### *Twin Lakes Fishery*

#### Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in the Twin 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 piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

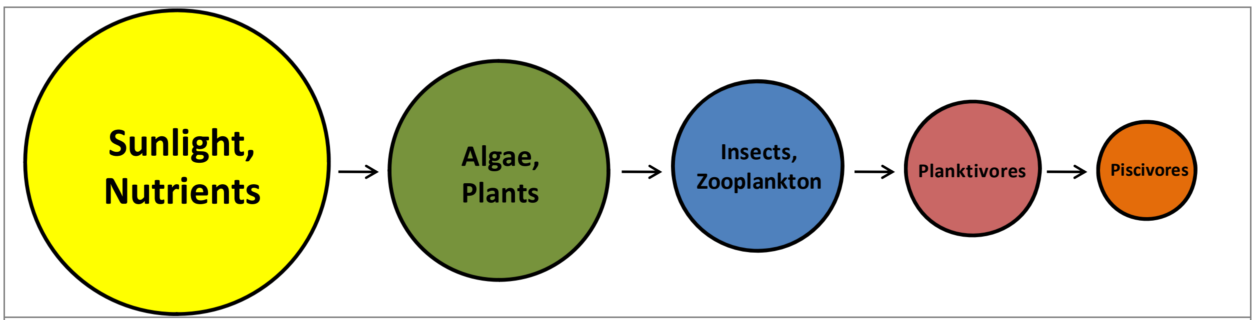



**Figure 3.6-1. Aquatic food chain.** Adapted from (Carpenter, Kitchell and Hodgson 1985).

As discussed in the Water Quality section, the Twin Lakes is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means the Twin Lakes should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present. The invasive common carp (*Cyprinus carpio*) is also present in the Twin lakes, see Section 3.5 for more information.

**Table 3.6-1. Gamefish present in the Twin Lakes with corresponding biological information (Becker 1983).**

| Common Name (*Scientific Name*) | Max Age (yrs) | Spawning Period | Spawning Habitat Requirements |
|---|---|---|---|
| Black Crappie (*Pomoxis nigromaculat* | 7 | May - June | Near *Chara* or other vegetation, over sand or fine gravel |
| Bluegill (*Lepomis macrochirus*) | 11 | Late May - Early August | Shallow water with sand or gravel bottom |
| Green Sunfish (*Lepomis cyanellus*) | 7 | Late May - Early August | Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm |
| Largemouth Bass (*Micropterus salmo* | 13 | Late April - Early July | Shallow, quiet bays with emergent vegetation |
| Pumpkinseed (*Lepomis gibbosus*) | 12 | Early May - August | Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom |
| Walleye (*Sander vitreus*) | 18 | Mid April - Early May | Rocky, wavewashed shallows, inlet streams on gravel bottoms |
| Yellow Perch (*Perca flavescens*) | 13 | April - Early May | Sheltered areas, emergent and submergent veg |

## Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

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

**Photograph 3.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).**

## Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. The Twin Lakes were stocked in 2000 with 1,500 brown trout.

**Photograph 3.6-2. Brown trout**

## Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water) was the third most important reason for owning property on or near the Twin Lakes (Question #9). Figure 3.6-2 displays the fish that the Twin Lakes stakeholders enjoy catching the most, with bluegill/sunfish, crappie, and yellow perch being the most popular. Approximately 86% of these same respondents believed that the quality of fishing on the lake was either excellent, good, or fair (Figure 3.6-3). Approximately 45% of respondents who fish the Twin Lakes believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.6-4).

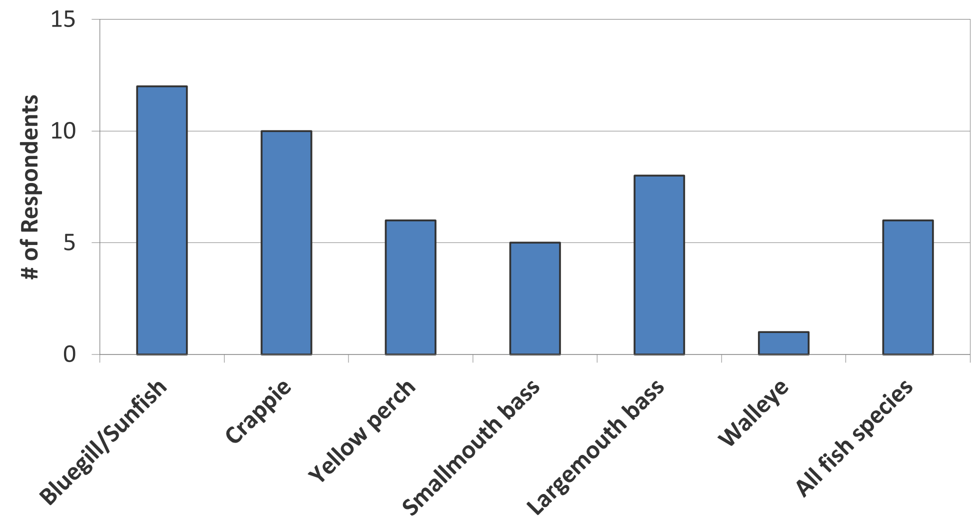



**Figure 3.6-2. Stakeholder survey response Question #9.** What species of fish do you like to catch on the Twin Lakes?

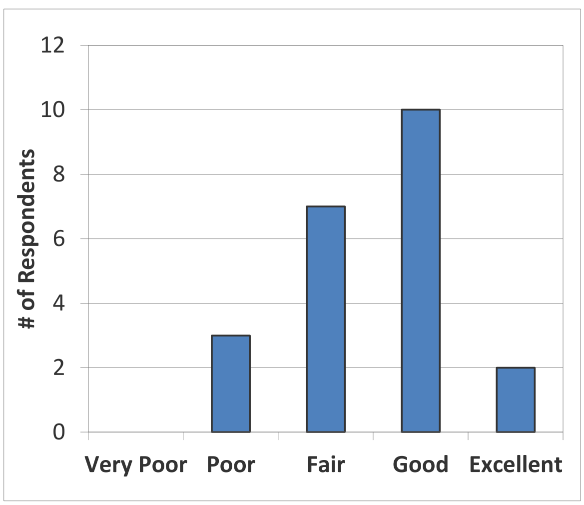



**Figure 3.6-3. Stakeholder survey response Question #10.** How would you describe the current quality of fishing on the Twin Lakes?

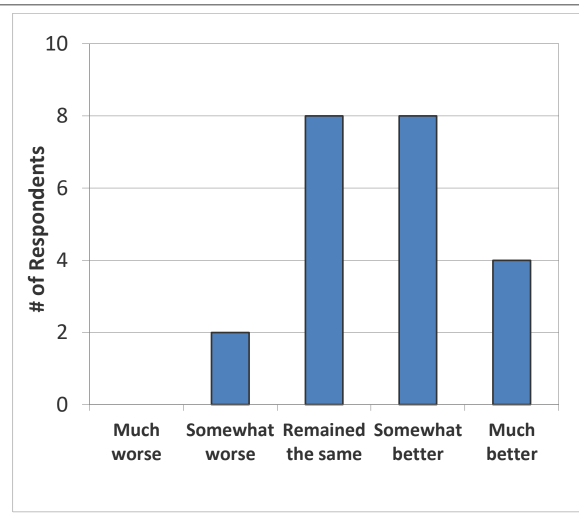



**Figure 3.6-4. Stakeholder survey response Question #11.** How has the quality of fishing changed on the Twin Lakes since you started fishing the lake?

## *Fish Populations and Trends*

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

In 2015, DNR biologists conducted an electrofishing survey on the Twin Lakes using a mini-boom barge. During this survey, gamefish captured were counted and length was recorded (Table 3.6-2, top frame). Common carp were encountered frequently during this survey as well. Biologist noted that most carp measured between 9-11 inches and seemed to be in poor health. This is an indicator that the carp population in the Twin Lakes was high at the time (WDNR 2021).

Fisheries biologists conducted a subsequent electroshocking survey in spring 2022. These results indicated improved growth structure and populations of many popular gamefish in the lake compared to the 2015 survey. The number of fish captured per mile of survey was much higher in 2022 for bluegill, largemouth bass, and yellow perch (Appendix E). The statewide rank for catch rate of yellow perch (96%) and largemouth bass (97%) in the 2022 survey were particularly notable (Table 3.6-2, bottom frame).

**Table 3.6-2. Data from 2015 (top frame) and 2022 electrofishing surveys (bottom frame).** Data from WDNR.

| | East Twin | | West Twin | |
|---|---|---|---|---|
| | *Number Sampled* | *Length Range (Inches)* | *Number Sampled* | *Length Range (Inches)* |
| Black Crappie | 1 | 8.7 | 0 | - |
| Bluegill | 6 | 2.1 - 7.1 | 0 | - |
| Green Sunfish | 1 | 4.3 | 2 | 3.1 - 6.0 |
| Largemouth Bass | 28 | 3.5 - 11.5 | 11 | 4.2 - 18.8 |
| Pumpkinseed | 1 | 4.0 | 1 | 3.2 |
| Yellow Perch | 9 | 2.6 - 6.8 | 0 | - |

| Species | Count | CPUE/Mile Total | Statewide % Rank |
|---|---|---|---|
| BLACK CRAPPIE | 10 | 5.5 | 47 |
| BLUEGILL | 165 | 90.7 | 52 |
| LARGEMOUTH BASS | 188 | 103.3 | 97 |
| PUMPKINSEED | 2 | 1.1 | 7 |
| YELLOW PERCH | 100 | 54.9 | 96 |
| Carp | 23 | 12.6 | NA |

## *Twin Lakes Fish Habitat*

### Substrate Composition

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

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye are another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in West Twin Lake in 2020, 58% of the substrate sampled in the littoral zone were soft sediments and 42% was composed of sand. In East Twin Lake, 77% of the substrate sampled in the littoral zone were soft sediments, 22% was composed of sand, and 1% was composed of rock.

### Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2009). A summer 2020 survey documented 45 pieces of coarse woody habitat along the shores of West Twin Lake and 55 pieces along East Twin Lake's shores. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how the Twin Lake's coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

### Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


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

Fish cribs are a type of fish habitat structure placed on the lakebed. These structures are more commonly utilized when there is not a suitable shoreline location for fish sticks. Installing fish cribs may also be cheaper than fish sticks; however, some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure. Having multiple locations of fish cribs can help mitigate that issue.

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

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

Placement of a fish habitat structure in a lake may be exempt from needing a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

*(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)*

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

### Fishing Regulations

Regulations for Wisconsin fish species as of May 2021 are displayed in Table 3.6-3. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

**Table 3.6-3. WDNR fishing regulations for the Twin Lakes (As of May 2021).**

| Species | Daily bag limit | Length Restrictions | Season |
|---|---|---|---|
| Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch) | 25 | None | Open All Year |
| Largemouth bass and smallmouth bass | 5 | 14" | May 1, 2021 to March 6, 2022 |
| Muskellunge and hybrids | 1 | 40" | May 1, 2021 to December 31, 2021 |
| Northern pike | 5 | None | May 1, 2021 to March 6, 2022 |
| Walleye, sauger, and hybrids | 5 | 15" | May 1, 2021 to March 6, 2022 |
| Bullheads | Unlimited | None | Open All Year |
| Cisco and whitefish | 10 | None | Open All Year |

Common carp are typically targeted by anglers with the use of hook and line, bow and arrow, and spearing. A Wisconsin fishing license is required for eligible anglers using these methods. Harvesting carp through the use of dip net, landing net, or seine net does not require a license for Wisconsin residents. A full summary of regulations and season dates regarding rough fish harvest can be found within the Wisconsin Spearing, Netting, and Bait Harvest Regulations document produced by the DNR.

### *Mercury Contamination and Fish Consumption Advisories*

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

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-8. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

**Figure 3.6-8. Wisconsin statewide safe fish consumption guidelines.** Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

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

## *Fishery Management & Conclusions*

Twin Lakes are currently managed as a bass and bluegill fishery. Common carp were previously found within the lakes in high abundance with WDNR fisheries staff recommending carp control. During the course of this management planning project, the WDNR conducted a fisheries study during 2022 on Twin Lakes which provided an updated census of the status of the fishery. The TLC met virtually with the WDNR fisheries representative Adam Nickel on December 15, 2022 during which the results of the 2022 study were discussed. The carp population was now considered to be "present" rather than "abundant" as it had been in the past. A total of 23 carp were encountered during the 2022 fisheries survey and no young of the year fish were encountered (Appendix E). The 2022 fisheries study showed an overall improved quality of the fishery as compared to the 2015 assessment. The number of fish captured per mile of surveyed area was increased for black crappie, bluegill, largemouth bass, and yellow perch compared to 2015. The statewide rank for fish caught per mile was in the 97th percentile for largemouth bass and 96$^{th}$ percentile for yellow perch (Appendix E).

Carp can be managed in several ways in Wisconsin's inland lakes. In some larger systems, commercial harvesting is contracted out sometimes with subsidies to ensure economic viability. Commercially harvested carp are often sold to food markets that may distribute around the world. Commercial carp harvesting is not an applicable technique on Twin Lakes at this time as these contractors are typically looking for more fish and larger fish that is currently known in the lakes. Another method of reducing carp populations in some systems is achieved by sport spear fishing. Some lake groups host an annual carp spearing tournament to facilitate carp population management.

On some degraded systems with a carp or rough fish dominated fishery, an aquatic pesticide containing the active ingredient of rotenone is applied to the waterbody. This chemical application is used to eliminate all fish from the system and is typically followed up with a re-stocking effort of desirable fish species. This approach is not likely to be supported by WDNR regulators or fisheries managers for Twin Lakes at this time.

The TLC has developed a management goal to ensure a healthy fishery in Twin Lakes through partnering with WDNR fisheries staff to install fishery habitat enhancement projects, while also encouraging the removal of carp by local lake users.

# 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 Twin Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil and curly-leaf pondweed.
3) Collect sociological information from Twin Lakes riparian stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

These three objectives were fulfilled during the project and have led to an understanding of the Twin Lakes ecosystem, the people that care about the lake, and what needs to be completed to protect and enhance these lakes.

A volunteer group of Twin Lake Conservancy (TLC) members formed a planning committee for this project and were instrumental in the development of the subsequent Implementation Plan. The planning committee served to provide the local perspective related to recreational use of the Twin Lakes and in developing the TLC's role in protecting, enhancing, and managing Twin Lakes for the years to come. Pairing the understanding of the technical data that has been collected over time as well as the TLC's sociological needs through this planning project has led to the creation of a realistic management plan for the TLC to implement in managing Twin Lakes.

Because Twin Lakes are seepage lakes fed by groundwater, they are subjected to large changes in water levels driven by changes in regional precipitation patterns. At the time of the project, Wisconsin had seen several consecutive years of record precipitation, resulting in rising water levels in many seepage lakes around the state including Twin Lakes. Water levels in Twin Lakes during 2020 were higher than they had been for many years, causing many near-shore areas to be inundated and drowning many trees and shrubs. Water levels have somewhat receded again since 2020.

East and West Twin lakes have some differences in water quality in part due to being different lake types. East Twin Lake is a shallow (mixed) seepage lake in which waters mix throughout the water column regularly and is currently in a meso-eutrophic state. West Twin Lake is a deep (stratified) seepage lake, meaning that the lake thermally stratifies during warmer months and is currently in a mesotrophic state. Historical data, as well as data collected during the management planning project indicate Twin Lakes have fair to good water quality based on phosphorus and chlorophyll-a levels. Water clarity in Twin Lakes is lower than expected and is believed to be a result of suspended sediments in the water column caused in part by sediment resuspension by invasive common carp. Nitrogen levels in Twin Lakes are higher than average for lakes in Wisconsin and is likely the result of agricultural practices in the region that then enters the groundwater which feeds Twin Lakes. The TLC has developed actions to monitor water quality in the lakes and work towards determining ways in which to meet a goal of improving the lake's water quality.

The shoreland condition assessment identified areas of the lake's shoreland that are important to protect and maintain in their natural state and also identified areas where restoration actions would have the most benefit. The majority of Twin Lakes relatively small 390-acre watershed is comprised of intact upland forest. Agricultural land use areas in the surficial watershed are not believed to be contributing phosphorus to the lakes based on watershed modeling and measured phosphorus concentrations in the lake. Further, most of the agricultural areas in Twin Lakes watershed are to the south or east of the lakes where the direction of ground water flow is away from the lakes.

Studies indicate a highly degraded aquatic plant community in Twin Lakes with very few native species present in the lake. It is suspected that foraging behavior of common carp contributes to the inability of aquatic plants to take root and establish in much of the lake. Recent rising water levels in the lake may also cause some plant species to struggle to adapt. Native plant populations may improve naturally in the future if conditions are conducive to their growth. An effort to plant native species in the lake is a challenging endeavor that the TLC may seek to investigate in the future with guidance from WDNR lake managers.

Eurasian watermilfoil (EWM) and curly-leaf pondweed (CLP) have been present in Twin Lakes for over twenty years. The TLC has conducted active management through herbicide treatment or hand pulling in the past, particularly in years where EWM caused nuisance conditions. The EWM and CLP populations were monitored in 2020 as a part of this management planning project. The EWM monitoring showed a relatively modest population with a few colonized areas in near shore areas of the lake and isolated plants within other littoral areas. Only a few isolated plants of CLP were located in the lake during monitoring conducted in 2020.

At the beginning of this project in 2020, no areas of EWM or CLP were causing significant nuisance conditions that would interfere with recreational use of the lake. A subsequent late-summer 2022 EWM mapping survey showed an increased population since 2020 with a few areas of dense plants that likely cause localized impacts to navigation or recreational use. Volunteer EWM monitoring during 2023 indicated that EWM had expanded further with impacts to recreational use becoming apparent in the channel connecting the east and west basins of Twin Lake. Continued monitoring of the EWM and CLP population is important in documenting the population dynamics and the distribution within the lake. Monitoring will be instrumental in determining whether considerations for actively managing the species become warranted in future years, particularly if the species expands back to levels that significantly impede recreational activities in the lake. As a part of this management planning project, the TLC has outlined how they will monitor EWM and CLP and the steps they would take to determine if future management actions will be pursued. The TLC has also developed plans to prevent further introductions of AIS into Twin Lakes.

Twin Lake's fishery is managed by the WDNR for bass and panfish such as bluegill, crappie, and perch. Carp have been documented in high abundance in the past although a 2022 fisheries survey indicates a more modest population with improved population structure for largemouth bass, yellow perch, and other panfish species. Many of the stakeholder survey respondents described the quality of the fishery to be fair or good as of 2020. The TLC has made a management goal of working with WDNR fisheries managers to monitor common carp in the lake and investigate ways to improve the fishery resource in the lake.

# 5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Twin Lakes Conservancy Planning Committee and ecologist/planners from Onterra. It represents the path the TLC 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 Twin Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

## Management Goal 1: Improve Current Water Quality Conditions in Twin Lakes

| **Management Action:** | Monitor water quality through WDNR Citizens Lake Monitoring Network. |
|---|---|
| **Timeframe:** | Ongoing |
| **Facilitator:** | Ken Klemm or current CLMN volunteer |
| **Description:** | Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring.<br><br>The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. The TLC would like to include both East and West Twin Lakes in the CLMN program; however, they will prioritize East Twin Lake if needed. The TLC volunteers would be trained to monitor the deep hole site as a part of the advanced CLMN program. This includes collecting Secchi disk transparency and sending in water chemistry samples (chlorophyll-α and total phosphorus) to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. The samples are collected once during the spring and three times during the summer. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).<br><br>The TLC may also want to have additional people trained in the collection of water quality in the event the current volunteer is not able to fulfill their duties on short notice (i.e., backup volunteers). The TLC can contact Ted Johnson (920.362.0181) or the appropriate WDNR/UW-Extension staff to coordinate the training. If and when a change in the collection volunteer occurs, Ted Johnson or the appropriate WDNR/UW-Extension staff will need to be contacted to |

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| | ensure the proper training occurs and the necessary sampling materials are received by the new volunteer.<br><br>As discussed in Section 3.1 above, elevated levels of nitrogen were measured within samples collected and analyzed in 2020 during the management planning project. In addition to phosphorus and chlorophyll-α testing, the TLC will also collect an additional water sample in July and send to the State Lab to analyze for total nitrogen. The nitrogen sample will be collected from near-surface waters at the same locations in the lake where the other CLMN samples are being collected. The TLC will need to pay out-of-pocket for WSLH fees to complete the nitrogen analysis. Costs for total nitrogen analysis as of 2021 were $30/sample. |
| **Action Steps:** | |
| 1. | Ken Klemm with TLC recruits backup CLMN volunteer(s) in the event he is no longer able to fulfill sampling duties. |
| 2. | Ken Klemm contacts WDNR lake biologist Ted Johnson (920.362.0181) to acquire necessary materials and training for CLMN volunteer(s). |
| 3. | Ken Klemm collects data and reports results to WDNR and to Conservancy members. |
| 4. | Ken Klemm and TLC recruit new volunteer(s) as needed. |

| **<u>Management Action:</u>** | Share results of elevated nitrogen levels in Twin Lakes with local land and water managers. |
|---|---|
| **Timeframe:** | Beginning in 2022 |
| **Facilitator:** | Gretchen Miller |
| **Description:** | The TLC will inform Marquette and Adams County Conservationists of the elevated nitrogen levels in Twin Lakes. Communications may aid in furthering the understanding of the potential sources of nitrogen in Twin Lakes. Further, the TLC will educate members on the importance of testing their wells for nitrate and other contaminants on an annual basis per WI Department of Health guidelines and encourage members to voluntarily report their results to local water managing entities including the Marquette and Adams County Conservationists. |
| **Action Steps:** | |
| 1. | Forward the results of the nitrogen analysis from Twin Lakes to Marquette County Conservationist (Pat Kilby) and to the Adams County Conservationist (Colton Wolosek). |
| 2. | TLC will educate membership on importance of testing well drinking water on an annual basis for nitrates and other potential contaminants. TLC will encourage members to report well testing results to the TLC and county conservation departments. The TLC will consider creating a database to maintain and track private well drinking water data. |

## Management Goal 2: Manage Current Aquatic Invasive Species in Twin Lakes and Prevent Further Introductions

| **Management Action:** | Ensure there is AIS signage at the public boat landing. |
| --- | --- |
| **Timeframe:** | Completed |
| **Facilitator:** | Joann Pelletier |
| **Description:** | The public boat landing on Twin Lakes is owned and maintained by the Springfield Township. The TLC understands the importance of preventing additional new AIS from being introduced into Twin Lakes. The TLC will contact the Springfield Township to inquire about improving signage at the public boat landing as needed to make users aware of AIS and to encourage users to inspect their boats, trailers, and equipment prior to use. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Provide educational materials to Twin Lake riparians about AIS prevention. |
| --- | --- |
| **Timeframe:** | Ongoing |
| **Facilitator:** | TLC Board |
| **Description:** | The TLC will provide Twin Lake stakeholders with educational materials relating to AIS prevention on a regular basis as necessary. This will be achieved through providing resources such as web links, newsletter articles, and discussion at TLC meetings or events. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Conduct periodic quantitative vegetation monitoring on Twin Lakes through whole-lake point-intercept surveys. |
| --- | --- |
| **Timeframe:** | Point-Intercept Survey every 3-5 years |
| **Possible Grant:** | WDNR AIS Grant Program |
| **Facilitator:** | TLC Board |
| **Description:** | The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been conducted on the Twin Lakes during 2019 by WDNR staff and in 2023 by Golden Sands RC&D. The TLC will maintain a regular monitoring schedule for the aquatic plant population in the Twin Lakes. This will be achieved through the completion of a whole-lake point-intercept survey every three to five years. The survey would be initiated sooner if perceived changes in the aquatic plant community are believed to be occurring or if the lake |

| | |
|---|---|
| | enters a period of significant active aquatic plant management. This will allow a continued understanding of the submergent aquatic plant community dynamics within Twin Lakes.<br><br>The last point-intercept survey on Twin Lakes was conducted in summer 2023. The TLC will plan for the next point-intercept survey to take place between 2026-2028. The TLC may contract with a professional firm or a local non-profit organization to conduct future point-intercept surveys. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Conduct annual volunteer monitoring of curly-leaf pondweed and Eurasian watermilfoil in Twin Lakes. |
|---|---|
| **Timeframe:** | Ongoing |
| **Facilitator:** | Michelle Crombie |
| **Description:** | The most recent census of the AIS population in Twin Lakes indicates a modest population of CLP and a moderate population of EWM. At these population levels, impacts to recreation and navigation are likely limited to locally dense pockets of EWM, and not likely causing changes in ecological function. The TLC understands that AIS populations are dynamic and can fluctuate on an annual basis based on environmental factors including variations in the lake water levels.<br><br>Volunteer(s) from the TLC will monitor the CLP and EWM populations on multiple occasions each year. Monitoring would be completed by visually searching the littoral areas of the lake and documenting the population of these two species through a combination of photographs, GPS data, and thorough note taking. The TLC will share the findings of these monitoring efforts with the membership and use these efforts to assess whether populations of these species are increasing. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Conduct professional monitoring of curly-leaf pondweed and Eurasian watermilfoil in Twin Lakes. |
|---|---|
| **Timeframe:** | When prompted by volunteer-based AIS monitoring |
| **Facilitator:** | TLC Board |
| **Description:** | When volunteer-surveys locate an AIS population that may have expanded to levels being considered for management, the TLC would give consideration to having a professional mapping survey completed. |

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| | This survey would include a complete meander survey of the system's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). The EWM population would be assessed through the completion of a late-summer mapping survey (August or September) when the species is expected to be at its peak growth stage of the year. The CLP population would be evaluated through the completion of an early-season mapping survey, likely during the month of June, while this species is expected to be near its peak growth stage for the season. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Conduct Eurasian watermilfoil management |
|---|---|
| **Timeframe:** | When needed and appropriate control measures are available. |
| **Facilitator:** | TLC Board |
| **Description:** | It is expected that at some point in the future, perhaps during another period of low water levels, the EWM population will return to levels that were observed in past years during which large contiguous colonies contributed to nuisance growth conditions. The TLC has developed this management action to ensure it is in a position to conduct management towards EWM if warranted.<br><br>The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. For instance, small 2,4-D spot treatments were the BMP for EWM control in the 2000s, but alternative actions are now more commonly sought.<br><br>It is important to note that this management action provides a framework to guide potential management and monitoring activities, but does not outline the specific control plan for a given year. A written control plan, consistent with this framework, would be produced prior to the action outlining the management and monitoring strategy. The control plan is useful for WDNR regulators when considering approval of the action, as well as to convey the control plan to TLC members for their understanding.<br><br>**Hand-Harvesting**<br>As discussed earlier in the Aquatic Plant Section (3.4), hand-removal of EWM can be an effective way to manage low or emerging populations. This can be conducted either through a volunteer effort |

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| | or by contracting professionals. Permits are only required if mechanical methods are used in the process, such as Diver Assisted Suction Harvest (DASH) techniques used by some contractors.<br><br>Hand-harvesting of EWM can occur at any time of the year, as long as the roots are fully extracted. Hand-harvesting typically occurs between mid-June and mid-September, as the plants are brittle and harder to get complete extraction outside that window.<br><br>It is important to understand that each riparian owner can legally harvest EWM and native plant species in a 30' wide area of one's frontage directly adjacent to one's pier without a permit. This could include the use of a rake or other non-mechanical handheld devices. A permit is required if an area larger than the 30' corridor is being harvested or if a mechanical assistance mechanism, like DASH, is being used. Professional services to remove EWM also do not require a permit unless DASH or a mechanical device is being used in the process. Simply wading into the lake and removing EWM by hand with or without the aid of snorkeling accessories can be helpful in managing EWM on a small and individual property-based scale. Some professional firms offer services to remove aquatic vegetation from within the riparian property owner's 30' frontage zone, though it is more economical to solicit these efforts from local sources if available.<br><br>The TLC will educate its stakeholders on proper hand-harvesting techniques, so they can properly target EWM in their recreation footprint. The TLC may consider a coordinated hand-harvesting effort in high use areas such as the narrow constriction between East and West Twin Lakes. If professional contracted services are sought, the TLC would develop a control plan, including a prioritized approach for the hand-harvesting firm to follow. If the contractor uses DASH, permit application should occur at least a month in advance to ensure sufficient time for WDNR review and approval. If WDNR grants are sought, a monitoring strategy will need to be in place to objectively evaluate the control strategy.<br><br>**Herbicide Spot Treatment**<br>If the AIS population is too large or dense to be reasonably addressed by a hand harvesting effort, an herbicide treatment strategy would be considered. Because herbicide treatments carry an environmental risk when implementing, the TLC would only consider this action when documented impacts to navigation or recreation occur. Ways of documenting these impacts could be through the observation of dense or surface matted plants by way of photographs or a professional mapping survey that indicates these conditions. |

While some herbicide spot treatments show promise, the unpredictability of spot treatments, particularly 2,4-D, state-wide has resulted in less favorability of this strategy with some WDNR regulators and lake managers. Future spot herbicide treatments would consider herbicides thought to be effective under short exposure situations. At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike™) are examples of herbicides with reported short exposure time requirements that are employed for invasive watermilfoil control in Wisconsin.

When conducting spot treatments on relatively small waterbodies, it is important to consider the concentration of the herbicide when diluted to the entire area of potential impact. The addition of multiple spot treatments may dilute to whole-lake concentrations impactful to certain aquatic plant species.

If TLC decides to pursue future herbicide spot treatment towards EWM, the following set of bullet points would occur:

- Early consultation with WDNR to discuss intentions. This should occur as soon as the TLC is considering herbicide management.
- Create a Control and Monitoring Plan. The Control and Monitoring Plan would likely be created based on the results of a late-summer EWM mapping survey or in combination with the results of a whole-lake point-intercept survey. These data would be used to create a specific EWM control strategy for the following year including information such as the herbicide to be used, dosing strategy, targeted areas, and an accompanying monitoring strategy. The Control and Monitoring Plan would include applicable risk assessment materials for the TLC to review, particularly if an herbicide strategy is being considered. This might include a summary of available research, toxicity, selectivity, etc. Local lake managers expressed concerns that managing the invasive plants in the lake when minimal native species are present could impact water quality in a negative way including favoring algae growth.
    - EWM control efficacy would be evaluated by comparing annual late-season EWM mapping surveys during the *year prior to treatment* to *year after the treatment*. *Year of treatment* (approx. 4 months post treatment) surveys can be helpful to drive follow-up management efforts, but do not allow sufficient time to elapse to understand if the target plants were controlled or simply seasonally suppressed to quickly rebound. For example, if a site is treated with herbicide in early 2025, late-summer EWM mapping surveys

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| | would be compared between 2024 (*year-before-treatment*) and 2026 (*year-after-treatment*).<br>• If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016).* This generally consists of collecting quantitative point-intercept data before and after the treatment, typically at the same interval described above for the comparative late-season EWM mapping surveys. These data will allow an understanding of the non-target native plant impacts from the treatment.<br>• Herbicide concentration monitoring may also occur surrounding the treatment if grant funds are being used or the TLC believes important information would be gained from the effort. Herbicide concentration monitoring typically includes volunteer members of the local lake group collecting water samples in the hours, days, or weeks after herbicide is applied in the lake. These water samples are then shipped to an accredited laboratory where analysis is completed.<br>• The TLC will take an Integrated Pest Management (IPM) approach, such that herbicide treatments are followed up with hand-harvesting activities to remove rebounding EWM. This will preserve the gains made by the treatment and lengthen the time between subsequent herbicide use. An example of an IPM approach would be conducting EWM hand harvesting actions during the year(s) after an herbicide treatment as appropriate based on the EWM population.<br>• When planning for an herbicide treatment during the following year, an herbicide applicator firm would be selected in late-winter and a permit application would be applied to the WDNR as early in the calendar year as possible, allowing interested parties sufficient time to review the control plan outlined within the annual report as well as review the permit application. The contracted applicator would be responsible for submitting the WDNR permit on behalf of the TLC to conduct an herbicide treatment.<br>• Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would likely occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in June) and active growth tissue is confirmed on the target plants.<br><br>**Grant Funding Opportunities**<br>The TLC will investigate WDNR grant funding opportunities to conduct AIS management and monitoring activities. The WDNR's |

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| | Surface Water Grant Program has cost-share grants to help lake groups implement management and monitoring activities.<br><br>https://dnr.wisconsin.gov/aid/SurfaceWater.html<br><br>Current grant applications are due on November 15 of each year, and pre-application intent materials due 60 days prior (September 15). Prior to applying for an AIS control grant, the applicant must request a determination of eligibility for AIS activities outlined within a WDNR-approved plan at least 60 days prior to the grant application date. This means the TLC would need to outline how the existing Management Plan supports and outlines the strategy for which grant funds are being sought.<br><br>Based on the increasing EWM population in Twin Lakes since 2020, the TLC intends to solicit a professional EWM mapping survey during summer 2024 from which a management strategy for 2025 would be designed. The TLC will consider applying for a WDNR AIS Control Grant during the fall 2024 cycle to seek funding assistance to carry out their EWM management strategy for 2025.<br><br>Because BMPs evolve quickly in the Aquatic Plant Management (APM) field, the WDNR requires the APM Plan to be no more than 5 years old in order to be eligible for grants that apply for AIS management. Further, a whole-lake point intercept survey also has to be completed within the past 5 years in order to be eligible for AIS Control Grants. The TLC will need to make sure the APM Plan portion of this Comprehensive Management Plan is updated periodically to be eligible for future AIS Control Grants and to evolve with changing BMPs. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Conduct curly-leaf pondweed management |
|---|---|
| **Timeframe:** | As needed |
| **Facilitator:** | TLC Board |
| **Description:** | As is discussed in the Aquatic Plant Section (3.5), the goal of CLP management is to annually kill or remove the plants before they are able to produce and deposit new turions, and thus, over continued annual removal, deplete the existing reserve of turions in the sediment. To achieve this goal with hand-harvesting, the removal of CLP plants must occur in spring (May to early-June) before the development of turions. |

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| | Following multiple years of removal, the turion reserve becomes exhausted and the CLP population declines. Typically, CLP management involves annual management for 5-7 years within the same areas before the turion reserve is depleted. When populations exceed levels that can be managed with hand-harvesting/DASH, herbicide spot treatments using endothall are typically employed. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.<br><br>The TLC will educate its stakeholders on proper hand-harvesting techniques, so they can properly target CLP in their recreation footprint. TLC may consider a coordinated hand-harvesting/DASH approach to managing CLP if documented impacts to navigation or recreation occur. The TLC would only consider herbicide management actions towards CLP if populations reach levels that are impacting use of the lake and are potentially causing ecological impacts to the lake. |
| **Action Steps:** | |
| | See description above. |

## Management Goal 3: Increase Outreach/Educational Capacity of the Twin Lakes Conservancy and Facilitate Partnerships with other Management Entities

| **Management Action:** | Update the Twin Lakes Conservancy website |
|---|---|
| **Timeframe:** | Completed |
| **Facilitator:** | Rebecca Fallow |
| **Description:** | At the start of this project, the Twin Lakes Conservancy had an existing website that was out of date. The TLC website was updated to include educational materials, information about meetings, and a link to the annual newsletter. The TLC website can be found here: https://twinlakesconservancy.org/ |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Initiate TLC newsletter and post on TLC website |
|---|---|
| **Timeframe:** | Completed |
| **Facilitator:** | Rebecca Fallow |
| **Description:** | The TLC will draft newsletters on an annual basis to provide lake updates and educational materials to members. The newsletter may be distributed at meetings, over email, and will be posted on the TLC website. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Investigate forming a local page on online platforms such as social media sites. |
|---|---|
| **Timeframe:** | Completed |
| **Facilitator:** | Rebecca Fallow |
| **Description:** | The TLC will consider creating social media accounts for the purpose of connecting more members and increasing the routes for which to distribute information. Facebook and Instagram are two popular social media platforms that will be explored. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Investigate the formation of an educational committee. |
|---|---|
| **Timeframe:** | Completed |
| **Facilitator:** | Rebecca Fallow |

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|---|---|
| **Description:** | Understanding Twin Lakes ecosystem including aquatic plants, fisheries, and water quality is important to help protect the lake and its positive qualities. The TLC will investigate the formation of an educational committee that would serve to compile and distribute educational materials to members. These materials may be related to any number of relevant topics relating to lake stewardship, or lake protection and restoration. Materials would be provided through the many routes of communication between members including handouts or guest speakers at in-person meetings, newsletters, or hosted on the TLC's website or social media pages. |
| **Action Steps:** | |
| | See description above. |

| **<u>Management Action:</u>** | Continue TLC's involvement with other entities that have responsibilities in managing Twin Lakes |
|---|---|
| **Timeframe:** | Continuation of current efforts |
| **Facilitator:** | TLC Board |
| **Description:** | The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the TLC actively engage with all management entities to enhance the understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity is specifically addressed in the table below. |
| **Action Steps:** | |
| | See table guidelines on the next pages. |

| Partner | Contact Person | Role | Contact Frequency | Contact Basis |
|---|---|---|---|---|
| **Marquette County Lakes Association** | https://marquettecla.blogspot.com/ | Promotes environmental protection locally | Annually | Local partnership |
| **Adams County Land and Water Conservation Department** | Colton Wolosek County Conservationist | Oversees conservation efforts for land and water projects | Annually to share water quality analysis results | Twin Lake's groundwatershed extends into Adams County. |
| **Marquette County Land and Water Conservation Department** | Pat Kilbey County Conservationist | Oversees conservation efforts for land and water projects | Twice a year or more as needed. | Can provide assistance with shoreland restorations and habitat improvements. |
| **Wisconsin Department of Natural Resources** | Fisheries Biologist Adam Nickel Adam.Nickel@wisconsin.gov (920) 647-6571 | Manages the fishery of Twin Lakes | Once a year, or more as issues arise. | Stocking activities, scheduled surveys, survey results, coarse woody habitat enhancement activities, volunteer opportunities for improving fishery. |
| | Lakes Coordinator Ted Johnson– Ted.Johnson@wisconsin.gov (920) 362-0181 | Oversees management plans, grants, all lake activities. | Continuous as it relates to lake management activities | Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management. |
| | Citizens Lake Monitoring Network (CLMN) contact: Ted Johnson | Provides training and assistance on CLMN program | Twice a year or more as needed. | Contact to arrange for training as needed, in addition to monitoring and reporting of data. |
| | Conservation Warden Ben Nadolski Benjamin.Nadolski@wisconsin.gov (920) 960-6700 | Oversees regulations handed down by the state. | As needed. WDNR Tip Line (1.800.847.9367) | Suspected violations pertaining to recreational activity, including fishing, boating safety, ordinance violations, etc. |
| **Golden Sands Resource Conservation & Development Council** | Staff (715) 343-6215 | Nonprofit organization that covers central WI | As needed. | Provides information on conservation and natural resource preservation |
| **Wisconsin Lakes** | General staff (800.542.5253) | Facilitates education, networking and assistance on all matters involving WI lakes. | As needed. May check website (www.wisconsinlakes.org) often for updates. | TLC members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc. |

## Management Goal 4: Enhance Fishery Resource

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|---|---|
| **Management Action:** | Maintain communication with WDNR fisheries biologist and complete habitat improvement activities |
| **Timeframe:** | Ongoing |
| **Potential Grant:** | WDNR Healthy Lakes & Rivers Grants |
| **Facilitator:** | TLC Board |
| **Description:** | Twin Lakes are an important resource for the local community. The TLC would like to ensure the lakes contain a viable fishery into the future.<br><br>Lake stakeholders realize the complexities and capabilities of the Twin Lakes ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation, shore-fishing, or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail.<br><br>The TLC facilitators for this action will maintain communication with the WDNR fisheries biologist on all matters relating to the fishery of Twin Lakes. The TLC would like to support fishery habitat enhancement projects, encourage carp harvest and removal, and ensure a healthy fishery in the lake.<br><br>The installation of fish habitat structures in Twin Lakes is an activity that could be included in a Healthy Lakes & Rivers Grant application. More information on this program is included in the Shoreland Condition section (3.3).<br><br>The TLC, through partnering with WDNR fisheries staff, has a project underway to utilize some of the many dead standing trees around the margins to the lake to construct fish cribs in the lake and to place tree drops around the margins of the lake. These activities are carefully coordinated and planned with assistance from TLC representatives and WDNR fisheries staff. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Monitor carp population in Twin Lakes and encourage their removal. |
|---|---|
| **Timeframe:** | Ongoing |
| **Facilitator:** | TLC Board |
| **Description:** | As discussed in the Water Quality, Aquatic Plants, and Fisheries Sections of the report, common carp are believed to be negatively impacting the ecology of Twin Lakes. A 2015 WDNR fisheries survey of Twin Lakes indicated a high carp population with abundant 9–11-inch fish. Carp appeared to be a problem at that time and WDNR recommended carp management although no management efforts were undertaken. As this project was being completed, the WDNR conducted a fisheries survey during 2022 to reassess the carp population and the fishery as a whole. The 2022 survey indicated an improved fishery condition with many panfish and a lower abundance of carp (Appendix E). Carp are now considered ‘present’ in the system but do not appear to be ‘abundant’ as they were in the past. Reasons for the shift in the fisheries population are theorized to be influenced by the recent high water levels in the lakes that resulted in a great amount of additional fish habitat through submerged trees around the margins of the lake. The additional habitat may have aided the population increase in panfish in the lake which in turn, resulted in a greater deal of panfish predation on carp eggs. As this newer information became available, the TLC and lake managers shifted the original intent of this management action from ‘controlling and reducing the carp population’ to monitoring carp and encouraging their removal through a local volunteer-based effort.<br><br>The TLC will maintain a line of communication with the local WDNR fisheries biologist to understand the latest fisheries survey information and when the next surveys may take place. The TLC will inform WDNR fisheries managers if they believe the carp population is increasing in the lake such that a new carp survey population estimate might be appropriate or if the WDNR believes carp management needs to be considered.<br><br>The TLC will continue with the collection of supporting environmental data parameters such as Secchi disk transparency, water quality sampling, and/or aquatic plant monitoring that may indicate changes to the lake’s water quality that may be tied to the carp population in the lake. This activity also supports the TLC’s Management Goal 1 above.<br><br>The TLC will encourage the removal of carp through local anglers or bowfishing. The TLC has included information about carp harvesting on their website including a call for volunteers to participate in the effort to remove carp from the lake. |
| **Action Steps:** | |
| 1. | See description above. |

# 6.0 METHODS

## Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Twin Lakes such as elevated phosphorus levels, anaerobic conditions, etc. Water quality was monitored at the deepest point in the 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) in West Twin Lake and at the subsurface in East Twin Lake. 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 Nitrogen | ● | ● | | | ● | ● | | | | | ● | ● |
| True Color | ● | | | | ● | | | | | | | |
| Laboratory Conductivity | ● | ● | | | ● | ● | | | | | | |
| Laboratory pH | ● | ● | | | ● | ● | | | | | | |
| Total Alkalinity | ● | ● | | | ● | ● | | | | | | |
| Hardness | ● | | | | ● | | | | | | | |
| Total Suspended Solids | ● | ● | | | ● | ● | | | ● | ● | | |
| Calcium | ● | | | | ● | | | | | | | |

In addition, during each sampling event Secchi disk transparency was recorded and a temperature and dissolved oxygen profile was completed using a HQ30d with a LDO probe.

## Watershed Analysis

The watershed analysis began with an accurate delineation of Twin Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – USGS, 2019) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska & Kreider 2003)

## Aquatic Vegetation

### *Curly-leaf Pondweed Survey*

Surveys of curly-leaf pondweed were completed on Twin Lakes during a June 25, 2020 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

## Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Twin Lakes to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on August 6 & 9, 2019 by WDNR field staff. A point spacing of 20 – meters resolution on West Twin Lake and 25-meter spacing on East Twin Lake was used resulting in 151 and 116 sampling points respectively.

### Community Mapping

During an August 27, 2020 survey by Onterra ecologists, the aquatic vegetation community types within Twin Lakes (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

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

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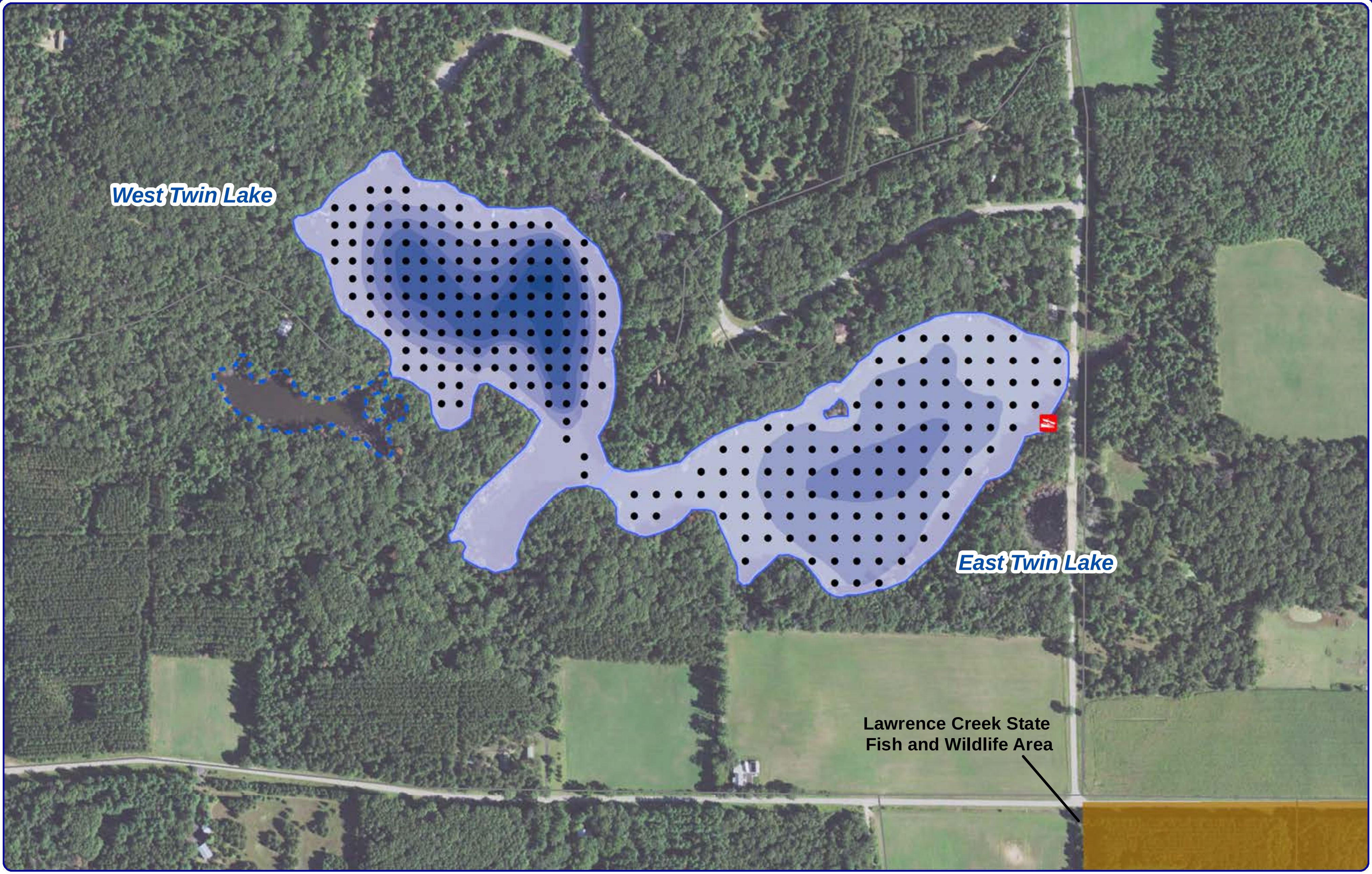


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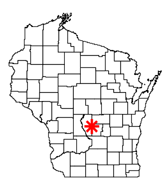
Sources:
Hydro: WDNR
Ortho: NAIP 2017
PI Data: WDNR 2019
**Map Date:** December 5th, 2019 AMS



Project Location in Wisconsin

## Legend

Twin Lakes ~ 32.9 acres
*WDNR Definition*

Public Access

West Twin Lake Point-Intercept Sample Location (WDNR 2019)
*20 meter points, 151 points*

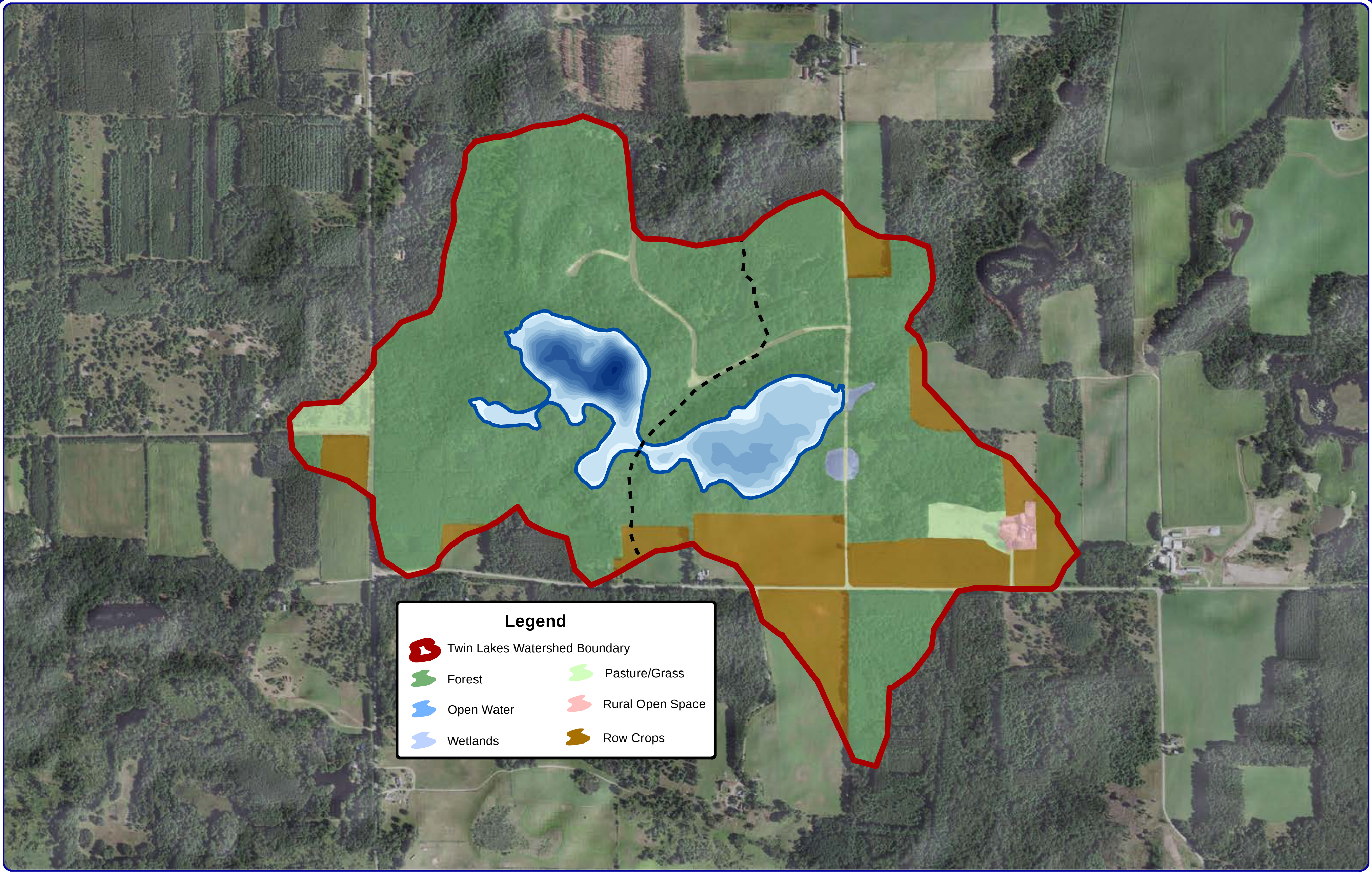
East Twin Lake Point-Intercept Sample Location (WDNR 2019)
*25 meter points, 116 points*

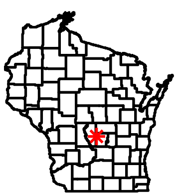
Map 1

Twin Lakes

Marquette County, Wisconsin

**Project Location & Lake Boundaries**



Project Location in Wisconsin

Rural Residential

**Legend**

- Twin Lakes Watershed Boundary
- Forest
- Non-Forested Wetlands
- Rural Open Space
- Rural Residential
- Pasture/Grass
- Row Crop Agriculture

# Map 2
# Twin Lakes
Marquette County, Wisconsin
## Watershed Boundaries & Land Cover Types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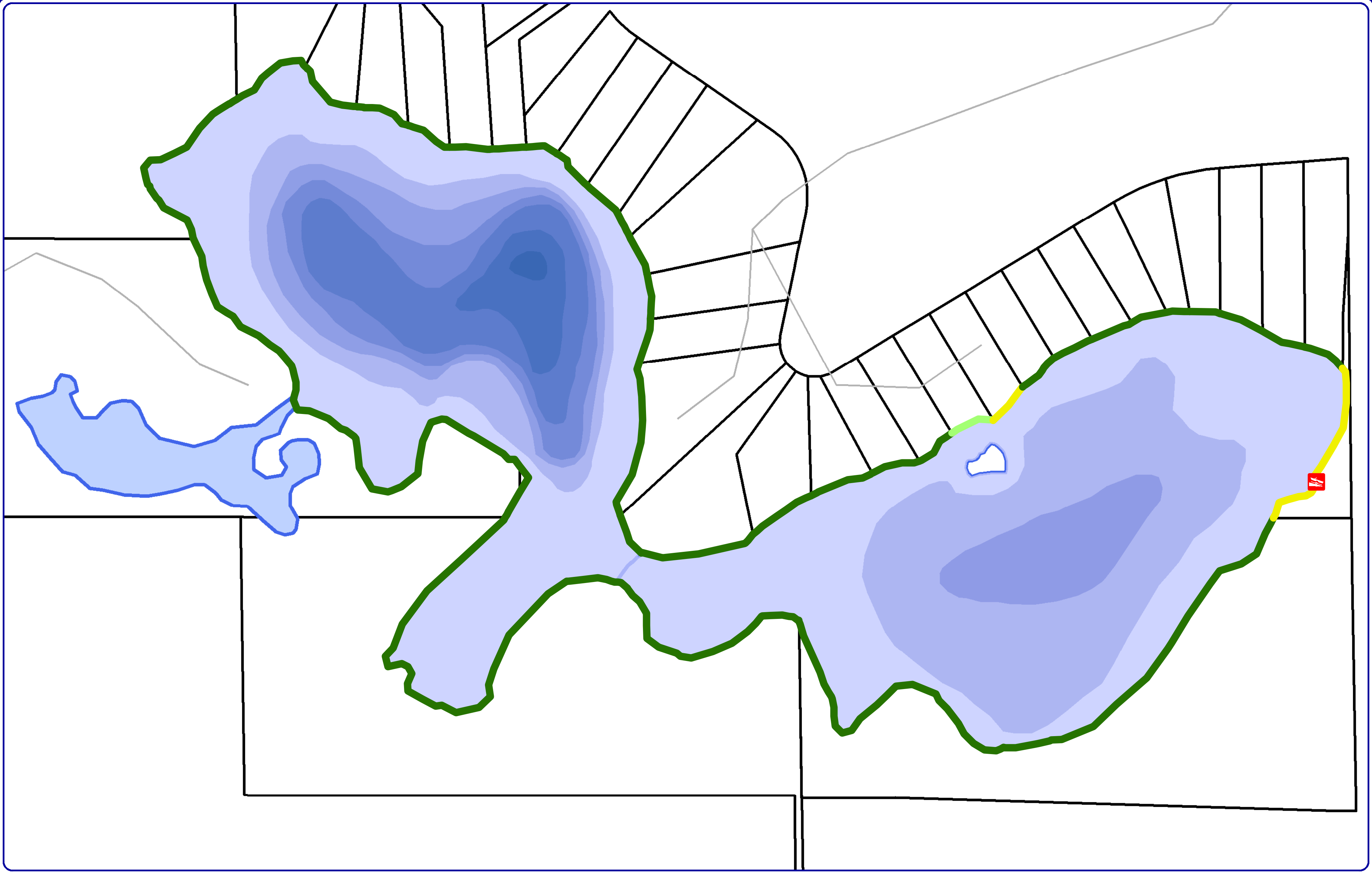
**Sources:**
Hydro: Onterra 2020
Orthophotography: NAIP 2020
Land Cover: NLCD, 2016
Watershed Boundaries: Onterra, 2020
Map date: April 29, 2021 BTB
*Filename:Map2_TwinLakes_WS.mxd*





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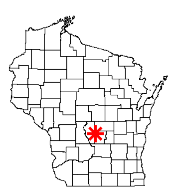
**Sources**
Hydro: WDNR
Shoreland Assessment: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 11, 2020 AMS

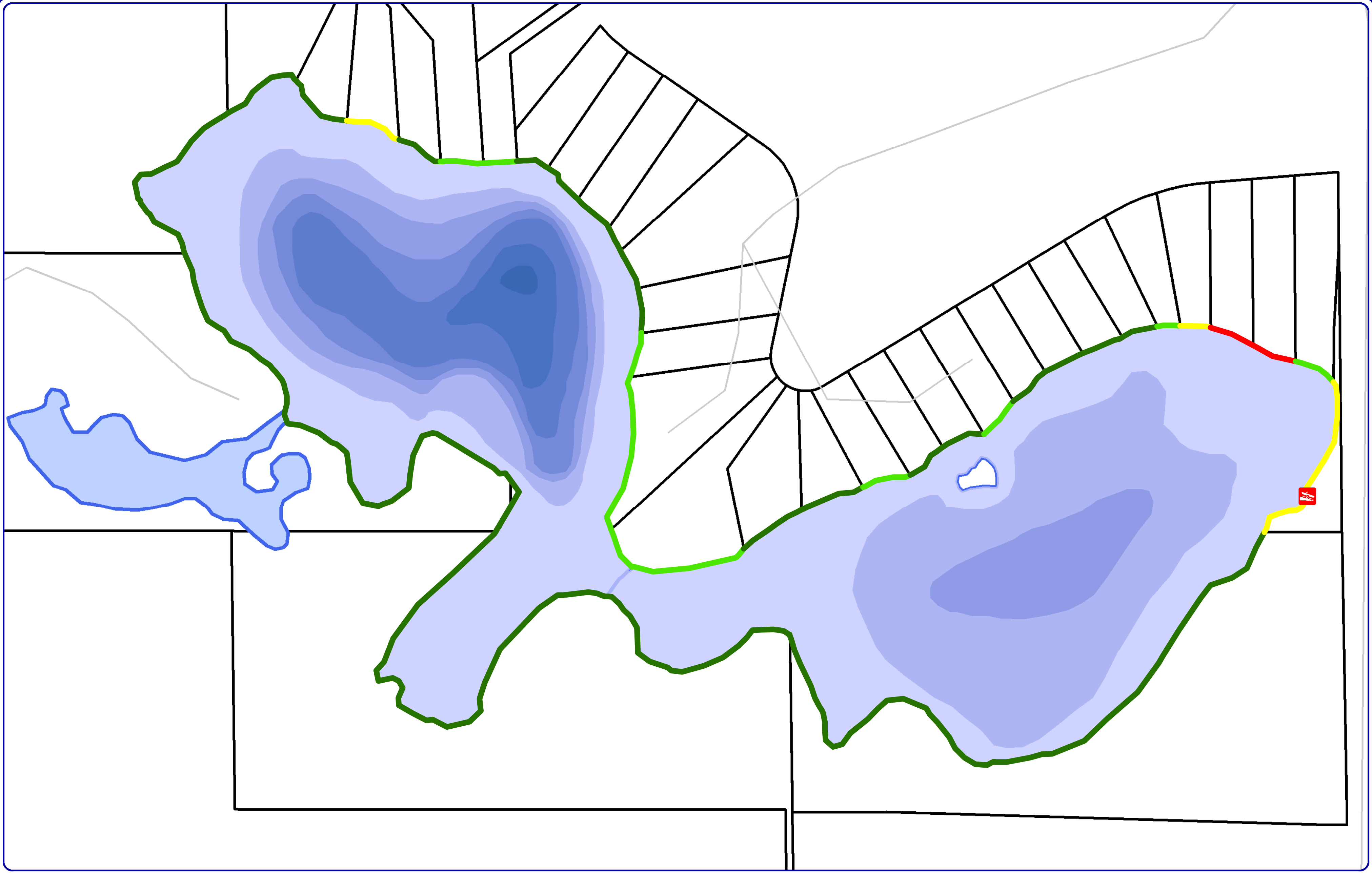


Project Location in Wisconsin

## Legend

81 - 100
61 - 80
41 - 60
21 - 40
0 - 20
Local Road
Shoreland Parcels

Map 3
Twin Lakes
Marquette County, Wisconsin
**2020 Parcel Canopy Cover**



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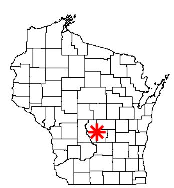
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 14, 2020 AMS

Project Location in Wisconsin

**Legend**

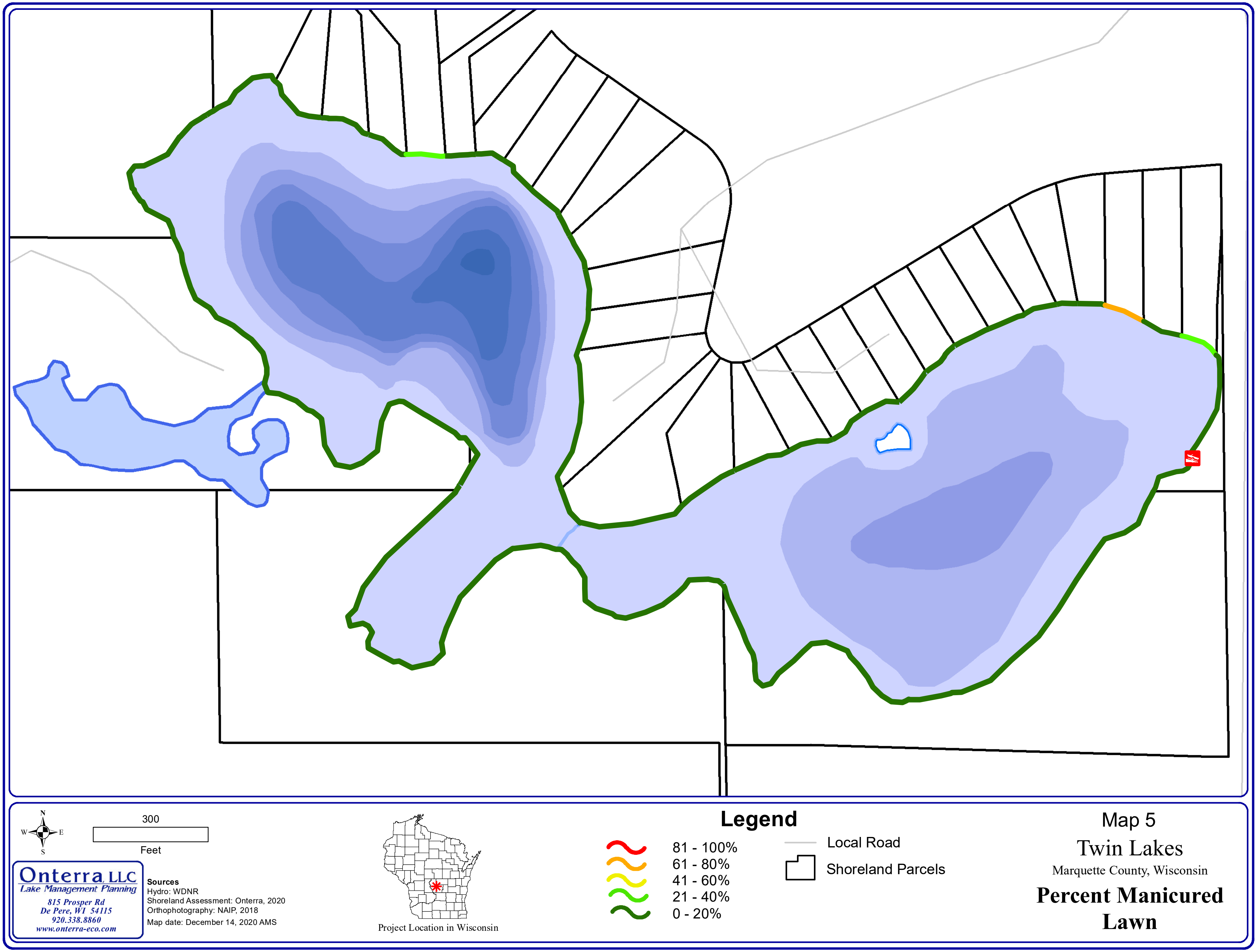
- 81 - 100
- 61 - 80
- 41 - 60
- 21 - 40
- 0 - 20
- Local Road
- Shoreland Parcels

Map 4

Twin Lakes

Marquette County, Wisconsin

**2020 Parcel Shrub-Herbaceous Cover**



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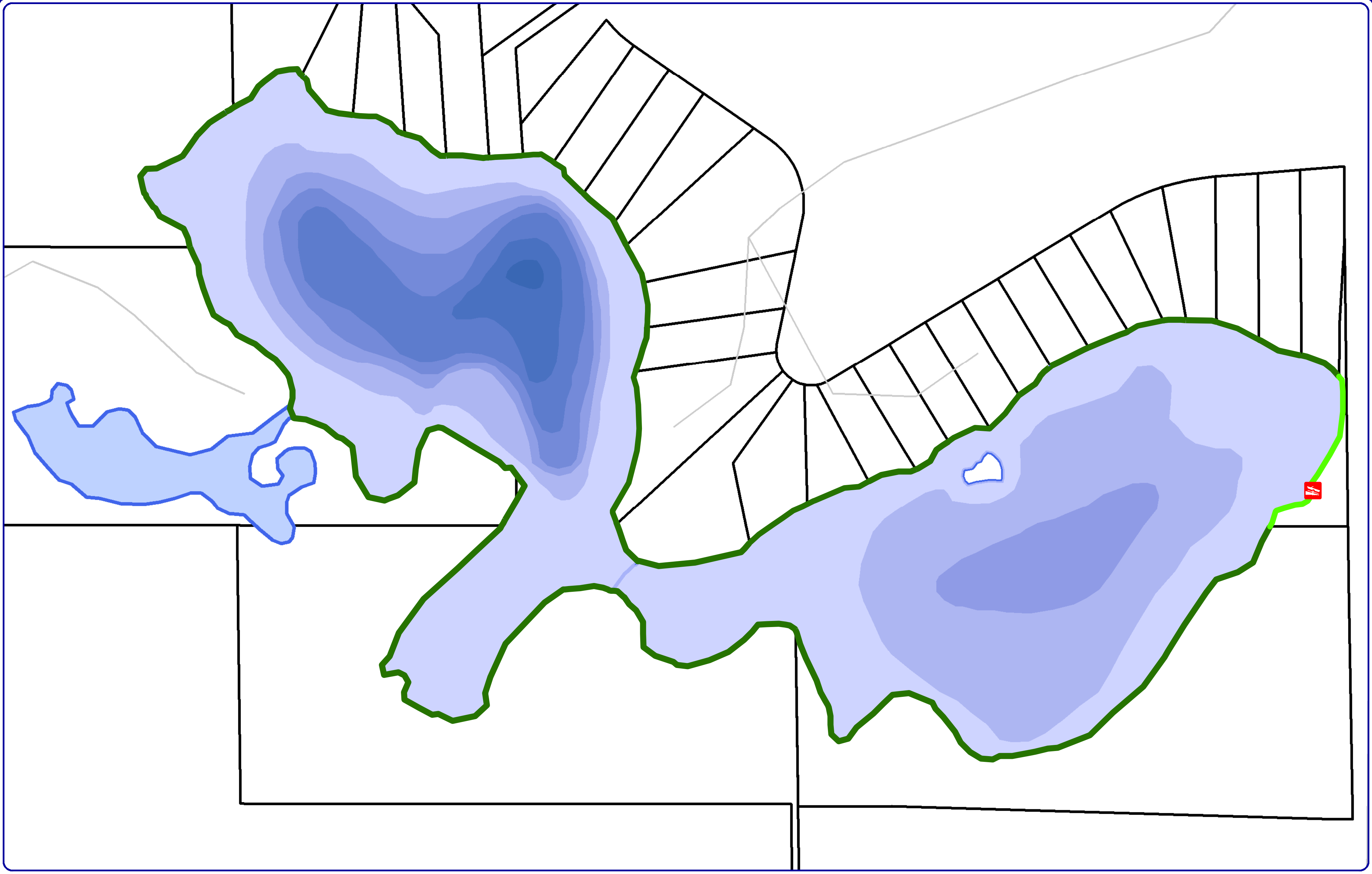
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 14, 2020 AMS
Project Location in Wisconsin
Legend
81 - 100%
61 - 80%
41 - 60%
21 - 40%
0 - 20%
Local Road
Shoreland Parcels
Map 5
Twin Lakes
Marquette County, Wisconsin
Percent Manicured Lawn



Map 6
Twin Lakes
Marquette County, Wisconsin
**Percent Impervious Surfaces**

## Legend

- 81 - 100%
- 61 - 80%
- 41 - 60%
- 21 - 40%
- 0 - 20%
- Local Road
- Shoreland Parcels

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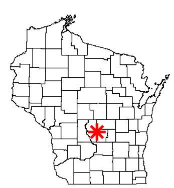

Project Location in Wisconsin

**Sources**
Hydro: WDNR
Shoreland Assessment: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 14, 2020 AMS

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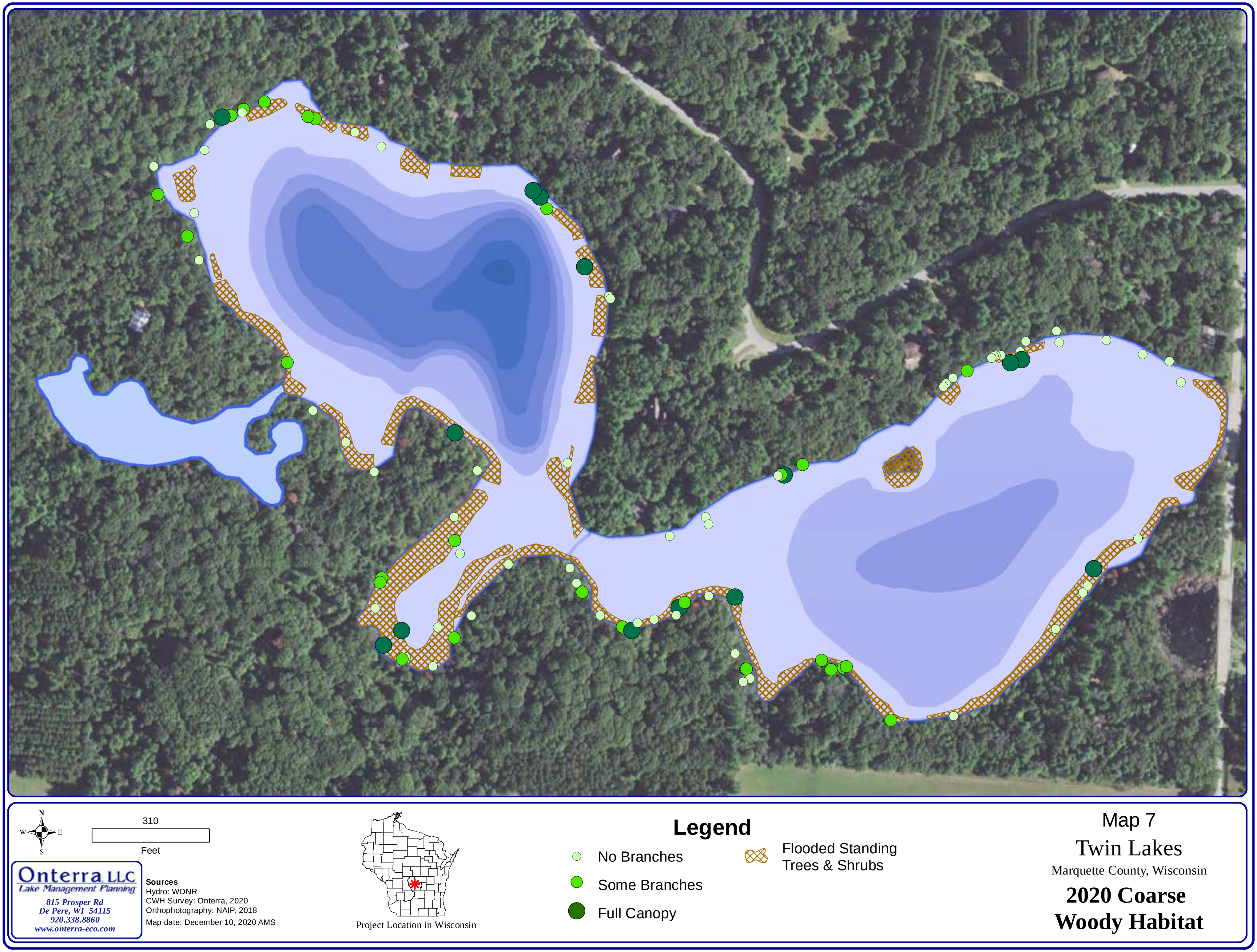

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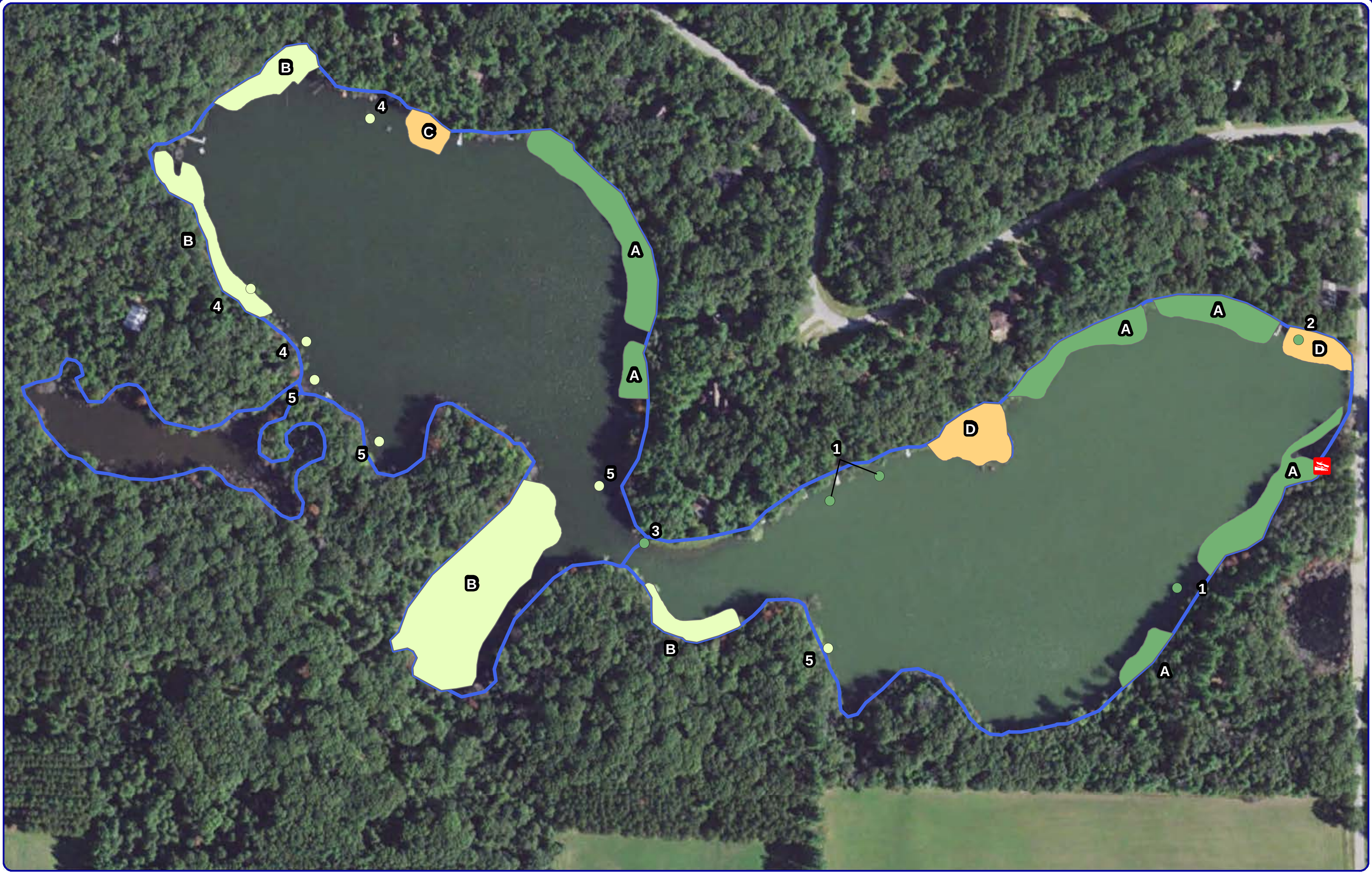
Sources
Hydro: WDNR
CWH Survey: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 10, 2020 AMS
Project Location in Wisconsin
Legend
No Branches
Some Branches
Full Canopy
Flooded Standing Trees & Shrubs
Map 7
Twin Lakes
Marquette County, Wisconsin
2020 Coarse Woody Habitat



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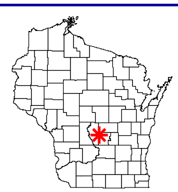
**Sources**
Hydro: WDNR
Aquatic Plants: Onterra, 2020
Orthophotography: NAIP, 2020
**Map date:** November 25, 2020 AMS



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

Map 8
Twin Lakes
Marquette County, Wisconsin

# 2020 Emergent & Floating-Leaf Aquatic Plant Communities

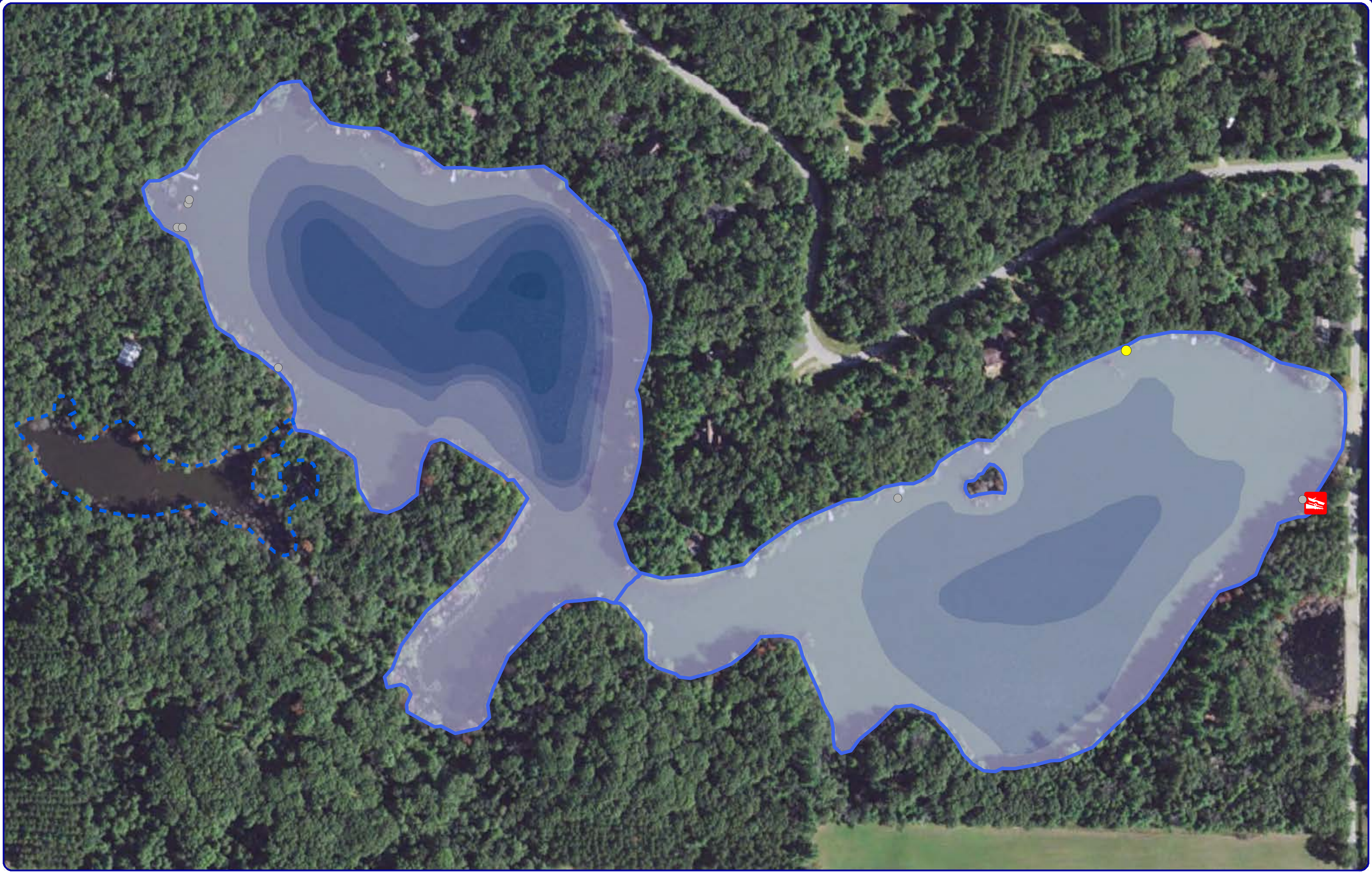
# Twin Lakes 2020 Emergent & Floating-Leaf Plant Species

## Corresponding Community Polygons and Points are displayed on Twin Lake - Map 8

| Large Plant Community (Polygons) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Emergent** | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** | **Species 6** | **Species 7** | **Species 8** | **Acres** |
| A | **Hardstem bulrush** | | | | | | | | 2.61 |
| **Floating-leaf** | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** | **Species 6** | **Species 7** | **Species 8** | **Acres** |
| B | **Water smartweed** | | | | | | | | 3.10 |
| **Floating-leaf & Emergent** | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** | **Species 6** | **Species 7** | **Species 8** | **Acres** |
| C | **Water smartweed** | **Hardstem bulrush** | | | | | | | 0.17 |
| D | **Hardstem bulrush** | **Water smartweed** | | | | | | | 0.70 |

| Small Plant Community (Points) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Emergent** | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** | **Species 6** | **Species 7** | **Species 8** |
| 1 | **Hardstem bulrush** | | | | | | | |
| 2 | **Prairie cordgrass** | | | | | | | |
| 3 | **Arctic rush** | | | | | | | |
| **Floating-leaf** | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** | **Species 6** | **Species 7** | **Species 8** |
| 4 | **Spatterdock** | | | | | | | |
| 5 | **Water smartweed** | | | | | | | |
| **Floating-leaf & Emergent** | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** | **Species 6** | **Species 7** | **Species 8** |
| | | | | | | | | |

*Species are listed in order of dominance within the community; Scientifc names can be found in the species list in Table 3.4-2*



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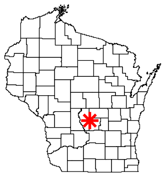
**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2020
Orthophotography: NAIP, 2018
**Map Date:** June 29, 2020 JMB
Filename:TwinLakes_CLP_June20.mxd



Project Location in Wisconsin

**Legend**

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

Map 9
Twin Lakes
Marquette County, Wisconsin

**June 2020 CLP Survey Results**

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Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2020
Orthophtography: NAIP, 2018
**Map Date:** October 23, 2020 JMB
Filename:TwinLakes_EWM_Sept20.mxd

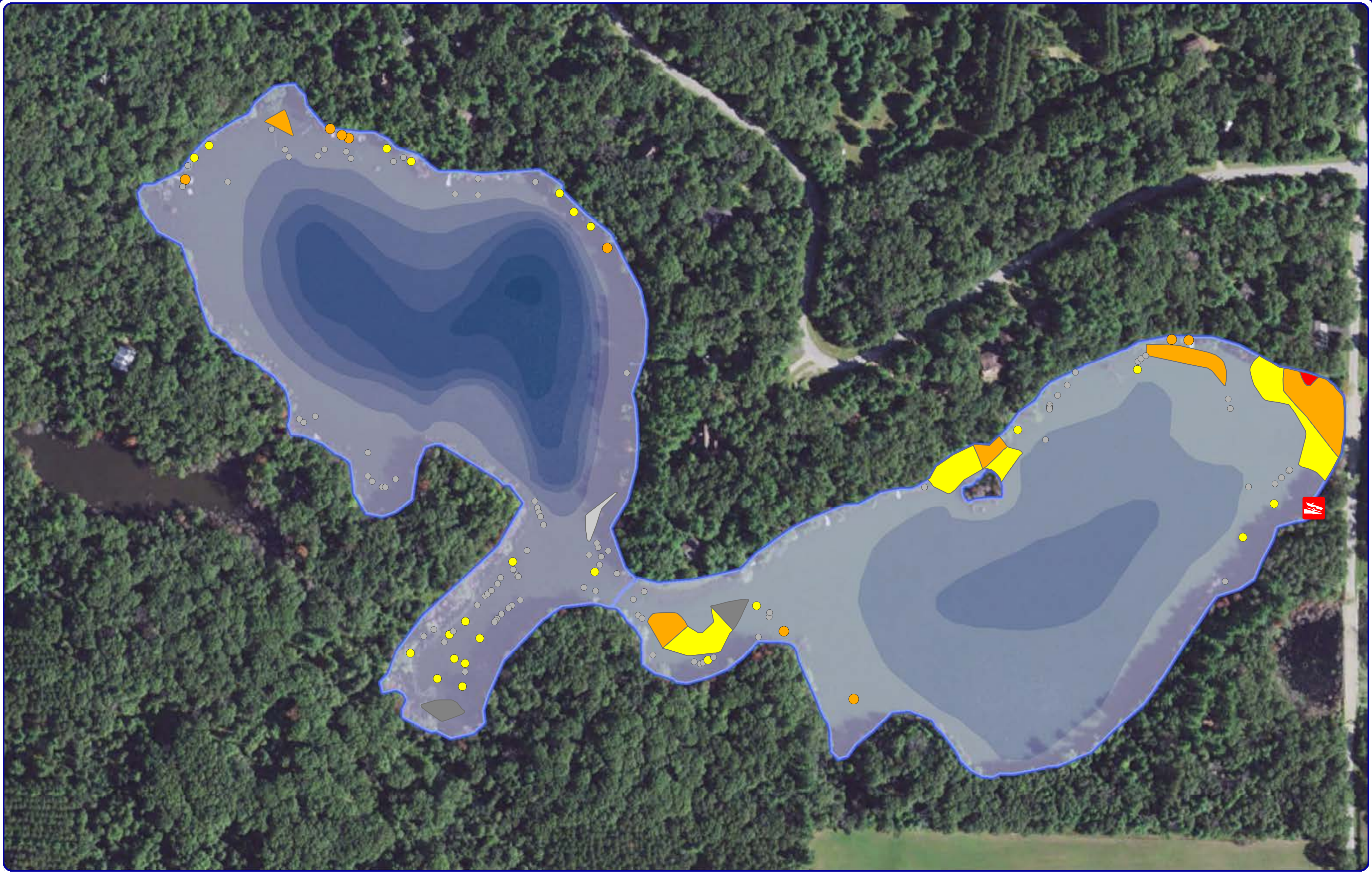
Project Location in Wisconsin

**Legend**

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

Map 10
Twin Lakes
Marquette County, Wisconsin

**September 2020 EWM Survey Results**



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**Sources:**
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2022
Orthophotography: NAIP, 2020
**Map Date:** September 30, 2022 AMS

Project Location in Wisconsin

**Legend**

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

Map 11
Twin Lakes
Marquette County, Wisconsin

**September 2022 EWM Survey Results**