Auburn Lake

Fond du Lac County, Wisconsin

Comprehensive Management Plan

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Created by: Todd Hanke, Josephine Barlament, Andrew Senderhauf, Eddie Heath, and Tim Hoyman
Onterra, LLC
De Pere, WI

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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:

Auburn Lake Planning Committee

Bob Albriet	Ken Depperman	Mary Kay Depperman
Katrina Hanson	Kevin Hanson	Troy Hanson
Mary Hayes	Kevin Kulhanek	Greg Mueller
Jerry Zier		

Wisconsin Department of Natural Resources

Mary Gansberg

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1.0 INTRODUCTION

Auburn Lake is an approximate 90-acre, meso-eutrophic deep lowland drainage lake in Fond du Lac County, Wisconsin (Map 1). The lake is comprised of two primary basins connected via a narrow channel. The northern basin has a maximum depth of 29 feet while the southern basin has a maximum depth of 26 feet. The lake's watershed encompasses approximately 4,261 acres (6.7 square miles) within the East-West Branch Milwaukee River Watershed, the majority of which is comprised of intact forested wetlands and upland forests. The lake is fed and drained via Auburn Lake Creek.

Lake at a Glance - Auburn Lake

Morphometry	
Lake Type	Deep Lowland Drainage
Surface Area (Acres)	90
Max Depth (feet)	29
Mean Depth (feet)	12
Perimeter (Miles)	2.3
Shoreline Complexity	3.0
Watershed Area (Acres)	4,261
Watershed to Lake Area Ratio	46:1
Water Quality	
Trophic State	Meso-eutrophic
Limiting Nutrient	Phosphorus
Avg Summer Phosphous (μg/L)	22.9
Avg Summer Chlorophyll-α (μg/L)	7.8
Avg Summer Secchi Depth (ft)	7.0
Summer pH	8.5
Alkalinity (mg/L as $CaCO_3$)	239
Vegetation (2008-2021)	
Number of Native Species	33
NHI-Listed Species	0
Exotic Species	5
Average Conservatism	5.9
Floristic Quality	25.7
Simpson's Diversity (1-D)	0.89

Descriptions of these parameters can be found within each respective section of this report
NHI = WDNR Natural Heritage Inventory Program

The Town of Auburn and the Auburn Lake Homeowner's Association are the two primary organizations leading management and conservation efforts for Auburn Lake. In an effort to conserve and enhance the Auburn Lake ecosystem for future generations, the Town of Auburn and other proactive lake stakeholders decided to initiate the development of the first comprehensive management plan for Auburn Lake. In early 2021, the Town of Auburn was awarded a Wisconsin Department of Natural Resources (WDNR) Comprehensive Planning for Lakes and Watersheds grant to complete the first management plan for Auburn Lake.

The management plan development included a comprehensive assessment of Auburn Lake through baseline studies completed by Onterra over the course of 2021 and early 2022. These baseline studies were designed to evaluate the lake's water quality, watershed, and aquatic plant community. In addition, sociological data were collected from Auburn Lake property owners through the distribution of an anonymous stakeholder survey.

The data collected as part of this project in combination with available historical data were used to determine the current ecological state of Auburn Lake and aid in the development of management goals to conserve and enhance this important natural resource. A detailed discussion of these study results can be found in sections 2.0 and 3.0 of this report. The data show that water quality for Auburn Lake is overall good; however, there are indicators within the aquatic plant community data that nutrient input to the lake has increased in recent years. This increase in nutrient input is believed to be largely driven by record rainfall that occurred in recent years, flushing nutrients from the extensive forested wetland complex that buffers the majority of Auburn Lake Creek.

The water quality parameters assessed indicate good conditions for a deep lowland drainage lake in Wisconsin, and analysis of a sediment core collected from the lake indicate that nutrient levels (phosphorus) are higher at present when compared to levels 150-200 years ago. Development within Auburn Lake's watershed remains minimal, with most of the land cover comprised of intact wetlands and upland forests. However, there are some areas of agriculture within the watershed and areas of urban development near the lake that pose concern for nutrient and runoff of other pollutants.

The lake supports a diverse native aquatic plant community with 33 native aquatic plant species documented in surveys completed since 2008. During the surveys completed in 2021, 31 native aquatic plant species were identified, of which coontail, flat-stem pondweed, muskgrasses, and northern watermilfoil were the most frequently encountered. The lake was also found to support approximately 22 acres of emergent and floating-leaved aquatic plant communities in shallow, near-shore areas around the lake. The lake also supports moderate levels of the invasive aquatic plant species Eurasian watermilfoil and curly-leaf pondweed.

Following the completion of the studies on Auburn Lake, Onterra ecologists worked with a planning committee comprised of Auburn Lake stakeholder representatives to develop short- and long-term management goals using the information collected from the lake and its stakeholders as a guide. The management goals created during the planning process are included in the Implementation Plan section (5.0) of this report.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa.

The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

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

On June 6, 2021, a project kick-off meeting was held at the Town of Auburn Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact to Auburn Lake stakeholders. The approximately 20+ attendees observed a presentation given by Todd Hanke and Brenton Butterfield, both aquatic ecologists with Onterra. Their presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question-and-answer session.

Project Wrap-up Meeting

A project Wrap-Up meeting is tentatively planned to occur in fall 2023. This meeting will be open to the public. An Onterra ecologist will present at the meeting with the materials focusing on the overall results of the project and the Implementation Plan that was developed. Attendees will have an opportunity to ask questions about the lake or the Plan that was created.

Committee Level Meetings

Planning Committee Meeting I

On April 21, 2022, Onterra staff met with volunteer members from around Auburn Lake comprising the Planning Committee for this project. During this approximate two and a half hour meeting, Onterra presented the results of the studies that have taken place and answered questions about Auburn Lake. 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 April 28, 2022, Onterra staff met once again with members serving on the Planning Committee for this project. During this approximately two and a half hour meeting, discussions revolved around meeting the challenges facing Auburn Lake 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

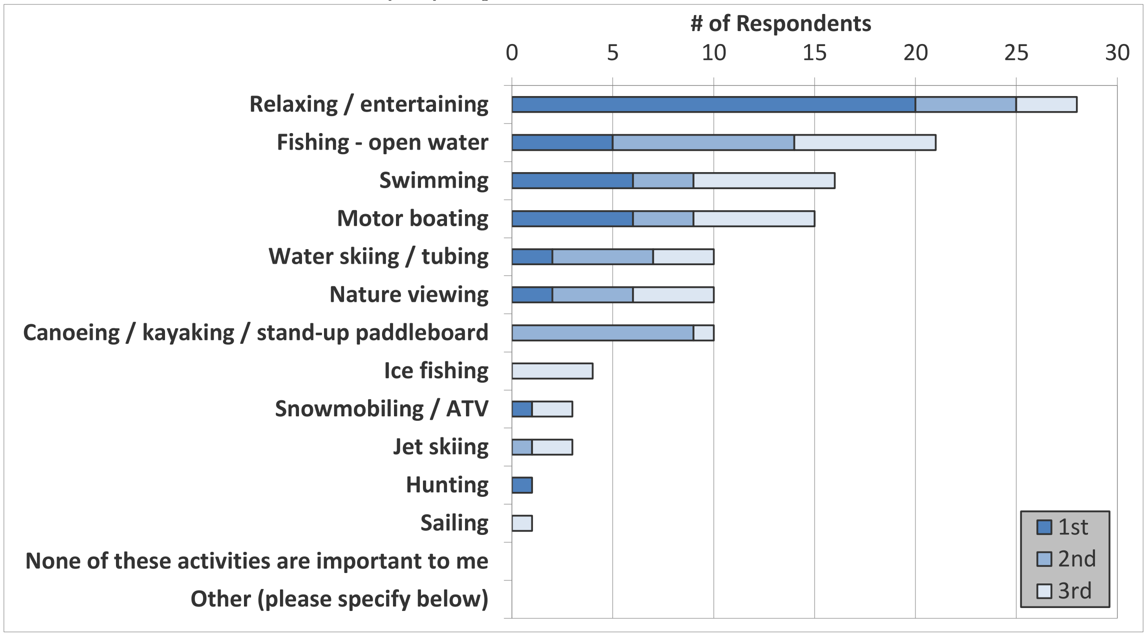
As a part of this project, a stakeholder survey was distributed to lake association members and riparian property owners around Auburn Lake. The survey was designed by Onterra staff and the ALA planning committee and reviewed by a WDNR social scientist. During November-December of 2021, the eight-page, 34-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 third-party for analysis.

Fifty-two percent (43) of the 82 surveys distributed were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. Therefore, the survey results represent the perceptions of the population that completed the survey and not necessarily the perceptions of the entire population the survey was distributed to. 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 in this section.

Based upon the results of the Stakeholder Survey, much was learned about the people who use and care for Auburn Lake. Fifty-eight percent of respondents indicated that they live on the lake year-round, while 26% visit on weekends or vacations, 14% are seasonal residents, and 2% have a rental property. Half of respondents have owned their property for over 25 years.

The following result sections (Water Quality, Watershed, Aquatic Plants, and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use a canoe, kayak, or stand-up paddleboard on Auburn Lake (Question 13). Motor boats, jet skis, and pontoons were also popular options. On a relatively small lake such as Auburn Lake, the importance of responsible boating activities is increased. The need for responsible boating increases even more during weekends, holidays, and during times of nice weather or good fishing conditions, due to increased traffic on the lake. Although boat traffic was listed as a factor potentially impacting Auburn Lake in a negative manner, it was ranked quite low on a list of stakeholder's top concerns regarding the lake (Question 16).

Question 8: Please rank up to three activities that are important reasons for owning your property on or near the lake.



Question 13: What types of watercraft do you currently use on the lake?

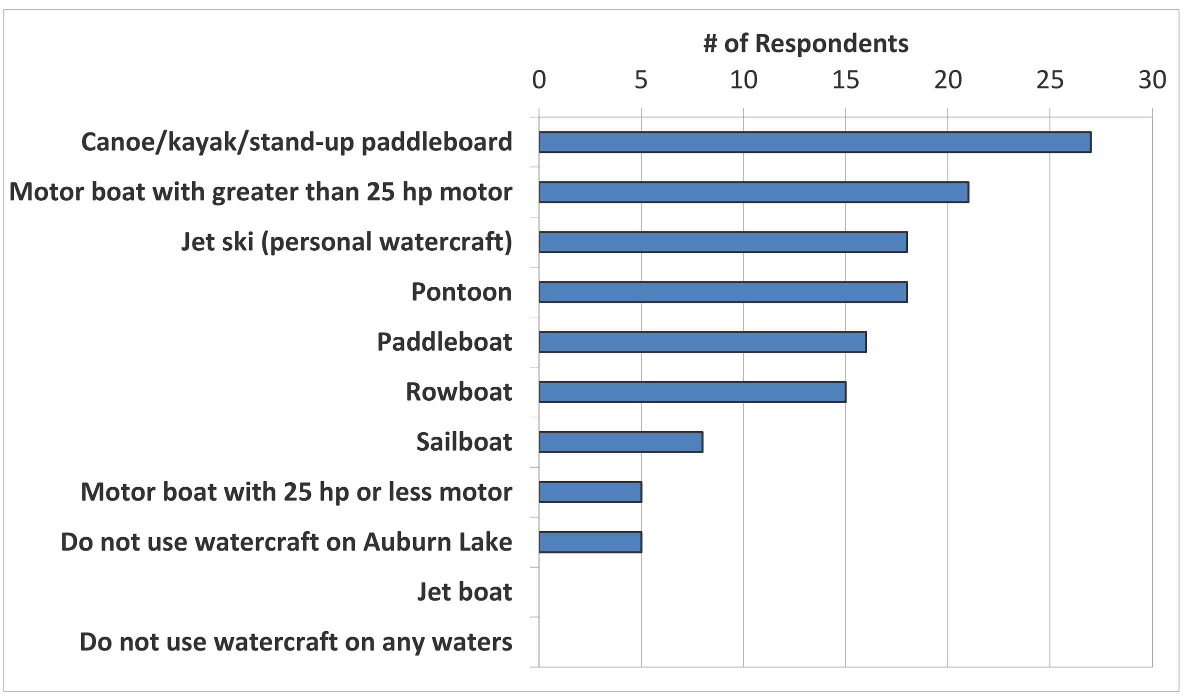
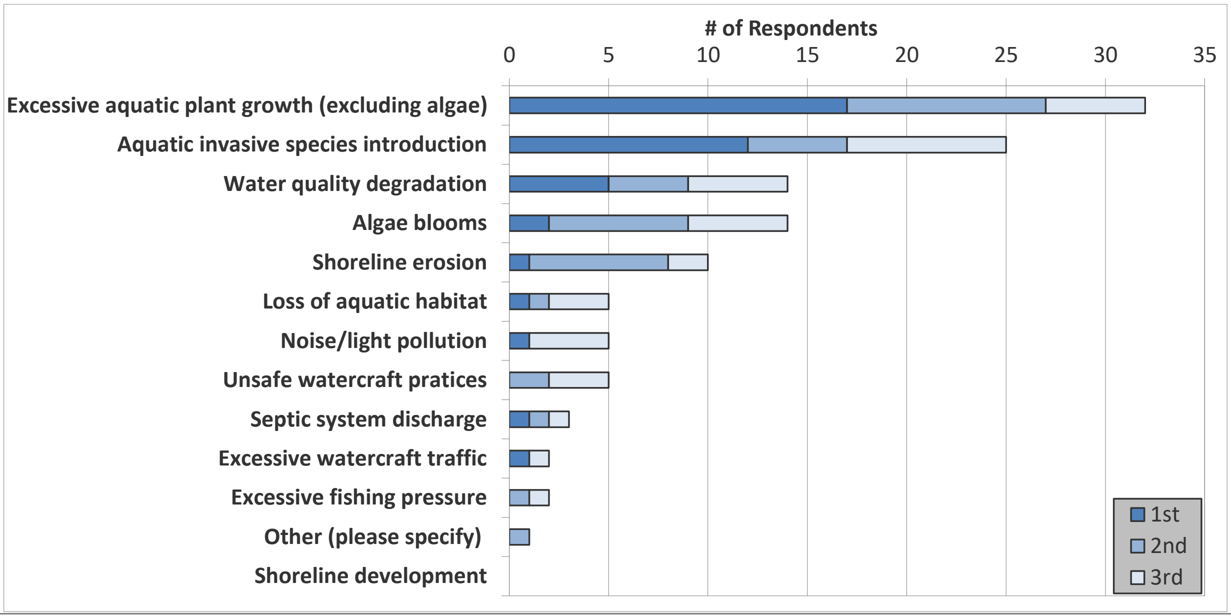


Figure 2.0-1. Select survey responses from the Auburn Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 16: Please rank your top three concerns regarding Auburn Lake.



Question 20: What impact, if any, do you believe each of the following practices have on the water quality of Auburn Lake?

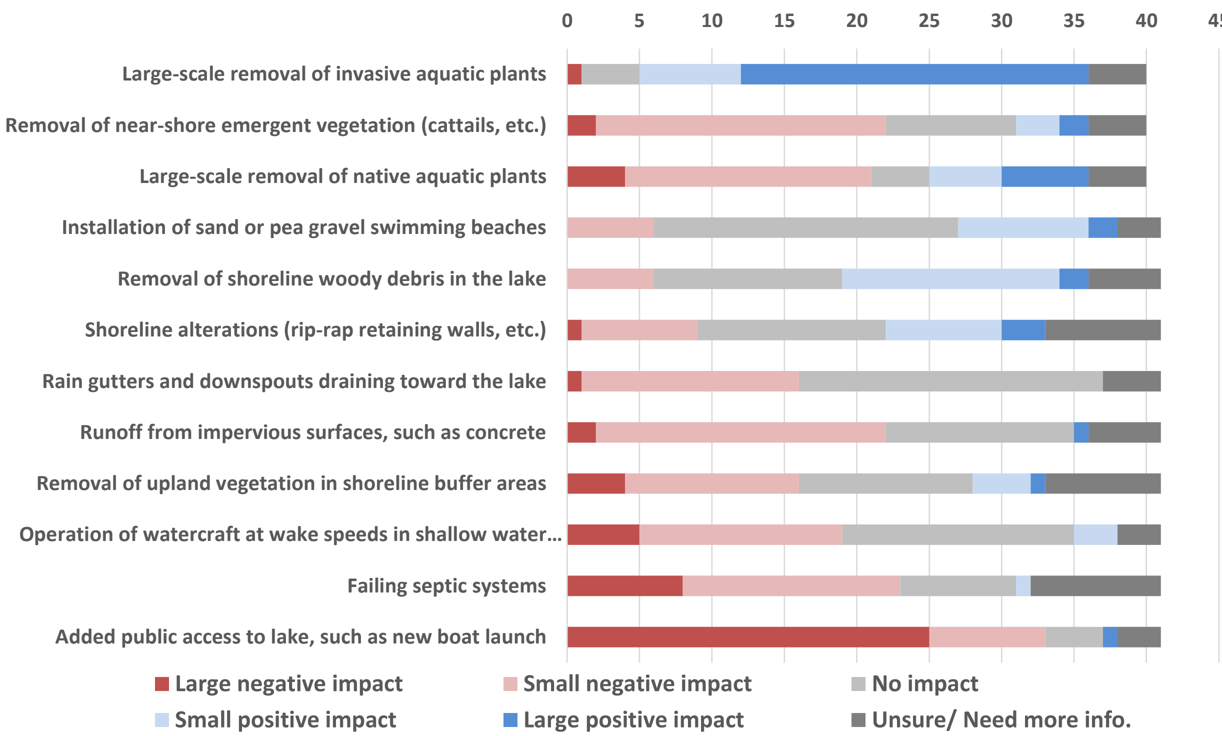


Figure 2.0-2. Select survey responses from the Auburn Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

In November 2022, a draft of the Implementation Plan was sent to the Planning Committee for review. The Committee submitted comments in February 2023 after which Onterra made edits and updates to the draft. An updated version of the Implementation Plan was issued to and accepted by the planning committee in April 2023.

The Official First Draft of the Management Plan was compiled in April 2023 and distributed to WDNR, County, ALHA, and other local project partners for official review. Comments were received from WDNR fisheries biologist - Ben Breaker and the local WDNR lakes coordinator – Mary Gansberg in May 2023. Onterra responded to the comments in August 2023 with additional communications into October 2023. A record of the agency comments and responses are included with the report in Appendix E. The final Plan was compiled in October 2023 and issued to the ALHA and WDNR.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

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

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality 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 Auburn Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Auburn Lake 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 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.

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Lake stratification occurs when temperature 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.

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.

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. Auburn Lake’s Osgood Index is 7.1, indicating the lake is considered dimictic. The temperature and dissolved oxygen data from 2021 indicate the lake remained stratified during the summer, confirming that Auburn Lake is dimictic.

To determine if internal nutrient loading occurs and has a detectable effect on Auburn Lake’s water quality, the dynamics of near-surface 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.

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.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2020 Consolidated Assessment and Listing Methodology* (WDNR 2019) 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 Auburn Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

Because of its depth, watershed size and hydrology, Auburn Lake is classified as a deep lowland drainage lake (category 5 on Figure 3.1-1).

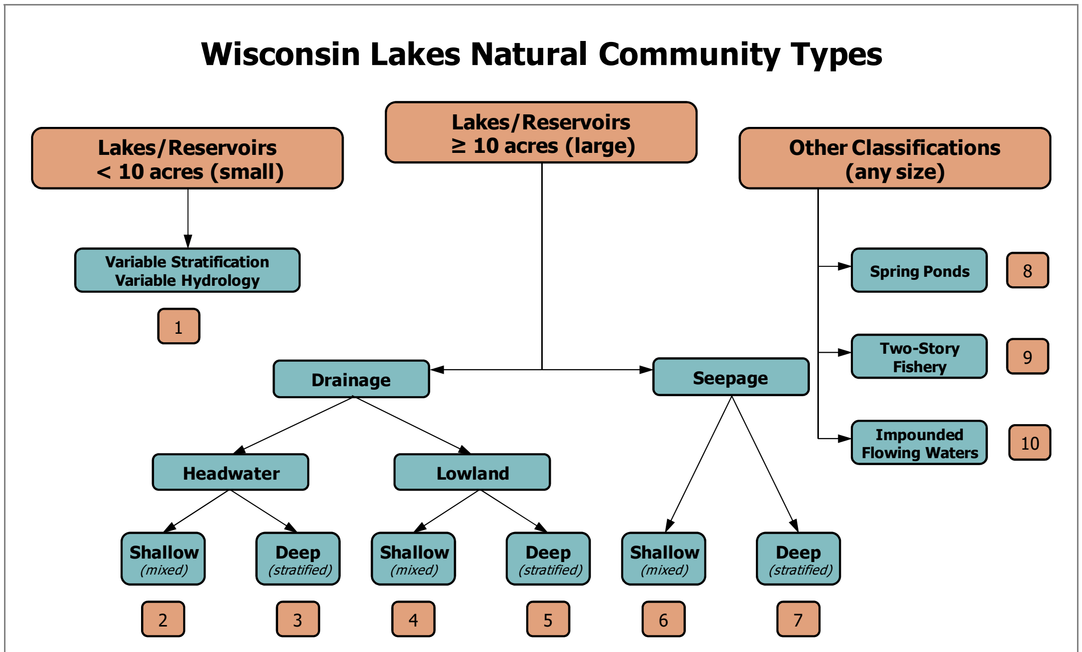


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

(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. Auburn Lake is within the Southeastern Wisconsin Till Plains ecoregion.

The Wisconsin 2020 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.

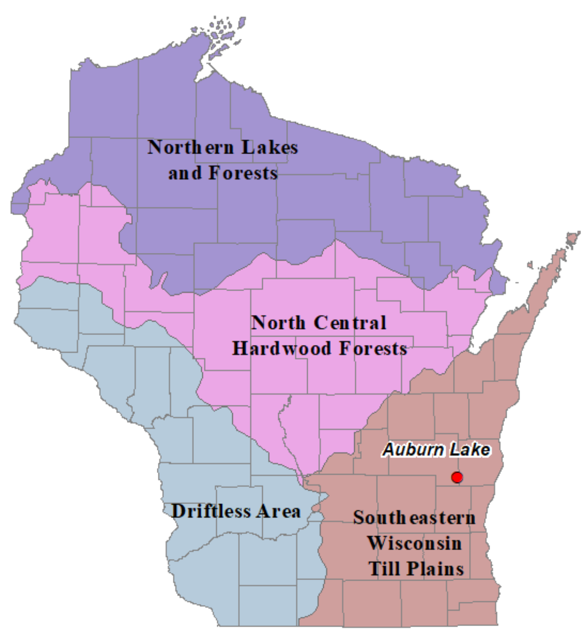


Figure 3.1-2. Location of Auburn Lake within the ecoregions of Wisconsin. After (Nichols 1999).

These data along with data corresponding to statewide natural lake means, historical, current, and average data from Auburn Lake is displayed in Figures 3.1-3 - 3.1-12. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Auburn Lake Water Quality Analysis

Limiting Plant Nutrient of Auburn Lake

Using midsummer nitrogen and phosphorus concentrations from Auburn Lake, a nitrogen:phosphorus ratio of 24:1 was calculated. This finding indicates that Auburn Lake is phosphorus limited, as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake, and increases in phosphorous will likely result in increased aquatic plant and algal production and lower water clarity.

Total Phosphorus

Near-surface total phosphorus (TP) data from Auburn Lake are available from 1990-1991, 1997, and 2018-2021 (Figure 3.1-3). The weighted average TP concentration from 1990-2021 was 24.0 µg/L, falling into the *good* category for Wisconsin's deep lowland drainage lakes (Figure 3.1-3). Auburn Lake's average summer TP concentrations are nearly equal to the median concentration for Wisconsin's deep lowland drainage lakes (23.0 µg/L) and slightly higher than the median TP concentration for lakes within the SWTP ecoregion (22.0 µg/L). The average summer TP concentration in 2021 was 22.9 µg/L, falling slightly below the long-term average. Years 2019-2021 showed similar levels of phosphorous when compared to 1990 and 1991 and slightly lower levels compared to 1997.

Phosphorous levels tend to be more dynamic from year to year in lowland drainage systems like Auburn Lake. These lake types commonly have expansive watersheds that contribute large influxes of water and nutrients following major precipitation events or rapid snowmelt. Given the limited data, it cannot be said if any trends (positive or negative) in TP concentration are occurring over time in Auburn Lake. However, as is discussed in the Aquatic Plant Section (Section 3.4), changes observed in the lake's aquatic plant community between 2008 and 2021 indicate that nutrient input to Auburn Lake may have increased over this period. It is believed these nutrients are being sequestered by and fueling increased growth of free-floating plants (i.e., coontail) rather than free-floating algae (phytoplankton). This is discussed further in Section 3.4.

Figure 3.1-4 displays available near-bottom total phosphorus concentrations and corresponding near-surface TP concentrations for Auburn Lake. As the summer progresses, near-bottom TP concentrations increase and are higher relative to those at the surface. These higher concentrations in near-bottom waters indicate that phosphorus is likely being released from bottom sediments during summer stratification when the hypolimnion is devoid of oxygen. In addition, phosphorus accumulates in the hypolimnion as dead algae and other organic matter sink to the bottom in summer. While this internal loading of phosphorus can become problematic in shallower lakes where it can be mobilized to the surface during summer mixing events, Auburn Lake is deep enough to maintain stratification and this phosphorus-rich water remains at the bottom where it is unavailable to algae at the surface. While internal nutrient loading occurs in Auburn Lake to a small extent, this phosphorus remains unavailable to phytoplankton at the surface in summer and does not appear to have a significant impact to the lake's water quality.

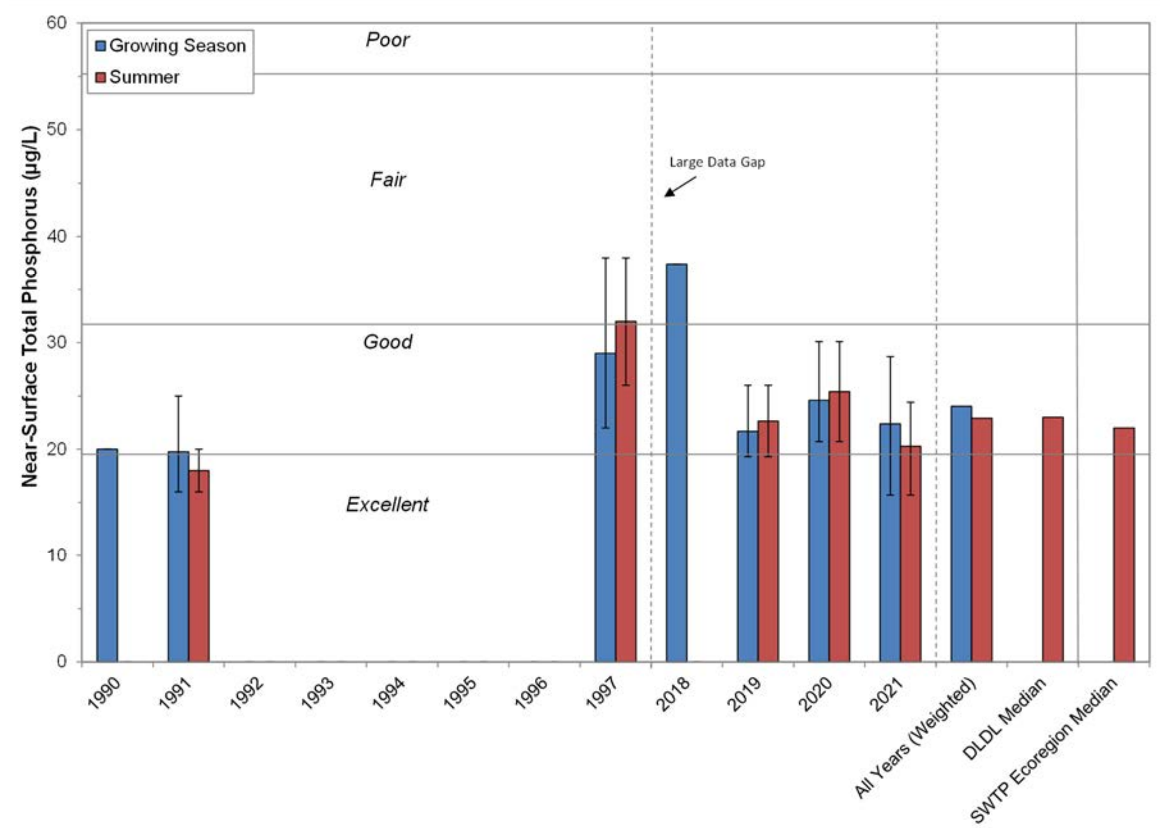


Figure 3.1-3. Auburn Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for statewide deep lowland drainage lakes (DLDL) and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes. Weighted average calculated using data from 1990-2021. Phosphorus criteria for Wisconsin DSL lakes (WisCALM) displayed at right. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Chlorophyll-α

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from Auburn Lake over the same time periods as TP concentrations (Figure 3.1-5). From 1990-2021, the weighted summer average chlorophyll-*a* concentration was 7.2 µg/L, falling into the *good* category for Wisconsin's deep lowland drainage lakes. The weighted average summer chlorophyll-*a* concentration is nearly identical to the median concentration for Wisconsin's deep lowland drainage lakes (7.0 µg/L) and slightly higher than the median concentration for all lake types within the SWTP ecoregion (5.3 µg/L). Like TP concentrations, chlorophyll-*a* concentrations in Auburn Lake appear to be variable from year to year, and likely correspond to changes in TP as well as other variables such as water temperature. Given the limited data, it cannot be said if any trends in chlorophyll-*a* concentrations are occurring over time in Auburn Lake.

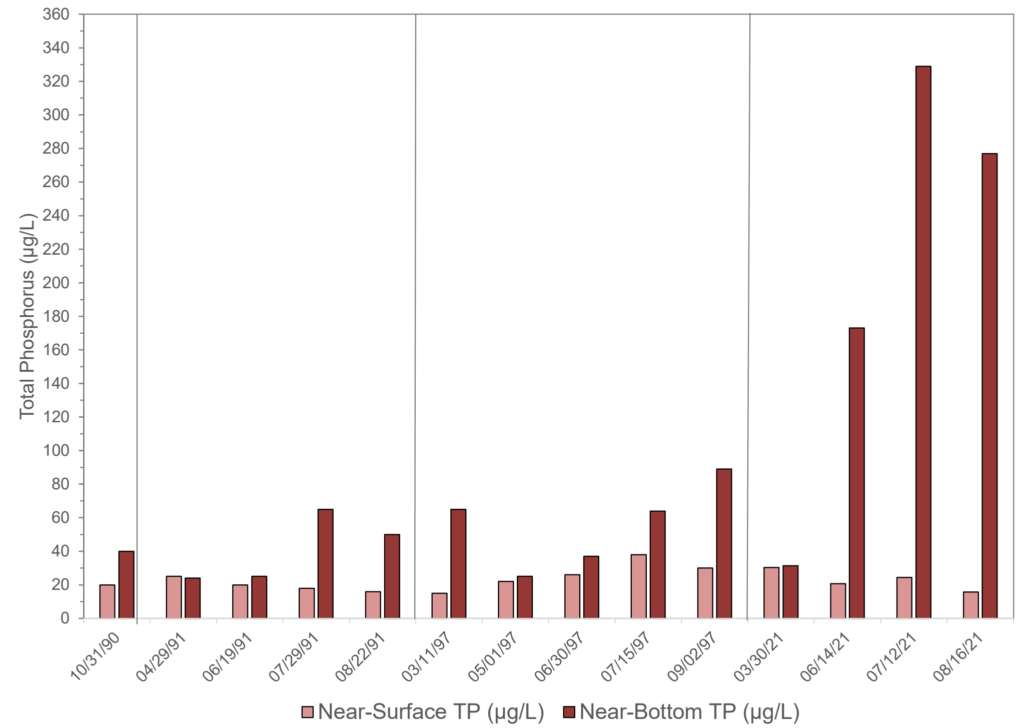


Figure 3.1-4. Auburn Lake available near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations. The data from 2021 indicate an accumulation of phosphorus in bottom waters during stratification, likely due to the release of phosphorus from bottom sediments during anoxia.

Water Clarity

Water clarity monitoring using Secchi disk depths has been conducted in Auburn Lake in 1990, 1991, 1997, and 2018-2021 (Figure 3.1-6). Average summer Secchi disk depths have ranged from 4.1 feet in 1991 to 9.4 feet in 2021. The weighted summer average Secchi disk depth over this period was 7.0 feet, falling into the *good* category for Wisconsin's deep lowland drainage lakes. Auburn Lake's average summer Secchi disk depth is lower than the median depth for Wisconsin's deep lowland drainage lakes (8.5 feet) and is slightly higher than the median depth for all lake types within the SWTP ecoregion (6.6 feet). Secchi disk depths in 2021 were the highest on record for Auburn Lake, with growing season and summer mean depths of 8.6 and 9.4 feet, respectively.

Given the limited historical Secchi disk transparency data, it cannot be determined if any trends in water clarity have been occurring over time in Auburn Lake. However, there has been an increasing trend in water clarity from 2019-2021 despite no corresponding decrease in chlorophyll-*a* concentrations. Average summer clarity has increased from 7.4, to 8.2, to 9.4 feet from 2019-2021, respectively. Given there is not a corresponding decrease in chlorophyll-*a* concentrations over this same period from 2019-2021, this increase in clarity is likely attributable to another factor that is influencing Auburn Lake's water clarity. This other factor is likely dissolved organic matter (DOM).

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. Precipitation events can have great influence on DOM levels within a lake. In years with lower precipitation levels, DOM levels tend to also be lower, resulting in less staining and higher water clarity. 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. Categorization of true color values range from clear to highly tea-colored. Auburn Lake had a color reading of 30 SU in 2021, indicating the lake's water is slightly tea-colored (Figure 3.1-7). While color measurements from previous years are not available, annual precipitation was over 10 inches lower in 2021 when compared to 2019 (Midwest Data Climate Center 2022). This decline in precipitation likely resulted in less DOM and clearer water in 2021.

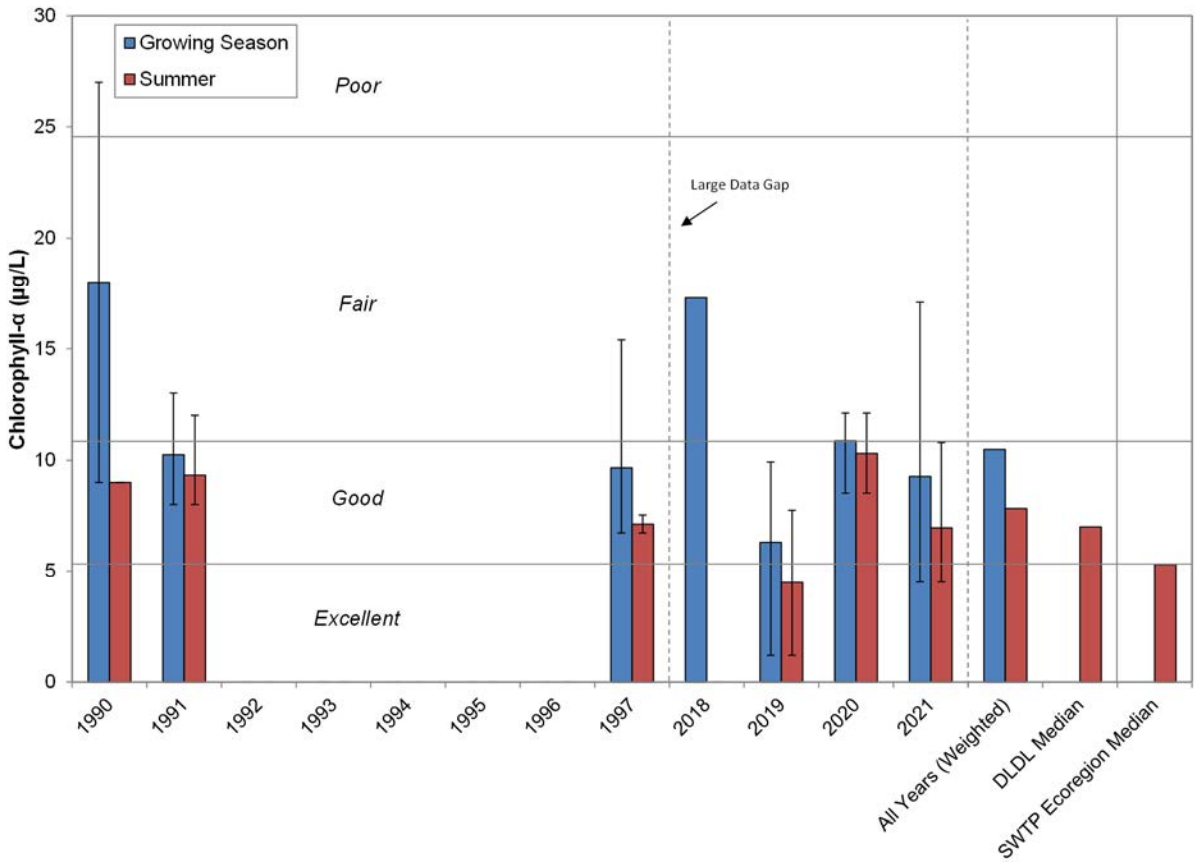


Figure 3.1-5. Auburn Lake's average chlorophyll-α concentrations and median chlorophyll-α concentrations for statewide deep lowland drainage lakes (DLDL) and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes. Weighted average calculated using data from 1990-2021. Chlorophyll criteria for Wisconsin DSL lakes (WisCALM) displayed at right. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

While water clarity data are not available between the late 1990s and present, water clarity in the most recent years is significantly higher than clarity measurements take in 1990, 1991, and 1997 (Figure 3.1-6). It cannot be said if there has been an increasing trend in clarity over this period, but the invasive zebra mussel (*Dreissena polymorpha*) was discovered in Auburn Lake in 2010. The establishment of a zebra mussel population may account for the higher clarity in recent years. Zebra mussels are small bottom-dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring.

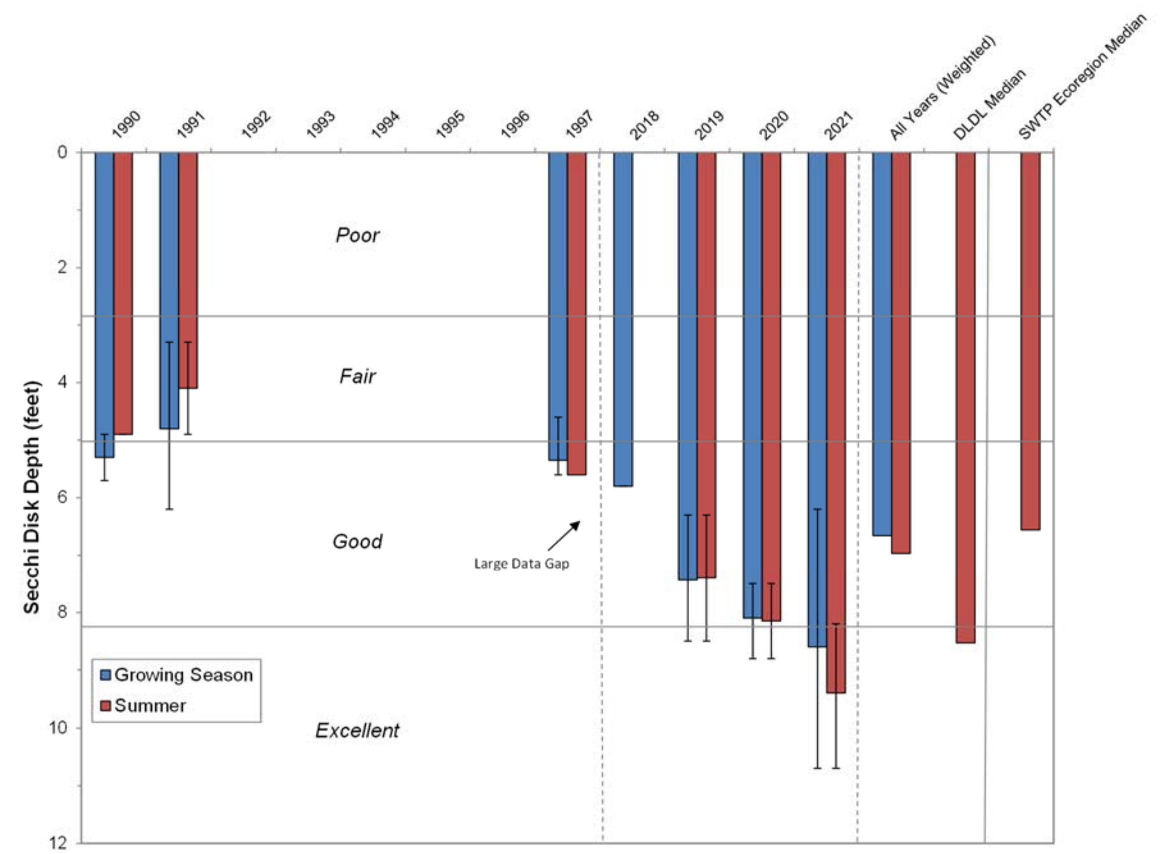


Figure 3.1-6. Auburn Lake's average Secchi disk depths and median Secchi disk depths for statewide deep lowland drainage lakes (DLDL) and Southeast Wisconsin Till Plains (SWTP) ecoregion lakes. Weighted average calculated using data from 1990-2021**.** Secchi disk criteria for Wisconsin DSL lakes (WisCALM) displayed at right**.** Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Numerous studies have shown that following the establishment of zebra mussels, many lakes experience increased water clarity as a result of decreased suspended material within the water from the filtering of zebra mussels (McIsaac 1996); (Karatayev, Burlakova and Padilla 1997); (Reed-Anderson et al. 2000); (Zhu 2006). Zebra mussels are very efficient filter feeders, and water that has been filtered is almost entirely devoid of suspended particles (Karatayev, Burlakova and Padilla 1997). Zebra mussels were first documented in

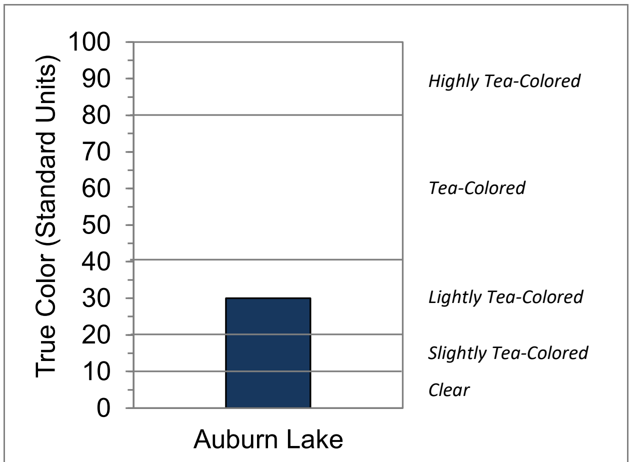


Figure 3.1-7. Auburn Lake mid-summer true color value. This indicates that Auburn Lake's water is lightly stained.

Auburn Lake in 2010. Studies have shown that zebra mussels usually do not have detectable effects on the lake's ecosystem until their population rapidly expands about five to 10 years after their introduction (Karatayev, Burlakova and Padilla 1997). Long Lake, located just a few miles north of Auburn Lake, has exhibited an increasing trend in water clarity following the introduction of zebra mussels, and this same phenomenon may be occurring in Auburn Lake.

Auburn Lake Trophic State

The Trophic State Index (TSI) values for Auburn Lake were calculated using current and historical summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data. 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 (e.g., dissolved organic material).

Figure 3.1-8 contains the TSI values for Auburn Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to lower eutrophic. Not much fluctuation in TSI values were recorded in 2019 or 2020. Values were also consistent with TSI values recorded in 1990 and 1991. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Auburn Lake is in a meso-eutrophic state. Auburn Lake's productivity is very similar to other deep lowland drainage lakes and is similar to all other lake types found in the southeast Wisconsin till plain region.

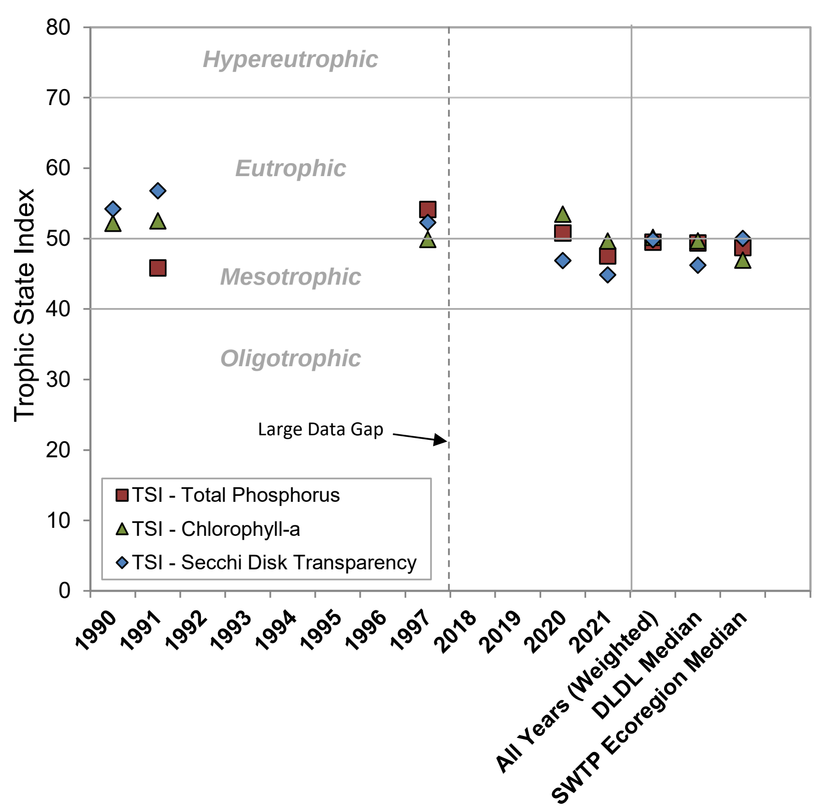


Figure 3.1-8. Auburn Lake Trophic State Index (TSI). Values calculated with summer month surface sample data using WDNR PUB-WT-193. Auburn Lake weighted average calculated using data from 1990-1991, 1997, 2019-2021.

Dissolved Oxygen and Temperature in Auburn Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Auburn Lake by Onterra staff (Figure 3.1-9). These profiles confirm that Auburn Lake is dimictic, meaning the lake remains stratified during the summer (and inversely stratified in winter) and experiences two mixing events – one in spring and another in fall. Profiles taken on March 30, 2021 show the lake was completely mixed with uniform temperatures and dissolved oxygen levels throughout the entire water column. By the middle of June, the lake had developed defined epilimnion, metalimnion, and hypolimnion layers. The hypolimnion was anoxic for the duration of the summer.

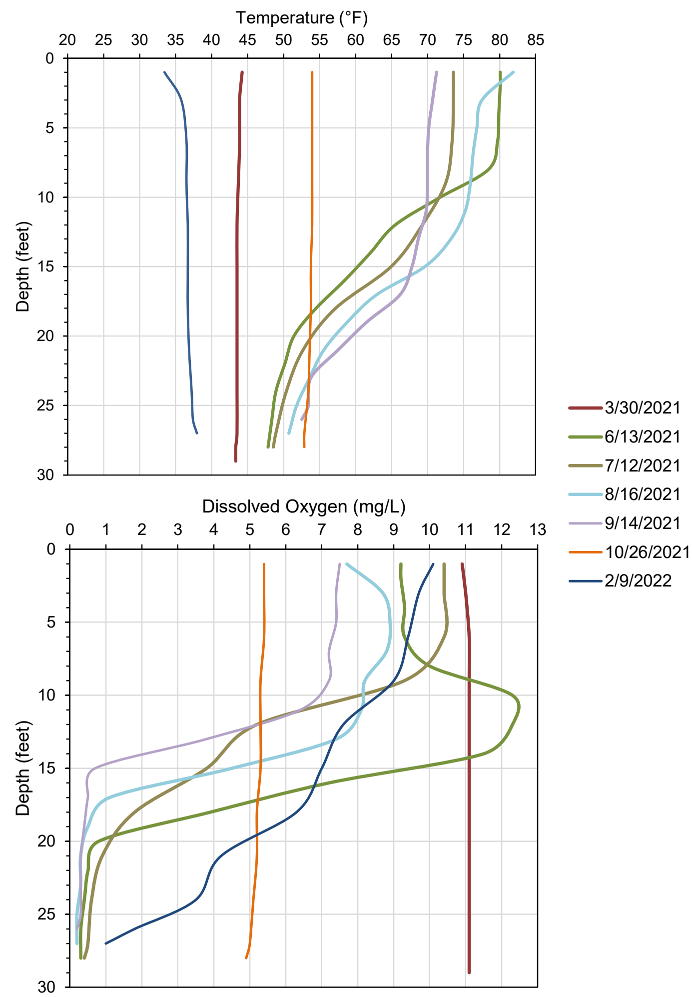


Figure 3.1-9. Auburn Lake 2021 temperature (top) and dissolved oxygen (bottom) profiles.

Also seen in June is the presence of a meta-limnetic oxygen maxima, or peak oxygen concentrations occurring in the metalimnion. In order for this to occur, the lake must have good water clarity in the epilimnion to allow enough light to support phytoplankton photosynthesis in the metalimnion. Algae thrive in this deeper water because there is sufficient light and higher amounts of nutrients, like phosphorous, in the deeper waters. Anoxic conditions were present in the hypolimnion during June-September samplings. By the end of October, as surface water temperatures cooled, and to the water column completely mix again. The profile in February 2022 showed sufficient oxygen in the lake to support fish.

Additional Water Quality Data Collected at Auburn Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). Auburn Lake is considered a marl lake with a mid-summer pH of 8.6 (Figure 3.1-10).

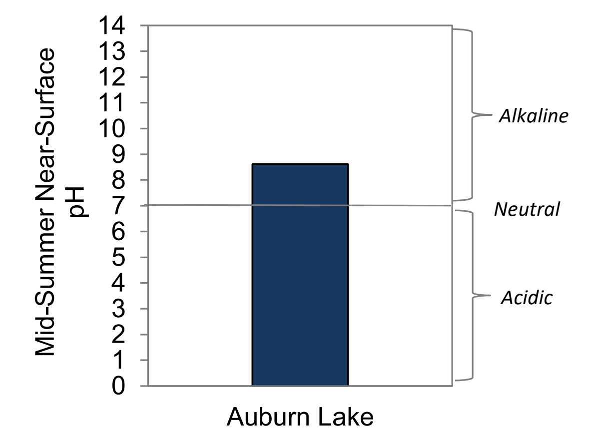


Figure 3.1-10. Auburn Lake mid-summer near-surface pH value.

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 in Auburn Lake was measured at 239 mg/L as $CaCO_3$ (Figure 3.1-11), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitivity to acid rain. This is another indication of a hardwater, marl lake.

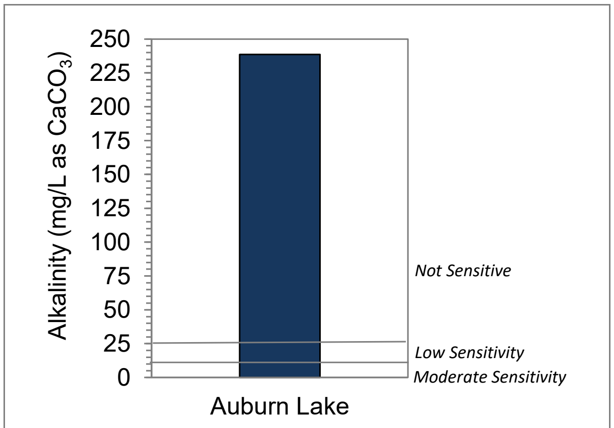


Figure 3.1-11. Auburn Lake average growing season total alkalinity and sensitivity to acid rain.

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 Auburn Lake's pH of 8.6 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Auburn Lake was found to be

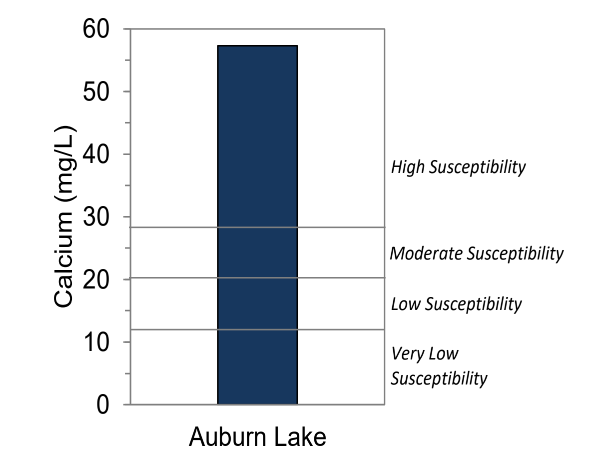
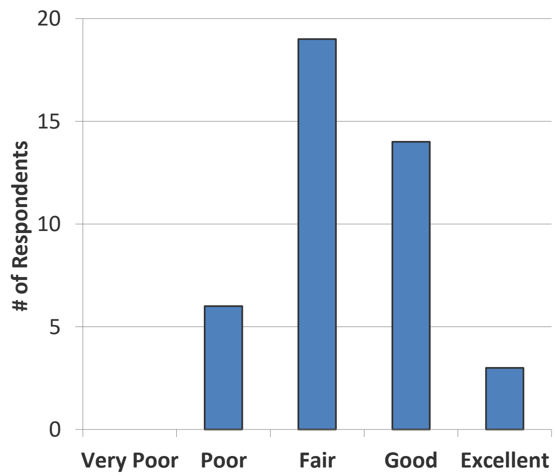


Figure 3.1-12. Auburn Lake near-surface calcium concentrations and zebra mussel susceptibility.

57.3 mg/L, indicating Auburn Lake is highly susceptible to zebra mussel establishment (Figure 3.1-12). As stated previously, Auburn Lake supports a zebra mussel population that was discovered in 2010.

Stakeholder Survey Responses to Auburn Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to stakeholders' perception of the lake and how it may have changed over the years. When asked what the most important aspect of water quality, 50% responded that aquatic plant growth (not including algal blooms) was the most important aspect, 21% indicated water clarity, and 12% indicated algal blooms. Figures 3.1-13 and 3.1-14 display the responses of members of Auburn Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Auburn Lake.



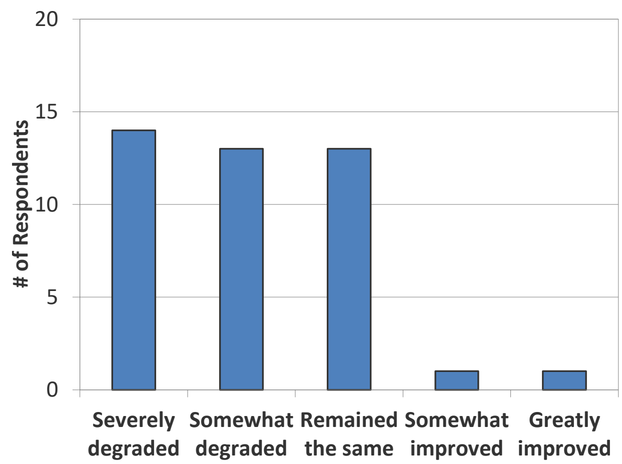


Figure 3.1-13. Stakeholder survey response Question #17. How would you describe the overall current water quality of Auburn Lake?	**Figure 3.1-14. Stakeholder survey response Question #18. How has the overall water quality changed in Auburn Lake since you first visited the lake?**

Approximately 60% of stakeholders believe the current water quality condition of Auburn Lake is either poor or fair. When asked what is the single most important aspect when considering water quality, 50% of respondents indicated that aquatic plants were the most important. While essential to the aquatic ecosystem, the level of aquatic plant growth is not taken into account when assessing a lake's water quality. While phosphorus, chlorophyll, and Secchi disk indicate the lake's water quality is overall good, the excessive aquatic plant growth is likely the reason why 60% of respondents indicated the lake's current water quality was fair or poor.

When asked about how Auburn Lake's water quality has changed, 64% of responses believed water quality had either somewhat degraded or severely degraded. It is likely that the increase in aquatic plant abundance in recent years influenced these responses as historical data indicates that water quality parameters such as total phosphorous levels have remained largely unchanged.

3.2 Watershed Assessment

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 land cover (land use) within the watershed and 2) the size of the watershed. The type of land cover and the amount of that land cover that exists in the watershed is largely going to determine 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. Areas within a lake's watershed that are naturally vegetated (e.g., forests, grasslands, and wetlands) strongly influence the way water behaves on the land surface after it falls as precipitation or is released by the melting of snow (Silk & Ciruna, 2005).

Runoff is slowed down in areas with denser vegetation and increases the time it takes for precipitation from a storm event to reach the lake. This allows more water to soak into the soil and reduces the potential for flooding. Intact wetlands within a lake's watershed have been likened to the "kidneys of the landscape" as they filter out nutrients, sediments, and other pollutants from water which passes through them (Silk & Ciruna, 2005). The water quality within a lake is largely a reflection of the health of its watershed, and maintaining natural land cover within a lake's watershed is essential for maintaining good water quality.

Among the largest threats to a lake's water quality is the conversion of natural areas to agriculture and urban development. Conversion of natural areas to agriculture disrupts the hydrologic regime and increases surface runoff due to increased soil compaction and reduced water infiltration. Wetlands which were drained and converted to farmland were shown to increase runoff by 200-400% (Silk & Ciruna, 2005). Agriculture accounts for 60% of the pollutants in lakes and rivers in the United States due to increased runoff in combination with the application of fertilizers, pesticides, and manure.

Similar to agriculture, urban development can significantly alter the hydrologic regime within a watershed, primarily through the installation of impervious surfaces (e.g., roads, driveways, roof-tops) which decrease water infiltration and increase runoff. As impervious surface cover increases, the time it takes water from a storm event to reach the lake decreases. With the increase in water velocity and volume entering the water body, nutrient and sediment input also increase, degrading water quality. Nutrient input can also increase from urban areas as the result of fertilizer application, wastewater treatment facilities, and other industrial activities.

In addition to land cover within the watershed, the size of the watershed relative to the water volume within the lake also influences water quality. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drain 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. 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 grasslands or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g., reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

In systems with high WS:LA ratios, like those 10-15:1 or higher, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of primary 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 measurable changes in primary 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 of 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 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.

Watershed Modeling

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.

Auburn Lake Watershed Assessment

Auburn Lake has a relatively large watershed encompassing an area of 4,261 acres (6.7 square miles), resulting in a watershed to lake area (WS:LA) ratio of 46:1 (Figure 3.2-1 and Maps 2-3).

The lake is fed via Auburn Lake Creek, the headwaters are which approximately five miles to the north. The majority of the creek is buffered by a large forested wetland complex. Water flows out of Auburn Lake through Auburn Lake Creek on the lakes southwest side where it ultimately flows into the Milwaukee River. The WiLMS model estimated that Auburn Lake has a water residence time of approximately 0.45 years, or slightly over five months. In other words, on average, the water in Auburn Lake is completely replaced 2.2 times per year.

The 2016 land cover data show that approximately 70% of Auburn Lake's watershed is comprised of intact wetlands (41%) and upland forests (29%). Approximately 14% is comprised of row crop agriculture, 13% is comprised of pasture/grasslands/rural open space, 2% is comprised of the lake's surface itself, 1% is comprised of rural residential areas, <1% is comprised of medium-density urban areas, and <1% is comprised of high-density urban areas.

Auburn Lake is comprised of two primary basins – the larger, more voluminous northern basin and the smaller, less voluminous southern basin. The lake's deepest location is in the northern basin, and this location is where water quality data have been collected. Given the lake is comprised of two distinct basins and water quality data are only available from the northern basin, the watershed modeling was set up to treat the northern basin as a distinct waterbody. In the model, the surface area, estimated water volume, and subwatershed for the northern basin were used. Inclusion of the southern basin in the modeling would inflate the volume of water actually being sampled and modeled, and would include a portion of the watershed that does not flow into the northern basin where water quality is being monitored. The northern basin's subwatershed used in the modeling is represented by the black dashed line in Figure (3.2-1 and Map 3).

The vast majority (94%) of Auburn Lake's watershed is comprised of the northern basin's sub-watershed (Figure 3.2-1). The sub-watershed for the southern basin is approximately 251 acres. In other words, 94% of the land cover within Auburn Lake's watershed drains into the northern basin first before flowing into the southern basin, while the 251 acres in the southern basin's sub-watershed drains to the southern basin directly. Using the land cover types and their acreages within the northern basin's sub-watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to the northern basin from its watershed. In addition, using data obtained from the 2021 stakeholder survey, an estimate of potential phosphorus loading to the lake from riparian septic systems was also incorporated into the model.

The WiLMS model estimated that approximately 934 pounds of phosphorus are delivered to Auburn Lake's northern basin from its watershed on an annual basis (Figure 3.2-2). Based on this potential annual load, the WiLMS model predicted that the northern basin would have a growing season mean total phosphorus concentration of 73 μg/L, approximately 200% times higher than the measured growing season mean of 24 μg/L. The discrepancy between the predicted and measured phosphorus concentrations indicates that the WiLMS watershed model is significantly over-predicting the amount of phosphorus being loaded to Auburn Lake.

The model estimates that approximately 56% (527 pounds) and 14% (132 pounds) of the annual phosphorus load originate from row crop agriculture and pasture/grasslands, respectively. The loading from these agricultural areas is believed to be highly over-estimated given that these areas are on the fringes of the lake's watershed not immediately near the lake, and they are buffered from Auburn Lake Creek by the large, contiguous wetland complex. These wetlands are likely intercepting and retaining the majority of phosphorus runoff from these agriculture areas, acting as filters and removing pollutants before the water reaches the stream.

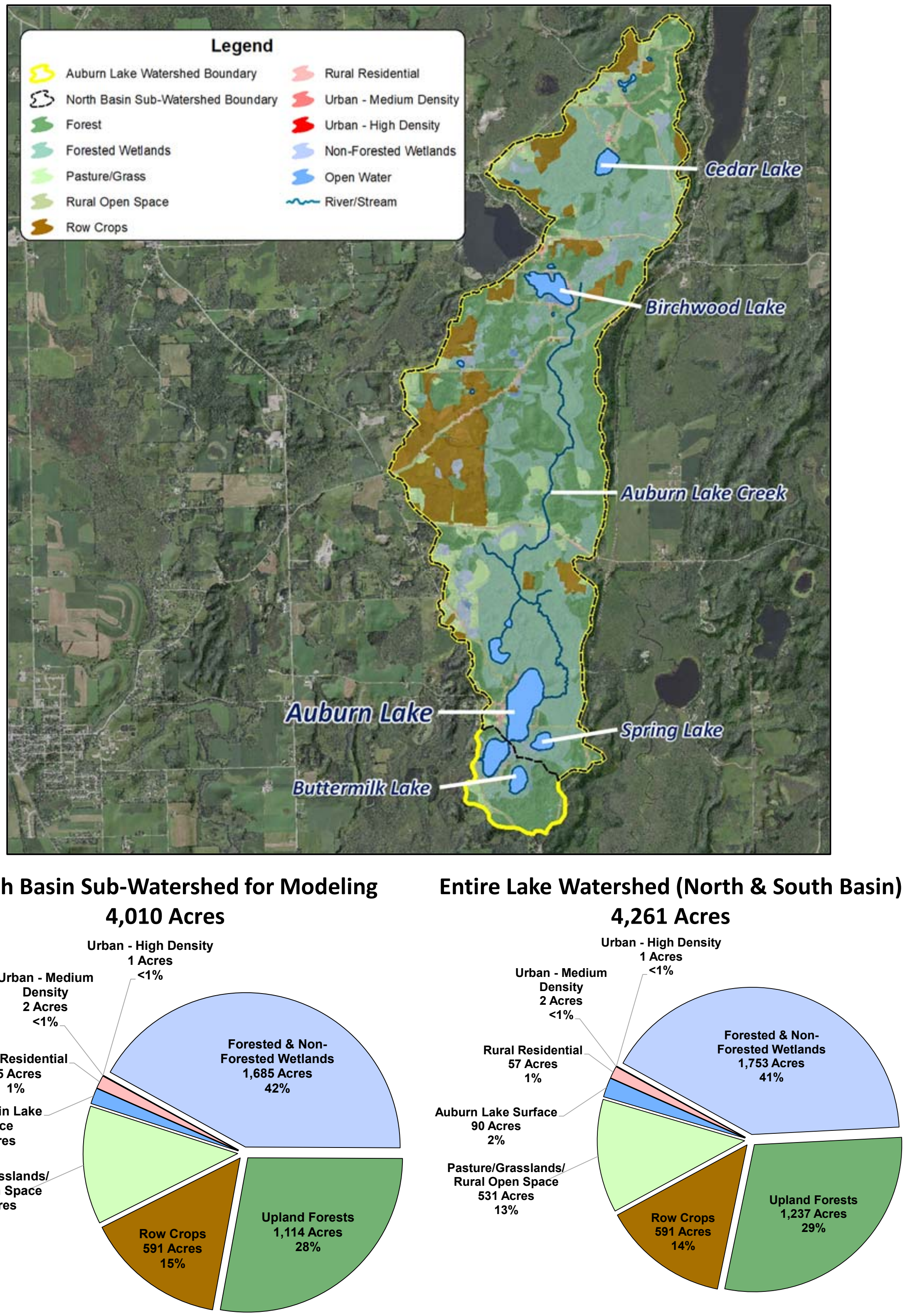


Figure 3.2-1. Auburn Lake watershed and land cover types. Based upon National Land Cover Database (USGS 2016).

To achieve the measured in-lake phosphorus concentration of 24 µg/L, the predicted annual phosphorus load of 934 pounds had to be reduced by nearly 75% to approximately 250 pounds. Reducing the predicted phosphorus export for each land cover type within the watershed by 75% to represent more accurate loading is illustrated in Figure 3.2-2. Row crop agriculture is still predicted to account for 51% (128 pounds) of the annual phosphorus load, while wetlands account of 15% (36 pounds), pasture/grasslands/rural open space accounts of 13% (32 pounds), upland forests account for 9% (22 pounds), atmospheric deposition onto the lake surface accounts for 7% (18 pounds), riparian septic systems may account for up to 5% (12 pounds), and rural residential areas account for <1% (1 pounds).

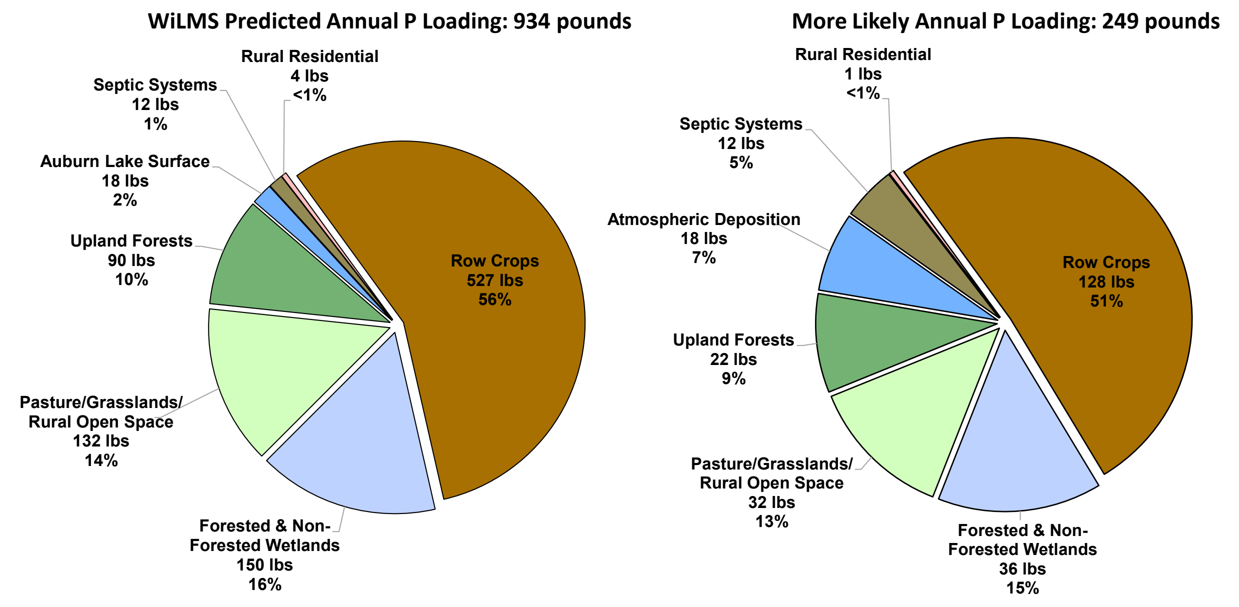


Figure 3.2-2. Auburn Lake WiLMS model estimated annual watershed phosphorus loading. The chart on the left is the original WiLMS-predicted phosphorus loading. Based on this annual load, the model predicted an in-lake phosphorus concentration over 200% higher than those measured. The chart on the right is more accurate in terms of actual loading and creates a predicted in-lake phosphorus concentration that aligns with those that were measured. The large wetland complex along Auburn Lake Creek likely acts as a buffer against nutrient runoff from adjacent farmlands, protecting the lake's water quality.

As is discussed in the Paleoecology Section (Section 3.3), the sediment core that was collected and analyzed from Auburn Lake indicates that prior to Euro-American settlement, total phosphorus concentrations in Auburn Lake were lower around 18-20 µg/L. To achieve this background level concentration, the model indicates that annual phosphorus loading would have to be reduced by 50-60 pounds, or at least 20% of current loading. However, despite the conversion of natural areas to agriculture and rural residential areas in Auburn Lake's watershed, water quality remains good and phosphorus concentrations have not increased significantly since Euro-American settlement.

This modeling highlights the importance of maintaining the integrity of the wetland and upland forest complexes within the lake's watershed. These natural areas are essential for maintaining Auburn Lake's water quality. The model shows how Auburn Lake's water quality would degrade if these natural communities were not in place. Without these wetlands, the predicted in-lake phosphorus concentration of 73 µg/L would result in significant algal blooms, with a predicted summer chlorophyll-*a* concentration of over 40 µg/L and an average Secchi disk transparency of just 2.0 feet. Conservation of Auburn Lake's water quality depends on the conservation of natural areas beyond the immediate shoreland zone.

Watershed Areas of Concern

As part of Auburn Lake's watershed assessment, six *areas of concern* were delineated. These areas were identified based on their potential to degrade Auburn Lake's water quality. Three areas of row crop agriculture which are closest to Auburn Lake were identified (Map 4). The LiDAR (Light Detection and Ranging) data from Fond du Lac County, show that these fields have direct drainages into the wetlands immediately adjacent to Auburn Lake Creek. The wetland buffer between these drainages and the creek are relatively small, and these areas may contribute nutrients and sediments to Auburn Lake Creek and Auburn Lake.

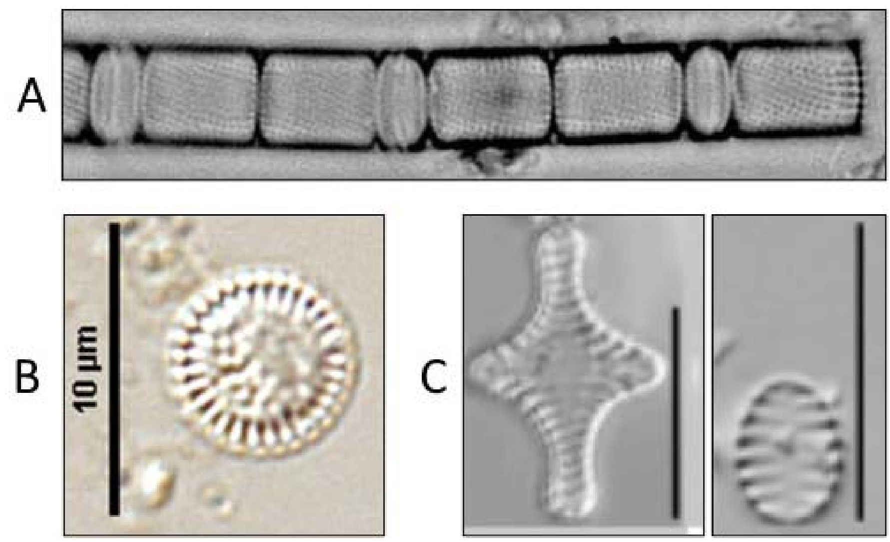
Three other areas were identified, comprised of rural residential development immediately adjacent to Auburn Lake (Map 4). These areas are comprised of homes and manicured lawns on hillsides which slope towards the lake. These areas likely contribute nutrients and any other pollutants (lawn fertilizers, pesticides, etc.) directly to Auburn Lake. The subsequent Shoreland Condition Section (Section 3.3) discusses Auburn Lake's immediate shoreland zone and best management practices that riparians can implement to minimize pollution and improve habitat.

3.3 Paleoecology

Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution.

These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The diatom community are especially useful in reconstructing a lake's ecological history as they are highly resistant to degradation and are ecologically diverse. Diatom species have unique features as shown in Photograph 3.3-1, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as aquatic plants or the lake bottom.



Photograph 3.3-1. Photomicrographs of the diatoms commonly found in the sediment core from Auburn Lake. The top diatom (A) is *Aulacoseira ambigua* is common with moderate phosphorus levels and was most common in the bottom sample. *Cyclotella comensis* (B) is an invasive that was imported from the northern Europe. It was common in the top sample. *Staurosira construens* (C left) *Staurosirella pinnata* (C right) are typically found growing on macrophytes and lake sediments and are common components of benthic *Fragilaria*.

The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

One often-used paleoecological technique is collecting and analyzing top/bottom cores. The top/bottom core only analyzes the top (usually 1 cm) and bottom sections. The top section represents present day conditions and the bottom section is hoped to represent pre-settlement conditions by having been deposited at least 100 years ago. While it is not possible to determine the actual date of deposition of bottom samples, a determination of the radionuclide lead-210 estimates if the sample was deposited at least 100 years ago. The primary analysis conducted on this type of core is the diatom community leading to an understanding of past nutrients, pH, and general macrophyte coverage.

Auburn Lake Paleoecological Results

A sediment core was collected from the deep area in Auburn Lake by Onterra staff on September 14, 2021. The total length of the core was 30 cm. The top 5 cm of the core was black in color, while the color from 5 to 23 cm was brown, and the color from 23 to 30 cm was dark gray in color (Photograph 3.3-2). While it is not clear why these color changes have occurred, it does indicate that Auburn Lake has experienced ecological changes during the time period encompassed by the core, likely 100+ years. The top 1 cm was kept for analysis and it is assumed this represents present day water quality conditions in the lake. A bottom sample, 27-29 cm, was analyzed and this is assumed to represent conditions before the arrival Euro-American settlers in the middle of the nineteenth century.

Photograph 3.3-2. Paul Garrison, a paleoecologist at Onterra, collects a sediment core from Auburn Lake. There were several color changes in the core suggesting ecological changes have occurred in the lake during the last 100 years.

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Auburn Lake, an exploratory detrended correspondence analysis (DCA) was performed (Braak C.J.F. 2012). The DCA analysis has been done on many WI lakes to examine the similarities of the diatom communities between the top and bottom samples of the same lake. These lakes are those that are relatively deep and stratify during the summer much as Auburn Lake does.

The results revealed two clear axes of variation in the diatom data, with 32% and 21% of the variance explained by axis 1 and axis 2, respectively (Figure 3.3-1). Sites with similar sample scores occur in close proximity reflecting similar diatom composition. The arrows symbolize the trend from the bottom to the top samples. The amount of change in Auburn Lake is more than seen in some lakes but less than in many other lakes. Auburn Lake shows less change than Silver Lake and a similar amount of change in Little Spider Lake. While it is not possible to determine what environmental factors are ordering the diatom community in Auburn Lake the changes are largely along the second axis.

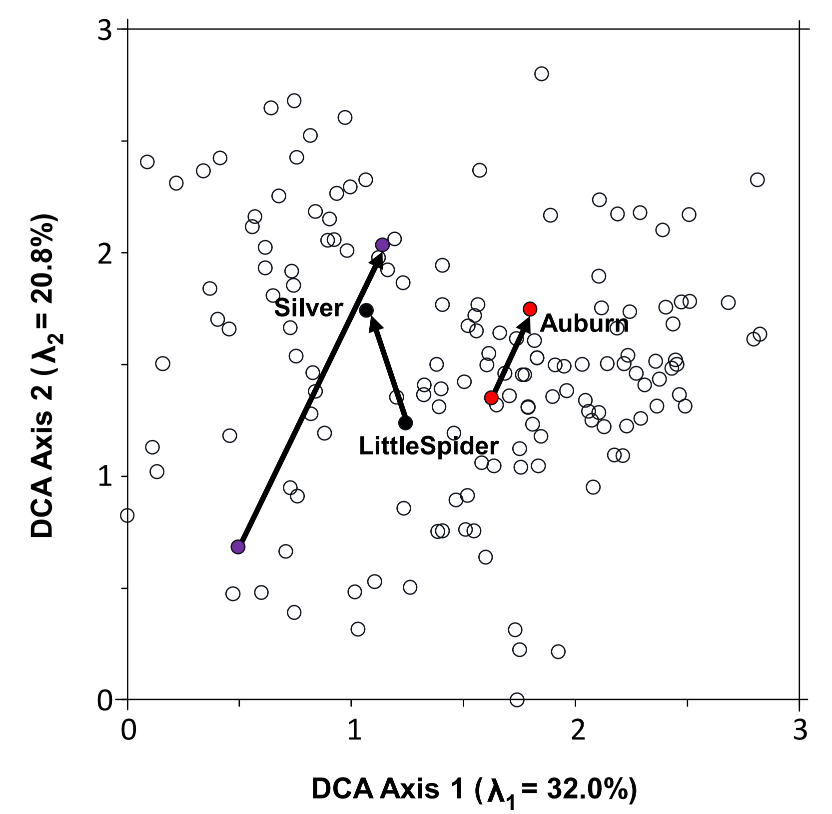


Figure 3.3-1. DCA plot of top/bottom samples from Auburn Lake. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. Auburn Lake has changed only a moderate amount since the arrival of Euro-American settlers over 100 years ago.

Diatom Community Changes

The diatom community in the bottom and top samples of Auburn Lake are dominated by the plankton diatoms which are diatoms that float in the open water. In the bottom sample, the dominant species was *Aulacoseira ambigua* (Photograph 3.3-1A) while its numbers were greatly reduced in the top sample and this diatom had been replaced by species in the genus *Cyclotella* (Figure 3.3-2). *A. ambigua* is common in stratified lakes in the Upper Midwest with low to moderate phosphorus concentrations. In the top sample, which represents present day conditions, *A. ambigua* has been replaced by diatoms in the *Cyclotella*. In the top sample, the most common taxa of the genus *Cyclotella* are *C. comensis* (Photograph 3.3-1B) and *C. ocellata*. The increase in these diatoms suggest an increase in phosphorus concentrations at the present time compared to historical conditions.

Cyclotella comensis is believed to have been introduced from northern Europe (Stoermer E. F. 1993). This diatom has been found in sediments deposited since 1950 in the Great Lakes (W. J. Stoermer E. F. 1985), (Kociolek J. P. 1990); (W. J. Stoermer E. F. 1993) as well as inland lakes in northern lower Michigan (Fritz S. C. 1993); (Wolin J. A. 2005) and over 20 lakes in Wisconsin.

In lakes from New Jersey and New York, this diatom was only found in the top samples of the 26 lakes examined (Enache M. D. 2012). The diatom *C. comensis* is typically found growing in the open water in the middle part of the water column. This means that this taxon is found in lakes with good water clarity but elevated nutrient levels in the deeper waters. Studies indicate that this diatom responds to increased phosphorus and nitrogen levels (Schelske et al. 1972; (Wolin J. A. 2005). In Auburn Lake *C. comensis* was found at a concentration of 14.2% which is moderately high and was the most common diatom in the top sample.

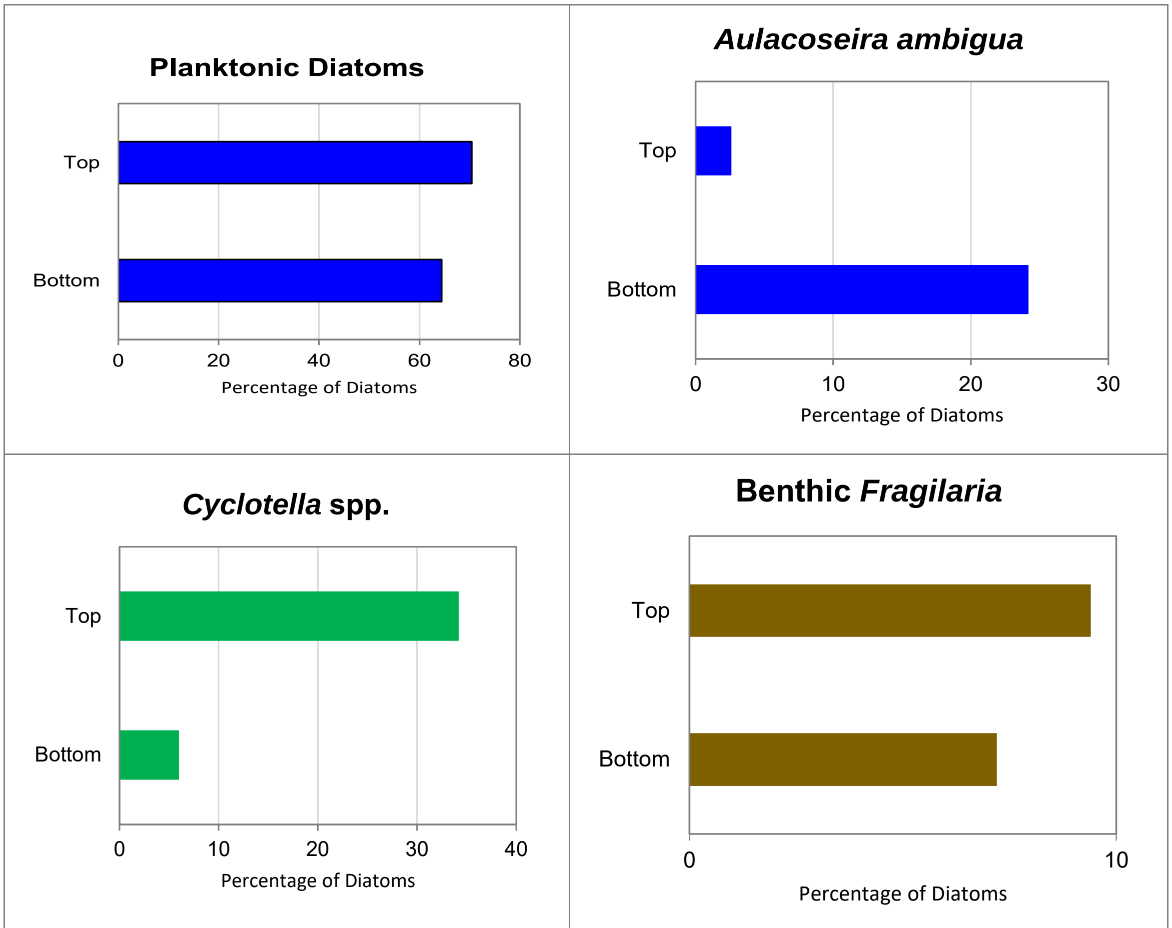


Figure 3.3-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Auburn Lake. The top and bottom samples were dominated by diatoms that float in the open water (planktonic diatoms). The dominant taxon in the bottom sample was *A. ambigua* but in the top sample diatoms in the genus *Cyclotella* replaced *A. ambigua*. This suggests a small increase in phosphorus at the present time.

Benthic *Fragilaria*, e.g., *Staurosira construens, Staurosirella pinnata* (Photograph 3.3-1C), usually grow on the bottom sediments or more commonly in lakes like Auburn Lake, attached to submerged aquatic vegetation. In many lakes these diatoms become more prevalent with shoreland development as this development results an increase in the density and type of macrophytes growing in the lake. (Borman 2007) found that in northwestern Wisconsin, the macrophyte community often changed in seepage lakes, from one dominated by low growing plants to a community dominated by larger macrophytes, as a result of shoreline development. The structure of the macrophyte community changes because the increased runoff of sediment during construction on the shoreline enables the establishment of the larger plants. With the larger plants there is much more surface area available on which diatoms and the other periphytic algae are able to grow. Since the amount of benthic *Fragilaria* in the top sample is similar to that present in the bottom sample suggests that there has been little change in the extent of macrophyte coverage during the last 100 years. There may have been changes in the species composition of the community but the extent of coverage now is similar to what it was in historical times.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson, Zalack and Wolin 2013). The LDCI uses diatoms to assess the ecological condition of lakes. The LDCI ranges from 0 to 100 with a higher score representing better ecological integrity. The index is weighted towards nutrients, but also incorporates ecological integrity by examining species diversity where higher diversity indicates better ecological condition. The index also incorporates taxa that are commonly found in undisturbed and disturbed conditions. The breakpoints (poor, fair, good) were determined by the 25th and 5th percentiles for reference lakes in the Upper Midwest. The LDCI was used in the 2007 National Lakes Assessment to determine the biological integrity of the nation's lakes.

The LDCI in the top sample places Auburn Lake in the *poor* category (Figure 3.3-3), while the bottom sample places the lake in the fair category. The ecological degradation in the top sample is largely the result of the invasive species *Cyclotella comensis*. The condition at the top is also somewhat the result of higher phosphorus concentrations at the present time compared with historical conditions.

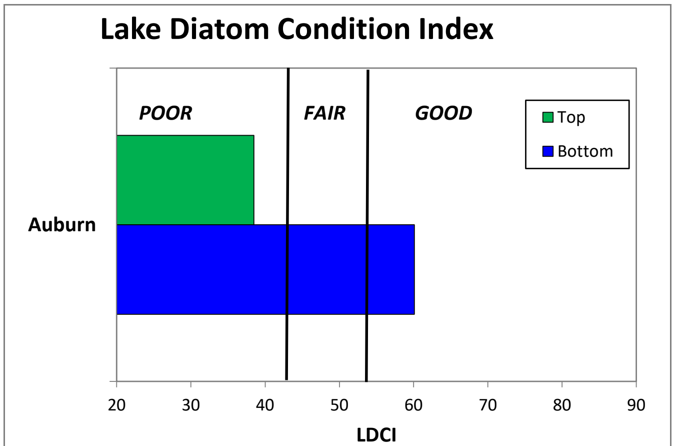


Figure 3.3-3. The Lake Diatom Condition Index (LDCI) for Auburn Lake. The biotic integrity is worse in the top sample compared with the bottom sample. This is largely the result of the invasive diatom *C. comensis* but also higher nutrient concentrations.

In recent years the mean summer phosphorus concentration in the lake is 24 µg/L which places it on the border between mesotrophic and eutrophic. The changes in the diatom community between the bottom and top samples suggest that this is higher than the concentration was historically. The historical concentration was probably in the range of 18-20 µg/L.

Summary

Auburn Lake historically was a good water quality lake with phosphorus concentrations less than 20 µg/L and a thriving macrophyte community. Even with the extensive macrophyte community, the diatom community was dominated by taxa that float in the open water as opposed to taxa that grow attached to the plants. The diatom community at the present has a significant amount of the invasive diatom *C. comensis* which lowers the lake's ecological integrity. This diatom prefers moderate nutrient concentrations so its presence is not the result of a large increase in the phosphorus concentration. The presence of this taxa as well as the significant increase in other taxa which prefer higher phosphorus concentrations suggest that phosphorus levels in the lake have increased around 5 µg/L.

3.4 Shoreland Condition

Lake Shoreland Zone and its Importance

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet inland). 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.

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

Photograph 3.4-1. Example of coarse woody habitat in a lake.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin, 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) (Radomski 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 3.4-2. Example of a biolog restoration site.

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

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

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 3.4-1).

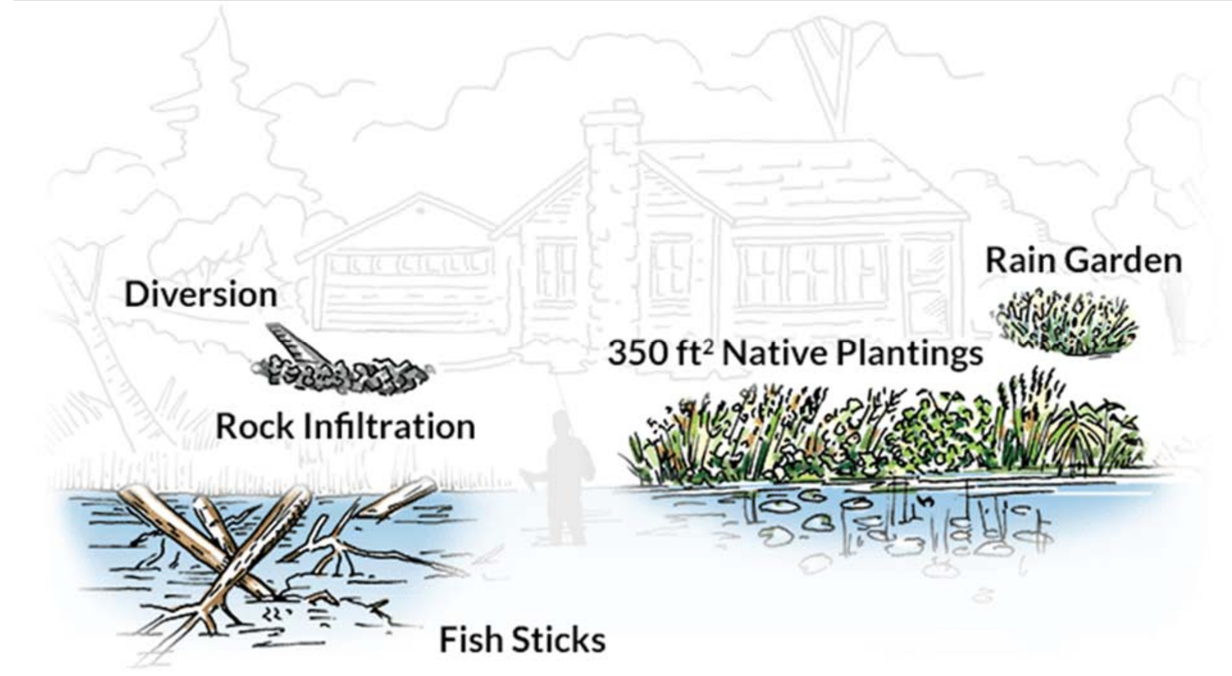


Figure 3.4-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- 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.

Auburn Lake Shoreland Zone Condition

Shoreland Development

The entire shoreline of Auburn Lake was surveyed on the July 19, 2021. 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 (Photo 3.3-3). 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.

Photograph 3.4-3. Example of canopy, shrub and herbaceous layers.

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.

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.

Canopy cover was defined as an area which is shaded by trees that are at least 16 feet tall (Photograph 3.4-3). The vast majority (69%) of Auburn Lake's shoreline has less than 40% canopy cover (Figure 3.4-2). Undeveloped parcels, such as wetland areas, that naturally do not have a canopy present are also factored into this result (Map 5).

Shrub and herbaceous layers are small trees and plants without woody stems less than 16 feet tall (Photograph 3.4-3). The shoreland assessment survey indicates that 1.6 miles, or 68% Auburn Lake's parcels contained between 81-100% shrub and herbaceous layers (Figure 3.4-2, Map 6). Another 0.56 miles (24%) only had between 0 and 20% shrub and herbaceous layer present on the parcel.

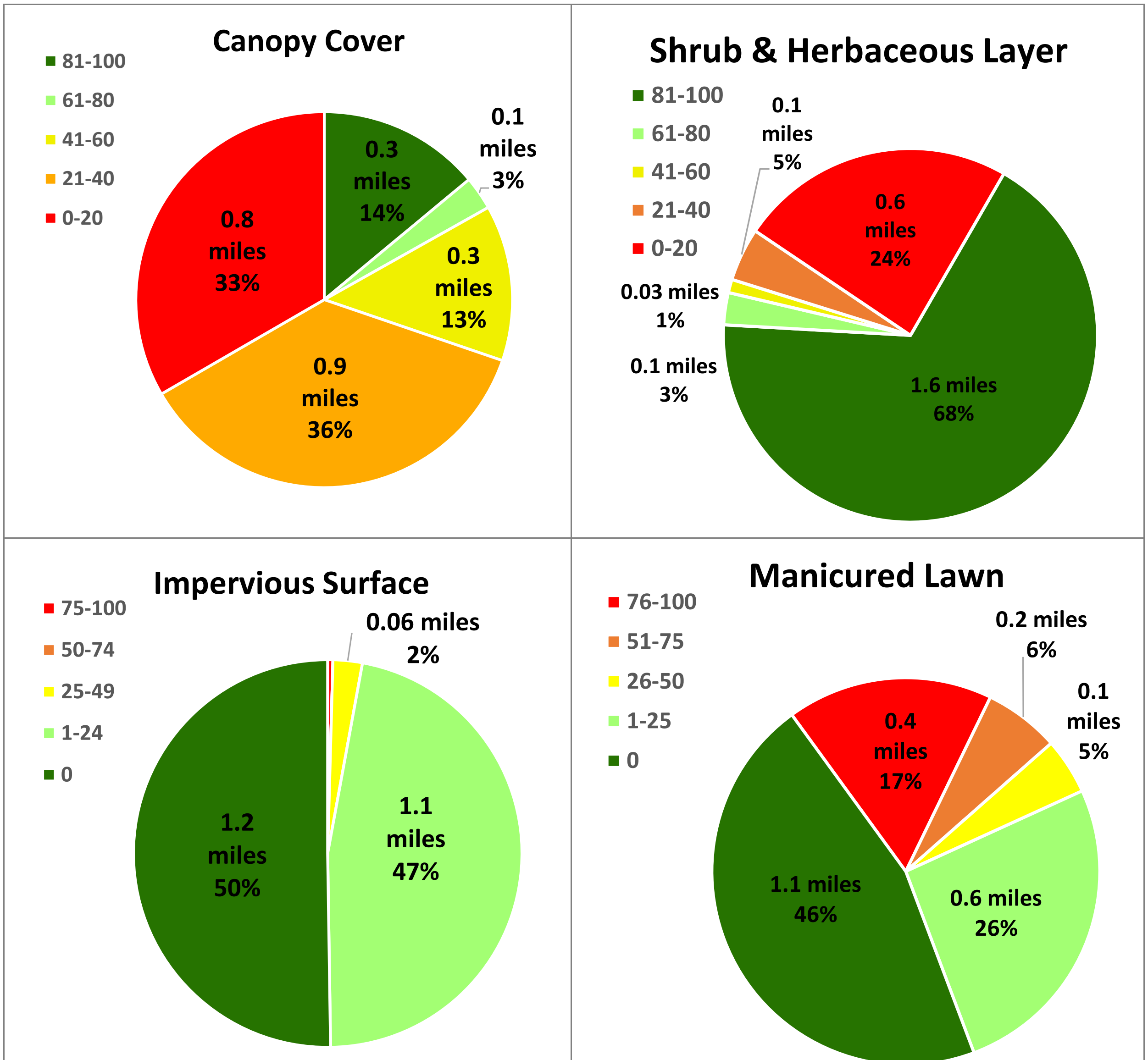


Figure 3.4-2. Auburn Lake 2021 shoreland parcel canopy cover, shrub-herbaceous cover, impervious surface, and manicured lawn. Data from Onterra 2021 Survey.

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. Approximately 46% of the parcels around the lake had no manicured lawn within the shoreland zone and another 26% of parcels had between 1-24% of the shoreland zone containing manicured lawn (Figure 3.3-2, Map 7). Approximately 17% of the shoreland parcels contained manicured lawn on 75% or greater of the shoreland zone.

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). Approximately 97% of the shoreline had parcels with less than 25% of impervious surface within the shoreland zone (Figure 3.3-2, Map 8).

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, Auburn Lake was also surveyed to determine the extent of its coarse woody habitat which is comprised of fallen trees that are under water in the lake and thus contributing habitat to fishes and other organisms within the lake. 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, or a full crown), noted if it touched shore, and whether or not it 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, 34 total pieces of coarse woody habitat were observed along 2.3 miles of shoreline (Map 14), which gives Auburn Lake a coarse woody habitat to shoreline mile ratio of 15:1 (Figure 3.4-4). The majority of these pieces did not cross the high-water level, meaning they were between the shoreline and the two-foot depth contour. No pieces were classified as a full canopy.

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 Auburn Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 128 lakes throughout Wisconsin since 2012. The number of coarse woody habitat pieces per shoreline mile in Auburn Lake falls below the 25th percentile of these lakes. (Figure 3.4-3). The lower amount of coarse woody habitat is likely due to the fact that most of the natural shoreland around Auburn Lake is wetland with minimal tree cover.

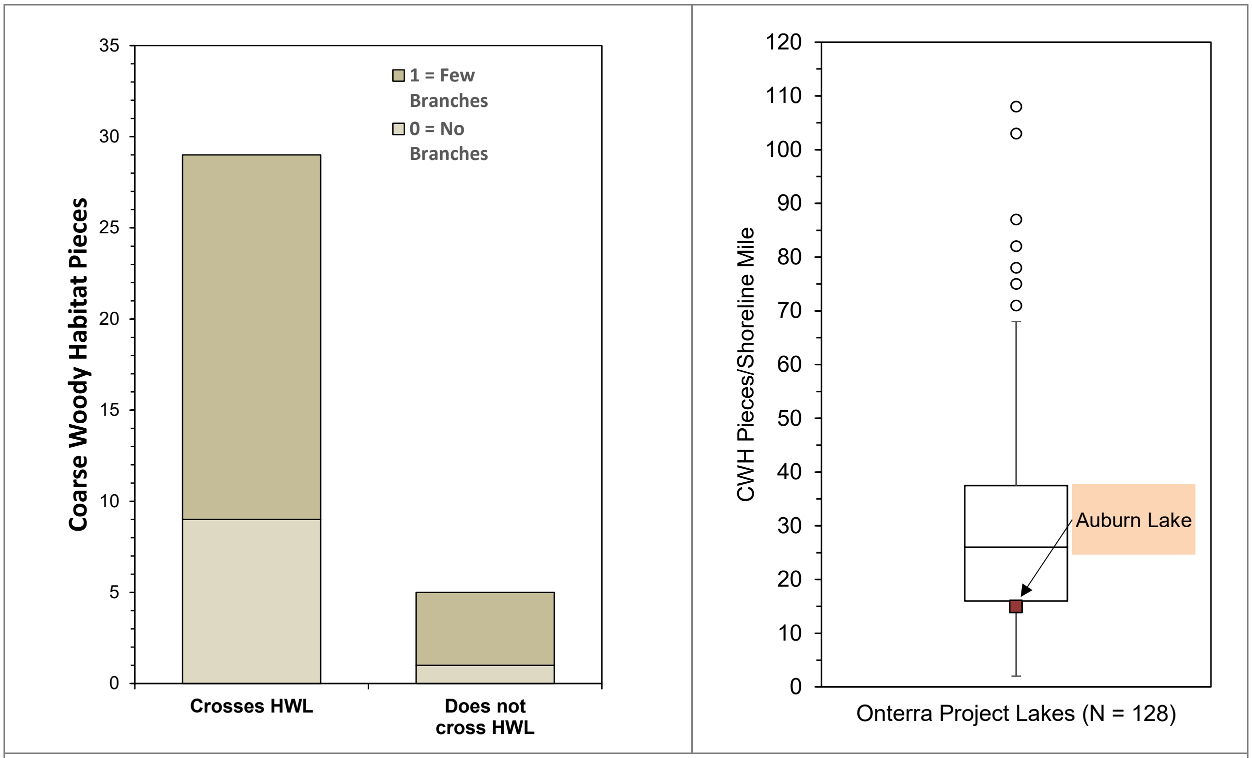


Figure 3.4-3. Auburn Lake coarse woody habitat survey results. Based upon a Summer 2021 survey. Locations of the Auburn Lake coarse woody habitat can be found on Map 14.

3.5 Aquatic Plants

Introduction

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

Photograph 3.5-1. Example of emergent and floating-leaf plant community.

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.

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

Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no “silver bullets” that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

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

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

Manual Removal (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 3.5-2. 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. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

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

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

Mechanical Harvesting


Photograph 3.5-3. Mechanical harvester.

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

Cost

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

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

Herbicide Treatment

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

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.

Table 3.5-1. 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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • Herbicides can be economical at certain scales compared with other management options. • Herbicide type and application timing can increase selectivity towards target species. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergents or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Auburn Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Auburn Lake since 2005. 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 Auburn Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

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

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

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

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

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species.

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

Community Mapping

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

Exotic Plants

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

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.5-1). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants: 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants and instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

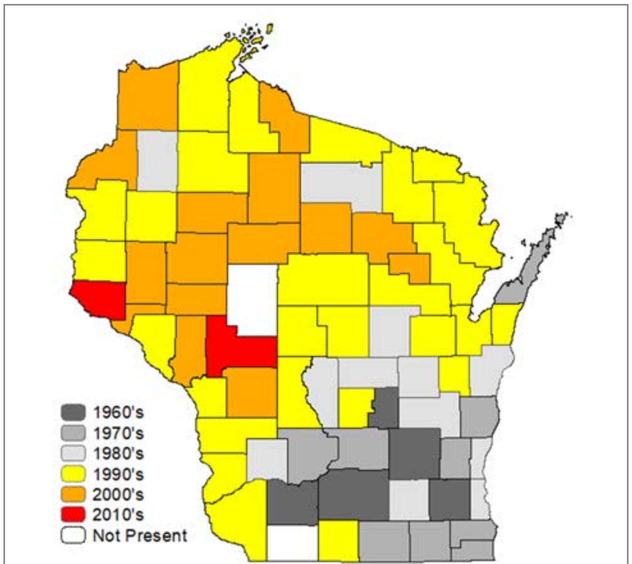


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties over time. Most recent infestations are colored in Red, Orange, and Yellow. WDNR Data 2021 mapped by Onterra.

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

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

Auburn Lake Aquatic Plant Survey Results

The first survey completed on Auburn Lake in 2021 was the Early-Season Aquatic Invasive Species (ESAIS) Survey completed on May 24, 2021. 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 mapped occurrences of curly-leaf pondweed and Eurasian watermilfoil, the latter of which was mapped again later in the summer when it was near or at its peak growth. Pale-yellow iris, a non-native wetland plant, was also found on the shoreline of Auburn Lake in 2021. These non-native plants will be discussed in detail in the subsequent Non-Native Aquatic Plant Section.

Whole-lake point-intercept surveys have been completed on Auburn Lake in 2008, 2019, and 2021. Over the course of these surveys, a total of 38 aquatic plant species have been identified, and 36 of these were located in 2021 (Table 3.5-2). In addition to Eurasian watermilfoil, curly-leaf pondweed, and pale-yellow iris mentioned above, giant reed and narrow-leaved cattail were the other non-native species recorded by Onterra in 2021.

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.

During Onterra's 2021 point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 89% of the point-intercept locations contained soft organic sediments, 10% contained sand, and 1% contained rock (Figure 3.5-2). Areas of sand or rock were primarily located in near-shore areas around the lake, while the majority of other sampling locations contained soft organic substrate.

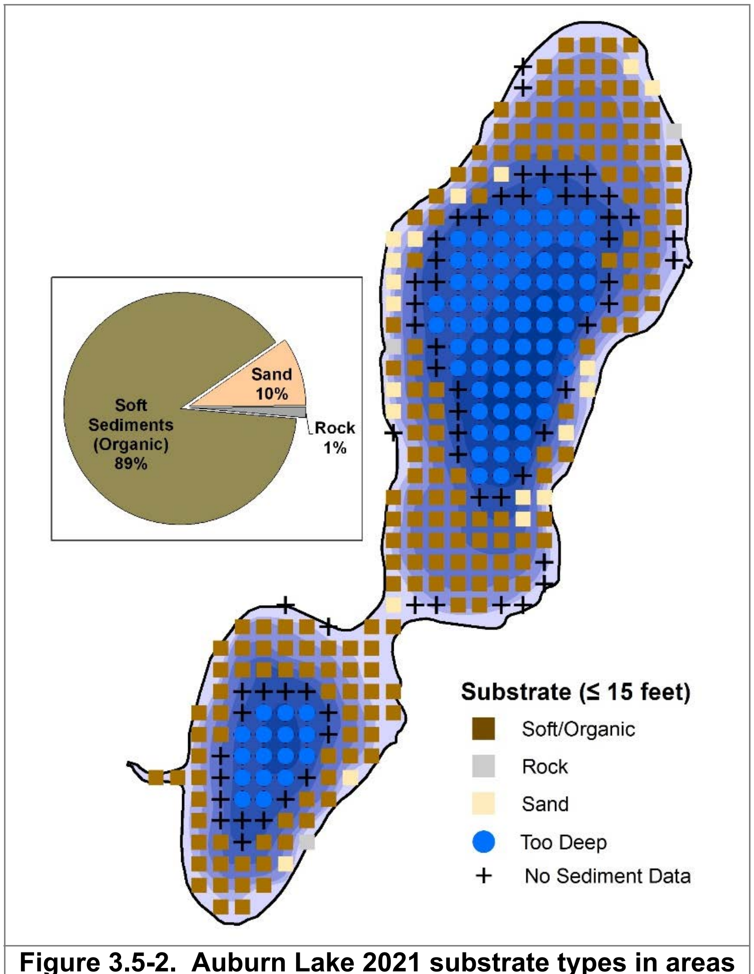


Figure 3.5-2. Auburn Lake 2021 substrate types in areas ≤ 15 feet deep. Created from data collected during the 2020 whole-lake point-intercept survey.

Table 3.5-2. Aquatic plant species located in Auburn Lake from 2008-2021.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2008	2019	2021
Emergent	*Iris pseudacorus*	Pale-yellow iris	Non-Native - Invasive	N/A			I
	Iris versicolor	Northern blue flag	Native	5			I
	Phragmites australis subsp. *australis*	Giant reed	Non-Native - Invasive	N/A			I
	Schoenoplectus acutus	Hardstem bulrush	Native	5	X		X
	Sparganium eurycarpum	Common bur-reed	Native	5			I
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A			I
	Typha latifolia	Broad-leaved cattail	Native	1			I
FL	*Nuphar variegata*	Spatterdock	Native	6	X	X	X
	Nymphaea odorata	White water lily	Native	6	X	X	X
FL/E	*Sparganium emersum var. acaule*	Short-stemmed bur-reed	Native	8			I
Submergent	*Ceratophyllum demersum*	Coontail	Native	3	X	X	X
	Chara spp.	Muskgrasses	Native	7	X	X	X
	Elodea canadensis	Common waterweed	Native	3		X	X
	Heteranthera dubia	Water stargrass	Native	6			X
	Myriophyllum heterophyllum	Various-leaved watermilfoil	Native	7	X	X	X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X		X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X
	Myriophyllum verticillatum	Whorled watermilfoil	Native	8		X	
	Najas flexilis	Slender naiad	Native	6	X		X
	Najas guadalupensis	Southern naiad	Native	7		X	
	Nitella spp.	Stoneworts	Native	7	X	X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X	X
	Potamogeton friesii	Fries' pondweed	Native	8			X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7			X
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	X	X
	Potamogeton natans	Floating-leaf pondweed	Native	5	X		X
	Potamogeton nodosus	Long-leaf pondweed	Native	5	X	X	X
	Potamogeton pusillus	Small pondweed	Native	7			X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8			X
	Sagittaria sp. *(rosette)*	Arrowhead sp. (rosette)	Native	N/A			I
	Stuckenia pectinata	Sago pondweed	Native	3	X	X	X
	Utricularia vulgaris	Common bladderwort	Native	7	X	X	X
	Vallisneria americana	Wild celery	Native	6			X
SE	*Schoenoplectus subterminalis*	Water bulrush	Native	9	X	X	X
FF	*Lemna minor*	Lesser duckweed	Native	5			I
	Lemna trisulca	Forked duckweed	Native	6			X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey

Data regarding aquatic plant bio-volume was collected during the acoustic survey throughout the entire lake. Aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2021 aquatic plant bio-volume data are displayed in Figure 3.5-3 and Map 9. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2021 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 18 feet, which is deeper than the maximum depth of 13 feet recorded in 2008. Aquatic plant abundance is high throughout all depths of the littoral zone. Aquatic plant growth is sparse in near-shore areas comprised of sand and in the deepest areas of the lake. Aquatic plants grew closest to the surface in near-shore areas comprised of soft organic sediments.

The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of two to three times the average Secchi disk depth. The maximum depth of aquatic plant growth in Auburn Lake was 13.0 feet in 2008, 19 feet in 2019, and 18.0 feet in 2021. As is discussed in the Water Quality Section (Section 3.1), water clarity has been higher in the past three years than when compared to the next available measurements from the late 1990s. The increase in the maximum rooting depth of aquatic plant growth between 2008 and 2021 corresponds to this increase in clarity. As is discussed, this increase in clarity may be due to the introduction of the invasive zebra mussel. With clearer water, light can penetrate further and support aquatic plant growth at deeper depths.

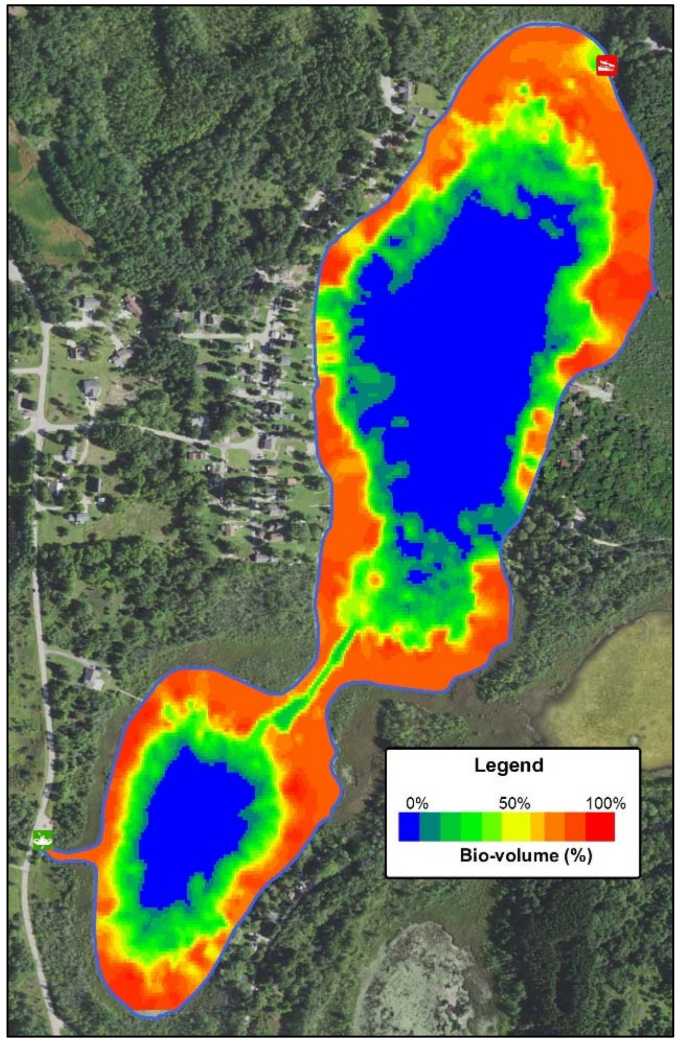


Figure 3.5-3. Auburn Lake spatial distribution of substrate hardness (left) and aquatic plant bio-volume (right). Created using data from July 2021 acoustic survey data.

The littoral frequency of occurrence of vegetation in Auburn Lake has ranged from 65% in 2019 to 75% in 2008 (Figure 3.5-4), indicating the majority of Auburn Lake's littoral zone supports aquatic plant growth. Total rake fullness (TRF) data collected in 2019 and 2021 were primarily comprised of TRF values of 2 and 3, indicating that where vegetation is present its density or biomass is moderate to high. There was a larger proportion of TRF ratings of 1 in 2008 compared to recent years, indicating aquatic plant biomass/density may have been higher in 2019 and 2021 compared to 2008. The higher biomass of aquatic plants in 2019 and 2021 may be the result of higher water clarity. With higher light availability, aquatic plant production and growth is also higher. As is discussed further, the increase in aquatic plant biomass may also be an indicator of increasing nutrient input to Auburn Lake.

The data collected from the whole-lake point-intercept survey is also used to quantify the abundance of individual plant species within the lake. Of the 38 aquatic plant species that have been recorded in Auburn Lake since 2008, 27 were encountered directly on the rake during the 2021 whole-lake point-intercept survey (Figure 3.5-5). In addition to these 27 species, 9 additional species were recorded as incidental during the emergent and floating-leaf community mapping survey. 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. Of the 27 species directly sampled with the rake during the point-intercept survey, coontail, flat-stem pondweed, muskgrasses, and northern watermilfoil were the four-most frequently encountered (Figure 3.5-5). Eurasian watermilfoil had a littoral occurrence of 9% in 2021. Curly-leaf pondweed had a littoral occurrence of 9% as well in 2021. Eurasian watermilfoil and curly-leaf pondweed in Auburn Lake are discussed in detail in the subsequent *Non-Native Aquatic Plants* sub-section.

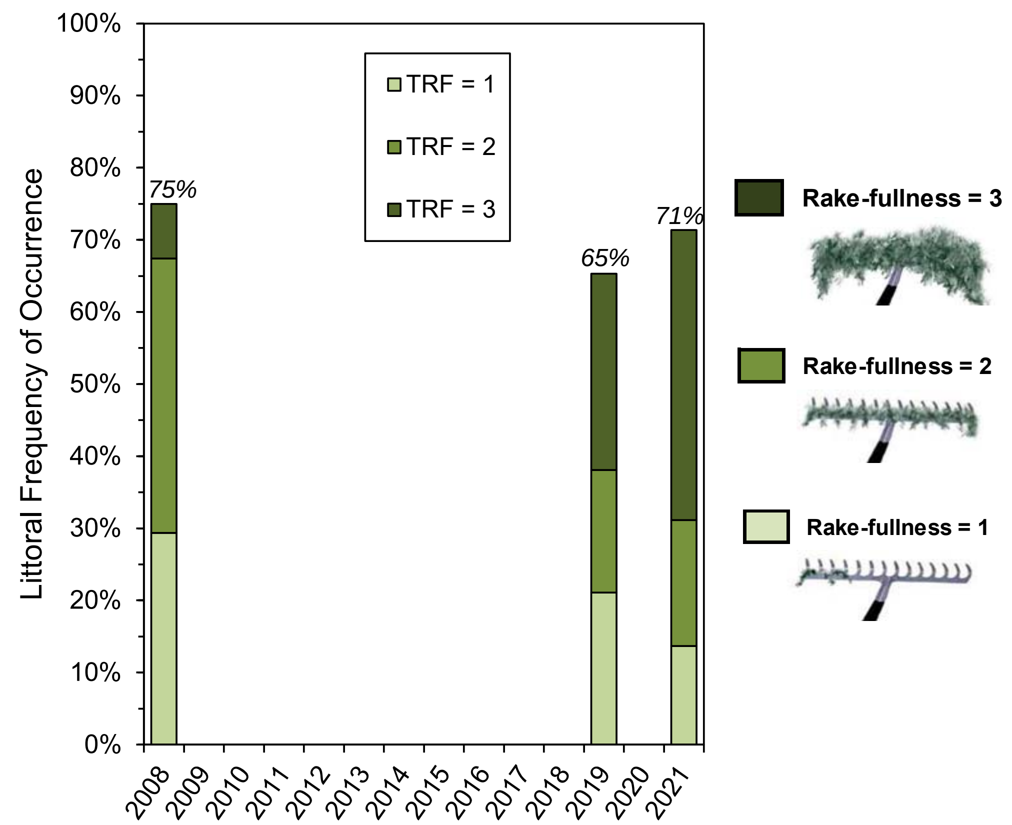


Figure 3.5-4. Auburn Lake littoral frequency of occurrence of vegetation and total rake fullness (TRF) ratings from 2008-2021.

A Chi-Square Test was utilized to determine if changes in the littoral occurrences between surveys from 2008-2021 are statistically valid ($\alpha = 0.05$). The most frequently encountered aquatic plant species and species which have seen the most significant changes in their littoral occurrence between the three surveys are discussed. The littoral occurrences of all species recorded from 2008-2021 in Auburn Lake can be found in a table in Appendix D.

Coontail was the most common aquatic plant from Auburn Lake in 2021 with a littoral occurrence of 42% (Figure 3.5-5 and Photograph 3.5-4). Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with higher nutrients and lower water clarity. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and helps to improve water clarity.

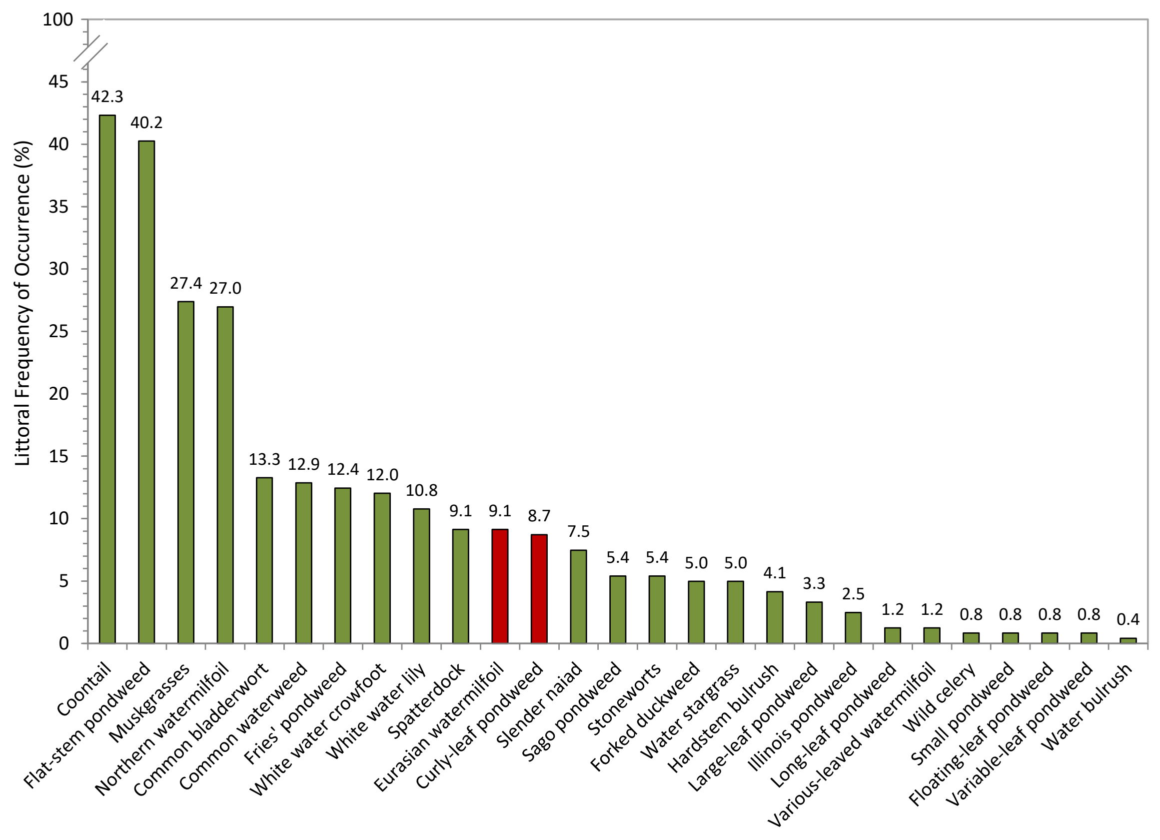


Figure 3.5-5. Auburn Lake 2021 littoral frequency of occurrence of aquatic plant species. Created using data from 2021 whole-lake point-intercept survey. Native species indicated in green; non-native species indicated in red.

Coontail has seen a significant increase in occurrence from the first survey in 2008 to the more recent surveys in 2019 and 2021. In 2008, its littoral occurrence was just 4%, and in 2019 and 2021 it had increased to become the most dominant plant in the lake with occurrences of 50% and 42%, respectively (Figure 3.5-6). This represents a statistically valid increase in occurrence of approximately 1,000%. As mentioned earlier, coontail obtains the majority of its nutrient uptake directly from the water. Coontail requires high inorganic nitrogen levels in the water during rapid growth (Mjelde M. 2003), and may be an indication of increasing nitrogen (and phosphorus) inputs to Auburn Lake. Studies have shown rapid uptake of phosphorus and nitrogen by coontail (Lombardo and Cooke 2003). Rather than fueling free-floating algal growth (phytoplankton), the increase in coontail biomass over this period is an indication these nutrients are being sequestered by the coontail population and fueling its growth.

Studies have shown that abundant coontail can inhibit the production of phytoplankton (Gross et al. 2003). Coontail also provides habitat for periphyton, a mixture of algae and other microbes which attach to aquatic plants and obtain nutrients from the water. Coontail has also been shown to release allelochemicals which inhibit the growth of phytoplankton (Gross et al. 2013). Systems dominated by coontail have been shown to withstand high phosphorus loading without producing algal blooms, and research has shown coontail can play an important role in maintaining a clear-water state under higher phosphorus concentrations (Mjelde M. 2003). While coontail is currently absorbing these nutrients and helping to maintain low algae levels in Auburn Lake, if nutrient inputs continue to increase, they will eventually reach a point where the aquatic plant community will no longer be able to suppress agal production. At higher nutrient levels, algal levels will increase, water clarity will decline, and aquatic plant growth will decline as well.

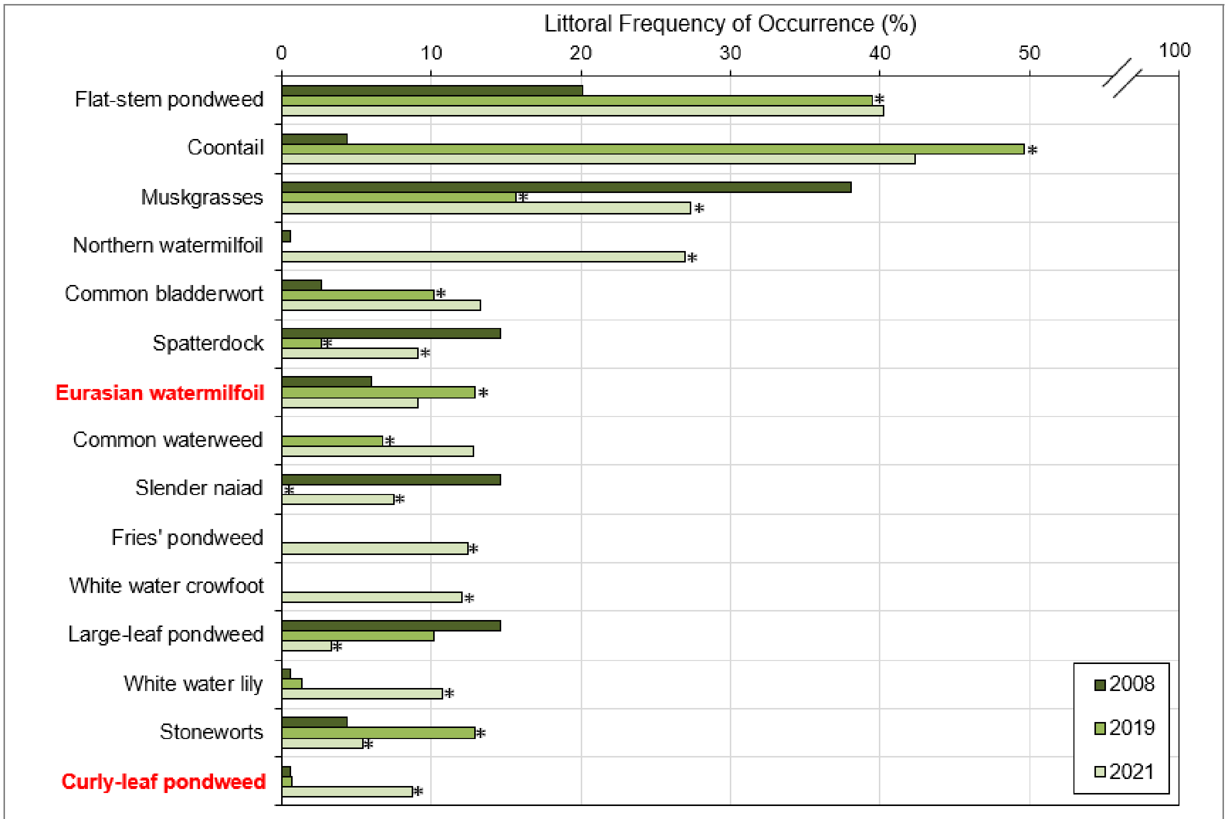


Figure 3.5-6. Littoral frequency of occurrence of the 15 most encountered plants in Auburn Lake. Asterisk denotes a statistical difference in occurrence from the previous survey (Chi-square α = 0.05).

As is discussed in the Water Quality Section (Section 3.1), nutrient data are limited from Auburn Lake. However, the significant increase in coontail between 2008 and 2019 is an indication of increasing nutrient input. This increase in nutrient input may the result of the record precipitation that was experienced over this time period. Between 2007 and 2020, annual precipitation in this area was above the annual average from 2010-2020. The years 2017, 2018, 2019, 2020 had the highest annual precipitation levels ever recorded since record keeping began. Auburn Lake has a relatively large watershed, with the largest portion being comprised of wetlands. While wetlands typically sequester nutrients, flooding events with higher precipitation can reduce their capacity to retain nutrients. The higher precipitation may have led to increases in nutrient inputs to Auburn Lake, spurring the increase in biomass and dominance by coontail.

Flat-stem pondweed was the second-most common aquatic plant from Auburn Lake in 2021 with a littoral occurrence of 40% (Figure 3.5-5 and Photograph 3.5-4). Flat-stem pondweed is one of several narrow-leaved pondweeds in Wisconsin. It has long, narrow linear leaves that alternate along a slender, flattened stem. Flat-stem pondweed has increased in its occurrence by approximately 100% since 2008 (Figure 3.5-6). In 2008, flat-stem pondweed was most prevalent in the northern and southern areas of the north basin, and in 2021 it was widespread throughout littoral areas of both the northern and southern basins. Flat-stem pondweed is typically found in more mesotrophic to eutrophic lakes with relatively clear water. The increase since 2008 may also be related to the presumed nutrient increase as hypothesized earlier.

Photograph 3.5-4. Select common aquatic plant species and species which exhibited large changes in occurrence in Auburn Lake between 2008 and 2021. Photo credits Onterra.

Muskgrasses, a group macroalgae, were the third-most frequently encountered aquatic plant in Auburn Lake in 2021 with a littoral occurrence of 27% (Figure 3.5-5 and Photograph 3.5-4). Muskgrasses were the most abundant plant in Auburn Lake in 2008 with a littoral occurrence of nearly 38%. In 2019, their occurrence had declined by 60% to an occurrence of 16%. In 2021, their littoral occurrence increased to 27%, a 75% increase from 2019 (Figure 3.5-6). Dominance of the aquatic plant community by muskgrasses is common in hardwater, alkaline lakes like Auburn Lake, and these macroalgae have been found to more competitive against vascular plants (e.g., pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002) (Wetzel 2001). Muskgrasses grow relatively low in the water column and thus need high water clarity. Their decline since 2008 is likely due to competition with taller plants, like coontail, which have increased over this period.

Northern watermilfoil was the fourth-most frequently encountered aquatic plant species in Auburn Lake in 2021 with a littoral occurrence of 27% (Figure 3.5-5 and Photograph 3.5-4). Northern watermilfoil is one of seven native milfoil species that can be found in Wisconsin, and is the most likely to be confused with Eurasian watermilfoil. Northern watermilfoil from Auburn Lake was collected and sent to Montana State University where it was genetically confirmed as northern watermilfoil. The northern watermilfoil population in Auburn Lake has increased significantly between 2008 and 2021. In 2008, it was recorded at just one sampling location, yielding a littoral occurrence of 0.5%, while it was not recorded at all in 2019. Its occurrence of 27% in 2021 represents a statistically valid increase of nearly 5,000% since 2008. An increase of this magnitude within a two-year period is surprising, and the reason(s) for why northern watermilfoil has increased may be related to an increase in water clarity and changes in the abundance of other aquatic plant species.

Common bladderwort was the fifth-most frequently encountered aquatic plant in Auburn Lake in 2021 with a littoral occurrence of 13% (Figure 3.5-5 and photograph 3.5-4). Common bladderwort is one of nine bladderwort species that can be found in Wisconsin. These plants are carnivorous, producing bladder-like traps which capture and feed on zooplankton. Common bladderwort increased in occurrence from 3% in 2008, to 10% and 13% in 2019 and 2021, respectively (Figure 3.5-6). Like coontail and common waterweed, common bladderwort does not produce roots and receives all of its nutrients directly from the water and through zooplankton. Studies have shown a strong relationship between phosphorus and common bladderwort growth (Kosiba 1992). The increase in common bladderwort in Auburn Lake also supports the hypothesis that nutrient input has increased in recent years.

Common waterweed was the sixth-most frequently encountered aquatic plant in Auburn Lake in 2021 with a littoral occurrence of 13% (Figure 3.5-5). Common waterweed can be found in waterbodies across Wisconsin, and like coontail, obtains much of its nutrients directly from the water. Common waterweed has increased in occurrence from 0% in 2008, to 7% in 2019, and 13% in 2021. The increase in occurrence of common waterweed in Auburn Lake is also likely due to the hypothesized increase in nutrients as discussed previously.

Fries' pondweed was the seventh-most frequently encountered aquatic plant in Auburn Lake in 2021 with a littoral occurrence of 12% (Figure 3.5-5 and Photograph 3.5-4). A common species in calcareous waters, Fries' pondweed is one of Wisconsin's several narrow-leaved pondweed species. Fries' pondweed was not recorded in 2008 or 2019 (Figure 3.5-6). Large fluctuations in the occurrence of Fries' pondweed have been observed on other lakes by Onterra ecologists. Onterra has observed this species reaching maximum growth early in the summer (like curly-leaf pondweed) before senescing by mid-summer. Survey timing may be one of the primary factors influencing whether or not this species is recorded during a survey.

White water crowfoot was the eighth-most frequently encountered aquatic plant in Auburn Lake in 2021 with a littoral occurrence of 12% (Figure 3.5-5 and Photograph 3.5-4). White water crowfoot is one of several species in the buttercup family, and one of a few in Wisconsin that are aquatic. It produces delicate, five-petaled white flowers above the surface. Like coontail, common waterweed, and common bladderwort, studies have shown that this species can obtain much of its nutrients directly from the water, and its increase in occurrence in Auburn Lake may be another indicator of higher nutrient input in recent years.

The final aquatic plant species for discussion that indicates a changing environment in Auburn Lake is large-leaf pondweed (Photograph 3.5-4). Large-leaf pondweed is the largest pondweed species in Wisconsin, and is relatively sensitive to environmental changes. The occurrence of large-leaf pondweed has declined over the course of the three point-intercept surveys (Figure 3.5-6). Its occurrence declined from 15% in 2008, to 10% in 2019, and just 3% in 2021. This represents a statistically valid decline in occurrence of 77% between 2008 and 2021. In 2008, large-leaf pondweed was primarily encountered growing in areas with muskgrasses. As discussed earlier, muskgrasses grow relatively low in the water column. These areas are now dominated by coontail, which is likely out-competing large-leaf pondweed for light and space.

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. The native aquatic plant species located on the rake during the point-intercept surveys from 2008, 2019, and 2021 and their conservatism values were used to calculate the FQI for each year (Figure 3.5-7). Native species richness, or the number of native plant species recorded on the rake, has ranged from 17 in 2008, 16 in 2019, to 25 in 2021. The higher species richness in 2021 (25) is likely a function of differences in surveyor ability to identify aquatic plants and/or the level of sampling effort in backwater areas where more species tend to occur. This average species richness value (25) falls well above the median value for lakes in the Northern Lakes and Forests ecoregion (21) and the median value for lakes statewide (19).

Between 2008-2021, average species conservatism in Auburn Lake has ranged from 5.4 to 6.1 with an average of 5.9 (Figure 3.5-7). These conservatism values fall between the median values for lakes in the SWTP ecoregion (5.4) and the state (6.3). In other words, Auburn Lake supports more environmentally-sensitive species when compared to other lakes in the ecoregion and slightly fewer species when compared to lakes statewide.

Using the species richness and average conservatism to calculate the Floristic Quality Index for Auburn Lake yielded values ranging from 22.3 to 30.5 with an average of 25.7, which falls above the median value for lakes in the SWTP ecoregion and near the median value for lakes statewide.

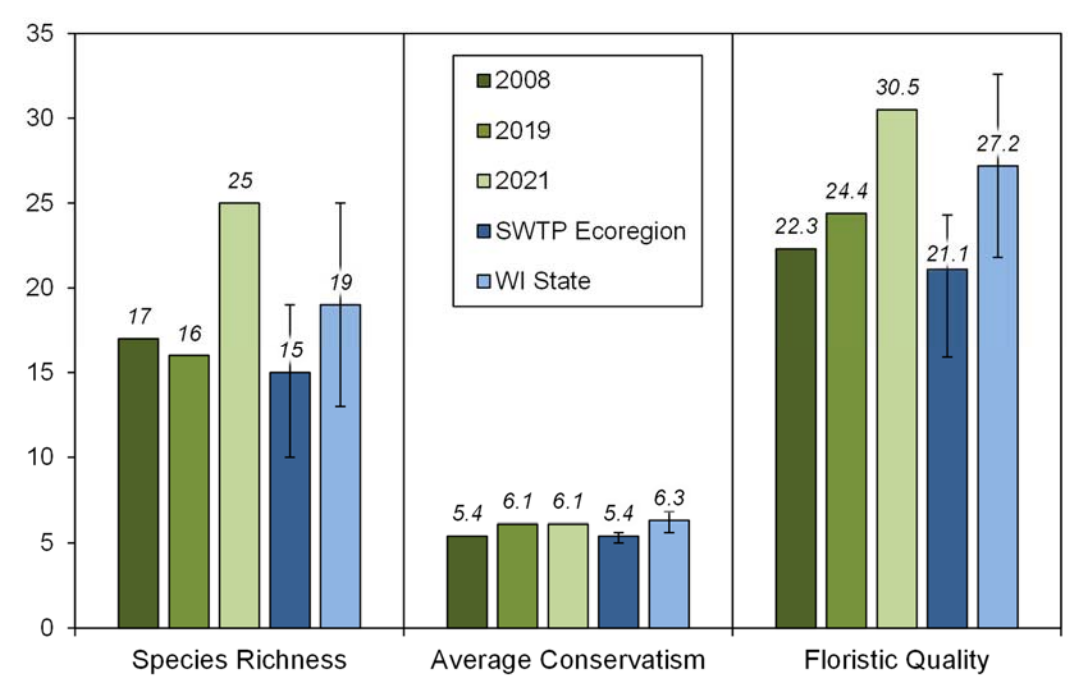


Figure 3.5-7. Auburn Lake species richness, average conservatism, and Floristic Quality from 2008-2021. Includes native aquatic plant species physically encountered on the rake during the point-intercept survey and does not include incidentally-located species.

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 Auburn Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP Ecoregion (Figure 3.5-8). Using the data collected from the whole-lake point-intercept surveys, Auburn Lake's aquatic plant species diversity has ranged from 0.85 to 0.92. Diversity has fluctuated from 2008-2021. The average diversity value over the period was 0.89, near the upper quartile range for lakes in the SWTP ecoregion.

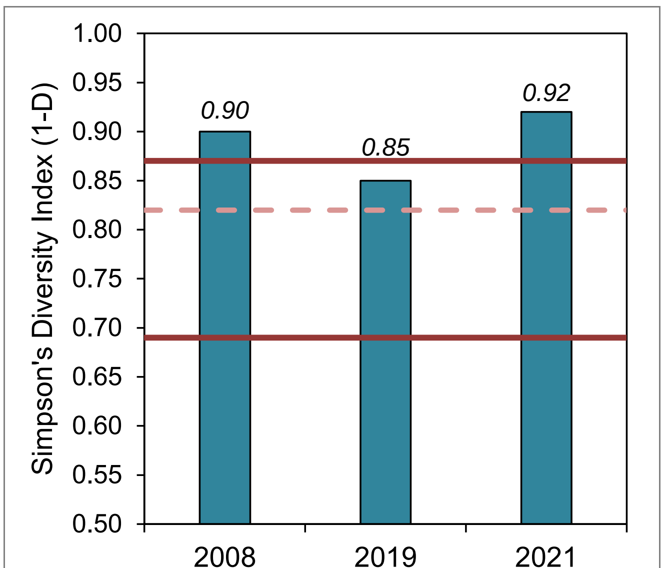


Figure 3.5-8. Simpson's Diversity Index for Auburn Lake. Created using data from 2008-2021 point-intercept surveys.

One way to visualize the diversity of Auburn Lake's plant community is to examine the relative frequency of occurrence of aquatic plant species (Figure 3.5-9). Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while coontail was found at 42% of the littoral sampling locations in Auburn Lake in 2021 (littoral occurrence), its relative frequency of occurrence was 16%. Explained another way, of 100 plants were randomly sampled from Auburn Lake in 2021, 16 of them would have been coontail, 15 flat-stem pondweed, 10 muskgrasses, etc. In 2019, the three most dominant species comprised approximately 57% of the lake's plant community, lowering species diversity. In 2021, the six most frequently encountered species accounted for this same percentage. The more even distribution of species in 2021 resulted in higher species diversity.

In 2021, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaved plant communities in Auburn Lake (Photograph 3.5-4). Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies. Like submersed aquatic plant communities, these communities also provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosion control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

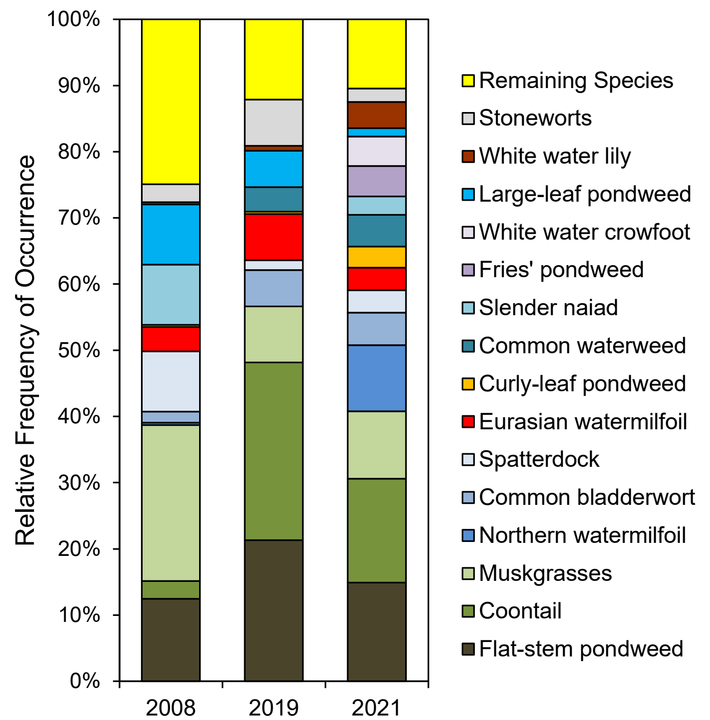


Figure 3.5-9. Relative frequency of occurrence of aquatic vegetation in Auburn Lake. Created using data from 2008, 2019 and 2021 point-intercept surveys.

This is important to note because these communities are often negatively affected by recreational use and shoreland development. (Radomski and Goeman 2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

The 2021 survey revealed that Auburn Lake supports 22 acres (24% of lake area) of emergent and floating-leaf aquatic plant communities (Figure 3.5-10 and Map 10). These communities were comprised of seven native species and three non-native species. White water lily, spatterdock, and hardstem bulrush were the three most dominant species within these communities in Auburn Lake. These communities were most often located in areas with little to no shoreline development.

Photograph 3.5-4. Emergent and floating-leaf plant communities in Auburn Lake. Photo credit Onterra 2021.

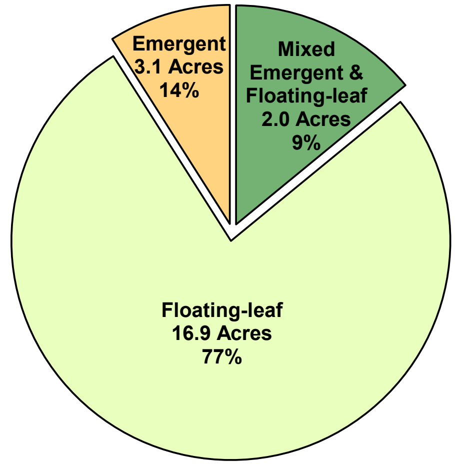


Figure 3.5-10. Acres of floating-leaf and emergent plant communities on Auburn Lake. Data from the 2021 community mapping survey conducted by Onterra.

Non-Native Aquatic Plants in Auburn Lake

Curly-leaf Pondweed (*Potamogeton crispus*)

Curly-leaf pondweed (CLP; Photograph 3.5-5) was first documented in Auburn Lake in 2008. Curly-leaf pondweed's primary method of propagation is through the production of numerous asexual reproductive structures called turions. Once mature, these turions break free from the parent plant and may float for some time before settling and overwintering on the lake bottom. Once favorable growing conditions return (i.e., spring), new plants emerge and grow from these turions. Many of the turions produced by CLP begin to sprout in the fall and overwinter as small plants under the ice. Immediately following ice-out, these plants grow rapidly giving them a competitive advantage over native vegetation. Curly-leaf pondweed typically reaches its peak biomass by mid-June, and following the production of turions, most of the CLP will naturally senesce (die back) by mid-July.

Photograph 3.5-5. Curly-leaf pondweed plants. Locations of CLP in Auburn Lake can be found on Map 11. Photo credit Onterra.

If the CLP population is large enough, the natural senescence and the resulting decaying of plant material can release sufficient nutrients into the water to cause mid-summer algal blooms. In some lakes, CLP can reach growth levels which interfere with navigation and recreational activities. However, in other lakes, CLP appears to integrate itself into the plant community and does not grow to levels which inhibit recreation or have apparent negative impacts to the lake's ecology. Because CLP naturally senesces in early summer, surveys are completed early in the growing season in an effort to capture the full extent of the population.

An Early-Season AIS Survey on Auburn Lake was completed on May 24, 2021 to capture the full extent of the lake's CLP population. The 2021 survey found that the CLP population in Auburn Lake has a fairly large footprint with localized dominant colonies (Map 11). The population was comprised of approximately 20.4 acres of CLP, 4.3 acres of which were delineated as dominant or greater density. Isolated locations of small plant colonies, clumps of plants, and single plants were also found throughout both basins.

Unlike many of our native aquatic plants, curly-leaf pondweed begins growing immediately after ice-out and reaches its peak growth in mid- to late-June and then naturally senesces (dies back) in early summer. The senescence of curly-leaf pondweed populations has been shown to release a significant amount of phosphorus into the water from decomposing plant tissues (Leoni et al. 2016). When considering water quality, the July total phosphorus concentration increases to an average of 26 ug/L, higher than the average of 22 and 20 ug/L, in June and August. It appears curly-leaf pondweed may be increasing total phosphorus concentrations slightly in July in Auburn Lake.

Curly-leaf Pondweed Management

The theoretical goal of CLP population 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 the creation of a sediment turion bank or reserve. Normally, a control strategy for an established CLP population includes multiple years of herbicide application of the same area to deplete the existing turion bank within the sediment. An example of this type of strategy would be through the annual application of the endothall for five or more consecutive years targeting the same areas of the lake. In instances where a large turion base may have already built up because of a long-term presence in the system, 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.

Research conducted by (Skogerboe et al. 2008) at the US Army Corps of Engineers Research and Development Center found that management strategies that fails to kill the entire CLP plant (including rhizomes and root crowns) does not prevent new turion formation. The research found that stressed CLP plants actually produced more turions, and when above-ground biomass has been removed, the plants produced turions in the sediment along the rhizomes (stick turions). This means that sub-lethal herbicide treatments could actually increase the population over time.

Because CLP has been present in Auburn Lake for at least 14 years, the population is considered established within the lake. It is possible that the CLP population may not expand its footprint beyond what has already been observed in the lake in recent years. It should be expected that the CLP population will be variable from year to year in Auburn Lake as environmental variables such as snow depth, ice cover, and water temperatures, may or may not be favorable for turion germination in any given year. Future CLP management may consider the use of mechanical harvesting in locally dense areas of CLP as a means of relief from nuisance conditions in early-summer. It is important to note that CLP naturally senesces in early-summer meaning that this species does not contribute to nuisance plant growth conditions that may be occurring on the lake from approximately mid-July through the remainder of the growing season.

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Eurasian watermilfoil (EWM) is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed but by shoot fragmentation, which has supported its transport between lakes via boats, boat trailers, and other equipment. In addition to its propagation method, EWM 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, and 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.

Photograph 3.5-6. Eurasian watermilfoil (left) and dominant EWM colonies in Auburn Lake in 2021. Locations of EWM in Auburn Lake can be found on Map 12. Photo credit Onterra.

Eurasian watermilfoil was first documented in Auburn Lake in 2008. In Auburn Lake, native milfoils are known to co-exist with EWM and exhibit morphological similarities. In 2021, Onterra staff collected native and non-native milfoil samples and submitted to Montana State University to be tested for hybridity. The lab DNA test showed the lake supports populations of both the native northern watermilfoil (*Myriophyllum sibiricum*) and non-native pure-strain Eurasian watermilfoil. Hybrid watermilfoil, a cross between northern and Eurasian watermilfoil was not identified in Auburn Lake. Knowing this fact, it may be reasonable to assume any plant that exhibits characteristics of hybrid milfoil in Auburn Lake are actually native northern watermilfoils. To a trained eye, the pure-strain EWM should be distinguishable from the other milfoil species in the lake.

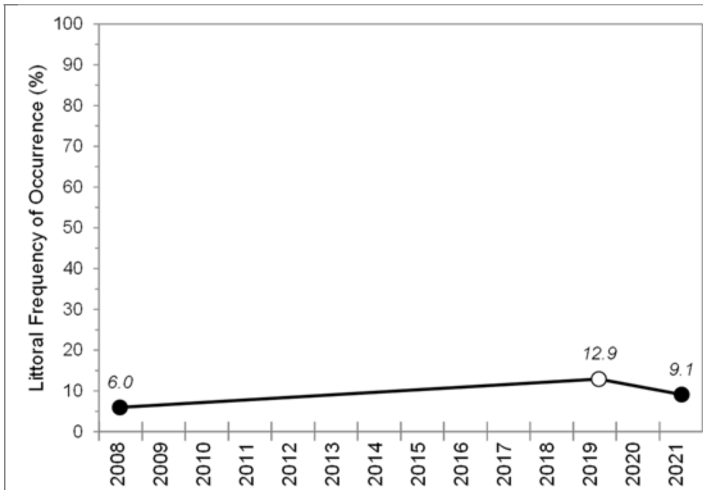


Figure 3.5-11. Littoral frequency of occurrence of Eurasian watermilfoil in Auburn Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square α = 0.05).

The 2021 point-intercept survey found that EWM had a littoral frequency of occurrence of 9%, representing a slight decline since 2019 but was not statistically valid (Figure 3.5-11). The point-intercept survey found that EWM is found throughout areas of Auburn Lake, including in deeper water to 12 feet. Auburn Lake's high water clarity allows for EWM (and native plants) to grow and colonize to deeper depths.

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 to understand where recreation and navigation impairment exists and how to direct management activities. Within this project, a series of AIS mapping surveys allowed this level of data to be understood.

As a part of this project, EWM was initially mapped during the Early-Season AIS Survey to get a first look at the distribution of this species. EWM continues to grow throughout the summer months and therefore, a Late-Season EWM Mapping Survey was completed in August when EWM is typically at or near its peak-biomass for the growing season. While EWM can be found throughout the littoral zone of Auburn Lake, approximately 3.3 acres of contiguous EWM colonies were mapped in Auburn Lake in the August 2021 mapping survey (Figure 3.5-11 and Map 12). Approximately 1.9 acres were comprised of *scattered* EWM, 1.4 acres were comprised of *dominant* or *highly dominant* EWM colonies. Dominant density colonies were located in both basins of the lake during the Late-Season EWM Mapping Survey in August.

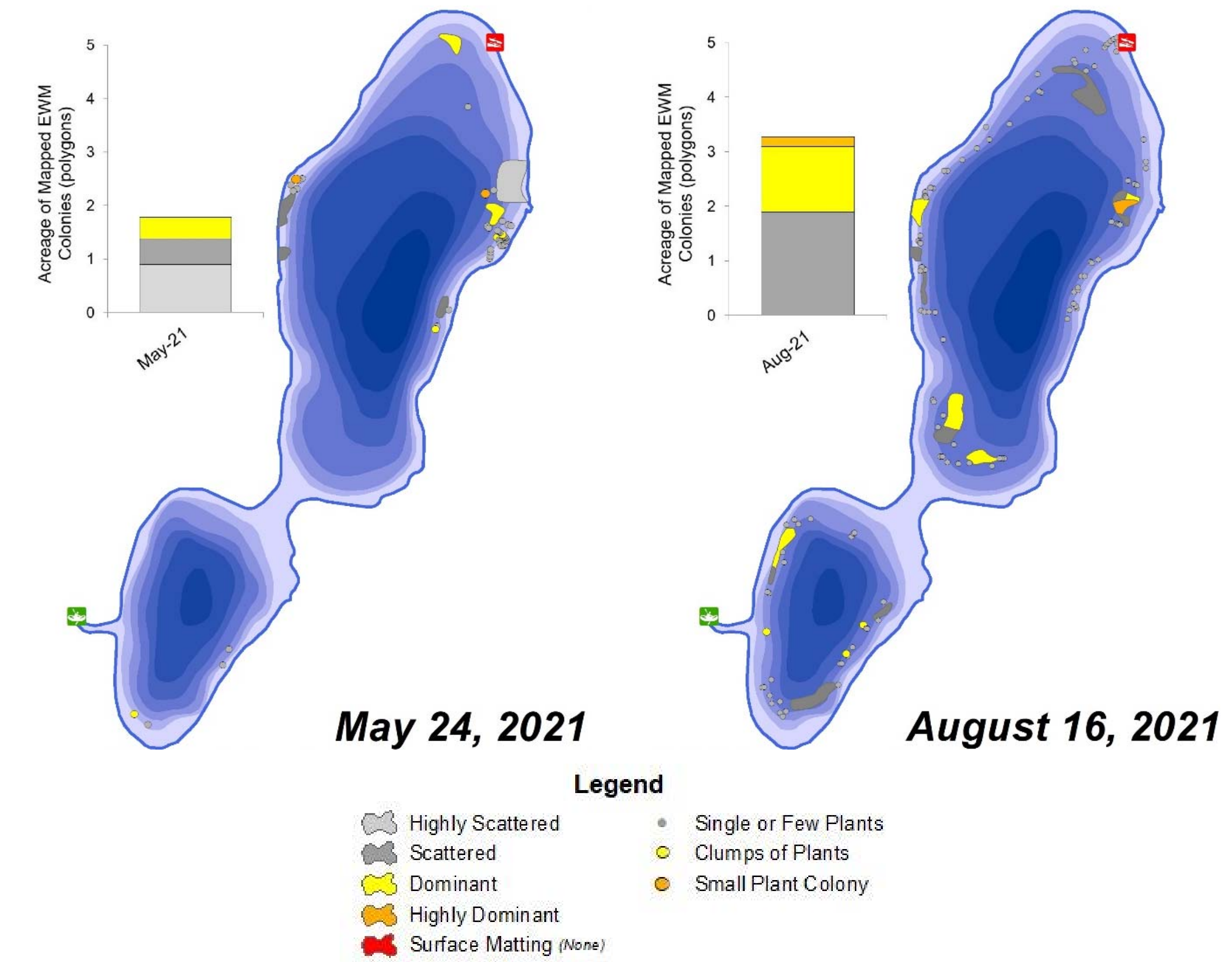


Figure 3.5-12. Auburn Lake 2021 Eurasian watermilfoil locations. Eurasian watermilfoil mapped by Onterra on May 24 and August 16, 2021.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. The ongoing collection of these data is showing that like other aquatic plants, EWM populations are dynamic. Annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). Figure 3.5-13 shows the EWM populations of four unmanaged EWM lakes in the Southeastern Till Plains ecoregion in comparison. To clarify, these lakes have not conducted herbicide treatments or any other forms of strategic EWM management during this period of study. As these data illustrate, the littoral occurrence of EWM can fluctuate widely from year to year and over longer periods of time. 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 (M. 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.

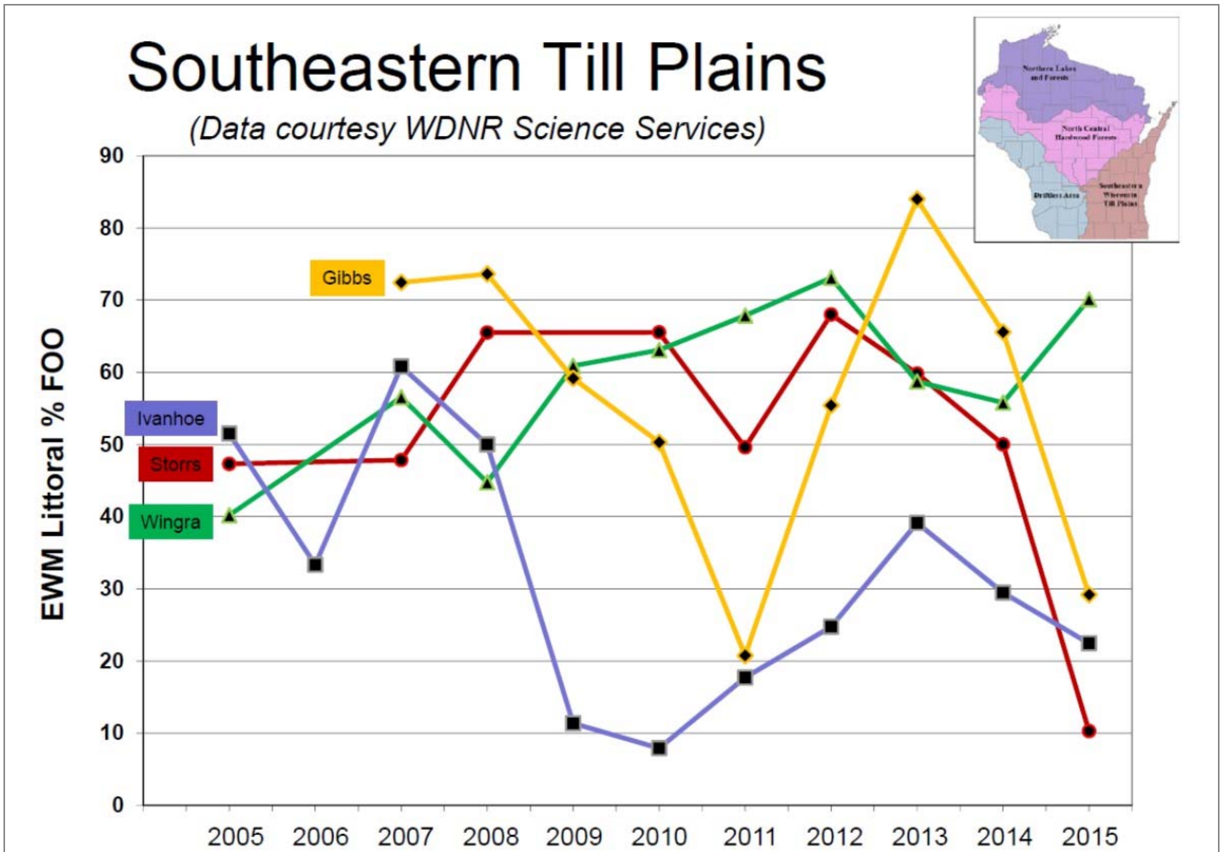


Figure 3.5-13. Littoral frequency of occurrence of unmanaged EWM populations in the Southeastern Till Plains ecoregion. Data provided by and used with permission from WDNR. For comparison, the littoral occurrence of EWM in Auburn Lake was 6% in 2008, 13% in 2019, and 9% in 2021.

The Science Behind the "So-Called" Super Weed (M. Nault 2016)

In 2015, the WDNR investigated the most recent point-intercept data from almost 400 Wisconsin Lakes that had confirmed EWM populations. These data show that approximately 65% of these lakes had EWM populations with a littoral frequency of occurrence of 10% or less (Figure 3.5-14). At these low population levels, there is not likely to be impacts to recreation and navigation, nor changes in ecological function. Only 25% of the lakes in the survey had EWM populations of 20% or higher. This may be due to the fact that the EWM population on some lakes may never reach that level or that management activities may have been enacted to suppress the EWM population to lower levels. At the time of this writing, Auburn Lake's most recent point-intercept survey (2021) yielded a littoral occurrence of EWM at 9%.

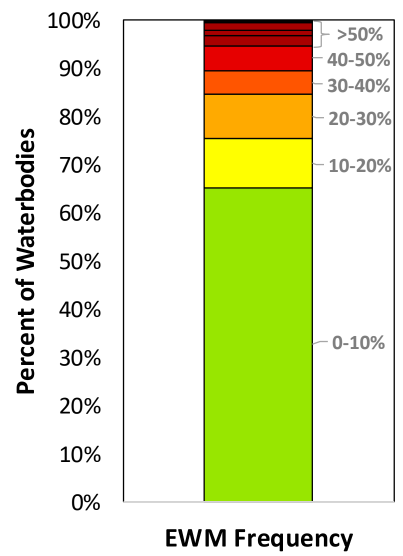


Figure 3.5-14. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

Invasive Watermilfoil Management

Invasive watermilfoil management is relatively straight forward compared to CLP management. The goal of invasive watermilfoil management is to kill the plant. While sexual reproduction (seeds) and asexual reproduction (turions in some EWM populations) do occur, their contribution to a lake-wide population is thought to be minimal. So unlike CLP management, one effective treatment is all that is needed. As a perennial plant, EWM is much harder to kill with herbicides compared to CLP. Contact herbicides, such as those discussed for CLP, may eliminate the aboveground biomass of EWM, but extensive storage reserves in the root crown will allow resprouting and rebound. Therefore, systemic herbicides that translocate throughout the plant into the root crown are required.

2,4-D is a weak-acid auxin mimic herbicide that has often been used for invasive watermilfoil management in Wisconsin and around the country. This herbicide gets translocated throughout the plant (acts systemically) and suppresses growth regulation hormones. Achieving EWM control with 2,4-D in a spot-treatment scenario has proven difficult as a result of rapid dissipation away from the direct application area resulting in insufficient concentration exposure times to achieve plant mortality. Larger spot-treatment application areas (greater than five acres in size), or targeting sites that are not subjected to significant water flow, or located in exposed locations in the center of a lake are more likely to meet control objectives with 2,4-D spot-treatment designs.

From an ecological perspective, whole-lake treatments are those where the herbicide may be applied to specific sites, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water (of the lake, lake basin, or within the epilimnion of the lake or lake basin), it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume. An article by Nault et al. 2018 investigated 28 large-scale herbicide treatments in Wisconsin and found that "herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lake-wide low-concentration equilibriums were reached within the first few days after application."

Some 2,4-D EWM management strategies have had more success when designed as a whole-lake treatment. Operationally, a lake-wide 2,4-D concentration above 0.1 ppm acid equivalent (ae) is considered by Onterra to represent a whole-lake treatment, assuming typical exposure time from herbicide degradation. Onterra has observed lake-wide impacts to some sensitive native plants when lake-wide concentrations were above 0.1 ppm ae; but being more durable, EWM impacts do not typically occur until lake-wide concentrations exceed 0.2 ppm ae. When prescribing whole-lake 2,4-D treatments, the traditional lake-wide target is 0.3-0.4 ppm ae with the higher concentrations targeting more difficult populations including hybrid watermilfoils.

The term Best Management Practice (BMP) is often used in environmental management fields to represent the management option that is currently supported by the 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. For example, granular herbicides historically were a BMP that is no longer supported in most instances. Emerging science demonstrated that liquid treatments provided more consistent results at a fraction of the cost of granular products, larger application areas appeared to retain herbicide concentrations and exposure times better, and attention needed to be paid to the addition of individual spot treatments that may cumulatively function as a whole-lake treatment.

Future AIS Management Philosophy

There are three broad potential aquatic invasive species (AIS) population goals for consideration including a recommended action plan to help reach each of the goals. Each management goal will be discussed and considered for applicability during the planning meeting. During these discussions, conversation regarding risk assessment of the various management actions will also be presented. Onterra will provide extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for the Town of Auburn and the Auburn Lake Homeowner's Association to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Auburn Lake ecosystem.

1. Let Nature Take its Course: On some lakes, invasive plant populations plateau or reduce without active management. Some lake groups decide to periodically monitor the AIS population, typically through an annual or semi-annual point-intercept survey, but do not coordinate active management (e.g., hand-harvesting or herbicide treatments). Individual riparians could choose to hand-remove the AIS within their recreational footprint, but the lake group would not assist financially or by securing permits if necessary. In most instances, the lake group may select an AIS population threshold or trigger where they would revisit their management goal if the population reached that level.

2. Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with their AIS population is the reduced recreation, navigation, and aesthetics compared to before the AIS became established in their lake. Particularly on lakes with large AIS populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve the navigability within the lake. This is typically accomplished by targeting AIS populations in high-use parts of the through mechanical harvesting or spot herbicide treatments. Most AIS management in southeastern Wisconsin would be considered nuisance management, where dense areas that are causing navigation or recreation issues are prioritized for management typically accomplished by designing common-use navigation lanes or clearing high use areas that would be managed through hand-harvesting or mechanical harvesting. Auburn Lake has enacted this form of aquatic plant management in 2020 as a part of a mechanical harvesting program, but not specifically for AIS management.

3. Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with AIS populations, that may mean to manage the AIS population at a reduced level with the perceived goal to allow the lake to function as it had prior to AIS establishment. Due to the inevitable collateral impacts from most forms of AIS management, lake managers and natural resource regulators question whether that is an achievable goal. The WDNR maintains a cost-share grant funding program for projects that aim to reduced established aquatic invasive species populations.

For newly introduced AIS populations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns (not applicable to Auburn Lake) or whole-lake herbicide treatment strategies. Large-scale management can reduce EWM populations for several years, but will not eradicate it from the lake. Subsequent smaller scale management (e.g., hand-harvesting or spot treatments) is typically employed to slow the rebound of the population until another large-scale effort may be considered again.

Large-scale control efforts, especially using herbicide treatments, can be impactful of some native plant species as well as carry a risk of environmental toxicity. Some argue that the impacts of the control actions may have greater negative impacts to the ecology of the system than if the AIS population was not managed. Whole-lake treatment impacts typically occur when greater than 10% of the lake acreage is targeted at a time, with whole-lake impacts to some sensitive plants occurring at lower concentrations. Because of the relatively small size of Auburn Lake, targeting all of the colonized EWM (e.g., 3.3 acres in 2021) with herbicides at spot treatment use rates would likely add up to a whole-lake treatment.

In Wisconsin, most large-scale invasive watermilfoil treatments use liquid 2,4-D amine. Properly implemented large-scale 2,4-D herbicide treatments can be highly effective on pure-strain EWM populations, with minimal EWM being detected for a year or two following the treatment on some systems. Some large-scale 2,4-D treatments have been effective at reducing EWM populations for 5-6 years following the application.

A few lake groups have subsequently embraced alternative treatment strategies that are less commonly used in Wisconsin to targeted difficult invasive watermilfoil populations while attempting to preserve the valuable native plant community of the system. Three such herbicide use patterns are investigated below: 1) whole-lake 2,4-D/endothall, 2) whole-lake pelletized fluridone, and 3) spot treatments with short contact-exposure time requirements (CETs).

Whole-Lake 2,4-D & Endothall

In lakes that have both EWM and CLP, combination treatments of 2,4-D and endothall are common in spot treatment scenarios. The simultaneous exposure to endothall and 2,4-D has been shown to provide increased control of EWM in outdoor growth chamber studies (Madsen et al. 2010). A handful of HWM treatments in Wisconsin have conducted combination whole-lake 2,4-D/endothall treatment targeting approximately 0.25 ppm ae and 0.75 ppm ai, respectively with promising results of control and selectivity towards native plants. However, some of these treatments have had similarly quick target species recovery. Native aquatic plants in Auburn Lake that are particularly susceptible to this herbicide use include flat-stemmed pondweed (*Potamogeton zosteriformis*), other pondweeds (*Potamogeton* spp.) perhaps to a lesser degree, and slender naiad (*Najas flexilis*).

Whole-Lake Pelletized Fluridone

Fluridone is a systematic herbicide that disrupts photosynthetic pathways (carotenoid synthesis inhibitor). This herbicide requires long exposure times (>90 days) to cause mortality to HWM and therefore is only applicable to whole-lake use-patterns. Herbicide concentrations within the lake are kept at target levels by periodically adding additional herbicide (bump treatments) over the course of the summer based upon herbicide concentration monitoring results.

The use of fluridone has a checkered past in Wisconsin, as early implemented treatments (mid-2000s) resulted in native plant impacts that exceeded acceptable levels (Wagner et al. 2007). These collateral impacts are based upon liquid fluridone treatments, typically employed at 6 ppb with a bump treatment later in the summer to bring the concentration back up to 6 ppb. This fluridone use-pattern, commonly referred to as 6-bump-6, produces two relatively high herbicide pulses that taper off slowly as the herbicide degrades. Manufacturers of fluridone (SePRO) believe that the high herbicide pulses are the mechanism causing the native plant impacts.

A somewhat newer use-pattern of fluridone uses a pelletized product that gradually reaches a peak concentration over time (extended release) and results in a lower, sustained lake-wide herbicide concentration (2.0 to 3.0 ppb). This "low-and-long" fluridone strategy is most effective when concentrations can be maintained over 2.0 ppb for 120 days and when herbicide can still be detected in the lake the following ice-out approximately one year after the initial treatment took place.

Within a few limited Wisconsin field-trials, this use-pattern of fluridone appears to provide a similar level of efficacy as the 6-bump-6 approach, but with a lower (but still notable) magnitude of native plant impacts (Heath et al. 2018). In addition to HWM, native aquatic plants in Auburn Lake that are usually impacted by fluridone include the naiads (*Najas* spp.) and common waterweed (*Elodea canadensis*).

Spot Treatments with Short CET Herbicides

An alternative to whole-lake population control is targeting nuisance areas with spot treatments. As previously discussed, many spot treatments targeting invasive watermilfoils are limited to a single season of effectiveness. Some feel that the financial costs and ecological risks are not commensurate with the gains made from these seasonally effective treatments.

To gain multi-year EWM suppression, future spot herbicide treatments would likely need to consider herbicides (diquat, florpyrauxifen-benzyl, etc.) or herbicide combinations (2,4-D/endothall, diquat/endothall, etc.) thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides (e.g., 2,4-D, triclopyr). 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.

ProcellaCOR™ (florpyrauxifen-benzyl) is a relatively new herbicide that has shown promise in spot treatments in Wisconsin Lakes in recent years. The manufacturer is currently working towards new formulations and guidance for whole-lake use patterns. ProcellaCOR™ is in a new class of synthetic auxin mimic herbicides (arylpicolinates) with short concentration and exposure time (CET) requirements compared to other systemic herbicides. Uptake rates of ProcellaCOR™ into EWM were two times greater than reported for triclopyr (Haug 2018)(Vassios et al. 2017). ProcellaCOR™ is primarily degraded by photolysis (light exposure), with some microbial degradation. The herbicide is relatively short-lived in the environment, with half-lives of 4-6 days in aerobic environments and 2 days in anerobic environments (WSDE 2017). The product has a high affinity for binding to organic materials (i.e., high KOC).

A series of spatially-targeted spot treatments with this chemistry may reduce nuisance conditions in high-use areas for multiple seasons post treatments. Because this herbicide is active at low concentrations, attention to additive impacts of multiple spot treatments in a given area should be discussed. Native watermilfoils including northern watermilfoil are known to be highly susceptible to ProcellaCOR™ with populations of this species showing little to no signs of recovery during the year after treatment. Because northern watermilfoil is one of the more prevalent species present in Auburn Lake, any future use of this product must be carefully considered.

Nuisance Aquatic Plants

Aquatic invasive species are not the only aquatic plants which can negatively impact navigation and recreation on Auburn Lake. Native plants have also contributed to these issues. Aquatic plants can thrive under the favorable growing conditions in the lake. As discussed in the native aquatic plant analysis, coontail was the most frequently encountered species during the 2021 point-intercept survey, and can grow into dense mats and hinder navigation. Several other species including muskgrasses, native milfoils, and pondweeds can also contribute to nuisance growth conditions in the lake. Because Auburn Lake is a high-use waterbody that supports many types of recreation, aquatic plant control efforts being considered are important for ensuring continued enjoyment of the lake. Recent nuisance aquatic plant controls actions have included a mechanical harvesting effort in 2020.

The Town of Auburn and the Auburn Lake Homeowner's Association supports reasonable and environmentally sound actions to facilitate navigability on Auburn Lake. These actions may target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those which meet WDNR regulatory and permitting requirements and do not impact any more shoreland or lake surface area than absolutely necessary. As a part of this project, a new mechanical harvesting plan may be created with the goal of securing a multi-year permit from WDNR. The specifics of the mechanical harvesting plan would be determined through subsequent conversations between Onterra, the ALHA, WDNR, and other project partners.

Mechanical harvesting occurred in Auburn Lake in 2020 of approximately 9.6 acres. Most of the plants harvested were comprised of native species (large-leaf pondweed, common waterweed, and common bladderwort) along with trace amounts of Eurasian watermilfoil. The harvesting occurred between July 8-14, 2020 when most of the curly-leaf pondweed population had likely already senesced. Respondents to the 2021 stakeholder survey were in strong support of future mechanical harvesting to create navigation lanes in Auburn Lake (Figure 3.5-15).

Question 29: What is your level of support or opposition for future mechanical harvesting to create navigation lanes in Auburn Lake?

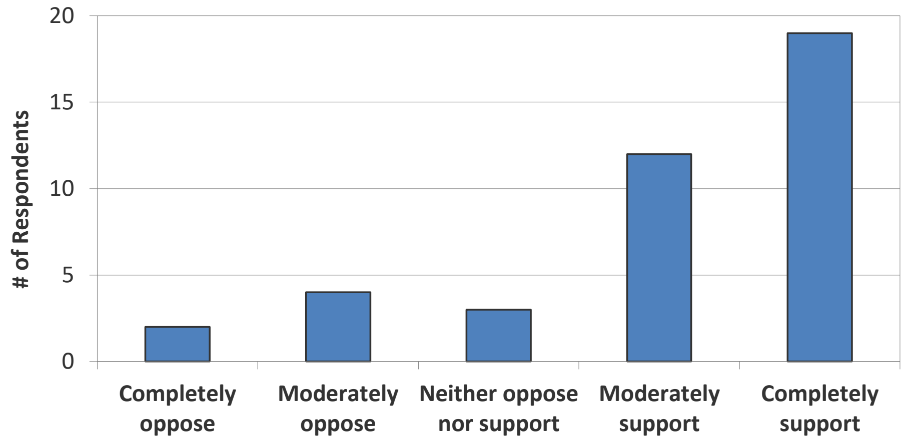


Figure 3.5-15. Select survey responses from the Auburn Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Considering the results from the 2021 stakeholder survey, the majority of respondents would be supportive of many different management techniques. Respondents were also strongly opposed of not managing plants at all (Figure 3.5-15).

Question 26: Aquatic invasive plants can be controlled using many techniques. What is your level of support for the responsible use of the following aquatic invasive plant management techniques on Auburn Lake?

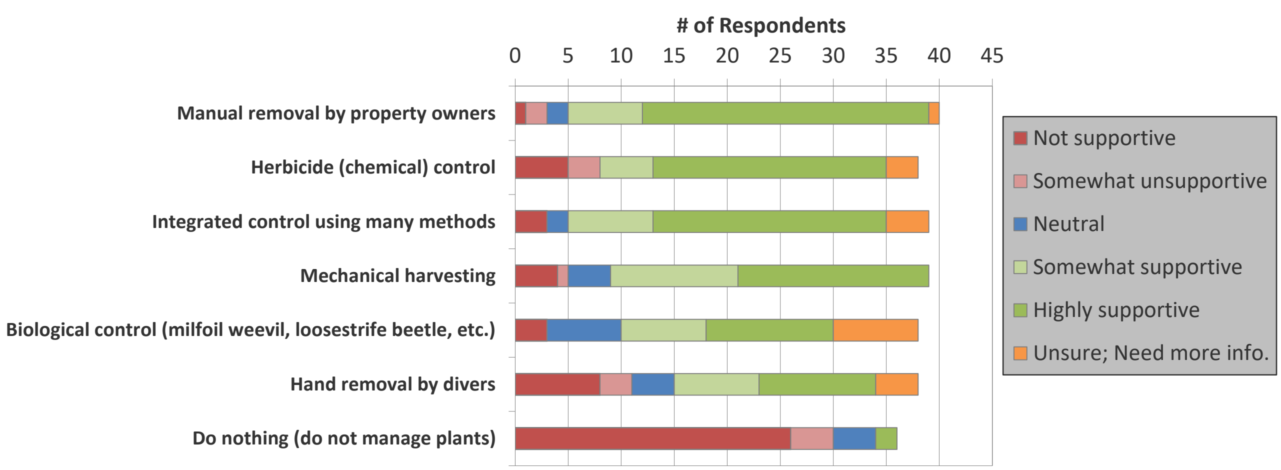


Figure 3.5-15. Select survey responses from the Auburn Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Pale-yellow Iris (Iris pseudacorus)

Pale-yellow iris (Photograph 3.5-7) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Several pale-yellow iris plants were located along the shoreline of Auburn Lake in 2021 (Map 10). This plant should be removed, likely dug out with a shovel, including all of the below-ground rhizomes and disposed of in a landfill. Some individuals show sensitivity to the sap, so care should be taken to avoid contact with the skin when hand-removing the plant.

Photograph 3.5-7. Pale-yellow iris plant. Locations in Auburn Lake can be found on Map 10. Photo credit Onterra.

Northern blue-flag iris (*Iris versicolor*) is a native iris that is known to be present around the margins of Auburn Lake as well. The native iris can be easily distinguished from the non-native iris simply be the color of its flower which is blueish to purple. Northern blue-flag and pale-yellow iris plants typically bloom in early-summer between approximately late-May and early July in Wisconsin, making this the ideal timeframe to distinguish between the two. During other times of the year, the iris plant's long blade-like leaves can look very similar between the native and non-native species making identification more difficult.

Narrow-leaved Cattail (Typha angustifolia)

Narrow-leaved cattail is a perennial invasive wetland plant which invades shallow marshes and other wet areas (Photograph 3.5-8). Like Wisconsin's native broad-leaved cattail (*T. latifolia*), narrow-leaved cattail produces tall, erect, sword-like leaves that can grow nearly 10 feet tall. The leaves are generally narrower than broad-leaf cattail, typically 0.15-0.5 inches wide. Unlike broad-leaf cattail in which the male and female flowers are typically touching, there is typically a gap of 0.5-4.0 inches between the male and female flowers of narrow-leaved cattail.

Photograph 3.5-8. Colony of narrow-leaved cattail on Auburn Lake. Location in Auburn Lake can be found on Map 10. Photo credit Onterra.

Many colonies of narrow-leaved cattail were located along the shorelines of Auburn Lake in 2021 (Photograph 3.5-8 and Map 10). The best method of control is likely the cutting of stems (both green and dead) in mid- to late-summer or early fall to below the water line. The following growing season, continually cut-back emerging stems to maintain them below the water for the remainder of the growing season. This process should be repeated until the plants do not reemerge.

3.6 Aquatic Invasive Species in Auburn Lake

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

Table 3.6-1. AIS present within Auburn Lake.

Type	Common name	Scientific name	Location within the report	NR 40 Classification
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.5 – Non-native Aquatic Plants	Restricted
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.5 – Non-native Aquatic Plants	Restricted
	Pale-yellow iris	*Iris pseudacorus*	Section 3.5 – Non-native Aquatic Plants	Restricted
	Narrow-leaved cattail	*Typha angustifolia*	Section 3.5 – Non-native Aquatic Plants	Restricted
Invertebrates	Zebra mussel	*Dreissena polymorpha*	Section 3.1 – Water Quality	Restricted
	Rusty crayfish	*Orconectes rusticus*	Section 3.6 - Below	Prohibited

Figure 3.6-1 displays the aquatic invasive species that Auburn Lake stakeholder survey respondents believe are in Auburn Lake. Only the species known to be present in Auburn Lake are discussed below or within their respective locations listed in Table 3.6-1. 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 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

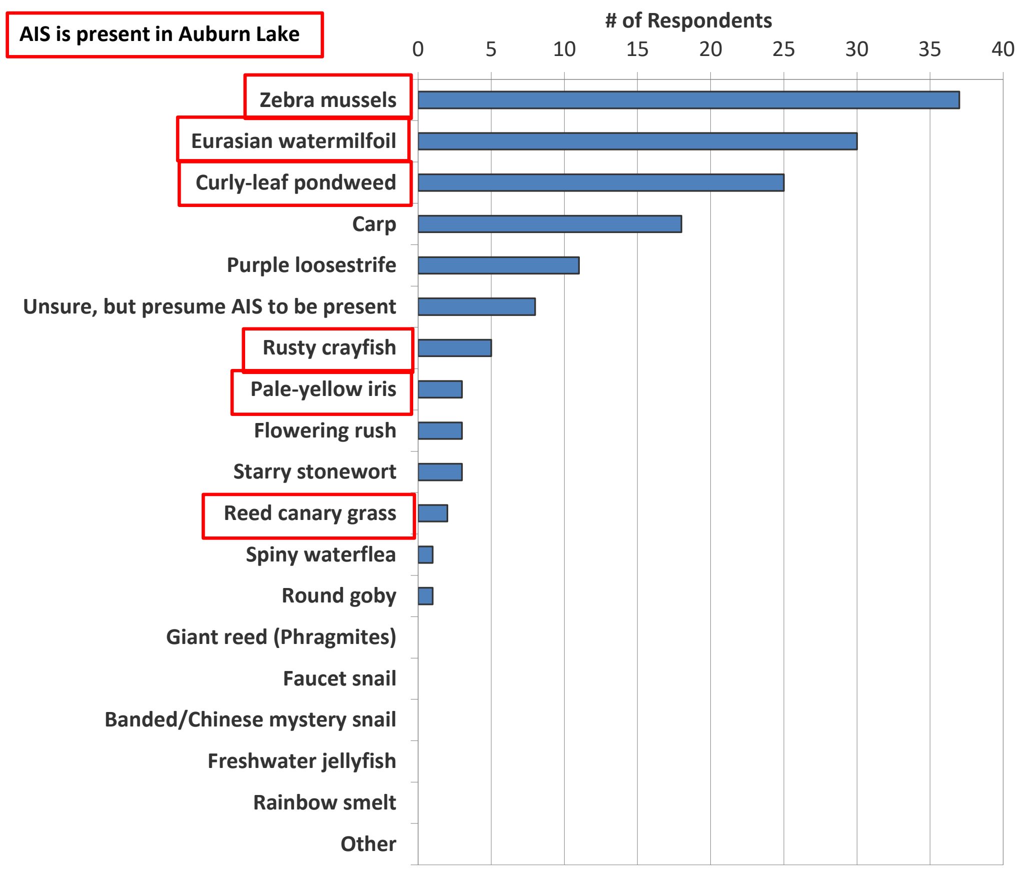


Figure 3.6-1. Stakeholder survey response Question #23. Which aquatic invasive species do you believe are present in or immediately around Auburn Lake?

Aquatic Animals

Rusty Crayfish

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell. They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

3.7 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Auburn Lake. The goal of this section is to provide an overview of some of the fisheries data that is available. While fisheries studies were not conducted 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 Travis Motl (WDNR 2021).

Auburn Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Auburn Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.7-1.

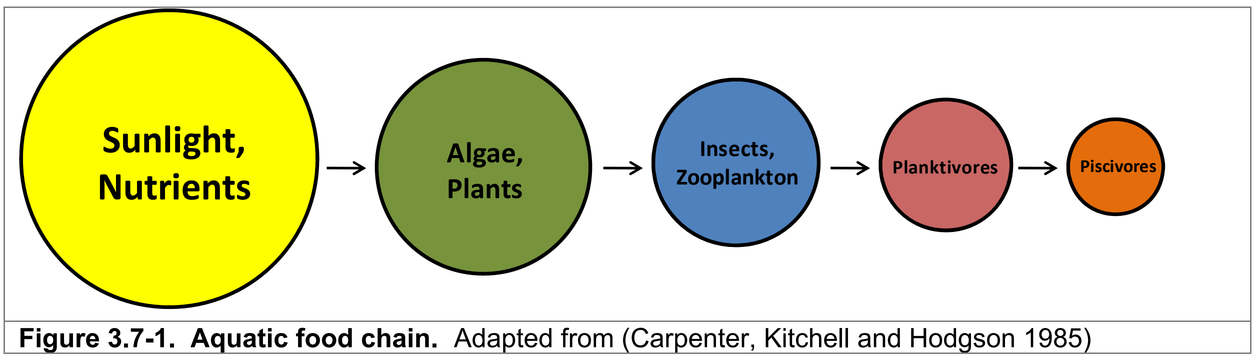


Figure 3.7-1. Aquatic food chain. Adapted from (Carpenter, Kitchell and Hodgson 1985)

As discussed in the Water Quality section, Auburn Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Auburn Lake should be able to support an intermediate sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.7-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional species documented in past WDNR surveys of Auburn Lake include central mudminnow (*Umbra limi*), golden shiner (*Notemigonus crysoleucas*), shorthead redhorse (*Moxostroma macroepidotum*), and the spottail shiner (*Notropis hudsonius*),

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

Common Name (*Scientific Name*)	**Max Age (yrs)**	**Spawning Period**	**Spawning Habitat Requirements**
Black Crappie *(Pomoxis nigromaculatus)*	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
Brown Bullhead *(Ameiurus nebulosus)*	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation
Largemouth Bass *(Micropterus salmoides)*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation
Northern Pike *(Esox lucius)*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves
Pumpkinseed *(Lepomis gibbosus)*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom
Rock Bass *(Ambloplites rupestris)*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep
Walleye *(Sander vitreus)*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms
Yellow Bass *(Morone mississippiensis)*	9	May - June	Tributary streams or lake over gravel reefs in 0.6 - 1 m deep.
Yellow Bullhead *(Ameiurus natalis)*	7	May - July	Heavy weeded banks, beneath logs or tree roots
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 3.7-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.7-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them 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 3.7-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

Photograph 3.7-2. Northern pike fingerling. Photo credit: Onterra.

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 3.7-2). 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. Several DNR stockings events have occurred in the history of Auburn Lake, however no stocking events have occurred since 1987. In 1976 and 1978, 600 fingerling northern pike were released and in years 1986 and 1987, a total of 800,000 walleye fry were stocked. (DNR communications, 2021).

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water) was the second-most important reason for owning property on or near Auburn Lake (Question #8). Figure 3.7-2 displays the fish that Auburn Lake stakeholders enjoy catching the most, with bluegill/sunfish, northern pike, and crappie being the most popular. Approximately 80% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure

3.7-3). Approximately 90% of respondents who fish Auburn Lake believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.7-4).

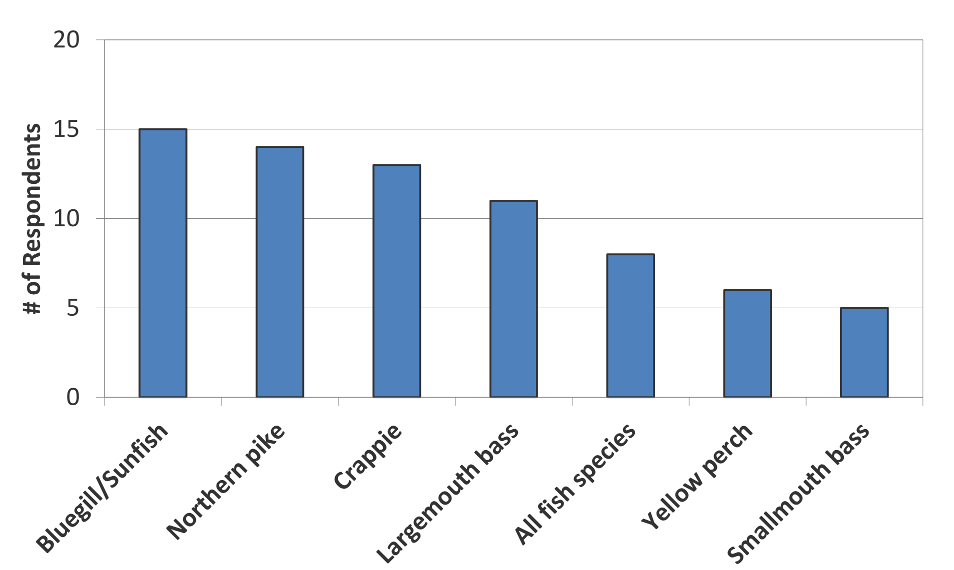


Figure 3.7-2. Stakeholder survey response Question #10. What species of fish do you like to catch on Auburn Lake?

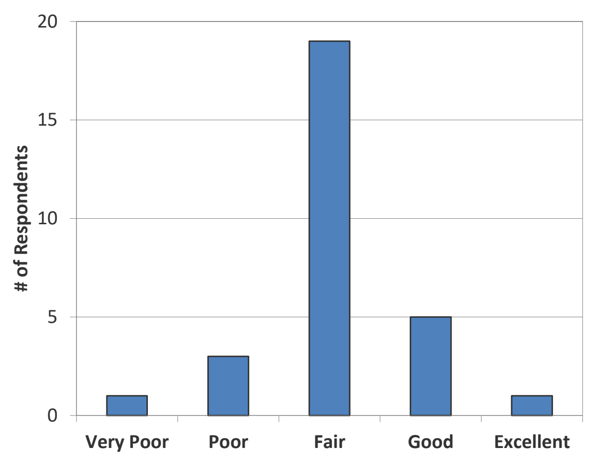


Figure 3.7-3. Stakeholder survey response Question #11. How would you describe the current quality of fishing on Auburn Lake?

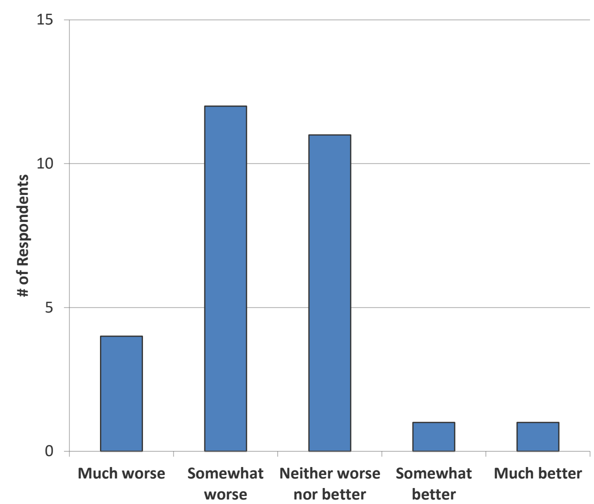


Figure 3.7-4. Stakeholder survey response Question #12. How has the quality of fishing changed on Auburn Lake since you started fishing the lake?

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. A one-night electrofishing survey was completed with a on Auburn Lake May 29, 2018. All fish species encountered were recorded.

Gamefish

The gamefish present in Auburn Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch northern pike and largemouth bass on Auburn Lake (Figure 3.7-2).

Largemouth bass are considered common in Auburn Lake. During the 2018 electrofishing survey, 74 largemouth were captured and both length and weight were recorded. On average, the bass captured measured 11.7 inches and weighed approximately one pound. The largest individual measured 19.8 inches and weighed 4.0 pounds.

Northern Pike are considered common in Auburn Lake; however, pike were not targeted during the 2018 survey. Only two individuals were captured during this survey. These fish measured 17.8 and 21.4 inches and both weighed approximately 1.5 pounds. Electrofishing is not the most effective method to survey northern pike populations; the use of a fyke may provide a better representation of the northern pike numbers.

Yellow bass are fairly uncommon in Wisconsin, but are present in Auburn Lake in low numbers. In the 2018 survey, four individuals were captured. All four fish measured between 10.5-11.5 inches. Since Auburn Lake lies outside of the native range of yellow bass and no there is no record of DNR stocking, the origin of these bass is unknown.

Panfish

Bluegill and pumpkinseed were common during the 2018 WDNR fisheries survey (WDNR 2018). The results for the stakeholder survey show anglers prefer to catch both of these species on Auburn Lake (Figure 3.7-2).

Bluegill are the most abundant panfish on Auburn Lake. In the 2018 survey, 200 individuals were captured. The average size of fish was 4.5 inches and the largest individual measured was 8.3 inches.

Pumpkinseed were another common panfish captured in the electrofishing survey. In total, 31 individuals were captured and recorded. The largest fish measured7.2 inches and average size was 4.8 inches.

Yellow perch were not found in as high abundances as bluegill and pumpkinseed, but are still present in Auburn Lake. The average size of the perch sampled was 5.1 inches, with the largest individual being 8.5 inches.

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 like Beaver Dam Lake (Weber & Brown, 2011). Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber & 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 & 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 & 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 & 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.

Common Carp are present in Auburn Lake and have been recorded in DNR surveys as early as 1957. Currently, DNR biologists are aware of the population but do not believe the carp are in high abundance or that there is concern for the overall fishery of Auburn Lake (DNR Communications, 2022).

Auburn Lake Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2021, 89% of the substrate sampled in the littoral zone of Auburn Lake were soft sediments, 10% was composed of sand, and 1% were 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 2021 survey documented 34 pieces of coarse woody along the shores of Auburn Lake, resulting in a ratio of approximately 14.7 pieces per mile of shoreline. 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 Auburn 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 (WDNR, Fish sticks: Improving lake habitat with woody structure 2014). Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.7-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

Photograph 3.7-3. 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 3.7-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan and Haynes 2004). Additional 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 Auburn Lake Homeowners Association, 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 Auburn Lake.

Fishing Regulations

Regulations for Auburn Lake fish species as of January 2022 are displayed in Table 3.7-2.

For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.7-2. WDNR fishing regulations for Auburn Lake (As of January 2022).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass	5	14"	May 1, 2021 to March 6, 2022
Northern pike	5	The minimum length limit is 26" and the daily bag limit is 2	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

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer.

These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.7-8. 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	-

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

Figure 3.7-8. 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/)

Fishery Management & Conclusions

Because Auburn Lake is under 100 acres, DNR surveys are scheduled to occur once every 10 years in accordance to DNR sampling protocols. There is no specific management goal for Auburn Lake, however, largemouth bass and panfish populations will be monitored for any need of change to current regulations (Travis Motl, DNR communications).

3.8 Areas of Special Conservation Interest

Of all the water on earth, only 2.5% is freshwater and only 0.01% is available as freshwater in lakes and rivers (Silk & Ciruna, 2005). Species richness in freshwater ecosystems is greater relative to habitat extent when compared to marine and terrestrial ecosystems, and unfortunately, biodiversity loss in freshwater ecosystems is currently estimated to be five times faster than in any other aquatic or terrestrial ecosystem (Silk & Ciruna, 2005). This loss is driven by a growing human population and its need for water. Freshwater ecosystems are being degraded or lost due to increases in nutrient and pollutant input from land use change, water diversion and extraction, and climate change.

This degradation of freshwater ecosystems results in the loss of freshwater species, communities, and ecosystems, as well as the loss of all other species dependent upon freshwater. Their degradation also inhibits their ability to provide services for humans. Given we are in a period of unprecedented biodiversity loss and in a period of uncertainty associated with the effects of global climate change, it is imperative that conservation efforts be taken to maintain freshwater biodiversity and our natural heritage.

As is discussed in the previous results subsections (Sections 3.1-3.7), Auburn Lake has relatively high species diversity in terms of aquatic plants and fish. While conservation of the entire Auburn Lake ecosystem, surrounding riparian zone, and watershed is the ideal and ultimate goal, three areas termed as *Areas of Special Conservation Interest*, or ASCIs, were delineated within Auburn Lake based on the data collected from the 2021 surveys (Figure 3.8-1 and Map 13).

These ASCIs were created with the intent to encompass and highlight the full spectrum of native species and natural community diversity present in Auburn Lake. All three ASCIs fall within Auburn Lake's littoral zone, or the area of the lake where sunlight can sustain plant growth. The littoral zone is highly productive and contains most of the lake's biodiversity. This is the area where all aquatic plant species grow and supports spawning, rearing, refuge, and feeding habitat for diverse array of aquatic and terrestrial wildlife (Silk & Ciruna, 2005). The Auburn Lake ASCIs capture the areas of highest aquatic plant species richness and diversity that are also adjacent to minimally developed shorelands. While

Figure 3.8-1. Auburn Lake Areas of Special Conservation Interest (ASCIs). These areas contain high-quality intact native aquatic plant communities adjacent to minimally-developed shorelands. Descriptions of these areas can be found in Table 3.8-1.

surveys aimed at macroinvertebrates (mayflies, stoneflies, caddisflies, etc.) were not completed as part of this study, other studies have shown that macroinvertebrate species richness and diversity are positively correlated with aquatic plant richness and diversity (McCreary Waters & San Giovanni, 2002).

These three areas in Auburn Lake, the sites of the ASCIs were also chosen based on their proximity to largely natural, minimally disturbed shorelands. In these areas, the ecotone, or natural transition zone between the aquatic and terrestrial environment is largely intact. Many of these areas also contained some of the highest concentrations of coarse woody habitat mapped in 2021. In total, these three ASCIs in Auburn Lake encompass approximately 26.5 acres (Map 13). Table 3.8-1 contains information on the important natural communities these ASCIs encompass.

Table 3.8-1. Auburn Lake Area of Special Conservation Interest (ASCI) descriptions. Locations of these ASCIs can be found on Map 13.

Auburn Lake ASCI	Acres	Priority Natural Communities	Number of Native Plant Species	Description
A	5.4	Floating-leaved Marsh Submergent Marsh Benthic - Organic Natural Shoreline Coarse Woody Habitat	*17*	Area encompassess a mixed submergent and floating-leaf marsh community adjacent to contiguous undeveloped shoreline with course woody habitat. Some sand/rock cobble substrate was recorded near shore, but most of this area is comprised of organic sediments.
B	5.0	Floating-leaved Marsh Emergent Marsh Submergent Marsh Benthic - Organic Natural Shoreline Coarse Woody Habitat	*17*	Area encompassess a mixed submergent, floating-leaf, and emergent marsh community. Approximately half of the community is adjacent to undeveloped shoreline with course woody habitat, while the other half is adjacent to developed shoreline. Substrate in this area is comprised of organic sediments.
C	16.1	Floating-leaved Marsh Emergent Marsh Submergent Marsh Benthic - Organic Natural Shoreline	*22*	Area encompasses large, contigous floating-leaf, emergent, and submergent marsh in the southern area of the lake adjacent to area undeveloped shoreline. Contains the lake's largest hardstem bulrush (*Schoenoplectus acutus*) colonies and the only area where the sensitive species water bulush (*Schoenoplectus subterminalis*) was located. Mechanical harvesting should be restricted to a navigational channel between the basins to avoid damage of surrounding plant communities.

As discussed, the purpose of these ASCIs in Auburn Lake is to bring attention to the areas of the lake which encompass the majority of the species, natural communities, and habitats found in the lake and have minimal evidence of direct in-lake or shoreland impacts from human activity (Photo 3.8-1). While these areas are certainly influenced and impacted from human activity outside of these areas, the Town of Auburn can choose to take proactive action to educate lake users on the importance of these areas and how to minimize human-related disturbance (see Implementation Plan-Section 5.0). In addition, mechanical harvesting of aquatic plants and other activities which would directly impact these areas can be avoided to aid in maintaining the integrity of these important habitats.

Photograph 3.8-1. Emergent and floating-leaf marsh communities found in Auburn Lake Area of Special Conservation Interest C (Map 13). This area contained the highest number of aquatic plant species of the three ASCIs with 22 native species documented.

Please note that these ASCIs are not legal designations, and were delineated based upon the criteria discussed earlier. The integrity of these areas is also dependent upon the conservation of the larger Auburn Lake ecosystem and its watershed and does not devalue the importance of other areas around the lake. However, these ASCIs represent areas of Auburn Lake which harbor the majority of the lake's biodiversity and have the least amount of human-related shoreland development.

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 Auburn Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil and curly-leaf pondweed.
3) Collect sociological information from Auburn lake's 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 Auburn Lake ecosystem, the people that care about the lake, and what needs to be completed to protect and enhance the lake.

A group of Auburn Lake Homeowners Association (ALHA) members and other local partners 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 lakes and in developing their role in protecting, enhancing, and managing Auburn Lake for the years to come. Pairing the understanding of the technical data that has been collected over time as well as the local sociological needs through this planning project has led to the creation of a realistic management plan for the ALHA to implement in managing Auburn Lake.

Historical data, as well as data collected during the management planning project indicate Auburn Lake has good to excellent water quality for a deep lowland drainage lake based on phosphorus and chlorophyll-a levels. Increased water clarity in recent years may be a result of a recent infestation of zebra mussels in the lake. The ALHA has developed actions within the Implementation Plan to monitor water quality parameters in the lake.

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. Many of the developed properties on the shoreline showed little intact canopy cover, shrub and herbaceous layers, and had manicured lawns that would be candidates for restoration efforts.

The watershed is relatively large (4,000+ acres) and comprised of a variety of land covers including significant percentages of wetlands, forests, row crop agriculture, and pasture/grasslands. Modeling overestimates phosphorus levels compared to actual measured levels, likely as a result of wetland areas in the watershed retaining phosphorus. A few areas of watershed concern were identified for their potential to degrade Auburn Lake's water quality. The ALHA has developed a goal within the Implementation Plan to conduct restoration efforts within the watershed and to promote healthy shoreline practices.

Auburn Lake harbors a substantial aquatic plant community with many native species present. The plant community is near or above ecoregion and state median values for Floristic Quality. Non-native aquatic plants known to be present within the lake or on its immediate shoreline include Eurasian watermilfoil, curly-leaf pondweed, pale yellow iris, and narrow-leaved cattail.

Eurasian watermilfoil and curly-leaf pondweed have both been known to be in Auburn Lake for some time. Professional monitoring surveys completed during this project documented moderate populations of both species. Curly-leaf pondweed was most prevalent in the northern basin of the lake and included some particularly dense areas on the northern end of the lake. The EWM population was confirmed to be a pure-strain variety (not hybrid) through genetic testing during this project, and was present in many areas around the 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 guiding potential active management strategies in future years. As a part of this management planning project, the ALHA has outlined how they will monitor EWM and CLP and the management approach they will take moving forward.

The ALHA has developed management actions that will serve to ensure and improve recreational use of Auburn Lake, largely through a mechanical harvesting operation.

The ALHA has also developed a management goal to increase their capacity to manage Auburn Lake through increased educational opportunities, communications, and outreach.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of a Planning Committee comprised of members of the Auburn Lake Homeowners Association, Town of Auburn, and ecologist/planners from Onterra. It represents the path the Auburn Lake Homeowners Association 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 Auburn 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: Maintain or Improve Current Water Quality Conditions in Auburn Lake

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network
Timeframe:	Beginning 2023
Facilitator:	Greg Mueller or Auburn Lake Homeowners Association Water Quality Sampling 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. Volunteer water quality monitoring will be completed annually by Auburn Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. This includes collecting Secchi disk transparency, as well as sending in water chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. The samples are collected three times during the summer and once during the spring. 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). A requisite of the CLMN program is to collect at least one year of Secchi disk transparency data and water temperatures before water chemistry sampling begins. An ALHA volunteer will begin this monitoring during 2023. At the time of this writing, the CLMN program is at capacity and the ALHA will be added to a waiting list until an opening arises to enroll.

Action Steps:	
1.	Contact CLMN Coordinator (WDNR) to enroll in the program, or be placed on a waiting list
2.	Trained volunteer(s) collects data and reports results to WDNR by entering into the SWIMS database as well as sharing with ALHA members.
3.	Water sampling volunteer and ALHA facilitate the recruitment of new volunteer(s) as needed.

Management Action:	Conduct restoration efforts of areas of concern within Auburn Lake's watershed and promote healthy shoreland practices
Potential Grants:	Healthy Lakes and Rivers Grants
Timeframe:	Continuing
Facilitator:	ALHA Board
Description:	As discussed within the water quality section, Auburn Lake's water quality is influenced by the characteristics of its watershed. Having a relatively large watershed means that there may be many inputs of nutrients to the watershed, that ultimately can drive productivity in Auburn Lake. The ALHA has shown interest in quantifying phosphorus inputs from upstream sources. In order to quantify the inputs and locate areas of concern, water samples would need to be collected along with discharge (flow) data in order to determine the mass of nutrients and other pollutants entering the lake. Designing a study of this nature would likely cost in excess of $15,000 to study a few sites. The watershed delineation and modeling that took place as a part of this project identified a few areas of concern. The areas of concern were determined based on their potential to degrade Auburn Lake's water quality. Without the need for additional study, the ALHA can implement a plan to address the areas of concern within the Auburn Lake's watershed. For the agricultural areas that are in close proximity to the wetlands that drain into Auburn Creek, the ALHA will speak with the Fond du Lac County Land and Water Conservation Department about possible actions to provide additional vegetated buffers. For the residential properties that are included in the areas of concern, the county may be able to help by planning and implementing a large-scale project that could be funded through a Lake Management Plan Implementation Grant (previously called a lake protection grant), or through multiple Healthy Lakes Initiative Grants. The shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because

	of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. Some shoreland areas of Auburn Lake were found to contain developed or urbanized areas characterized by having impervious surface or manicured lawns (Figure 3.4-2). This limits shoreland habitat, but it also reduces natural buffering of shoreland runoff and allows nutrients to enter the lake. Much of the shoreline is undeveloped and in a natural condition. These areas provide important habitat and pollutant buffering benefits to the lake. Many riparian property owners do not understand the importance of shoreland condition and maintenance in the ecological health of their lake. The initial objective of this action will be to provide information to ALHA members and riparian property owners through a variety of educational opportunities, including newsletter articles, direct emailing of informational material, etc. Informational topics will include shoreland restoration resources, like the WDNR Healthy Lake Initiative grants, the importance of private onsite septic system maintenance, and general good-neighbor practices like reducing litter in the lake and minimizing light and sound pollution. The UW-Extension Lakes Program is an excellent source of information and articles. If shoreland property owners are interested in restoring all or a portion of their shoreline, the WDNR's Healthy Lakes Initiative Grant program allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. The Healthy Lakes & Rivers Grant program provides cost share for implementing the following best practices: • Rain Garden • Rock Infiltration • Diversion • Native Plantings • Fish Sticks The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program are included within the Shoreland Condition Section (3.4) and can be found at: https://healthylakeswi.com
Action Steps:	
	See description above.

Management Goal 2: Monitor aquatic plant populations in Auburn Lake

Management Action:	Conduct periodic vegetation monitoring on Auburn Lake
Timeframe:	Point-Intercept Survey every five years, community mapping survey every 10 years
Potential Grant:	WDNR Surface Water Planning Grant ($10,000 max)
Facilitator:	Town of Auburn
Description:	Whole-lake point-intercept surveys have been completed in Auburn Lake in 2008, 2019, and 2021. The ALHA will plan to have a point-intercept survey completed at least once every five years. The survey would be initiated sooner if perceived changes in the aquatic plant community are believed to be occurring. This will allow a continued understanding of the submergent aquatic plant community dynamics within Auburn Lake. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Auburn Lake, a community mapping survey would be conducted every 10 years. The Town of Auburn/ALHA may contract with a professional firm or partner with local organizations to conduct these monitoring surveys. Additionally, the ALHA and Town of Auburn may consider applying for a WDNR surface water planning grant that if awarded, would provide funds towards the completion of aquatic plant monitoring surveys. A grant application of this nature would be a stronger candidate for receiving funding if it also included surveys aimed at monitoring AIS populations in lake such as CLP and EWM mapping surveys. These surveys would provide the supporting data necessary to complete an update to the ALHA's aquatic plant section of their comprehensive management plan. The ALHA will have the next point-intercept survey conducted during 2026, and the next community mapping survey in 2031. In the fall prior, the ALHA will apply for a WDNR grant to provide funding assistance to complete the anticipated aquatic plant monitoring surveys. The point-intercept survey data would be analyzed and compared to past surveys. If an updated mechanical harvesting permit application is needed, the WDNR requires a recent point-intercept survey to ensure that native plant monitoring is occurring and that these populations are not being overly impacted in a negative way by the harvesting program.
Action Steps:	See description above.

Management Action:	Conduct annual volunteer-led AIS monitoring
Timeframe:	Beginning 2023
Facilitator:	ALHA Board

Description:	Photograph 3.5-4 displays photographs of nine native species present within Auburn Lake and several of the common species within the lake are described within section 3.5 above. The ALHA will provide resources to members to aid in the identification of common native plants present in Auburn Lake as well as non-native species such as EWM and CLP. Riparian owners will then be able to differentiate between native and non-native species will enough to aid in decision making related to aquatic plant removal from within their individual property's recreational use area. Educating lake users in distinguishing between AIS and "look alike" native species will be one of the objectives of this action. There are a number of additional sources from which the ALHA can obtain aquatic plant identification educational materials including the WDNR website, published field guides, and the potential for in-person training by local partners such as the Fox-Wolf Watershed Alliance or the Fond du Lac County Land and Water Conservation Department. The ALHA will connect members with these resources through various communication channels available to them. Volunteers that have been trained in AIS identification would lead an effort to monitor invasive species including EWM, CLP, pale-yellow iris, and purple loosestrife within the Auburn Lake ecosystem. Monitoring would be completed by visually searching the littoral and shoreline areas of the lake and documenting the population of invasive species through a combination of photographs, GPS data, and thorough note taking. The ALHA will share the findings of these monitoring efforts with the membership and use these efforts to assess whether populations of these species are increasing. The ALHA would give consideration to purchasing a dedicated hand-held GPS unit to aid in the volunteer AIS monitoring program. Data from the GPS unit could be stored digitally for future reference or may be shared with partners in the future. A GPS unit would also be particularly helpful in documenting isolated occurrences of non-native shoreland plants such as pale-yellow iris, or purple loosestrife. If the ALHA believes that EWM or CLP populations have increased to a point that directed management is being considered, then services for professional mapping surveys would be solicited that would document CLP and/or EWM at their peak growth potential for the year. This survey would include a complete meander survey of the lake'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,

	between approximately late-May through late-June, while this species is expected to be near its peak growth stage for the season. If EWM or CLP management is sought, in particular with the use of aquatic herbicides, an updated aquatic plant management plan (APM) would be required. An updated APM plan would outline when AIS management would occur and for what goal it is intended to serve. At the time of the current management planning project, active AIS management is not being considered with the exception of the non-selective plant harvesting associated with a mechanical harvesting program detailed below.
Action Steps:	See description above.

Management Goal 3: Ensure and Improve recreational use of Auburn Lake

Management Action:	Use mechanical harvesting to create navigation lanes in Auburn Lake.
Timeframe:	Ongoing
Facilitator:	ALHA Board
Description:	The ALHA understands the importance of native aquatic vegetation within Auburn Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, sometimes caused by curly-leaf pondweed, and heavy native vegetation including coontail, muskgrasses, and native milfoils. The ALHA supports the reasonable and environmentally sound actions to facilitate navigability on Auburn Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact any more shoreland or lake surface area than absolutely necessary. Thirty two out of 40 (80%) of stakeholder survey respondents believe that aquatic plants should be managed in the lake and approximately 78% expressed support (pooled as completely support, or moderately support) for mechanical harvesting to create navigation lanes in Auburn Lake. The WDNR oversees the management of aquatic plants on inland lakes. The WDNR granted a 1-year mechanical harvesting permit in 2021 and again in 2022 while the ALHA was completing a lake management planning project. With an approved plan, the ALHA is seeking to obtain a 5-year permit moving forward until an updated aquatic plant management plan is requested. A five-year permit would potentially span from 2024-2028. During the final year of the permit, the ALHA would plan to collect data necessary to update the mechanical harvesting

plan. This would include a whole-lake point-intercept survey and a strategic meeting with the ALHA board to review the data and determine if any changes should be made to the mechanical harvesting plan prior to applying for another multi-year permit. The bulleted list below outlines guidelines that may accompany a mechanical harvesting permit:

- Harvesting is only allowed for submersed plants, no emergent species can be harvested
- Harvesting may not occur in waters less than 3 feet in depth
- WNDR notification is required four business days in advance of harvesting activities
- Harvested plants may not be disposed on State Forest property without prior approval
- Paper or electronic copy of approved permit must be with the individual conducting the harvesting
- Harvesting must comply with Wisconsin regulations and state statutes
- An annual report must be submitted within 30 days of the last treatment that includes details of harvested plant material weight, volume, and species, total acres harvested, and non-target impacts and number of fish encountered.
- Harvesting operations shall not disturb spawning or nesting fish. Harvesting shall be done in a manner to minimize accidental capture of fish. Any gamefish accidentally captured shall be released immediately.
- Aquatic plants that are cut must be removed from the water.

Map 15 displays the ALHA's Updated Mechanical Harvesting Plan. The harvesting plan includes six sites located directly in front of riparian properties in waters approximately 3' to 9' in depth. The placement of these harvest locations allows for improved navigational use in front of riparian properties. Additionally, a 60' wide common use lane is placed from the public boat landing out to deeper waters to ensure navigability in this high-use location. In total, 7.9 acres are included within the harvesting plan, the locations of which are similar compared to previously permitted harvesting activities that have occurred in 2021-2022.

Harvesting would occur after June 1 and before September 31 each year. The ALHA would contract for harvesting services utilizing a conventional cutting head, with the exact dates being variable depending on the scheduling availability. The ALHA would solicit harvesting activities on an "as needed" basis, but anticipates that it would occur annually due to the heavy aquatic plant growth that is typical for the lake. A representative of the ALHA will communicate with the harvesting contractor to ensure the equipment is clear of AIS

	prior to launching on Auburn Lake. If available, an ALHA member may inspect the harvester for AIS upon arrival to the lake. It is expected that the harvesting contractor would minimize direct impact to fish by returning captured fish to the lake and following any related WDNR permit conditions. The Association disposes of harvested aquatic plants at the Dundee sand and gravel pit on HWY F (Figure 5.0-1) as well as at a few individual homeowners' properties for composting or fertilizer. The ALHA will keep a detailed log of harvesting activities that ensures the efforts are organized and efficient. The ALHA will continue to generate an annual report that details the harvesting activities to satisfy the permit reporting requirements.

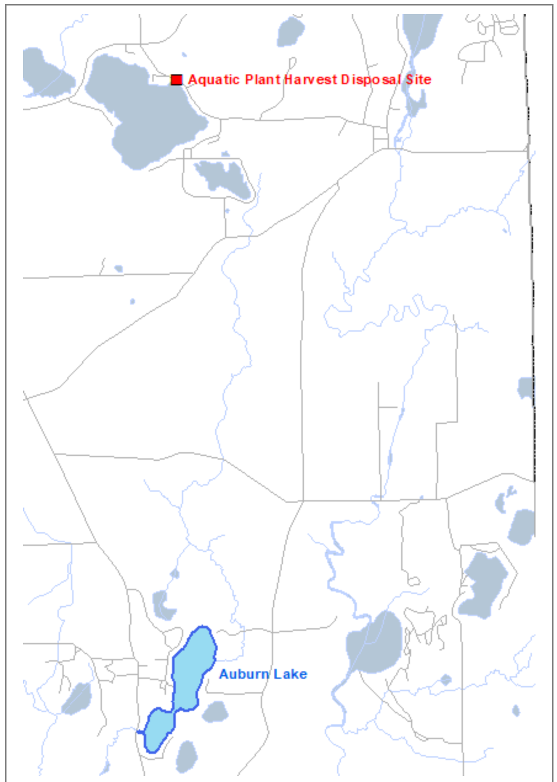


Figure 5.0-1. Aquatic Plant Harvest Disposal Site.

Action Steps:	
1.	Solicit bids from mechanical harvesting service providers
2.	Apply for and obtain a WDNR permit to implement mechanical harvesting plan
3.	Record harvesting data and complete reporting requirements associated with the approved permit
4.	Apply for WDNR grant in fall 2026 or 2027 (depending on the end date of the current permit) to seek funding assistance for the aquatic plant monitoring surveys and supporting steps necessary to update the ALHA's mechanical harvesting plan during in advance of seeking a new multi-year harvesting permit.

<u>Management Action:</u>	Determine and understand legal and permittable options available to property owners to improve recreational use of their individual frontage
Timeframe:	Ongoing
Facilitator:	ALHA Board

Description:	Riparian property owners on Auburn Lake, like many lake groups, wish to ensure that recreational use of their lake is available, particularly in the area surrounding their pier and frontage. In many areas around Auburn Lake, dense native or non-native aquatic plant growth is present in near shore areas of the lake, which results in the inability for lake users to use the area for activities including swimming or boating. The purpose of this management action is for the ALHA to build an understanding of what options are available to a property owner for manipulating the in-lake area directly in-front of their frontage. Each riparian owner can legally harvest any aquatic plants in a 30' wide area of one's frontage directly adjacent to one's pier without a permit. Simply wading into the lake and removing aquatic plant vegetation by hand or with the aid of a rake or other hand-held accessories can be helpful in managing aquatic plants on a small and individual property-based scale. Non-native species including CLP and EWM can be hand removed anywhere in the lake without a permit and therefore is not limited to the 30' corridor zone. A WDNR permit is required if an area larger than the 30' corridor is being harvested or if a mechanical assistance mechanism, like DASH (Diver Assisted Suction Harvesting), is being used. Individual property owners may seek a WDNR permit to utilize DASH to manage aquatic plants in their frontage zone. One or two days of harvesting each year would likely provide seasonal relief from dense aquatic plants in an area being used for recreational purposes. This technique has utility on a small scale in Auburn Lake, such as within a riparian's 30' use corridor; however, DASH is not feasible for use on a lake-wide scale for creating navigation lanes or for EWM or CLP population management. The use of DASH is a supported management technique for Auburn Lake riparians to improve recreational use of their frontage. Additional information about the use of DASH is included in section 3.5 of this report. 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. During the planning meetings for this project, the topic of deploying pea gravel, benthic barriers, or weed rollers in the lake was discussed. Benthic barriers are discussed within the Aquatic Plant Management and Protection sub-section of section 3.5. Riparian property owners can submit a permit to deploy benthic barriers in the lake. The local WDNR lakes biologist does not issue Chapter 30 permits, but may indicate their support or lack-thereof of applications. The lakes biologist has indicated they may not oppose a barrier under appropriate situations.

	Riparian property owners may apply WDNR individual permit to deploy a pea gravel blanket in the lake in the area in front of their property for the purpose of creating an area for swimming or recreational use. Depositing sand is typically not permitted because it is easily moved off site by natural processes. Up to six inches of pea gravel may be placed over a maximum surface area of 1,250 square feet. Placement of pea gravel is not permitted if emergent aquatic vegetation is present, if the lake bottom is already composed of sand/gravel, fish spawning habitat is present, or if the existing soft sediment is greater than six inches deep. Pea gravel may not be permitted in wetlands, sites with endangered or threatened resources, or sites with historical or cultural resources present. Site inspections are also required during periods of open water. Additional information is available on the WDNR website. The local WDNR lakes biologist has indicated they may not oppose a pea gravel blanket under appropriate situations. Deploying weed rollers in a lake a tool that is advertised by some companies and are utilized in some regions of the country. A weed roller typically involves a pivot beam that is attached to a pier and rolls slowly along a lake bottom. This process inhibits aquatic plant growth through constant agitation of the lake bottom. These submerged structures can cause navigation concerns and negatively impact habitat for fish and other aquatic life. For these reasons, weed rollers are not typically permitted in Wisconsin's lakes. A miscellaneous structure individual permit is required if a riparian property owner chooses to pursue a roller. The ALHA will provide information to riparian owners on these topics, but will not directly sponsor any permit applications.
Action Steps:	
1.	ALHA provides information on these topics to members
2.	Individual riparian property owners communicate with WDNR lakes biologist to seek guidance and determine applicability for seeking a permit
3.	Riparian submits permit application to WDNR regulators

Management Goal 4: Increase the ALHA Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	ALHA Board
Description:	Education represents an effective tool to address many lake issues. The ALHA aims to resume regular meetings or annual events. These mediums allow for exceptional communication with lake stakeholders. This level of communication is important within a management group because it facilitates the spread of important news, educational topics, and even social happenings. The ALHA will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. The ALHA will work with UW-Extension Lakes staff to use stock articles as appropriate to lessen the workload and ensure the messaging is accurate. *www.uwsp.edu/cnr-ap/UWEXLakes* *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic plant species identification • Aquatic invasive species • Blue-green Algae • Basic lake ecology • Water quality • Boating safety (promote existing guidelines) • Swimmer's itch • Shoreline habitat restoration and protection • Noise and light pollution • Fishing regulations and overfishing • Recreational use of the lakes
Action Steps:	See description above.

Management Action:	Seek volunteer to facilitate communications with WDNR fisheries biologist
Timeframe:	Beginning 2023
Facilitator:	ALHA Fisheries Committee volunteer
Description:	Open water fishing is a popular activity on Auburn Lake and is one of the main reasons why property owners live on the lake. The ALHA will

	recruit a volunteer to facilitate communications with WDNR fisheries staff. The volunteer will periodically reach out to the WDNR to obtain any updated fisheries studies that take place on the lake, to direct specific questions or concerns about the state of lake's the fishery, and to inquire about any habitat improvement recommendations, stocking activities, fishing regulations, etc. The designated volunteer will share any relevant information with the ALHA membership.
Action Steps:	See description above.

Management Action:	Promote more involvement in ALHA activities
Timeframe:	Continuation of current efforts
Facilitator:	ALHA Board
Description:	The ALHA will communicate with members through annual meetings, social media outreach, and emails to seek more involvement and participation in ALHA activities. Currently, the ALHA communicates with membership primarily through email. The ALHA also has a private social media page on Facebook as a method of getting information including links to specific information housed on other websites to Association members. 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 ALHA 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 will be specifically addressed in the table on the next page.
Action Steps:	See description above.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Auburn	Chairperson: Ken Depperman Kendepperman@yahoo .com	Partners with the ALHA for WDNR grants and other projects	As needed.	Provides a link between ALHA and Town of Auburn.
Fox-Wolf Watershed Alliance	Chris Acy – AIS Coordinator Chris@fwwa.org	Nonprofit organization that covers Fond du Lac County WI	Once a year, or more as issues arise.	Provide information on a variety of lake topic including AIS outreach
Fond du Lac County Land & Water Conservation Department	County Conservationist (Paul Tollard - 920-906-4680)	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 Laura Stremick laura.stremick@wisconsin.gov 920-387-7876	Manages the fishery of Auburn Lake	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 (*Formerly Mary Gansberg*) Andrew Hudak Andrew.hudak@wisconsin.gov 920-857-7271	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: Sandy Wickman Sandra.wickman@wisconsin.gov 715-365-8951	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
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.	ALHA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Auburn Lake (e.g., 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. Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll - *a*	●		●		●		●		●			
Total 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 Auburn Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003).

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Auburn Lake during a May 24, 2021 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 Auburn Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on July 6-7, 2021 (Hauxwell et al. 2010). A point spacing of 32 meters was used resulting in approximately 357 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Auburn Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

Representatives of all new 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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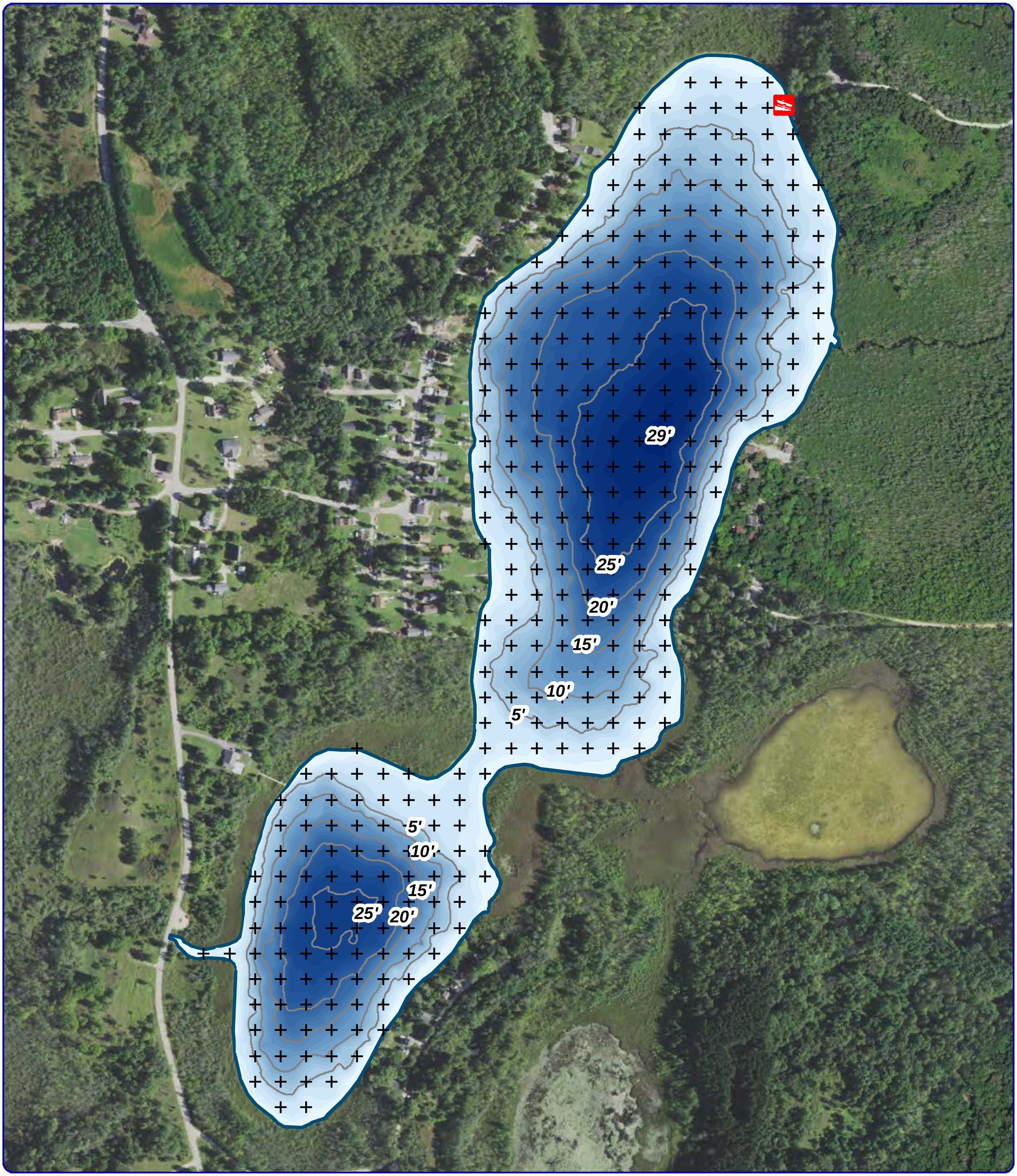

510
Feet

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920.338.8860
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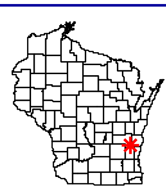
Sources:
Hydro: Onterra
Bathymetry: Onterar 2021
Orthophotography: NAIP 2020
Map Date: February 25, 2022 BTB
File Name Map1_Auburn_Location.mxd

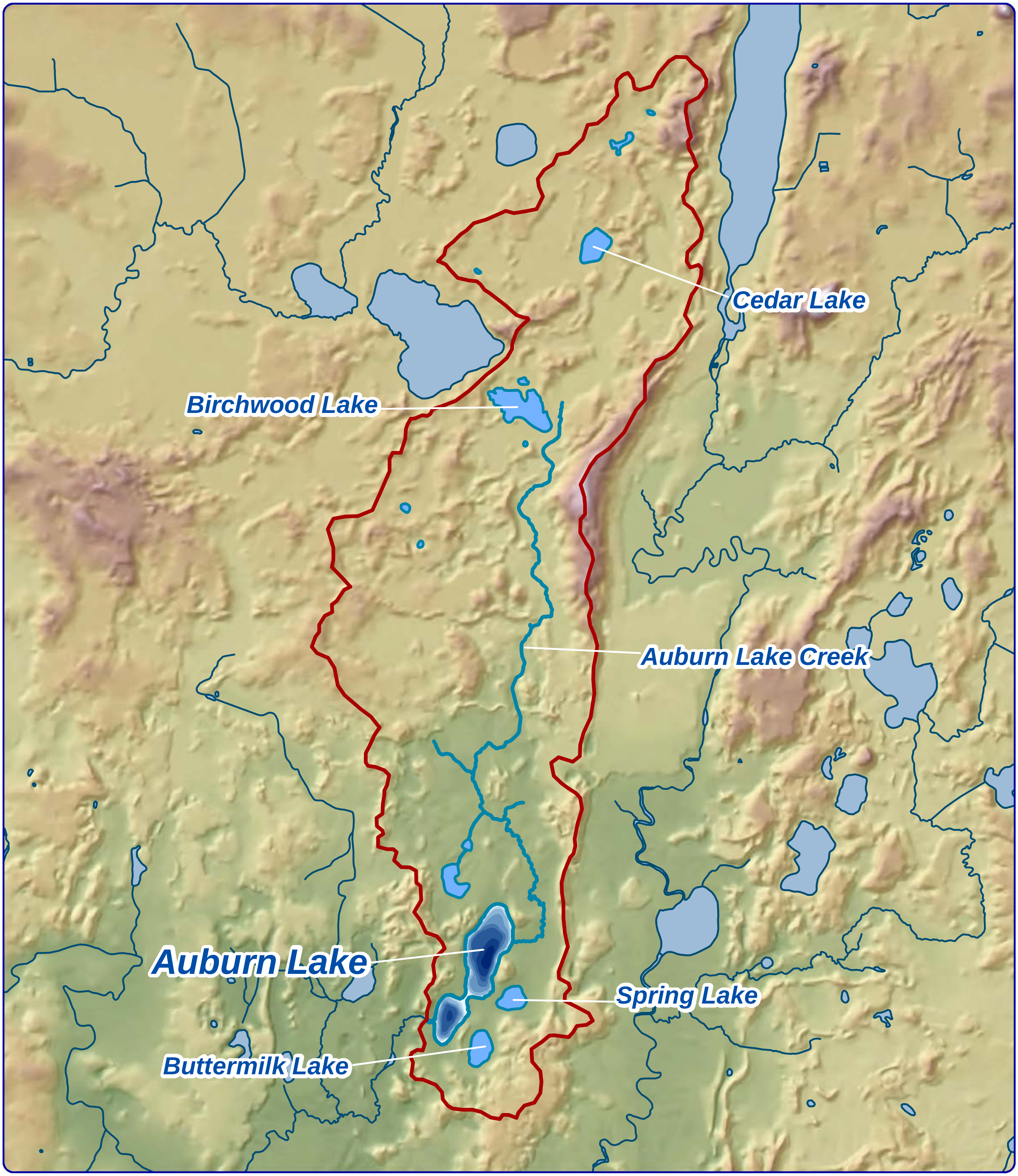


Project Location in Wisconsin

Legend

- Auburn Lake *(90 Acres)*
- Public Boat Launch
- \+ Point-Intercept Survey Sampling Location *(357 total points; 32-meter resolution)*

Map 1
Auburn Lake
Fond du Lac County, Wisconsin
Project Location & Lake Boundaries



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Auburn Lake Watershed Boundary

950 Elevation (feet) 1,160

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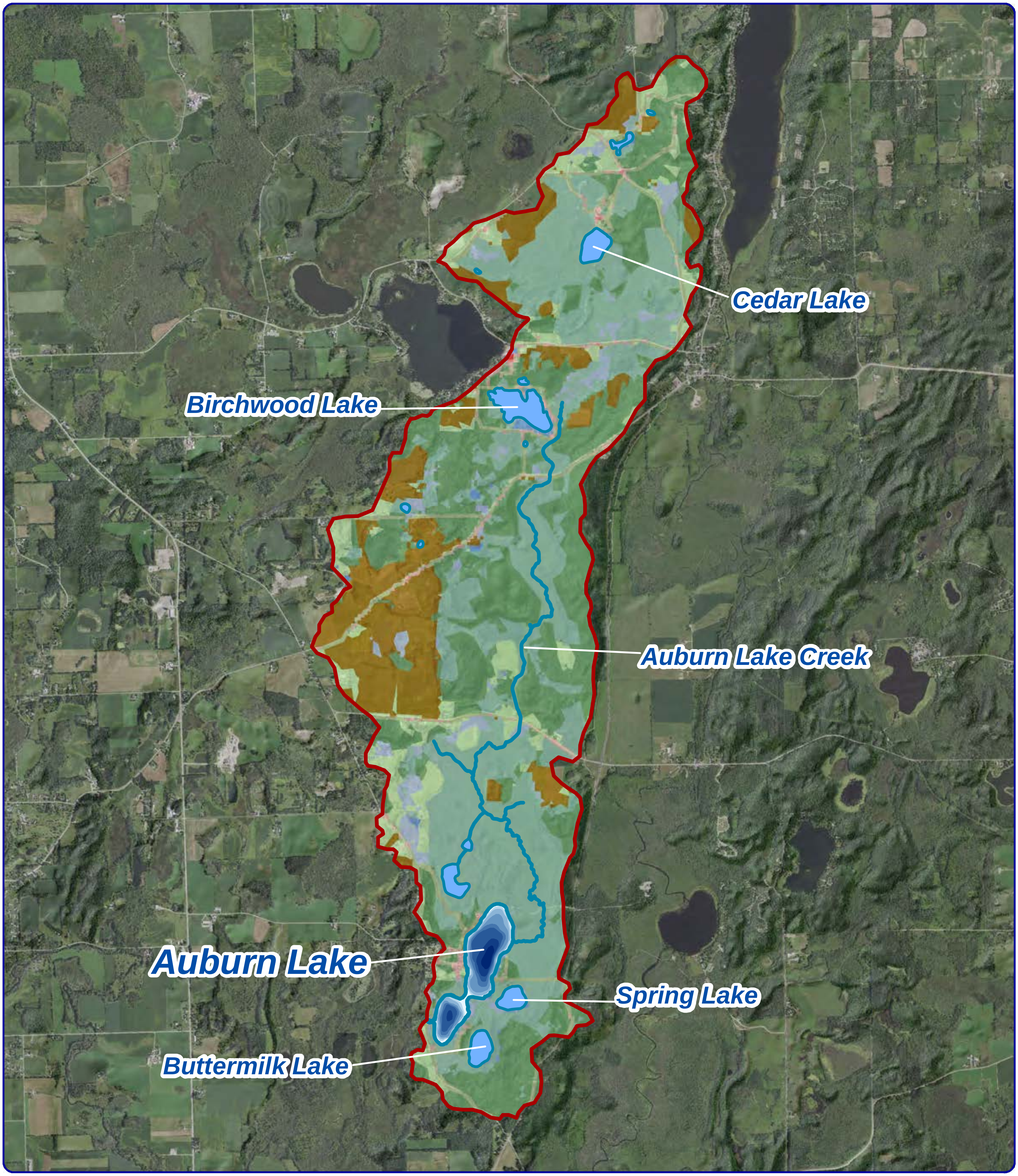
Sources:
Hydro: WDNR
Watershed: Onterra 2022
Orthophotography: NAIP 2020
Map Date: January 20, 2022 BTB
File Name Map3_Auburn_WS_LC.mxd

Map 2
Auburn Lake
Fond du Lac County, Wisconsin
Watershed Boundaries & Land Elevation



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Miles

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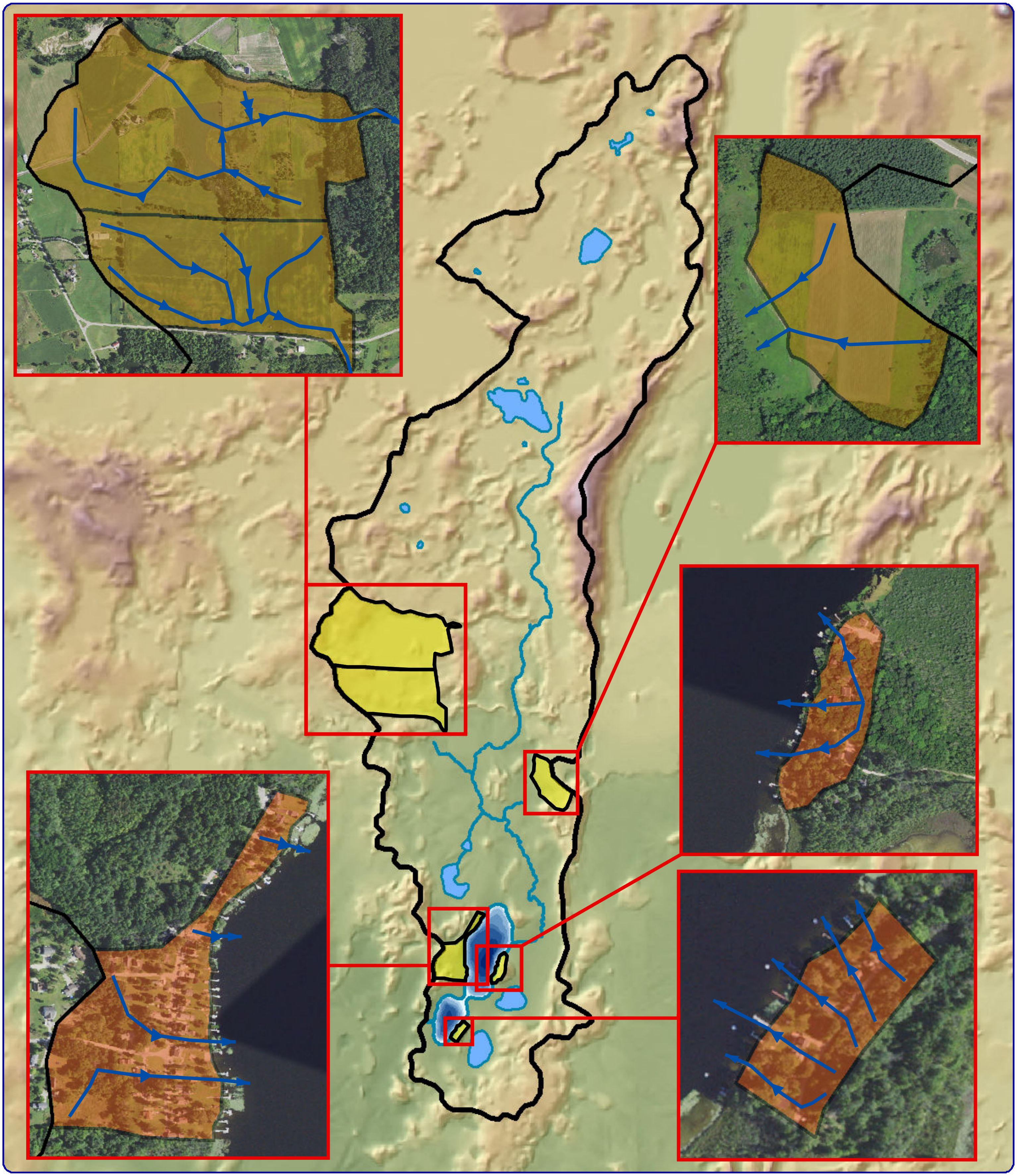
Sources:
Hydro: WDNR
Watershed: Onterra 2022
Orthophotography: NAIP 2020
Map Date: January 20, 2022 BTB
File Name Map3_Auburn_WS_LC.mxd

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

Map 3
Auburn Lake
Fond du Lac County, Wisconsin

Watershed Boundaries & Land Cover Types



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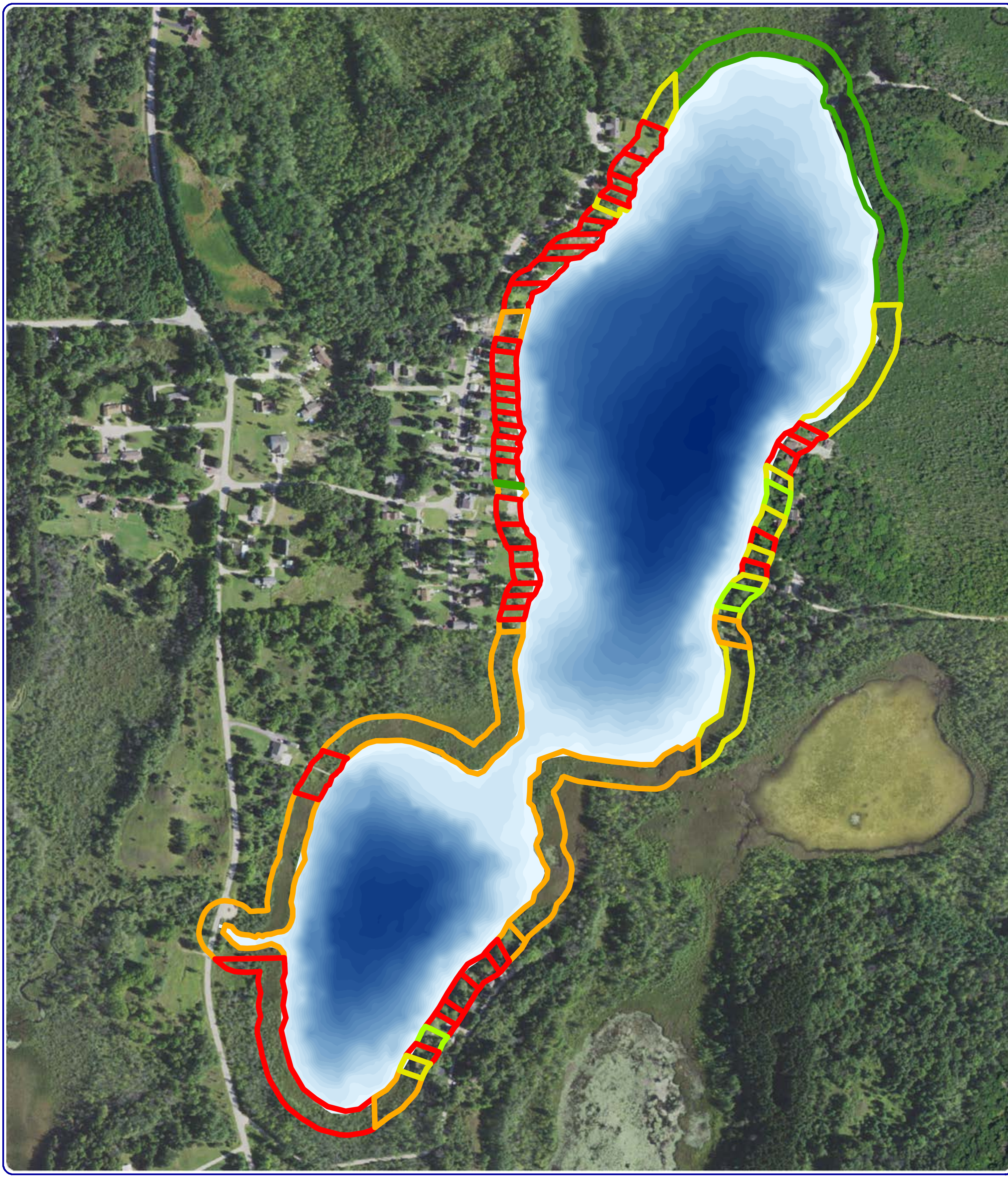
Sources:
Hydro: WDNR
Watershed: Onterra 2022
Elevation: Fond du Lac and Sheboygan Counties
Map Date: January 24, 2022 BTB
File Name Map4_Auburn_WS_AreasofConcern.mxd

Map 4
Auburn Lake
Fond du Lac County, Wisconsin

Watershed Areas of Concern



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525
Feet

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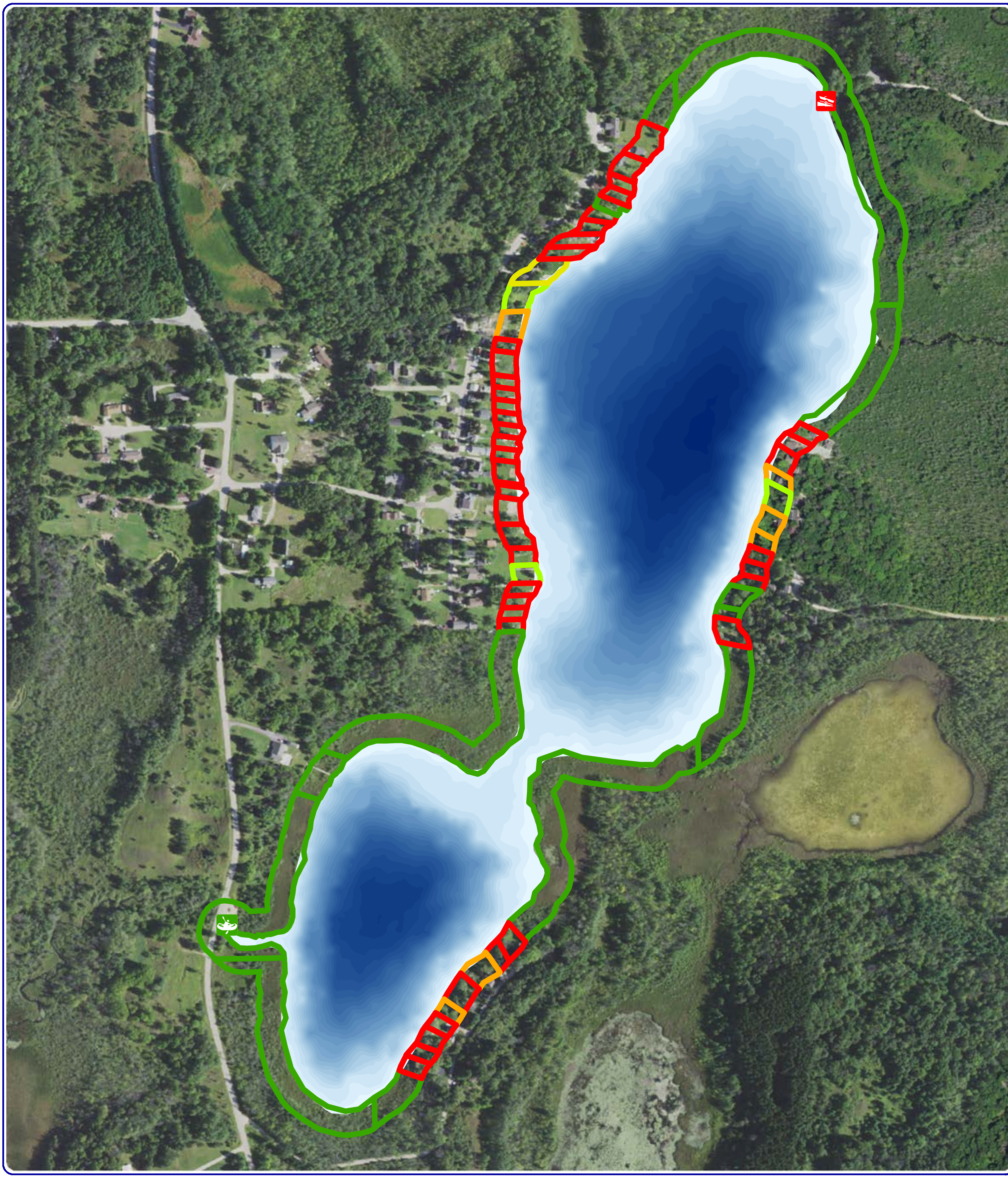
Sources:
Bathymetry: Onterra, 2021
Parcel Delineation: Onterra 2021

Map Date: February 25, 2022 BTB
Filename: Map5_Auburn_SA_Canopy_2021.mxd

Percent Shrub & Herbaceous

- 81 - 100%
- 61 - 80%
- 41 - 60%
- 21 - 40%
- 0 - 20%

Map 5
Auburn Lake
Fond Du Lac County, Wisconsin
Percent Canopy Cover



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Percent Shrub & Herbaceous

- 81 - 100%
- 61 - 80%
- 41 - 60%
- 21 - 40%
- 0 - 20%

Map 6
Auburn Lake
Fond Du Lac County, Wisconsin

Percent Shrubs & Herbaceous Cover

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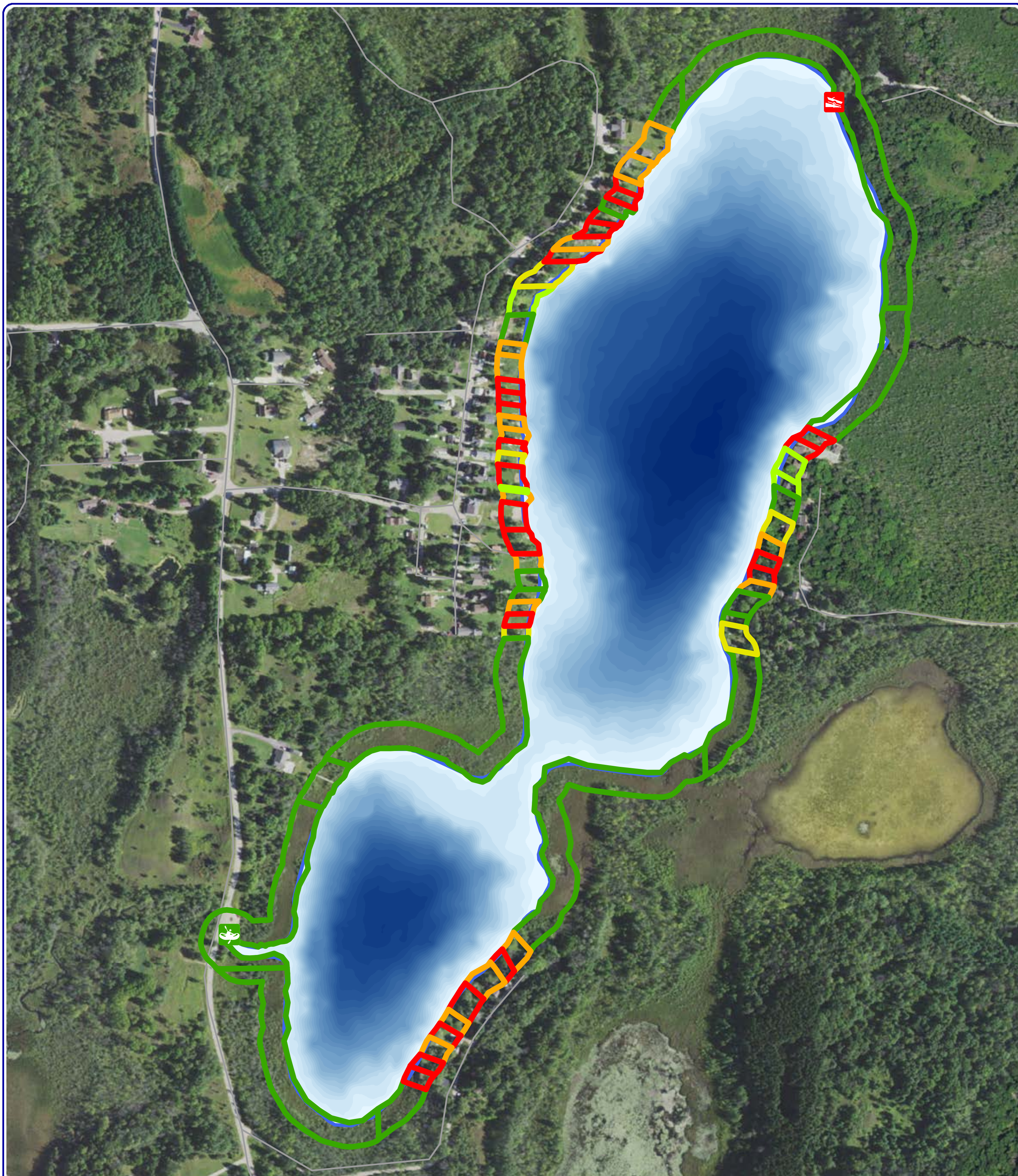
Sources:
Bathymetry: Onterra, 2021
Parcel Delineation: Onterra 2021
Map Date: February 25, 2022 BTB
Filename: Map6_Auburn_SA_ShrubHerb_2021.mxd



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Feet

Legend

81 - 100%
61 - 80%
41 - 60%
21 - 40%
0 - 20%

Map 7
Auburn Lake
Fond Du Lac County, Wisconsin

Percent Manicured Lawn

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Sources:
Bathymetry: Onterra, 2021
Parcel Delineation: Onterra 2021

Map Date: February 25, 2022 BTB
Filename: Map7_Auburn_SA_Lawn_2021.mxd

525

Feet

Legend

81 - 100%
61 - 80%
41 - 60%
21 - 40%
0 - 20%

Map 8

Auburn Lake

Fond Du Lac County, Wisconsin

Percent Impervious Surface

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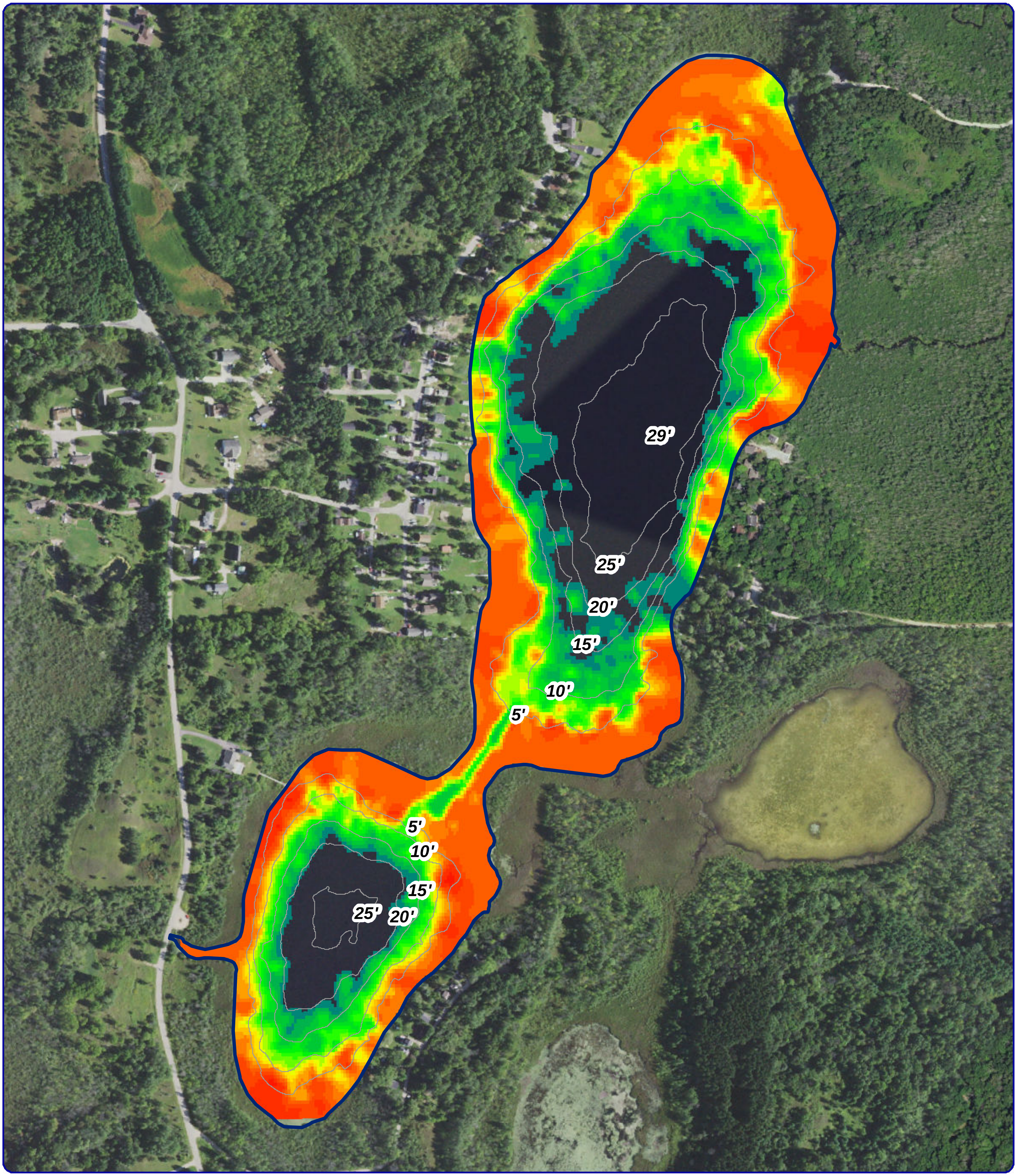
Sources:
Bathymetry: Onterra, 2021
Parcel Delineation: Onterra 2021

Map Date: February 25, 2022 BTB

Filename: Map8_Auburn_ImpSurface_Lawn_2021.mxd



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Feet

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Sources:
Hydro: Onterra
Bathymetry: Onterra 2021
Bio-Volume: Onterra 2021
Orthophotography: NAIP 2020
Map Date: February 25, 2022 BTB
File Name Map9_Auburn_BioVol_2021.mxd

Legend

0% 50% 100%

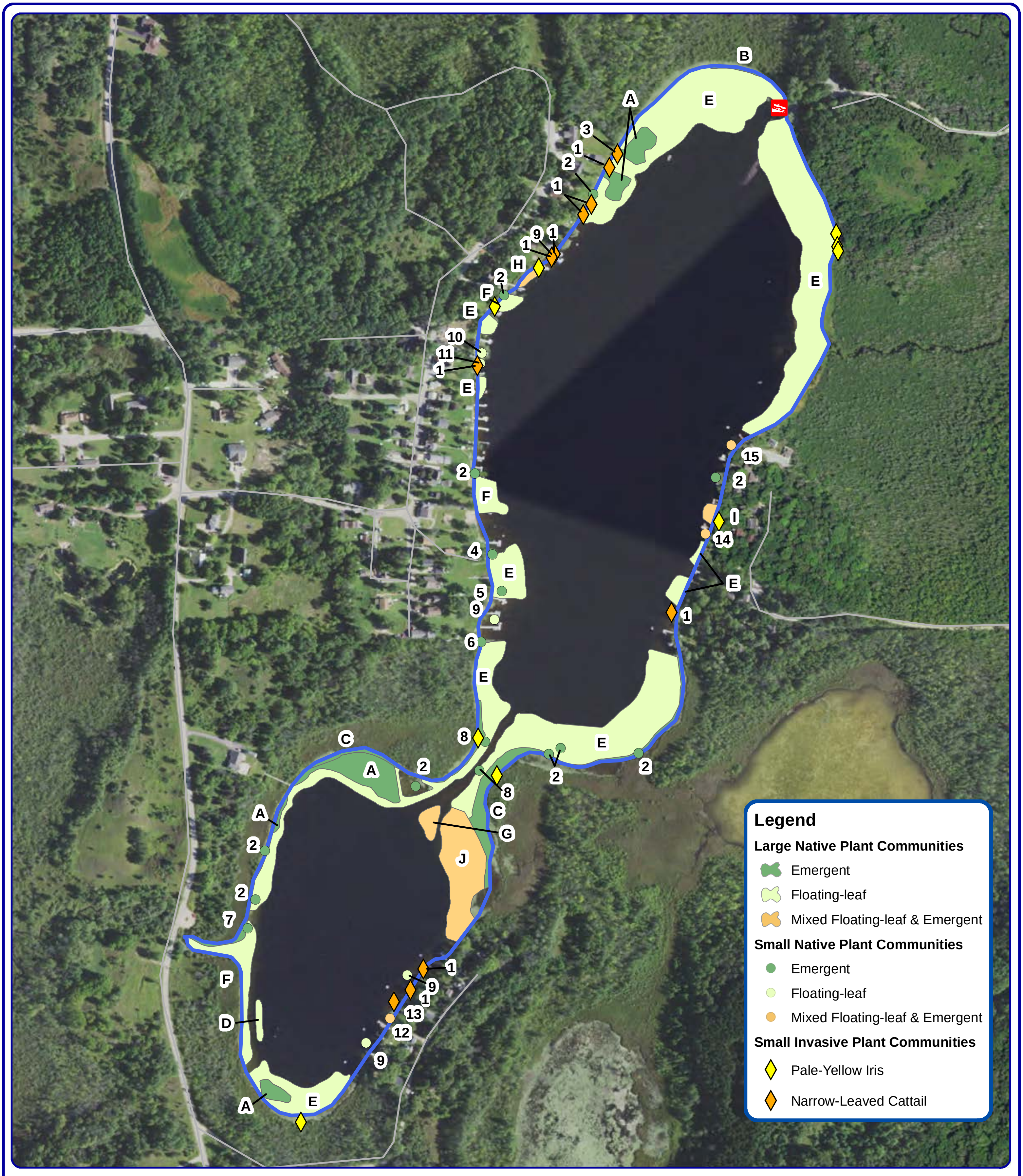
Aquatic Plant Bio-volume (%)

Map 9

Auburn Lake

Fond du Lac County, Wisconsin

2021 Acoustic Survey:
Aquatic Plant Bio-Volume



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Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2021
Orthophotography: NAIP, 2020
Map Date: October 5, 2021 AMS

Map 10
Auburn Lake
Fond du Lac County, Wisconsin

Emergent & Floating-leaf Plant Communities

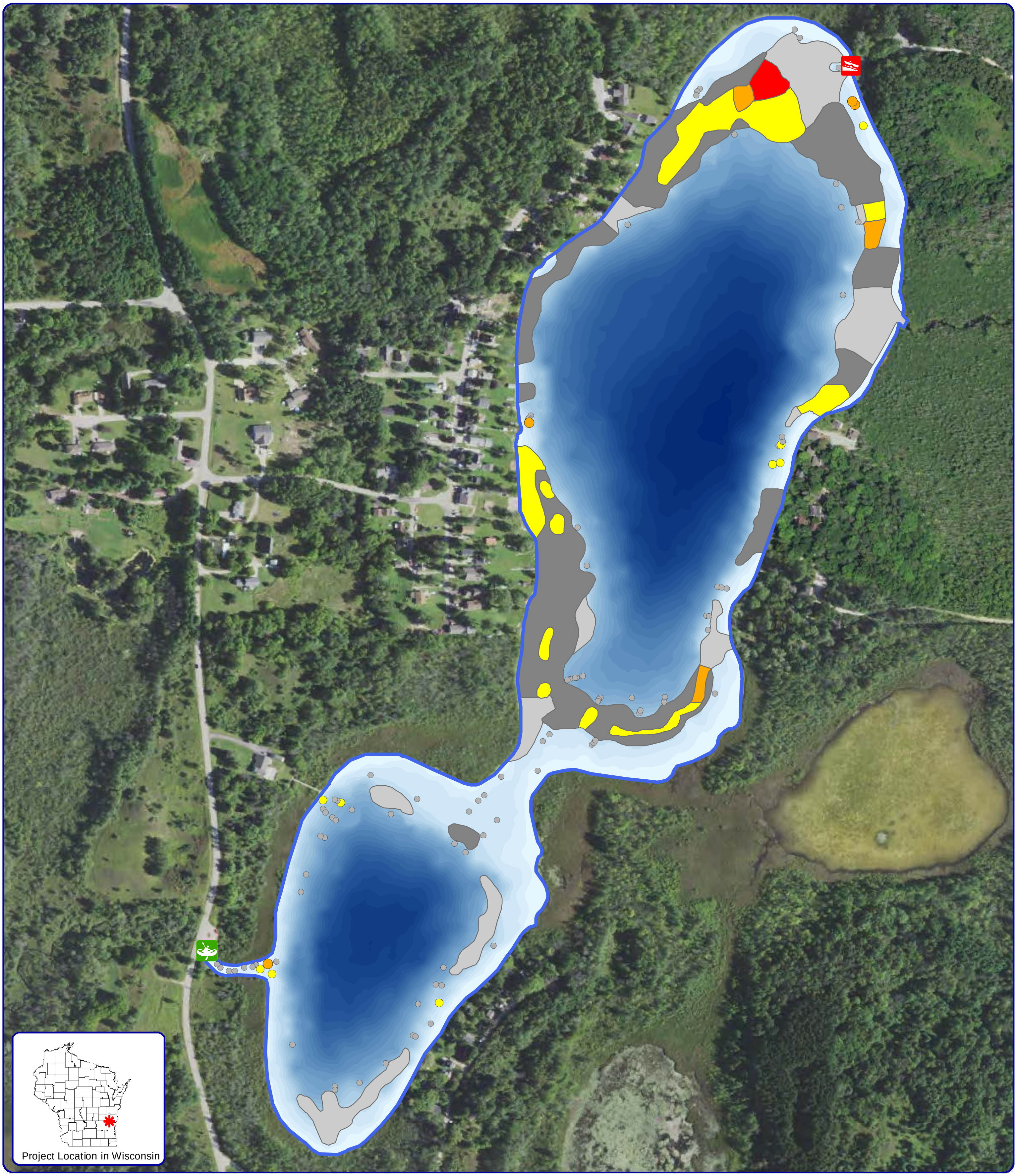
Auburn Lake 2021 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Auburn Lake - Map 10

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								1.62
B	Misc. Wetland Species								0.05
C	Misc. Wetland Species	Broad-leaf cattail							1.43
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
D	Spatterdock								0.10
E	White water lily	Spatterdock							1.26
F	Spatterdock	White water lily							
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
G	White water lily	Hardstem bulrush	Spatterdock						1.80
H	White water lily	Hardstem bulrush			Spatterdock				0.09
I	Hardstem bulrush	White water lily	Spatterdock						0.09

Small Plant Community (Points)								
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
1	Narrow-leaved cattail							
2	Hardstem bulrush							
3	Narrow-leaved cattail	Hardstem bulrush						
4	Common bur-reed	Narrow-leaved cattail						
5	Common bur-reed							
6	Arrowhead sp. (sterile)							
7	Phragmites	Misc. Wetland Species						
8	Short-stemmed bur-reed							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
9	White water lily							
10	Spatterdock							
11	White water lily	Spatterdock						
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
12	White water lily	Narrow-leaf bur-reed	Hardstem bulrush					
13	Narrow-leaved cattail	White water lily	Hardstem bulrush					
14	Spatterdock	Hardstem bulrush	White water lily					
15	Hardstem bulrush	White water lily			Spatterdock			

Species are listed in order of dominance within the community; Scientifc names can be found in the species list in Table 3.5-2



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550
Feet

Legend

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

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Sources
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2021
Orthophotography: NAIP, 2020

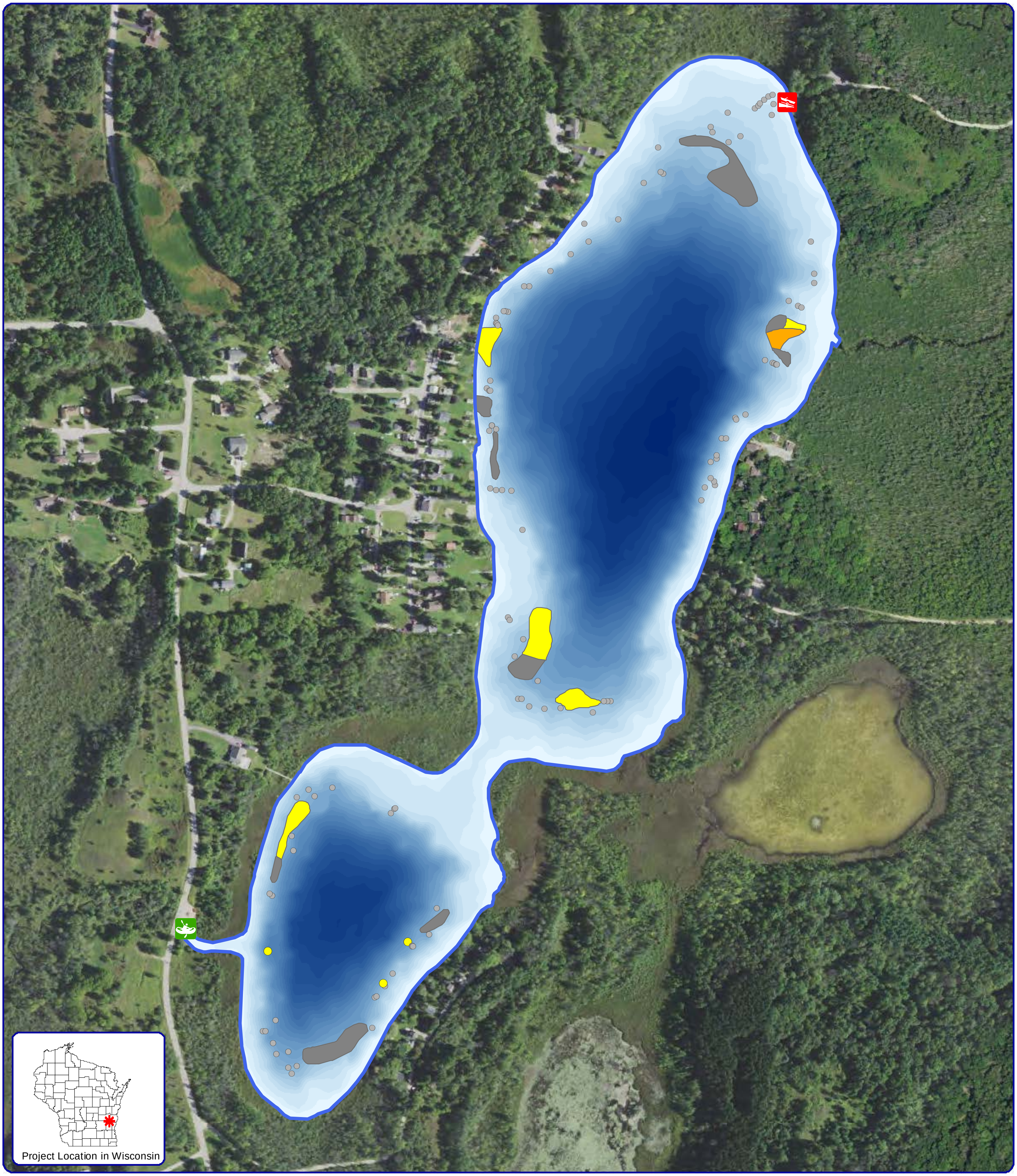
Map Date: May 25, 2021 JMB
Filename: *Map11_Auburn_CLP_May21.mxd*

Map 11

Auburn Lake

Fond Du Lac County, Wisconsin

May 2021 Curly-leaf Pondweed Survey Results



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Sources
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2021
Orthophotography: NAIP, 2020

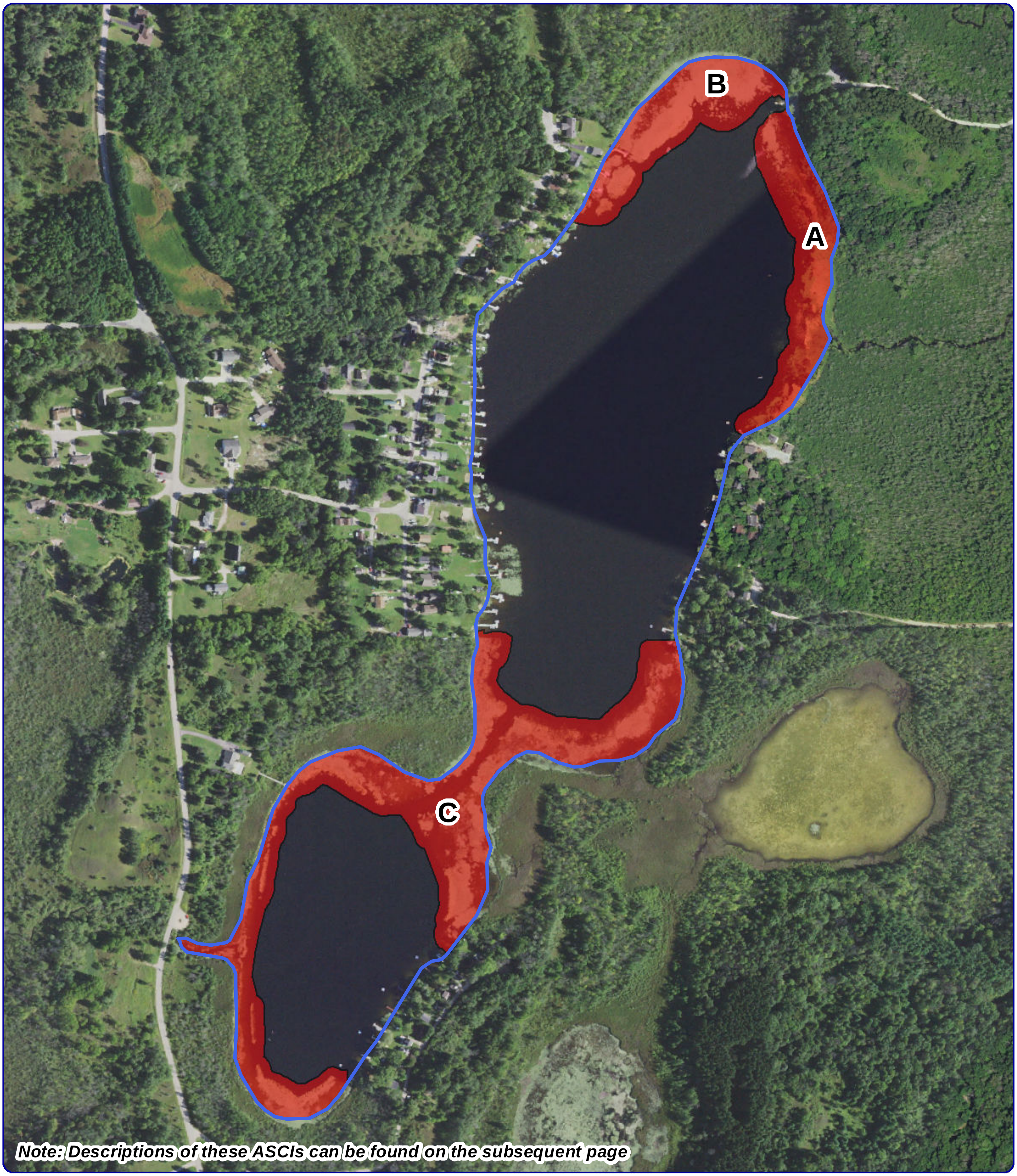
Map Date: August 29, 2021 JMB
Filename: *Map12_Auburn_EWM_Aug21.mxd*

Legend

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

Map 12
Auburn Lake
Fond Du Lac County, Wisconsin

August 2021 Eurasian Watermilfoil Survey Results



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510

Feet

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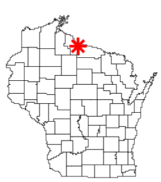
Sources:
Hydro: Onterra
Aquatic Plants: Onterra 2021
Orthophotography: NAIP 2020

Map Date: March 9, 2022 BTB

Filename: Map13_Auburn_ASCIs.mxd



Project Location in Wisconsin

Legend

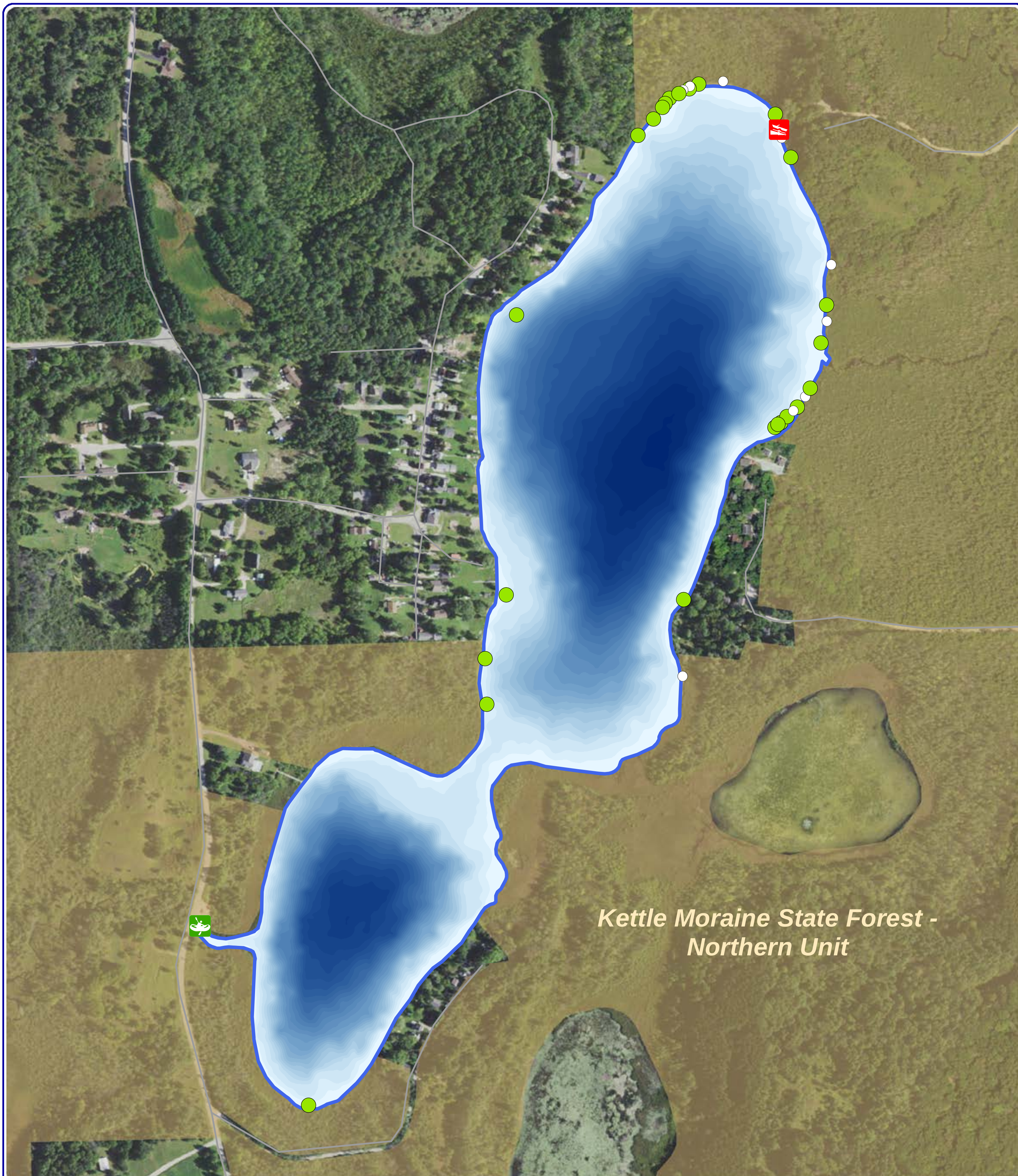
Area of Special Conservation Interest (ASCI)

Map 13

Auburn Lake

Fond du Lac County, Wisconsin

Areas of Special Conservation Interest (ASCIs)



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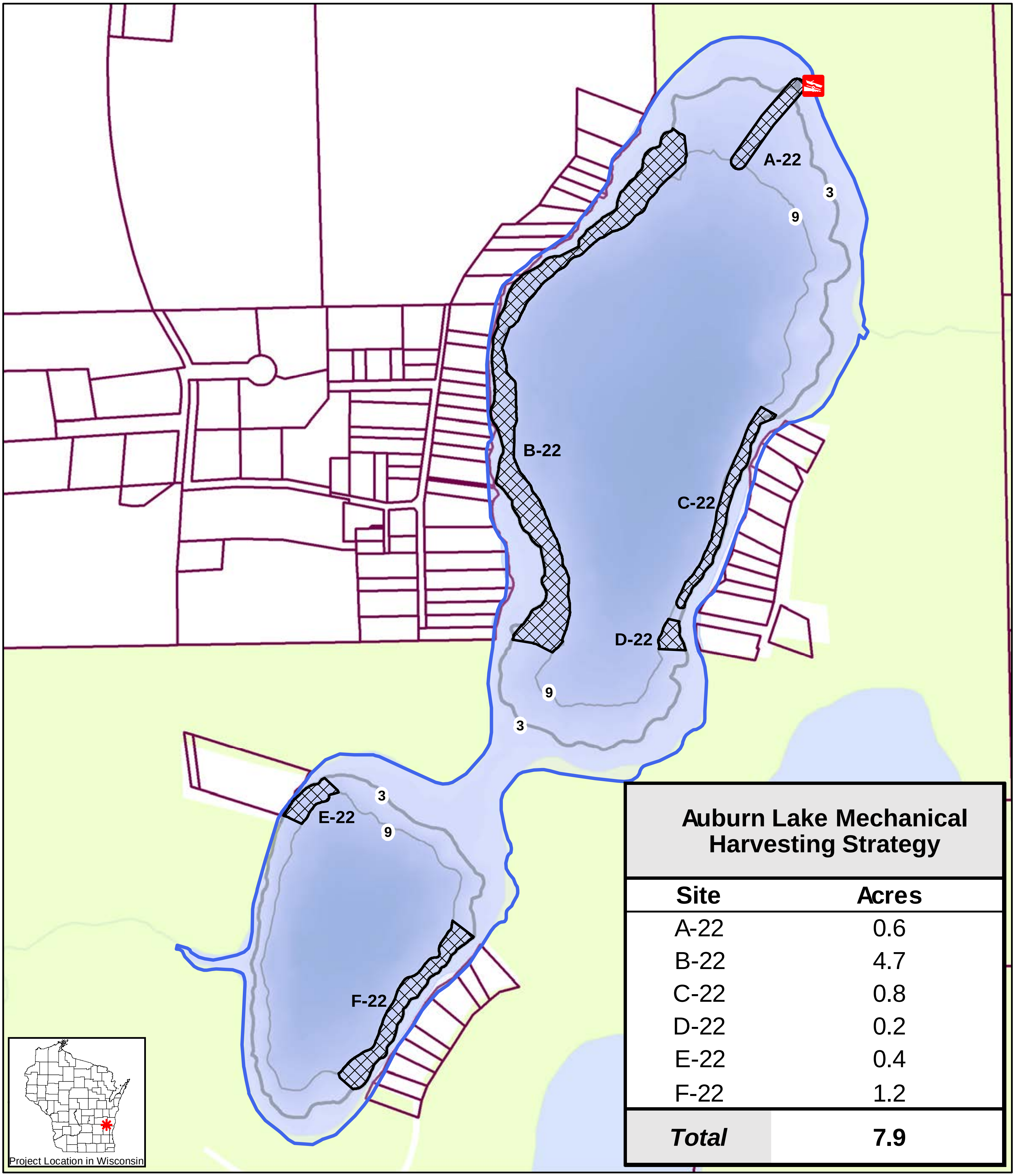
Sources
Hydro: WDNR
CWH Survey: Onterra, 2020
Orthophotography: NAIP, 2020
Map date: November 5, 2021 AMS
Filename: Mirror-Shadow_CWH_2020.mxd

Legend

- No Branches
- Some Branches
- Full Canopy

Map 14
Auburn Lake
Waupaca County, Wisconsin

Coarse Woody Habitat



Auburn Lake Mechanical Harvesting Strategy

Site	Acres
A-22	0.6
B-22	4.7
C-22	0.8
D-22	0.2
E-22	0.4
F-22	1.2
Total	**7.9**

500
Feet

Legend

- Auburn Lake Parcels
- Harvesting Area *(7.9 acres)*
- Kettle Moraine State Forest

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Sources:
Roads & Hydro: WDNR
Orthophotography: NAIP 2020
Aquatic Plant Survey: Onterra, 2021
Map Date: April 14, 2022

Map 15
Auburn Lake
Fond Du Lac County, Wisconsin

Mechanical Harvesting Plan v1