Towanda Lake

Vilas County, Wisconsin

Comprehensive Management Plan

June 2021

Sponsored by:

Towanda Lake Association, Inc.

WDNR Grant Program

LPL-1674-18

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Onterra, LLC
Lake Management Planning

Towanda Lake

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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:

Towanda Lake Planning Committee

Phil Blazkowski	Yolan Mistele	Michael Young
Helen Gurtner	Noreen Wiese	Cyndi Bane

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1.0 INTRODUCTION

According to the 1973 recording sonar WDNR Lake Survey Map, Towanda Lake is 145.7 acres. The WDNR website lists the lake as 139 acres. At the time of data analysis for this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2017. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 143.7 acres. Towanda Lake, Vilas County, is a seepage lake with a maximum depth of 27 feet and a mean depth of about 9.5 feet. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Stoneworts and fern-leaf pondweed were the most common plants in Towanda Lake, with one exotic plant species being found as well.

Field Survey Notes

During the 2018 surveys conducted on Towanda Lake, Onterra crews noted high water levels, with shoreland trees and terrestrial plants having a drowned appearance.

With a resort and a boys camp located on the northwestern part of the lake, and much of the shoreline containing natural emergent and floating-leaf vegetation supporting wildlife, recreational and sightseeing opportunities abound on the lake.

Photograph 1.0-1 Towanda Lake, Vilas County

Lake at a Glance - Towanda Lake

Morphology	
Acreage	143
Maximum Depth (ft)	27
Mean Depth (ft)	9.5
Shoreline Complexity	4.4
Vegetation	
Early-Season AIS Survey Date	June 20, 2018
Comprehensive Survey Date	July 11 & 12, 2018 and August 1 & 2, 2018
Threatened/Special Concern Species	Northern naiad, Northeastern bladderwort
Exotic Plant Species	Reed canary grass
Simpson's Diversity	0.92
Average Conservatism	7.2
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	6.8
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	3:1

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 an update that was handed out during the 2019 annual meeting.

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 July 28, 2018 a project kick-off meeting was held at the Blazkowski residence to introduce the project to the general public. The meeting was announced through a mailing and personal contact by the Towanda Lake Association board members. The approximately 10 attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Tim's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question-and-answer session.

Project Wrap-up Meeting

A recorded wrap-up meeting presentation was provided to the group via Onterra's YouTube Channel in June 2021. The presentation included highlights of the project results and plan.

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. These two meetings were open only to the planning committee and were held during the week. The first, following the completion of the draft report sections of the management plan. The planning committee members were supplied with the draft report sections prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of the first meeting was to fortify a solid understanding of their lake among the committee members. The second planning committee meeting was held a few weeks after the first and concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

The first Towanda Lake planning meeting was facilitated by Tim Hoyman on August 30, 2019. Tim's presentation detailed the information gathered as a part of the project field studies, historical data search, and the riparian stakeholder survey. Questions were answered throughout the presentation.

Planning Committee Meeting II

The second planning meeting took place on October 28, 2019. Tim Hoyman led the group through an exercise that resulted in a list of challenges facing the lake and the Towanda Lake Association. Those challenges were refined and converted to management goals. The meeting closed by creating one or more management actions the TLA could implement to meet each management goal. The list of goals and actions stood as the framework for the full written implementation plan drafted by Tim and delivered to the committee on November 22, 2019.

Stakeholder Survey

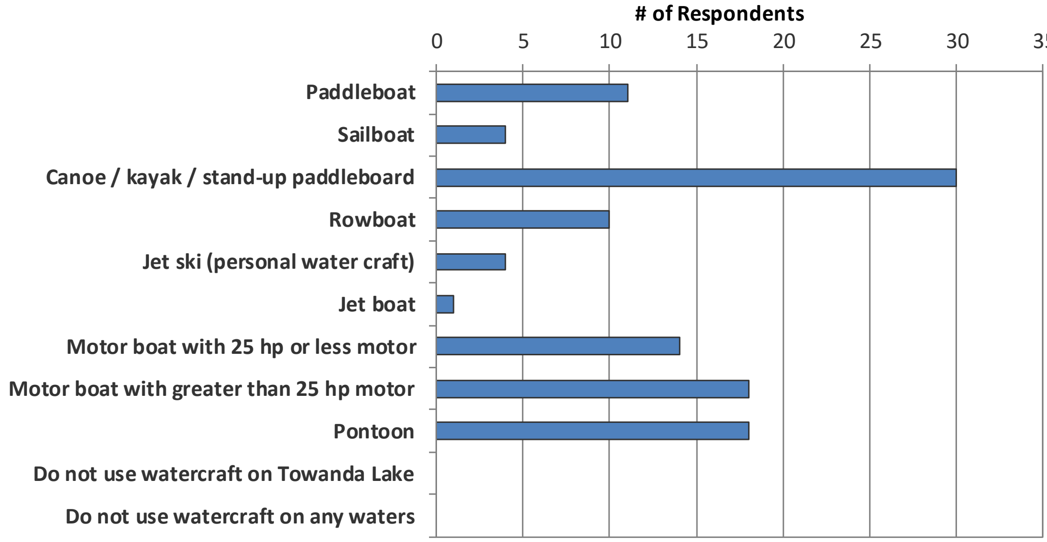
As a part of this project, a stakeholder survey was distributed to riparian property owners/Towanda Lake Association, Inc members around Towanda Lake. The survey was designed by Onterra staff and the Towanda Lake Association, Inc planning committee and reviewed by a WDNR social scientist. During May 2019, the eight-page, 31-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a Towanda Lake Association, Inc volunteer for analysis. Forty-six percent of the surveys 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. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people who use and care for Towanda Lake. Forty-two percent of survey respondents live on the lake as a seasonal vacation home only, while 34% are year-round residents, 17% are seasonal residents (longer than summer), and 2% are summer residents (June-August). Forty-six percent of stakeholders have owned their property for over 15 years, and 37% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a pontoon boat, larger motor boat, canoe/kayak, or a combination of these three vessels on Towanda Lake (Question 12). Canoe/kayak/stand-up paddleboards in particular were a popular option. On a relatively small lake such as Towanda Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 15, several of the top recreational activities on the lake involve boat use.

A concern of stakeholders noted throughout the stakeholder survey (see Question 23 and survey comments – Appendix B) was excessive plant growth within Towanda Lake. This topic is touched upon in the Summary & Conclusions section as well as within the Aquatic Plants section.

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



Question 15: Please rank up to three activities that are important reasons for owning your property on Towanda Lake.

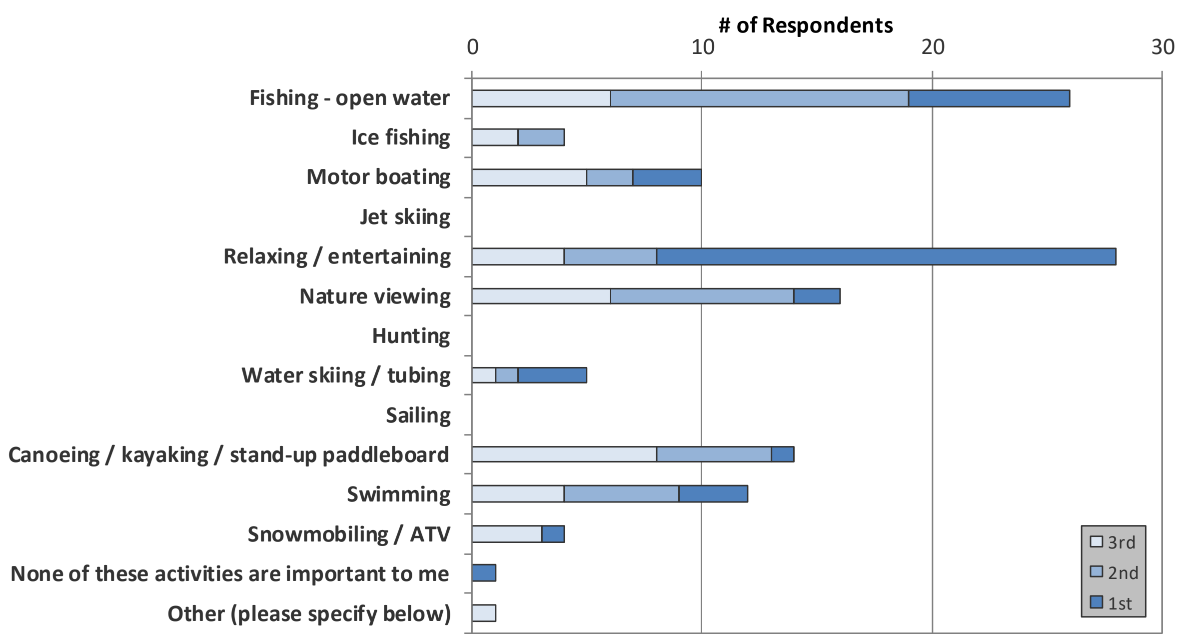
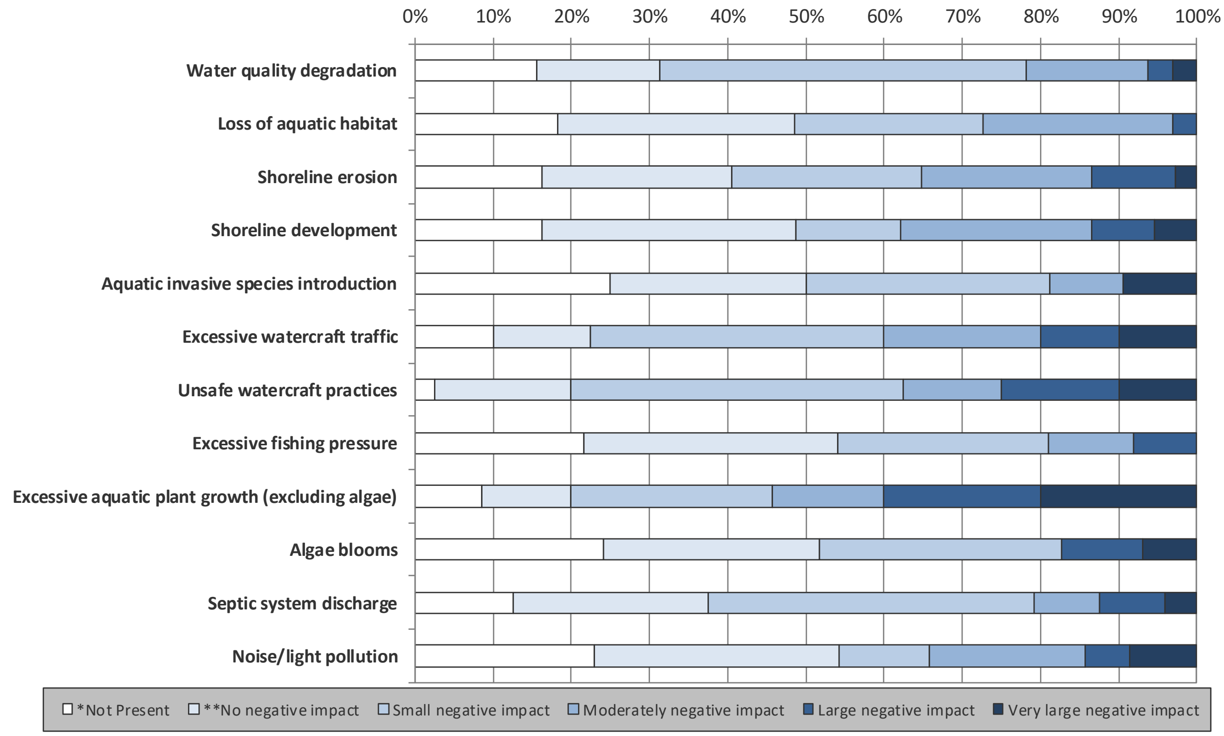


Figure 2.0-1. Select survey responses from the Towanda Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 23: To what level do you believe these factors may be negatively impacting Towanda Lake?



Question 24: Please rank your top three concerns regarding Towanda Lake.

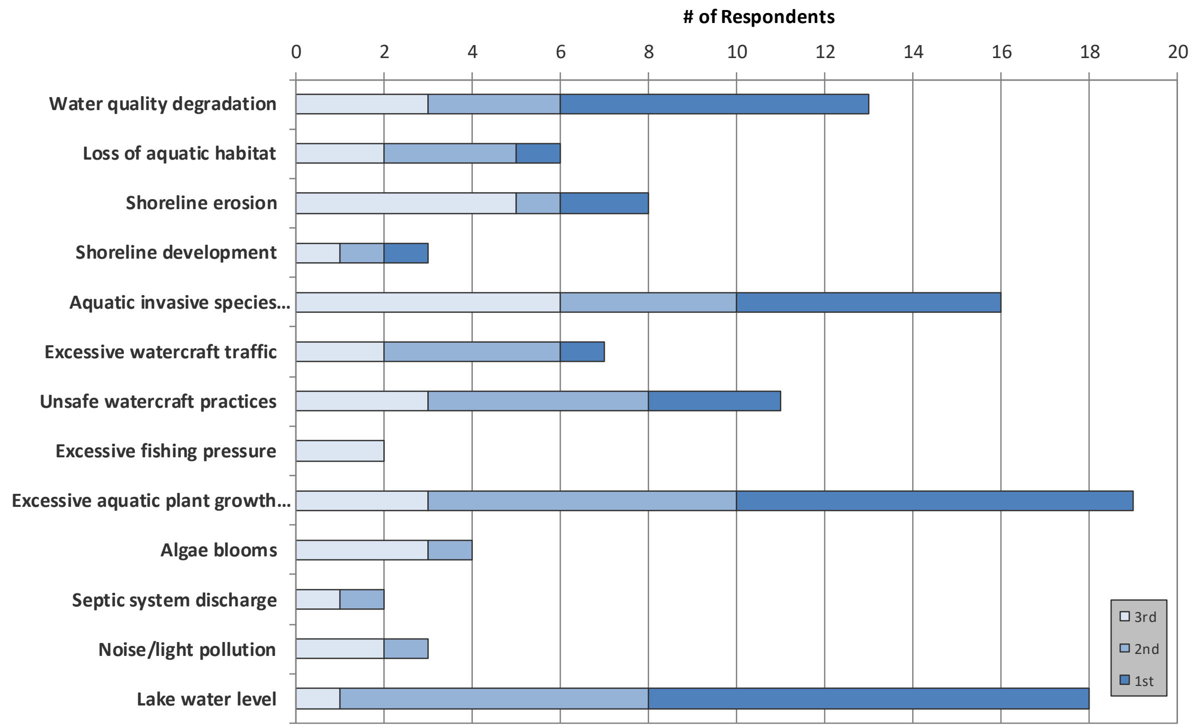


Figure 2.0-2. Select survey responses from the Towanda Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

Phil Blazkowski, Planning Committee Chair and Association President created a questionnaire for review by the planning committee members in spring 2021. Each committee member voted on the elements of the draft implementation plan and other suggestions brought up during the committee discussions. The results of the questionnaire are contained in Appendix F. Comments and changes suggested by the results of the questionnaire were integrated into the current implementation plan draft.

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 Towanda 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 Towanda Lake's water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white 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 et al. 1994, Dinius 2007, and Smith et al. 1991).

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

> **Lake stratification** occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The epilimnion is the top layer of water which is the warmest water in the summer months and the coolest water in the winter months. The hypolimnion is the bottom layer and contains the coolest water in the summer months and the warmest water in the winter months. The metalimnion, often called the thermocline, is the middle layer containing the steepest temperature gradient.

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

Internal Nutrient Loading*

In lakes that support stratification, whether throughout the summer or periodically between mixing events, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of the phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks at a time).
- Lakes with hypolimnetic total phosphorus values less than 200 µg/L.

Candidate Lakes

- Lakes with hypolimnetic total phosphorus concentrations exceeding 200 µg/L.
- Lakes with epilimnetic phosphorus concentrations that cannot be accounted for in watershed phosphorus load modeling.

Specific to the final bullet-point, during the watershed modeling assessment, the results of the modeled phosphorus loads are used to estimate in-lake phosphorus concentrations. If these estimates are much lower than those actually found in the lake, another source of phosphorus must be responsible for elevating the in-lake concentrations. Normally, two possibilities exist: 1) shoreland septic systems, and 2) internal phosphorus cycling. If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) 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 Towanda Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

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

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

Because of its depth, small watershed, and hydrology, Towanda Lake is classified as a deep seepage lake (category 7 on Figure 3.1-1).

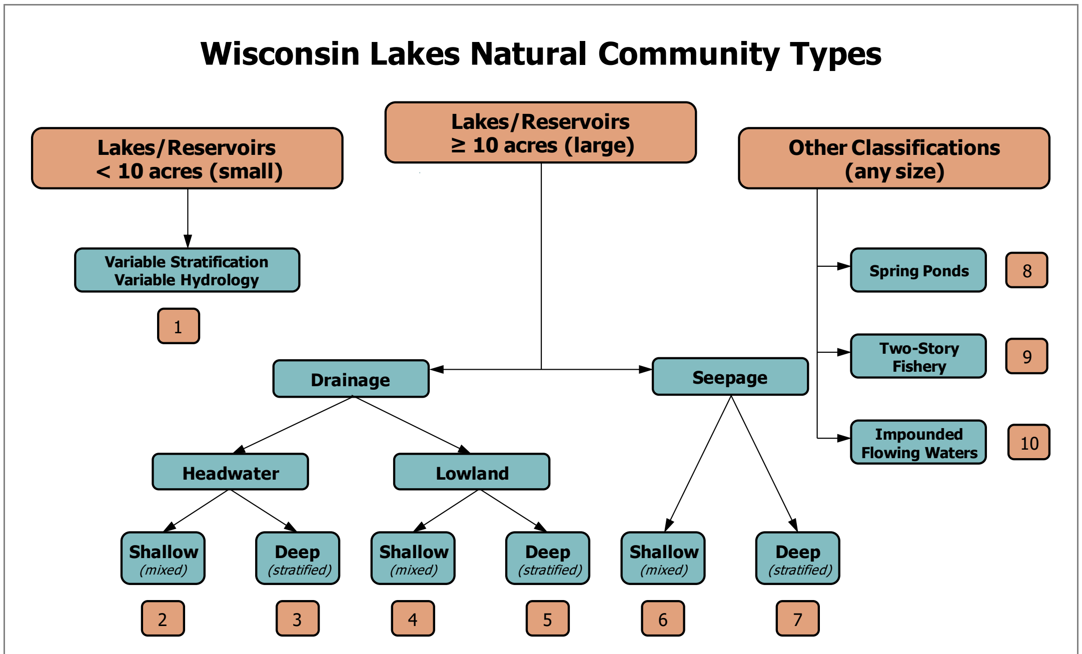


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

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

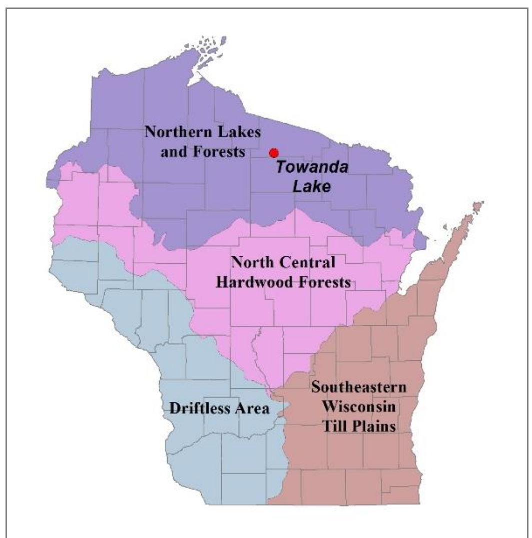


Figure 3.1-2. Location of Towanda Lake within the ecoregions of Wisconsin. After Nichols 1999.

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

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Towanda Lake is displayed in Figures 3.1-3 - 3.1-8. 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.

Towanda Lake Water Quality Analysis

Towanda Lake Long-term Trends

Towanda Lake has a long record of water quality data with Secchi disc depth being available from 1992 through 2018 while total phosphorus and chlorophyll-*a* data is available for 2001-2018. The summer mean total phosphorus (TP) is 13.9 µg/L (Figure 3.1-3) and the growing season mean concentration is nearly the same at 14.2 µg/L. Both of these averages fall within the *excellent* category and are better than the Northern Lakes and Forests ecoregion (NLF) median and the median for lakes of this type in the state. Phosphorus levels have remained largely unchanged during the last 20 years.

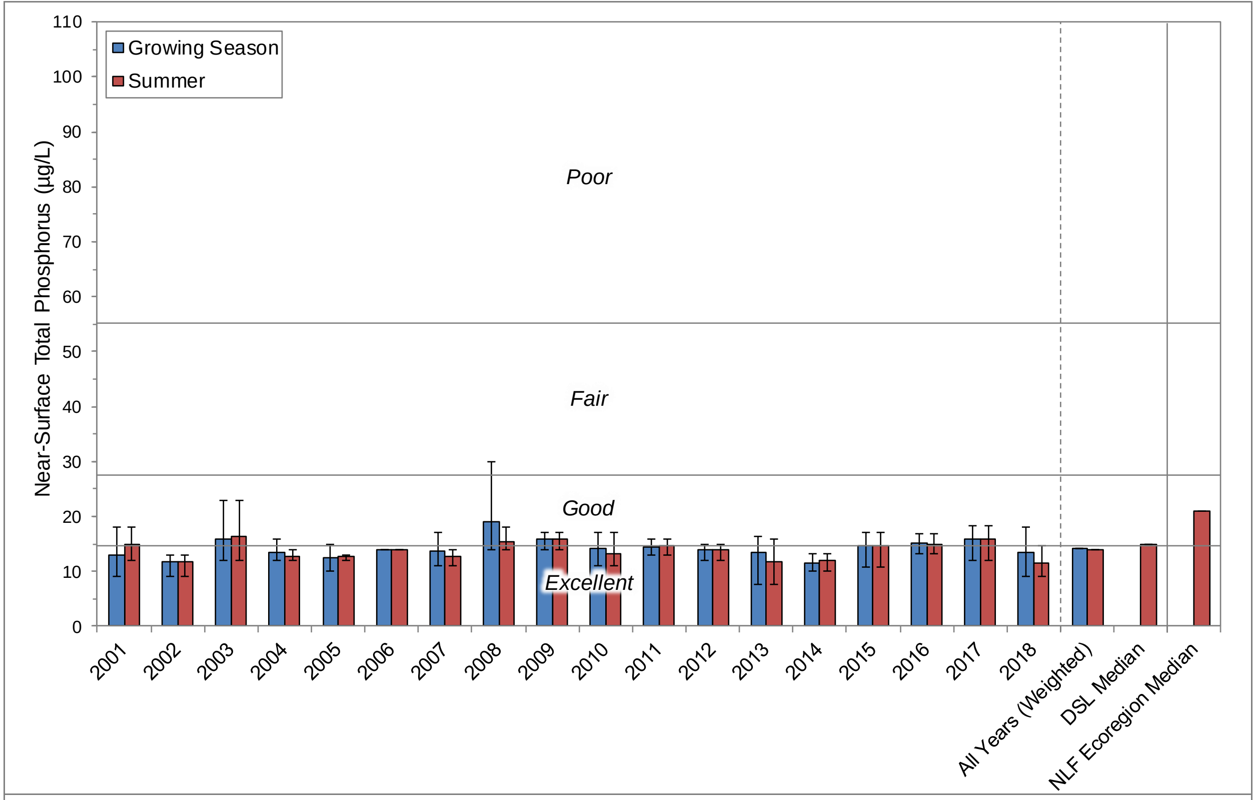


Figure 3.1-3. Towanda Lake, state-wide class 7 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The mean chlorophyll-*a* concentration for the last 20 years is 6.0 µg/L which places the lake in the *good* category (Figure 3.1-4). This mean concentration is higher than other deep seepage lakes in the state and nearly the median value for all lakes in the NLF ecoregion. Chlorophyll-*a* concentrations are more variable than they were for phosphorus, but in the last few years they have generally been lower than they were in the early 2010s.

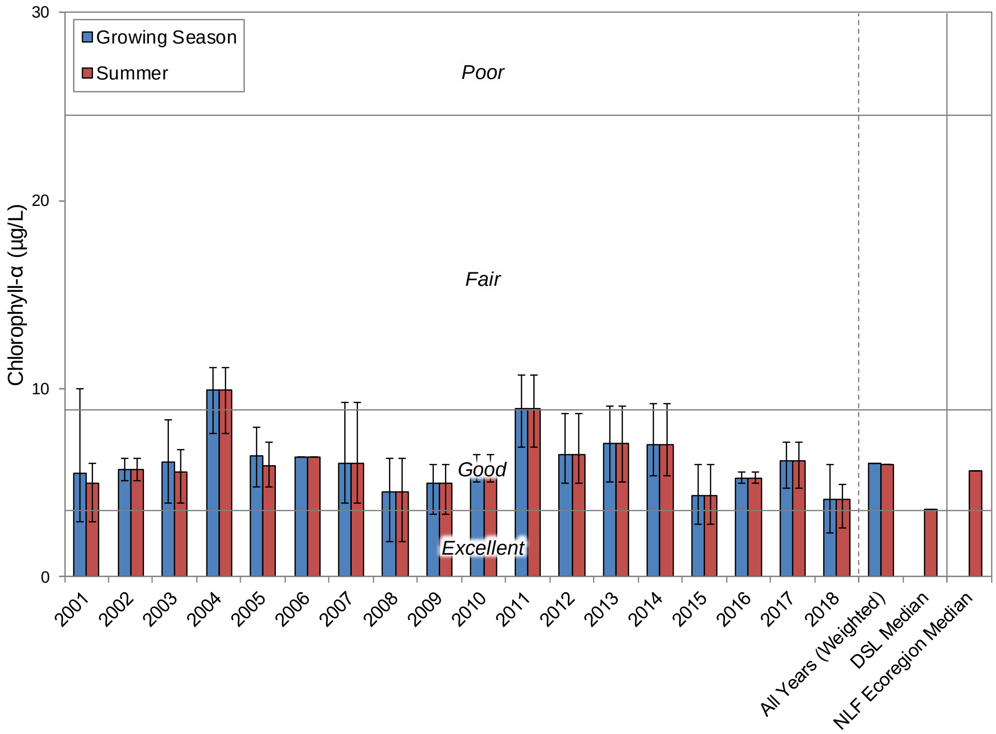


Figure 3.1-4. Towanda Lake, state-wide class 7 lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

There is a longer record for Secchi disc clarity which begins in 1992 (Figure 3.1-5). The long term mean summer water clarity is 8.9 feet which places the lake in the *good* category. The mean depth is not as good as the median value for other deep seepage lakes in the state, but is better than the median value of all lakes in the NLF ecoregion. In the 1990s, water clarity was better than it has been since 2000. Unfortunately, data for phosphorus or chlorophyll-*a* was not collected during this time, so it is difficult to know if nutrient levels were lower then or if another factor such as water color is the reason.

To determine if internal nutrient loading (discussed in the primer section) is a significant source of phosphorus in Towanda Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface for samples collected in 2018. The higher concentrations of phosphorus near the bottom occurred when Towanda Lake was stratified and the bottom layer of water (hypolimnion) was anoxic. These higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into overlying water during periods of anoxia. Even concentrations are higher in the bottom waters they are not elevated enough to be a significant source of internal loading (Figure 3.1-6).

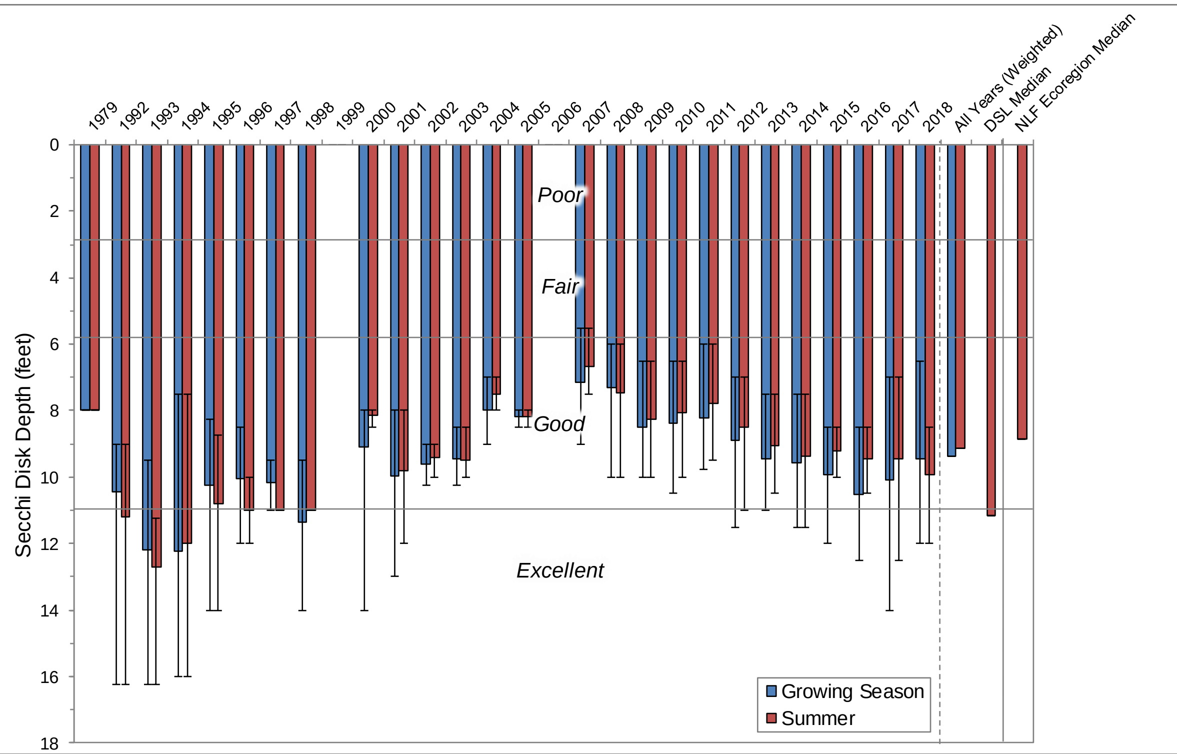


Figure 3.1-5. Towanda Lake, state-wide class 7 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

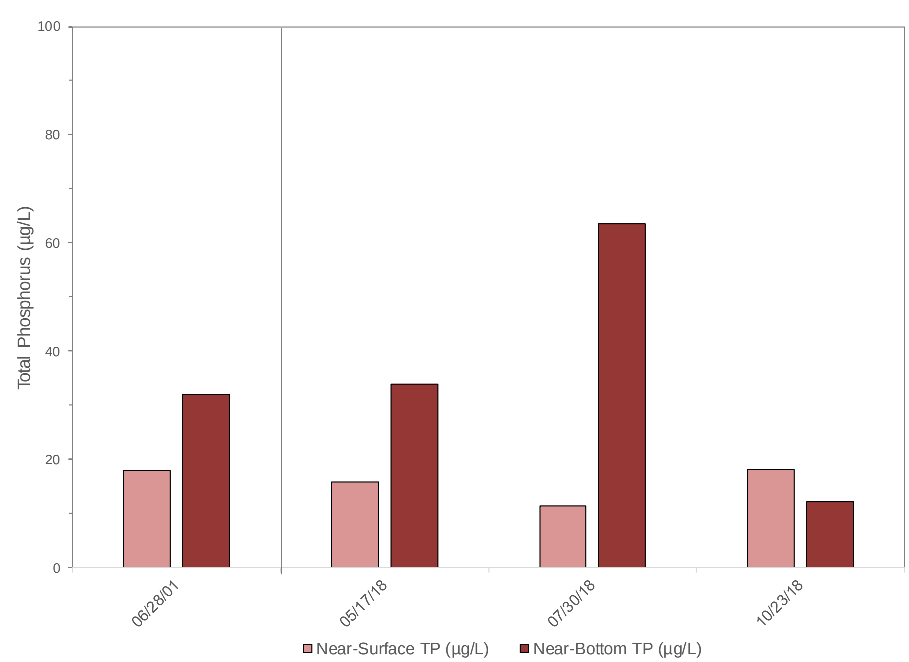


Figure 3.1-6. Towanda Lake near-surface and near-bottom total phosphorus concentrations in 2018.

Limiting Plant Nutrient of Towanda Lake

Using midsummer nitrogen and phosphorus concentrations from Towanda Lake, a nitrogen:phosphorus ratio of 51:1 was calculated. This finding indicates that Towanda Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Towanda Lake Trophic State

Figure 3.1-7 contains the Trophic State Index (TSI) values for Towanda Lake. The TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project. 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 Towanda Lake is in a mesotrophic state. Towanda Lake is more productive than a majority of other deep seepage lakes in the state and has a similar productivity to other lakes in the NLF ecoregion.

Towanda Lake has a higher TSI using chlorophyll-*a* and water clarity than when using phosphorus. It is not clear why more algae (chlorophyll-*a*) are produced than normal for the given phosphorus concentration. The similarity between chlorophyll-*a* and water clarity is as expected since in most lakes algal turbidity is the most important determinant of water clarity.

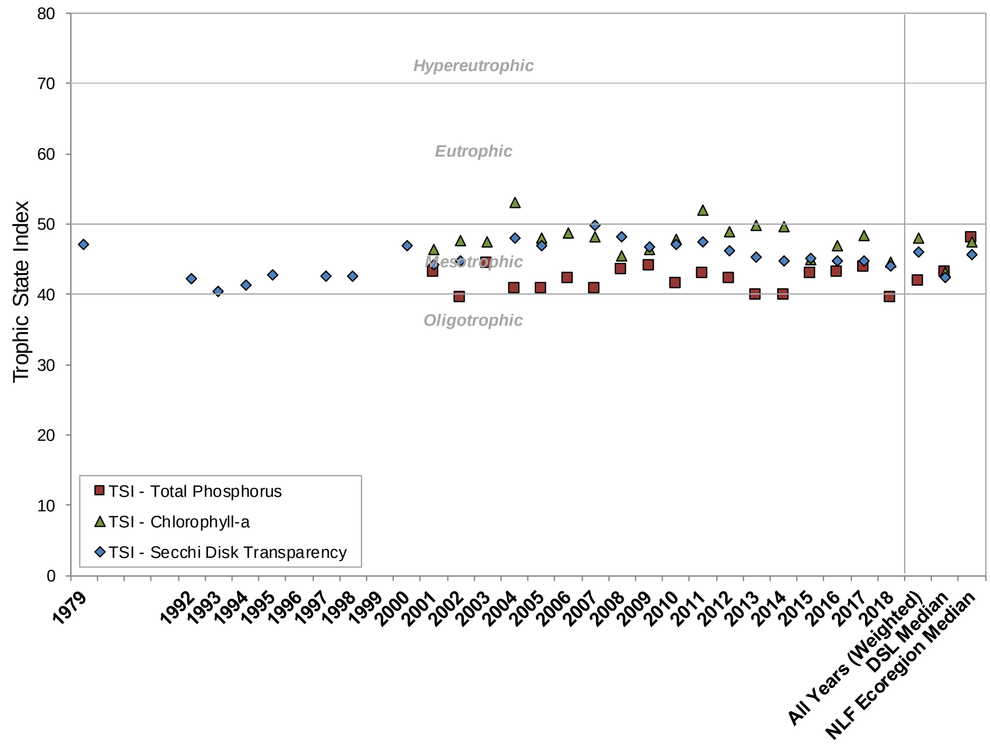


Figure 3.1-7. Towanda Lake, state-wide class 7 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Towanda Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Towanda Lake by Onterra staff in 2018. Profiles depicting these data are displayed in Figure 3.1-8. Towanda Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, during the spring and fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Towanda Lake's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake.

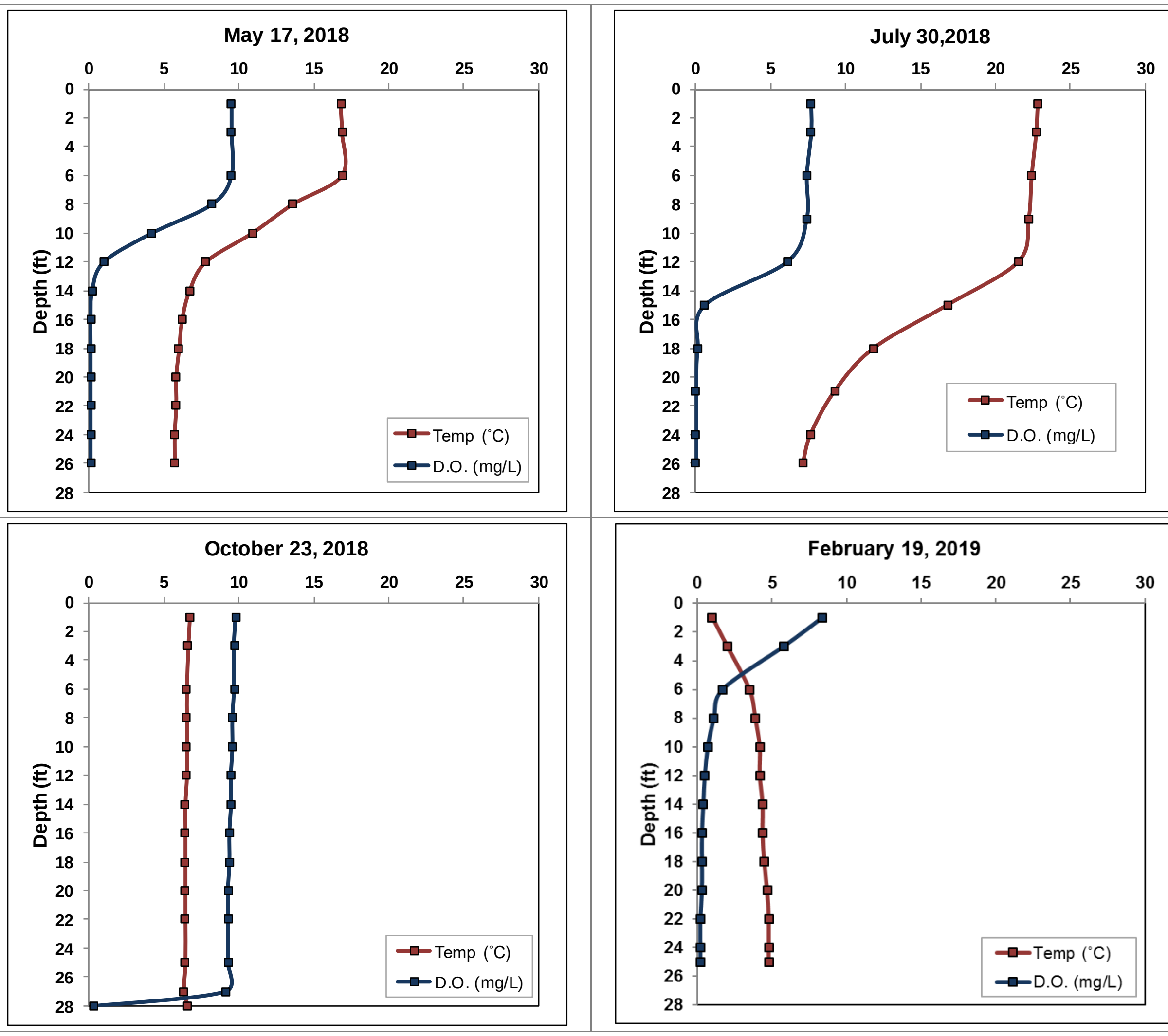


Figure 3.1-8. Towanda Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Towanda 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 Towanda Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Towanda Lake was found to be near neutral with a value of 6.8, and falls within the normal range for Wisconsin Lakes (Figure 3.1-9).

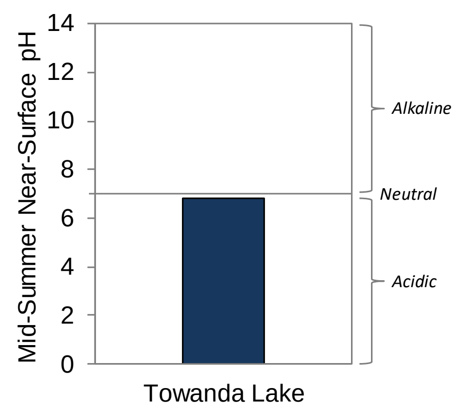


Figure 3.1-9. Towanda Lake mid-summer near-surface pH value.

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 Towanda Lake was measured at 30 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain (Figure 3.1-10).

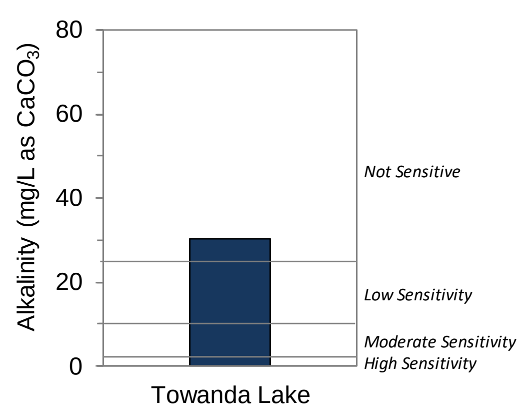


Figure 3.1-10. Towanda Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 (*Dreissena polymorpha*) is 7.0 to 9.0, so Towanda Lake's pH of 6.8 falls slightly outside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Towanda Lake was found to be 4.5 mg/L, falling well below the optimal range for zebra mussels (Figure 3.1-11). During the summer of 2018, Onterra staff completed plankton tows utilizing a specific net mesh. The water samples collected were provided to the WDNR and a technician searched the samples for zebra mussel veligers, a free-swimming life stage of the zebra mussel and the life stage at which the exotic is transported between waterbodies. No veligers were located in the samples.

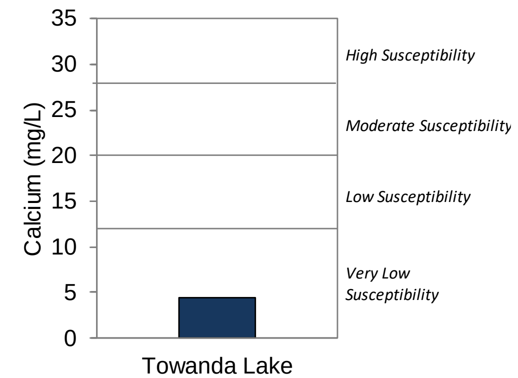


Figure 3.1-11. Towanda Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

Zebra mussels are a small, bottom-dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring.

Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days.

Stakeholder Survey Responses to Towanda Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. In 2018, a stakeholder survey was sent to 89 Towanda Lake riparian property owners. Forty-one (46%) of these 89 surveys were completed and returned. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Towanda Lake, but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

When asked about Towanda Lake's current water quality, 90% of survey respondents indicated the water quality is *good* or *excellent* and 5% indicated the water quality is *poor* (Figure 3.1-12). When asked how water quality has changed in Towanda Lake since they first visited the lake, 48% of respondents indicated water quality has *remained the same* and 15% indicated it has *somewhat* or *greatly improved* while 27% felt the water quality was *somewhat* or *severely degraded* (Figure 3.1-13). As was discussed earlier in this section, water quality data do indicate that phosphorus and algal production is unchanged in Towanda Lake over the past 3 decades.

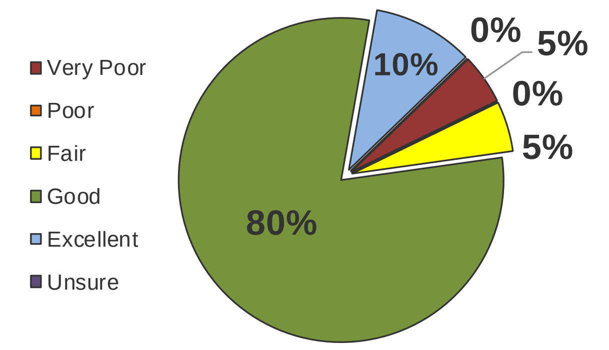


Figure 3.1-12. Stakeholder survey response Question #16. How would you describe the current water quality of Towanda Lake?

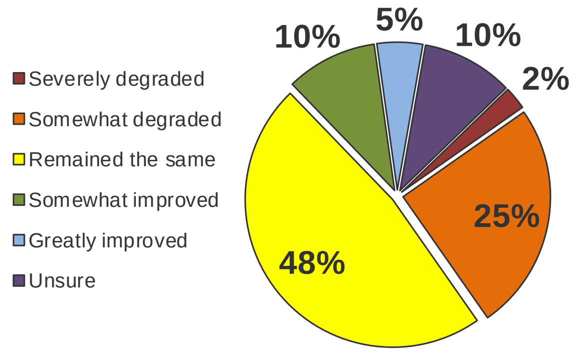


Figure 3.1-13. Stakeholder survey response Question #17. How as the water quality changed in Towanda Lake since you first visited the lake?

3.2 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 Photo 3.2.1, 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.

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

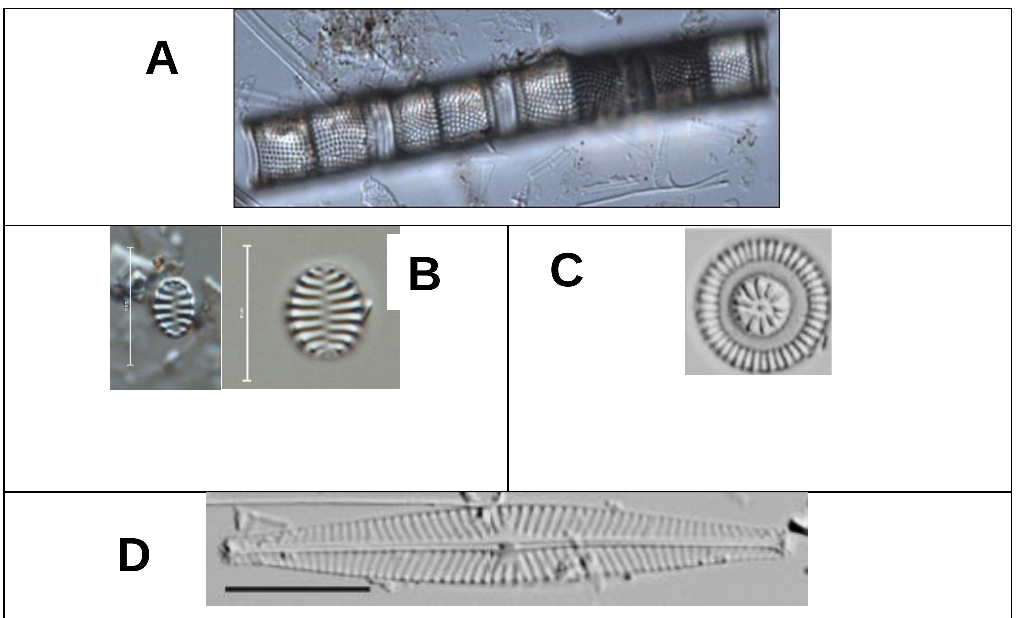


Photo 3.2-1. Photomicrographs of the diatoms commonly found in the sediment core from Towanda Lake. The top diatom (A) is *Aulacoseira ambigua* which was common in many Wisconsin lakes with low to moderate phosphorus concentrations. *Staurosirella pinnata (B)* grows on the lake sediments and was more common in the bottom sample. *Discostella stelligera* (C) was only found in the top sample where it was the most common diatom. *Navicula notha* (D) was found in the bottom and top samples and grows attached to aquatic plants.

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.

Towanda Lake Paleoecological Results

A sediment core was collected from the deep area in Towanda Lake by Onterra staff on July 30, 2018. The total length of the core was 45 cm. The top 20 cm of the core was dark brown in color. From 20 to 45 cm the sediment was medium gray in color (Photo 3.2-2). The color change in the lower part of the core likely indicates this sediment was deposited prior to the twentieth century. 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, 42-44 cm, was analyzed and this is assumed to represent conditions before the arrival Euroamerican settlers in the nineteenth century.

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Towanda Lake, an exploratory detrended correspondence analysis (DCA) was performed (CANOCO 5 software, ter Braak and Smilauer, 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 Towanda Lake does.

Photo 3.2-2. Photo of sediment core collected from Towanda Lake. Below 15 cm the color changed from dark brown to lighter brown which likely signifies when logging occurred.

The results revealed two clear axes of variation in the diatom data, with 31% and 21% of the variance explained by axis 1 and axis 2, respectively (Figure 3.2-1). 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.

Towanda Lake is on the right side of Figure 3.2-1 because even though the lake stratifies during the summer, most of the diatom community is composed of benthic taxa. This is because the lake has relatively low phosphorus concentrations and very good water clarity. There is only a moderate change in the diatom community indicating water quality conditions have not changed much between the time when the bottom sample was deposited and at the current time.

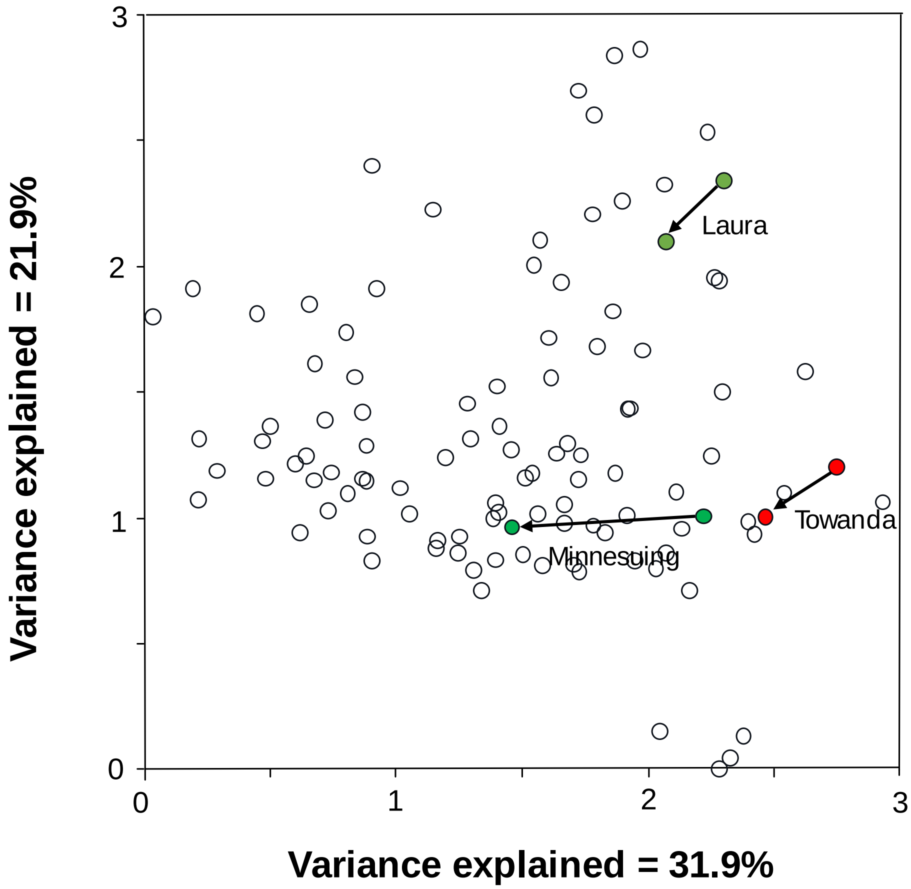


Figure 3.2-1. DCA plot of top/bottom samples from Towanda Lake. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. Towanda Lake has changed only a small amount since the arrival of Euroamerican settlers over 150 years ago.

While it is not possible to determine which were the most important environmental variables ordering the diatom communities, one trend is apparent. Axis 1 likely represents the alkalinity of the lakes. Other studies on Wisconsin and Vermont lakes indicate that the most important variable ordering the diatom communities is alkalinity. Lakes on the right side of the DCA graph tend to have the lowest alkalinity values while the highest are on the left side. A study by Eilers et al. (1989) on 149 lakes in north central Wisconsin found that as a consequence of lake shore development, alkalinity and conductivity concentrations increase. This is because of the sediment that enters the lake during cottage and road construction. The direction of the arrow in Towanda Lake indicates higher alkalinity at the present time compared to historical times.

Diatom Community Changes

The diatom community in the core is dominated by diatoms that grow on the lake bottom or attached to substrates like macrophytes. There has been an increase in planktonic diatoms from the bottom to the top of the core (Figure 3.2-2), which indicates a small decline in water clarity and a small increase in nutrients as these types of diatoms are favored with increased nutrient levels. The most common diatom in the top sample was *Discostella stelligera* which is common in lakes with good water clarity. Its absence in the bottom sample suggests that nutrient concentrations at the present time a slightly higher than they were historically. There were many species of the genera *Navicula* present in the bottom and top samples. The most common was *N. notha* which is shown in Photo 3.2-1D. The decline in these taxa from the bottom to the top sample is a further indication of increased nutrient levels at the present time.

Studies have found that the littoral area of a lake often responds earliest to increased nutrient input from the watershed. This is because the littoral zone is the interface between the surrounding watershed and the main body of the lake. Often the first sign of increased nutrients is an increased growth of periphyton (Goldman and deAmezaga, 1975, Loeb 1986, Jacoby et al. 1991, Garrison and Wakeman 2000). Often with early shore land development there is an increase in macrophyte growth. 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. In Towanda Lake

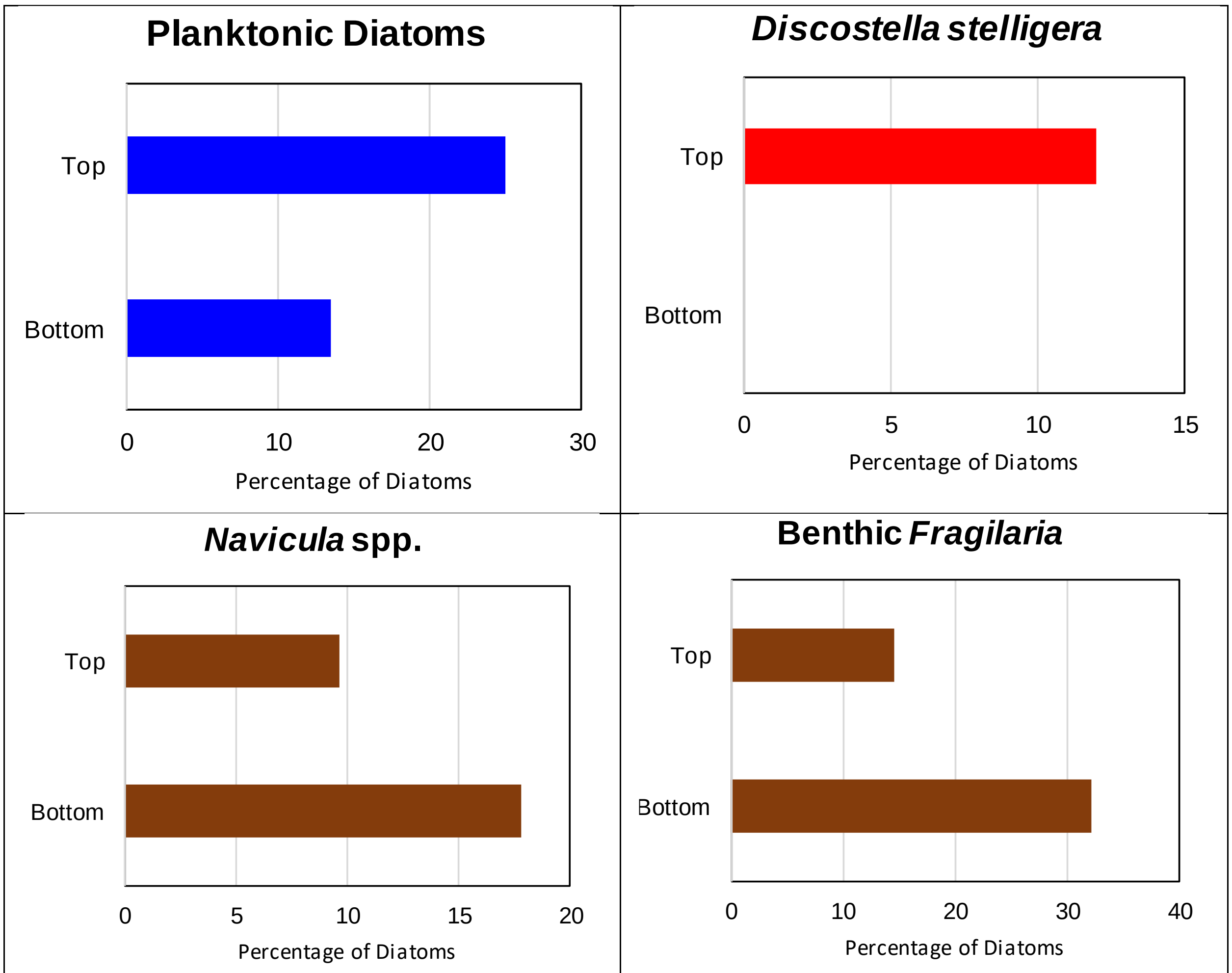


Figure 3.2-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Towanda Lake. The diatom community at the bottom of the core was dominated by benthic diatoms, esp. benthic *Fragilaria*. The decline in these taxa as well as the increase in planktonic diatoms indicates a small increase in the lake's productivity.

the decline in benthic *Fragilaria* as well as the increase in planktonic diatoms suggests the coverage of the macrophyte community at the present time is similar to historical times.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson et al. 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 25^{th} and 5^{th} 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 and bottom samples place Towanda Lake in the good category (Figure 3.3-3). The LDCI appears to be better in the top sample and this is an artifact of the model as diatoms that grow on the lake bottom or attached to macrophytes sometimes are perceived to indicate a poorer biologic integrity but in Towanda Lake the change is related more to a decline in water clarity between the bottom and top sample.

Inference models

Diatom assemblages have been used as indicators of trophic changes in a qualitative way (Bradbury 1975, Carney 1982, Anderson et al. 1990) but quantitative analytical methods exist.

Ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration (Birks et al. 1990). Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

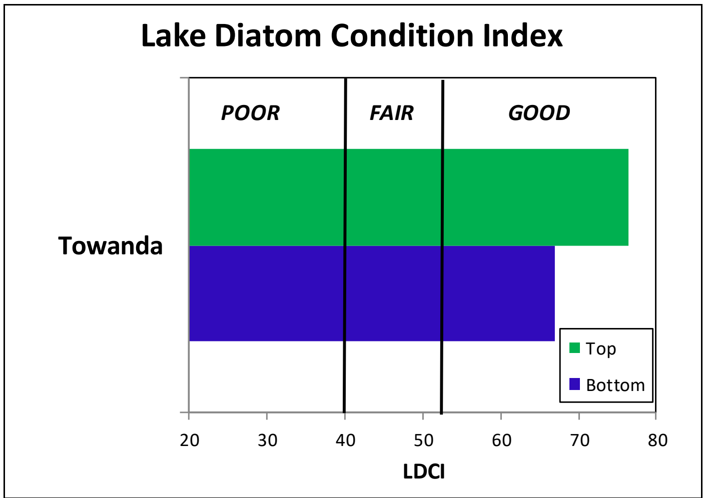


Figure 3.2-3. The Lake Diatom Condition Index (LDCI) for Towanda Lake. The biotic integrity is good and is similar in the top and bottom samples.

Weighted averaging calibration and reconstruction (Birks et al., 1990) were used to infer historical water column summer average phosphorus in the sediment cores. A training set that consisted of 60 stratified lakes was used. Training set species and environmental data were analyzed using weighted average regression software (C2; Juggins 2014).

The estimated phosphorus concentrations in the top and bottom samples of Towanda Lake are very similar at 12.4 and 12.2 µg/L, respectively (Table 3.2-1). The diatom inferred phosphorus concentration in the top sample is similar to the summer average in 2018 of 12 µg/L and a bit lower than the long-term average summer phosphorus concentration of 14 µg/L.

Table 3.2-1. Diatom inferred phosphorus concentrations in core samples (µg/L).

Lakes	Phosphorus
Towanda Top	12.4
Towanda Bottom	12.2

The sediment core indicates that the water quality in Towanda Lake at the present time is similar to what it was historically. Phosphorus concentrations are slightly higher at the present time and water clarity has likely declined a small amount. The diatom community indicates that the lake's biotic condition is good at the present, similar to what it was historically.

3.3 Watershed Assessment

Watershed Modeling

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

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

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

> A lake's **flushing rate** is simply a determination of the time required for the lake's water volume to be completely exchanged. **Residence time** describes how long a volume of water remains in the lake and is expressed in days, months, or years. The parameters are related and both determined by the volume of the lake and the amount of water entering the lake from its watershed. Greater flushing rates equal shorter residence times.

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

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

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

Towanda Lake's surficial watershed encompasses approximately 584 acres (Figure 3.3-1) yielding a watershed to lake area ratio of 3:1. The watershed is comprised of land cover types including forests (44%), the lake surface itself (25%), pasture/grass/rural open space (6%), shoreland homes (11%), wetlands (6%), and row crops (<1%) (Figure 3.3-1).

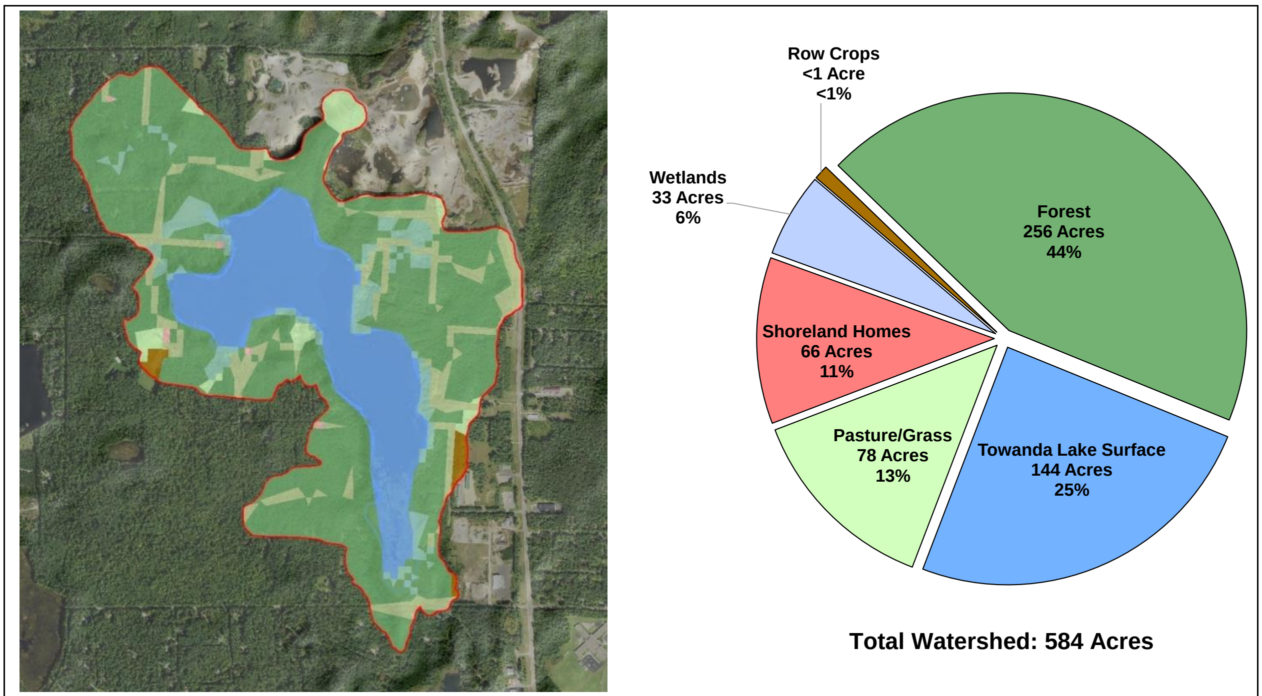


Figure 3.3-1. Towanda Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Towanda Lake's residence time is approximately 1.1 year, or the water within the lake is completely replaced 0.9 times per year.

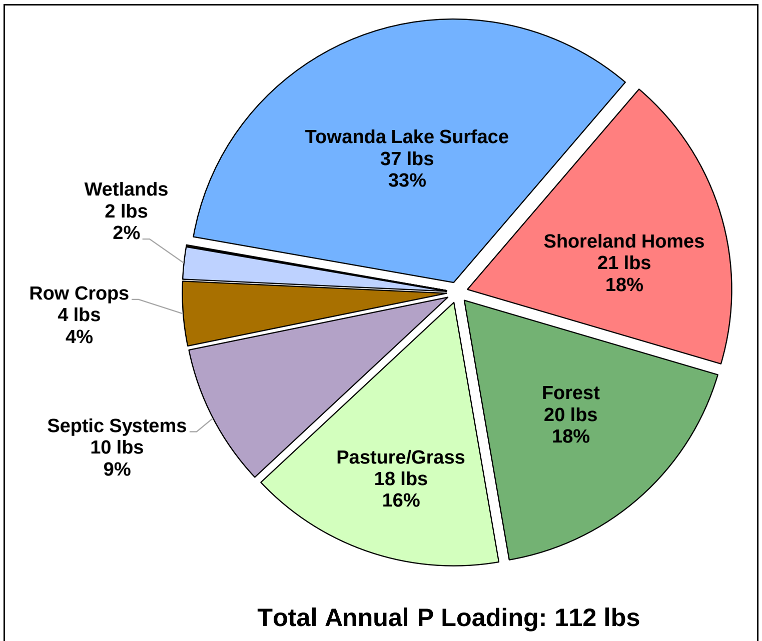


Figure 3.3-2. Towanda Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the land cover types and their acreages within Towanda Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Towanda Lake from its watershed. The land cover data derived from aerial photographs typically does not recognize shoreland homes as much of their image is masked by tree canopy. Using the stakeholder survey, the number of homes around the lake was determined to be 89. Studies conducted in Wisconsin have found that phosphorus runoff from shoreland home is higher than forested land cover. A runoff coefficient of 0.27 lbs/ac/year was used for shoreland homes. In addition, data obtained from a stakeholder survey sent to Towanda Lake riparian property owners in 2018 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that a total of approximately 114 pounds of phosphorus are delivered to Towanda Lake from its watershed on an annual basis (Figure 3.3-2).

Of the estimated 112 pounds of phosphorus being delivered to Towanda Lake on an annual basis, approximately 37 pounds (33%) originates through direct atmospheric deposition into the lake, 21 pounds (18%) from shoreland homes, 20 pounds (18%) from forests, 18 pounds (16%) from areas of pasture/grass, (9%) from riparian septic systems, 4 pounds (4%) from row crops, and 2 pounds (2%) from wetlands (Figure 8.10.2-2).

Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 15 µg/L, which is very similar to the measured growing season average total phosphorus concentration of 14 µg/L. The similarity between the predicted and measured total phosphorus concentrations in Towanda Lake is an indication that this is an accurate model of the lake's watershed and that there are no significant, unaccounted sources of phosphorus entering the lake.

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 shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

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

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

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

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

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

Native Species Enhancement

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

Photograph 3.4-2. 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.

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted areas from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

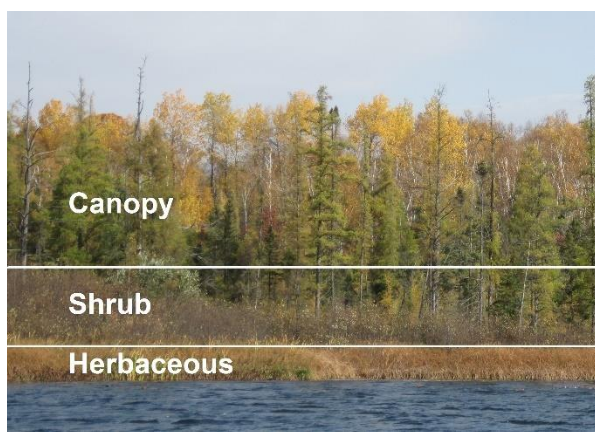
- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq ft and 2 shrubs/100 sq ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70' of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

Advantages	*Disadvantages*
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreland erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Once native plants are established, they require less water, maintenance, no fertilizer; provide wildlife food and habitat, and natural aesthetics compared to ornamental (non-native) varieties. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Towanda Lake Shoreland Zone Condition

Shoreland Development

Towanda Lake's entire 3.6-mile shoreline was surveyed in 2019. A draft WDNR protocol (WDNR 2016) 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. Within the shoreland zone the natural vegetation (canopy cover, shrub/herbaceous) was given an estimate of the percentage of the plot which is dominated by each category. Human disturbances (impervious surface, manicured lawn, agriculture, number of buildings, boats on shore, piers, boat lifts, sea wall length and other similar categories) were also recorded by number of occurrence or percentage during the survey.



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.

Canopy cover was defined as an area which is shaded by trees that are at least 16 feet tall (Photograph 3.4-3). Seventy-five percent (2.7 mi.) of the Towanda Lake shoreline contains a canopy that covers between 81-100% of the parcel (Map 2).

Shrub and herbaceous layers are small trees and plants without woody stems less than 16 feet tall (Photograph 3.4-3). Sixty-nine percent (2.5 mi) of the Towanda Lake shoreline contains a shrub/herbaceous layer that covers between 81-100% of the parcel (Map 3).

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. Roughly 0.33 miles or 9% of the Towanda Lake shoreline contains a manicured lawn that covers between 76-100% of the parcel (Map 4).

Impervious surface is an area that releases all or a majority of the precipitation that falls onto it (e.g. rooftops, concrete, stairs, boulders and boats flipped over on shore). About 3.3 miles or 92% of the Towanda Lake shoreline does not contain any impervious surfaces (Map 5).

Sections of Towanda Lake's shoreline which contain a manicured lawn and a small percentage of canopy, shrub and herbaceous cover are potential candidates for shoreline restorations. A few property parcels which meet these requirements are located on the southwest and southeast portions of Towanda Lake; however, the bulk of the shoreline would be considered as not overly impacting the lake ecosystem.

Coarse Woody Habitat

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

During the survey 97 total pieces of coarse woody habitat were observed along 3.6 miles of shoreline (Map 6) resulting in a 27:1 pieces per mile of shoreline ratio. Of the 97 total pieces of coarse woody habitat observed during the survey, 60 pieces had no branches, 35 had few branches, and 2 were found with a full tree crown.

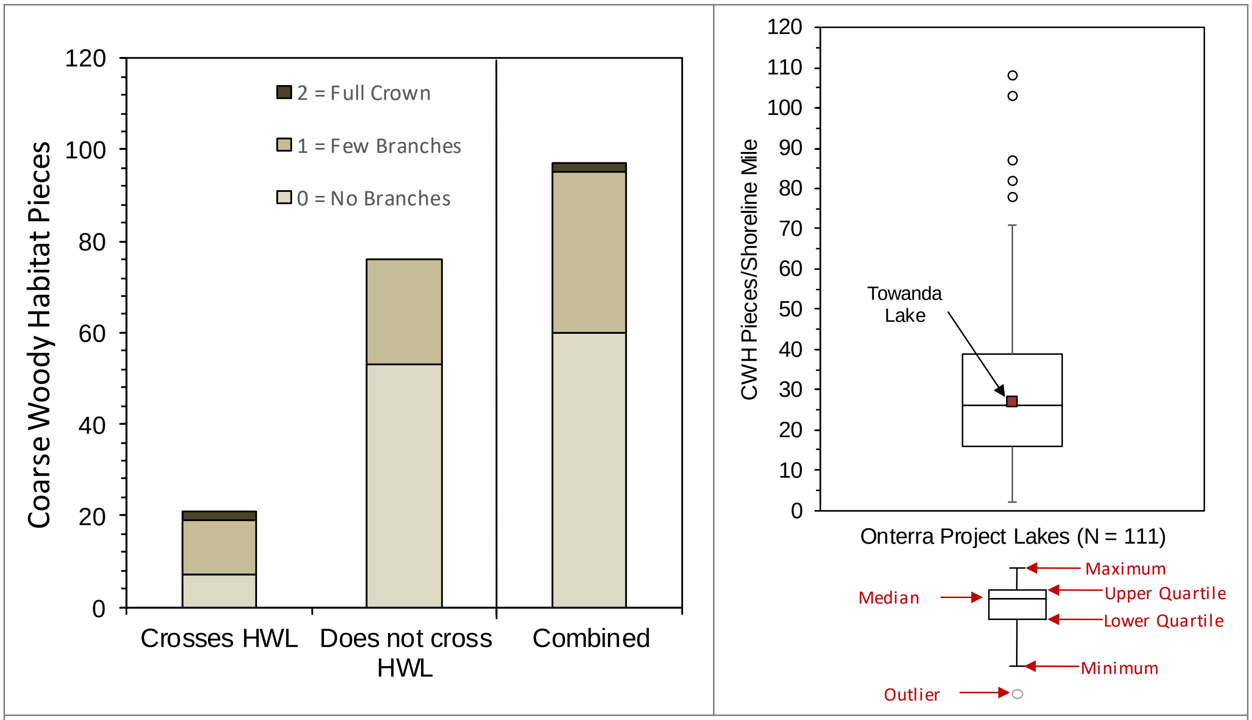


Figure 3.4-1. Towanda Lake coarse woody habitat survey results. Based upon a summer 2019 survey. Locations of Towanda Lake coarse woody habitat can be found on Map 6.

Onterra has completed coarse woody habitat surveys on 111 lakes throughout Wisconsin since 2018, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Towanda Lake fell into the 54th percentile of these 111 lakes (Figure 3.4-1). Note: based on the WDNR protocol all Towanda Lake coarse woody habitat was collected between the 2-foot contour line and the high-water level mark. The Onterra protocol, which all data from Onterra project lakes was collected from, only records data on coarse woody habitat which crosses the high-water level mark.

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 communities.

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

Photograph 3.5-2. Example of aquatic plants that have been removed manually.

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

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

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

Cost

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

Advantages	*Disadvantages*
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas.

	• Risk of spreading invasive species if fragments are not removed.

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian watermilfoil for a few years. • Allows some loose sediment to consolidate, increasing water depth. • May enhance growth of desirable emergent species. • Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.	• May be cost prohibitive if pumping is required to lower water levels. • Has the potential to upset the lake ecosystem and have significant effects on fish and other aquatic wildlife. • Adjacent wetlands may be altered due to lower water levels. • Disrupts recreational, hydroelectric, irrigation and water supply uses. • May enhance the spread of certain undesirable species, like common reed and reed canary grass. • Permitting process may require an environmental assessment that may take months to prepare. • Non-selective.

Mechanical Harvesting

Photograph 3.5-3. 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

Photograph 3.5-4. Granular herbicide application.

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

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

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

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

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

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain	• 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;

invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Towanda 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 Towanda Lake in 2018. 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 Towanda 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 Towanda 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 Towanda Lake is compared to data collected by Onterra and the WDNR Science Services on 112 lakes withn 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 Towanda 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 exotics, 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, 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.

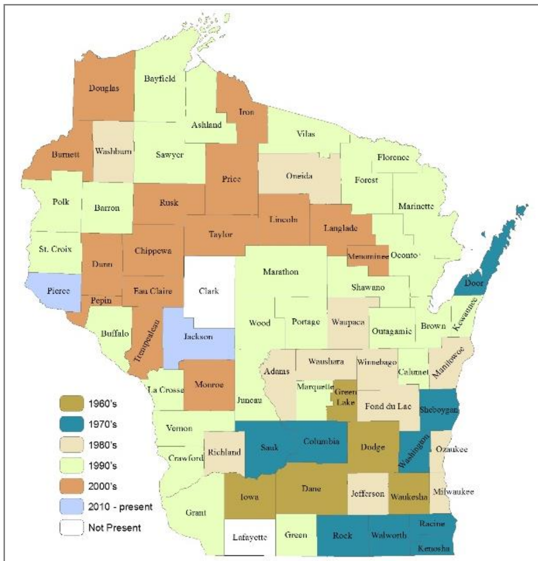


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

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.

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

Towanda Lake Aquatic Plant Survey Results

On June 20, 2018, Onterra ecologists completed the ESAIS Survey on Towanda Lake. While the intent of this survey was to locate any potential non-native species within the lake, the primary focus was to locate occurrences of the non-native curly-leaf pondweed which should be at or near its peak growth at this time. Curly-leaf pondweed nor any other non-native submersed plant species (e.g., Eurasian watermilfoil) were located in Towanda Lake during this survey. It is believed that these plants do not occur in Towanda Lake or they occur at yet undetectable levels. Reed canary grass, a non-native, invasive wetland grass, was located along Lake Towanda's shoreland zone during the 2018 emergent and floating-leaf community mapping survey. Because of its ecological significance, reed canary grass is discussed in detail in the subsequent Non-Native Aquatic Plants in Towanda Lake subsection.

The whole-lake aquatic plant point-intercept and emergent and floating-leaf aquatic plant community mapping surveys were conducted on Towanda Lake by Onterra ecologists on July 11 and 12, 2018. During these surveys, 44 native aquatic plant species were located (Table 3.5-1). 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 the 2018 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 80% of the point-intercept locations in 15 feet of water or less contained organic sediments, 15% contained sand, and 5% contained rock (Figure 3.5-2). Sampling locations with sand and/or rock were primarily located in near-shore areas in the northern two-thirds of the lake, while the majority of sampling locations with organic sediments were located in the southern third of the lake. The combination of both soft and hard substrates in Towanda Lake creates habitat types which support different aquatic plant community assemblages.

The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of approximately two to three times the average Secchi disk depth. Towanda Lake's mean Secchi disk depth in 2018 was 9.5 feet, and aquatic plants were found growing to a maximum depth of 16 feet in 2018. Aquatic plant growth was abundant between 2.0 and 11 feet, while plant occurrence declined rapidly between 12 and 16 feet.

Of the 267 point-intercept sampling locations that fell within Towanda Lake's littoral zone (≤ 16 feet) in 2018, 75% contained aquatic vegetation (Figure 3.5-2). Aquatic plant total rake fullness (TRF) data, a measure of plant abundance, showed that 54% of the 267 littoral sampling locations contained vegetation with a TRF rating of 1, 18% had a TRF rating of 2, and 3% had a TRF rating of 3 (Figure 3.5-2). These TRF ratings indicate that where vegetation is present in Towanda Lake, its biomass is relatively low.

Table 3.5-1. Aquatic plant species located on Towanda Lake during July 2018 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2018 (Onterra)
Emergent	*Carex comosa*	Bristly sedge	5	I
	Cladium mariscoides	Smooth sawgrass	10	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Glyceria canadensis	Rattlesnake grass	7	I
	Juncus brachycephalus	Small-headed rush	10	I
	Juncus effusus	Soft rush	4	I
	Phalaris arundinacea	Reed canary grass	Exotic	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Persicaria amphibia	Water smartweed	5	I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
Submergent	*Chara* spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Eriocaulon aquaticum	Pipewort	9	X
	Myriophyllum tenellum	Dwarf watermilfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Najas gracillima	Northern naiad	7 (Special Concern)	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Utricularia gibba	Creeping bladderwort	9	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Utricularia minor	Small bladderwort	10	X
	Utricularia resupinata	Northeastern bladderwort	9 (Special Concern)	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X
	Sagittaria graminea	Grass-leaved arrowhead	9	I
	Schoenoplectus subterminalis	Water bulrush	9	X
FF	*Lemna minor*	Lesser duckweed	5	X

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

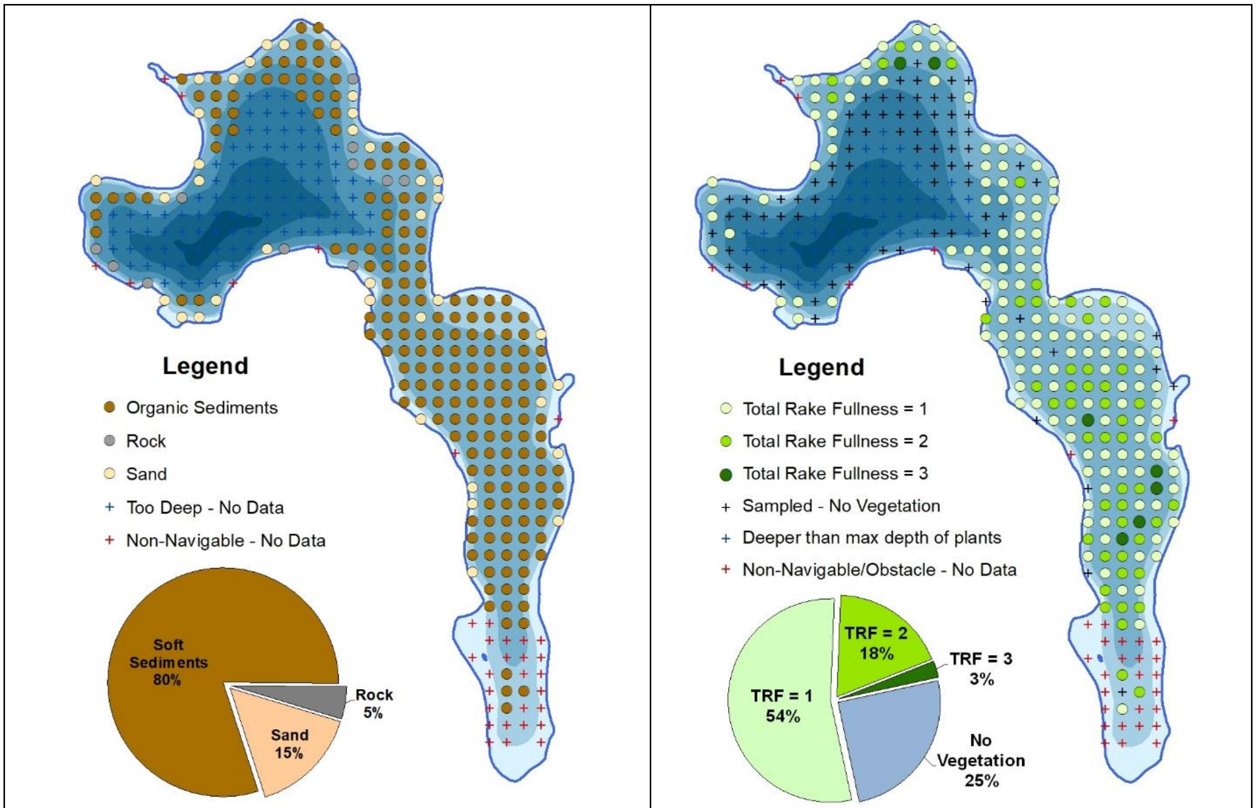


Figure 3.5-2. Towanda Lake 2018 substrate types and aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2018 whole-lake point-intercept survey (N = 267).

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 45 aquatic plant species located in Towanda Lake in 2018, 28 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 3.5-3). The remaining 17 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are rare within the plant community. Of the 28 species directly sampled with the rake during the point-intercept survey, stoneworts, fern-leaf pondweed, creeping bladderwort, and water bulrush were the four-most frequently encountered (Figure 3.5-3).

Stoneworts (Photograph 3.5-5) were the most frequently encountered plant in Towanda Lake in 2018 with a littoral frequency of occurrence of 30%. Stoneworts are a genus of macroalgae, not vascular plants, and there are eight known species in Wisconsin. Often difficult to identify from one another, stonewort species are often grouped together during surveys and for data analysis. Stoneworts are found in waterbodies with good water quality, and are often found growing at deeper depths where they provide structural habitat and supply oxygen to deeper areas of the littoral zone. In Towanda Lake, stoneworts were primarily located in the central portion of the lake between 7 and 10 feet of water.

Fern-leaf pondweed (Photograph 3.5-5) was the second-most frequently encountered aquatic plant species in Towanda Lake in 2018 with a littoral frequency of occurrence of 25% (Figure 3.5-4). Fern-leaf pondweed is a common plant in softwater lakes in northern Wisconsin, and is often one of the most abundant. It can be found in shallow to deep water typically over soft sediments. Large beds of fern-leaf pondweed provide excellent structural habitat for aquatic wildlife and help to prevent the suspension of the soft bottom sediments in which they grow. In Towanda Lake, fern-leaf pondweed was most abundant between 9 and 14 feet of water.

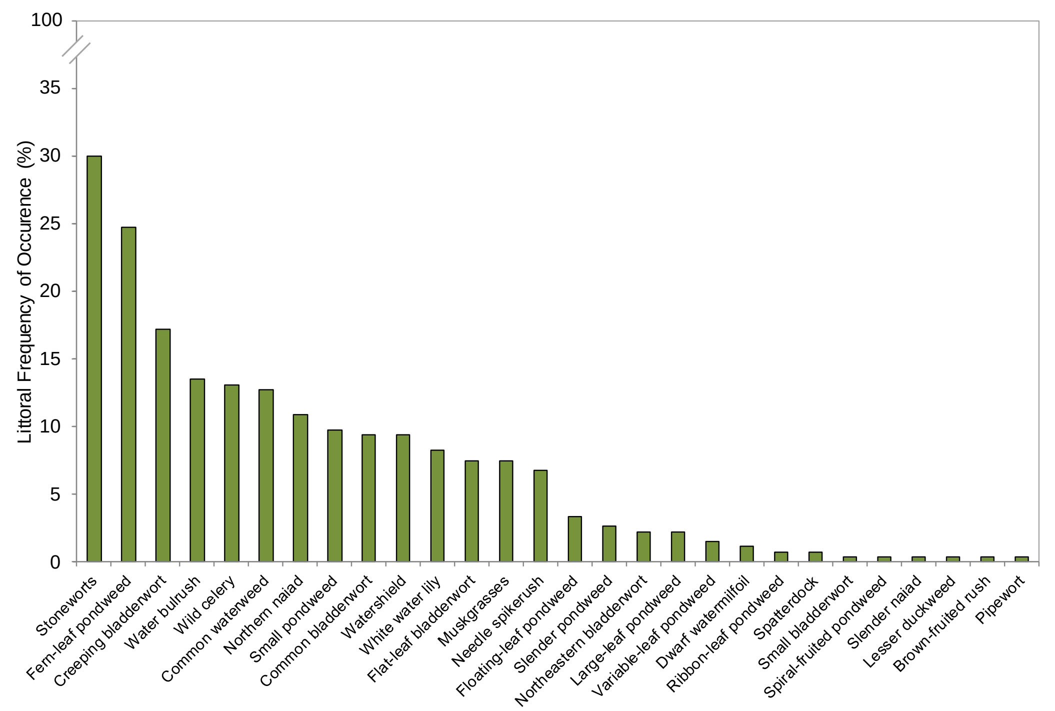
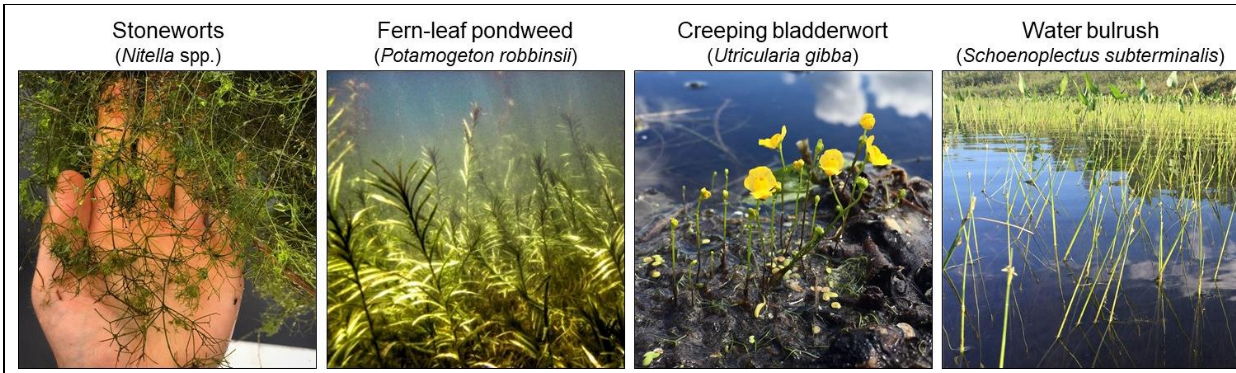


Figure 3.5-3. Towanda Lake 2018 littoral frequency of occurrence of aquatic plant species. Created using data from 2018 whole-lake point-intercept survey.



Photograph 3.5-5. Four-most frequently encountered aquatic plant species in Towanda Lake during the 2018 point-intercept survey. Photo credit Onterra.

Creeping bladderwort (Photograph 3.5-5) is one of nine species of bladderworts that can be found in Wisconsin and one of five bladderwort species located in Towanda Lake. In 2018, creeping bladderwort was the third-most frequently encountered aquatic plant species with a littoral frequency of occurrence of 17% (Figure 3.5-4). These plants possess bladders or traps which are used to trap insects, crustaceans, and tiny fish fry. Once inside, these organisms are digested by enzymes and bacteria, and the nutrients are taken up by the plant. Creeping bladderwort often forms large entangled masses which often float near the water's surface.

Water bulrush (Photograph 3.5-5) was the fourth-most frequently encountered aquatic plant species in Towanda Lake in 2018 with a littoral frequency of occurrence of 14% (Figure 3.5-3). Water bulrush is a sedge that grows almost completely submerged with the exception of a fertile stem which bears flowers above the water's surface. The submersed infertile stems are long and hair-like. Water bulrush is sensitive to environmental disturbance and typically only found in water bodies with good water quality.

Two native plants located in Towanda Lake in 2018, northeastern bladderwort and northern naiad (Photograph 3.5-6), are listed as special concern in Wisconsin by the WDNR's Natural Heritage Inventory (NHI) Program. These species are designated as special concern due to their rarity and relative uncertainty regarding their distribution and abundance within the state. Their occurrence in Towanda Lake has been reported to WDNR's NHI Program for their records. Like creeping bladderwort, northeastern bladderwort is a carnivorous plant. However, unlike creeping bladderwort which is free-floating, northeastern bladderwort grows rooted in the substrate and is often overlooked due to its small size. Northern naiad is the rarest of the four naiad species that occur in Wisconsin. Both of these species are only found in high-quality environments, and their presence in Towanda Lake is an indicator of good water quality and minimally-disturbed conditions.

Photograph 3.5-6. Northeastern bladderwort and northern naiad, two native species in Towanda Lake listed as special concern in Wisconsin.

As discussed in the Primer Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The 28 native species encountered on the rake during 2018 point-intercept survey in Towanda Lake and their conservatism values were used to calculate the FQI of Towanda Lake's aquatic plant community (equation shown below).

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

Figure 3.5-4 compares the 2018 FQI components of Towanda Lake to median values of lakes within the Northern Lakes and Forests (NLF) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2018 (28) falls above the median value for lakes in the NLF ecoregion (21) and for lakes throughout Wisconsin (19). The average conservatism of the 28 native aquatic plant species located in Towanda Lake in 2018 was 7.2, exceeding the 75th percentile for lakes within the NLF ecoregion and lakes throughout Wisconsin, indicating that a higher proportion of Towanda Lake's aquatic plant community is comprised of environmentally-sensitive species.

Using Towanda Lake's native aquatic plant species richness and average conservatism yields a high FQI value of 38.2 (Figure 3.5-4). Towanda Lake's FQI value exceeds the median values for lakes within the NLF ecoregion (30.8) and the median value for lakes throughout the state (27.2). Overall, the FQI analysis indicates that the aquatic plant community found in Towanda Lake is of higher quality when compared to the majority of lakes in Wisconsin.

It is believed that lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Towanda Lake contains a higher number of aquatic plant species, one may also assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

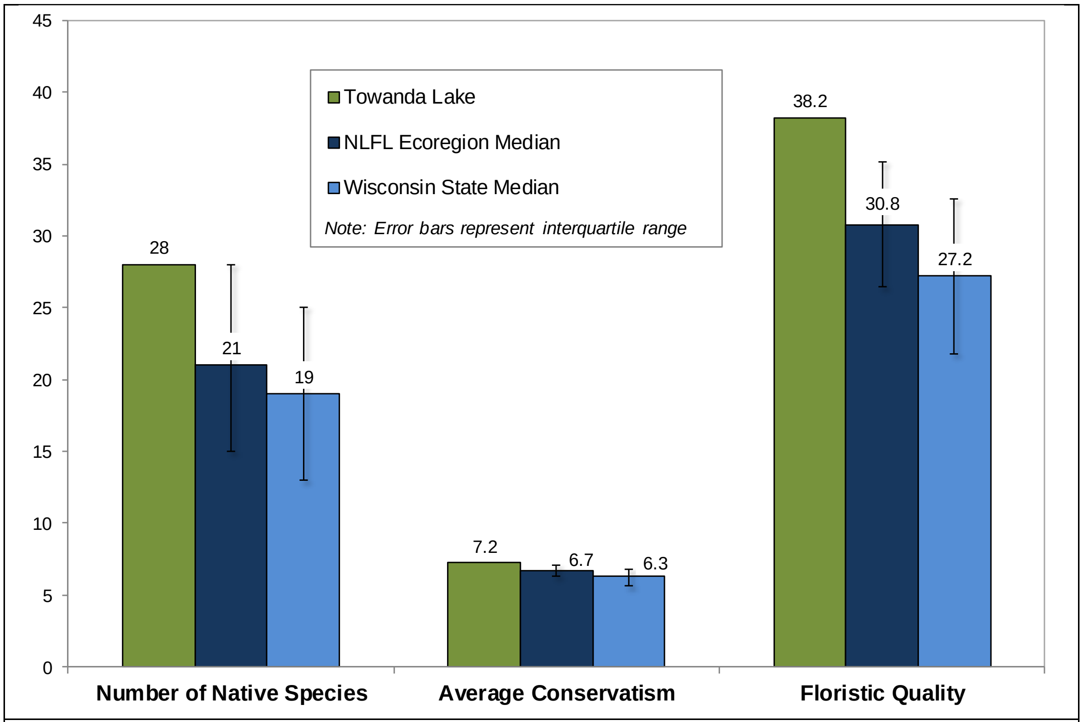


Figure 3.5-4. Towanda Lake Floristic Quality Assessment. Created using data from Onterra 2018 whole-lake point-intercept survey. Analysis follows Nichols (1999).

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 Towanda Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 3.5-5). Using the data collected from the 2018 point-intercept survey, Towanda Lake's aquatic plant was found to have high species diversity with a Simpson's Diversity Index value of 0.92. In other words, there was a 92% probability that two individual aquatic plants that were randomly sampled from Towanda Lake in 2018 were different species. Towanda Lake's Simpson's Diversity exceeds the median value for lakes in the NLF ecoregion (0.88) and the median value for lakes throughout Wisconsin (0.86).

One way to visualize Towanda Lake's species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.5-6 displays the relative frequency of occurrence of aquatic plant species created from the 2018 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while stoneworts were found at 30% of the littoral sampling locations in Towanda Lake in 2018, their relative frequency of occurrence was 15%. Explained another way, if 100 plants were randomly sampled from Towanda Lake in 2018, 15 of them would have been stoneworts.

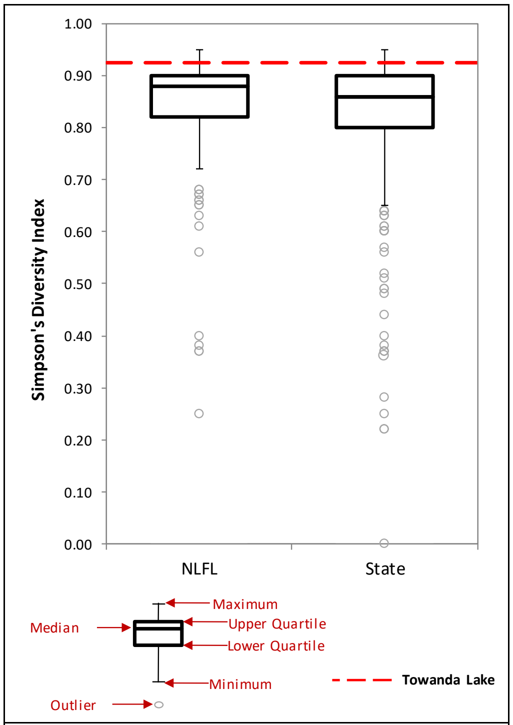


Figure 3.5-5. Towanda Lake species diversity index. Created using data from Onterra 2018 point-intercept survey.

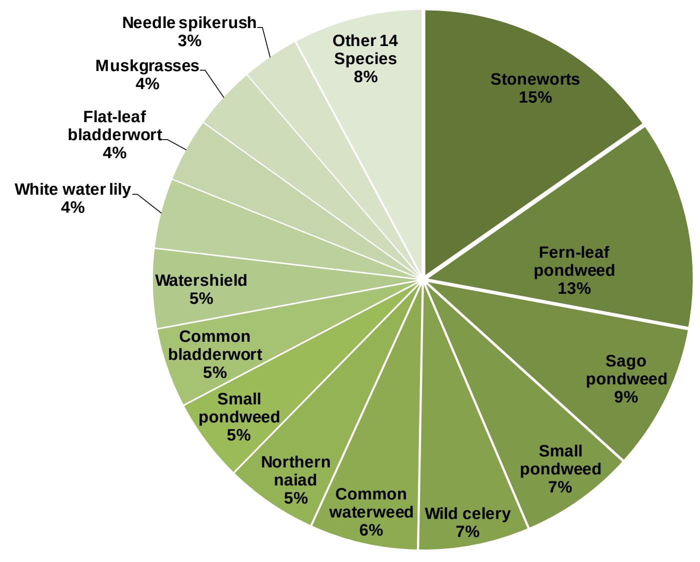


Figure 3.5-6. Relative occurrence of aquatic plant species in Towanda Lake. Created using data from Onterra 2018 point-intercept survey.

In 2018, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaved marshes in Towanda Lake. Emergent marshes are a wetland community type dominated by species such as cattails, bulrushes, and spikerushes, or plants which emerge above the water's surface. Floating-leaved marshes are communities dominated by species with leaves which float on the water's surface, such as white water lily and spatterdock. Emergent marshes are typically found in shallower water than floating-leaved marshes, but they do intergrade with one another. These wetland community types are important to overall lake health as they provide structural habitat for spawning and refuge and sources of food. In addition, they stabilize bottom sediments and reduce shoreland erosion. These communities are often particularly important during periods of low water levels when structural habitat provided by fallen trees become unavailable above the receding water line.

Towanda Lake was found to support extensive emergent and floating-leaf marsh communities throughout shallow, near-shore areas around the lake (Figure 3.5-7). Approximately 41 acres or 28% of the lake was found to contain these plant communities. These communities were largely dominated by watershield and white water lily, but a total of 19 emergent and floating-leaf plant species were found in these communities (Table 3.5-1). The community map created in 2018 represents a 'snapshot' of the important plant communities in Towanda Lake, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the lake. This is important because these communities are often negatively affected by recreational use and shoreland development.

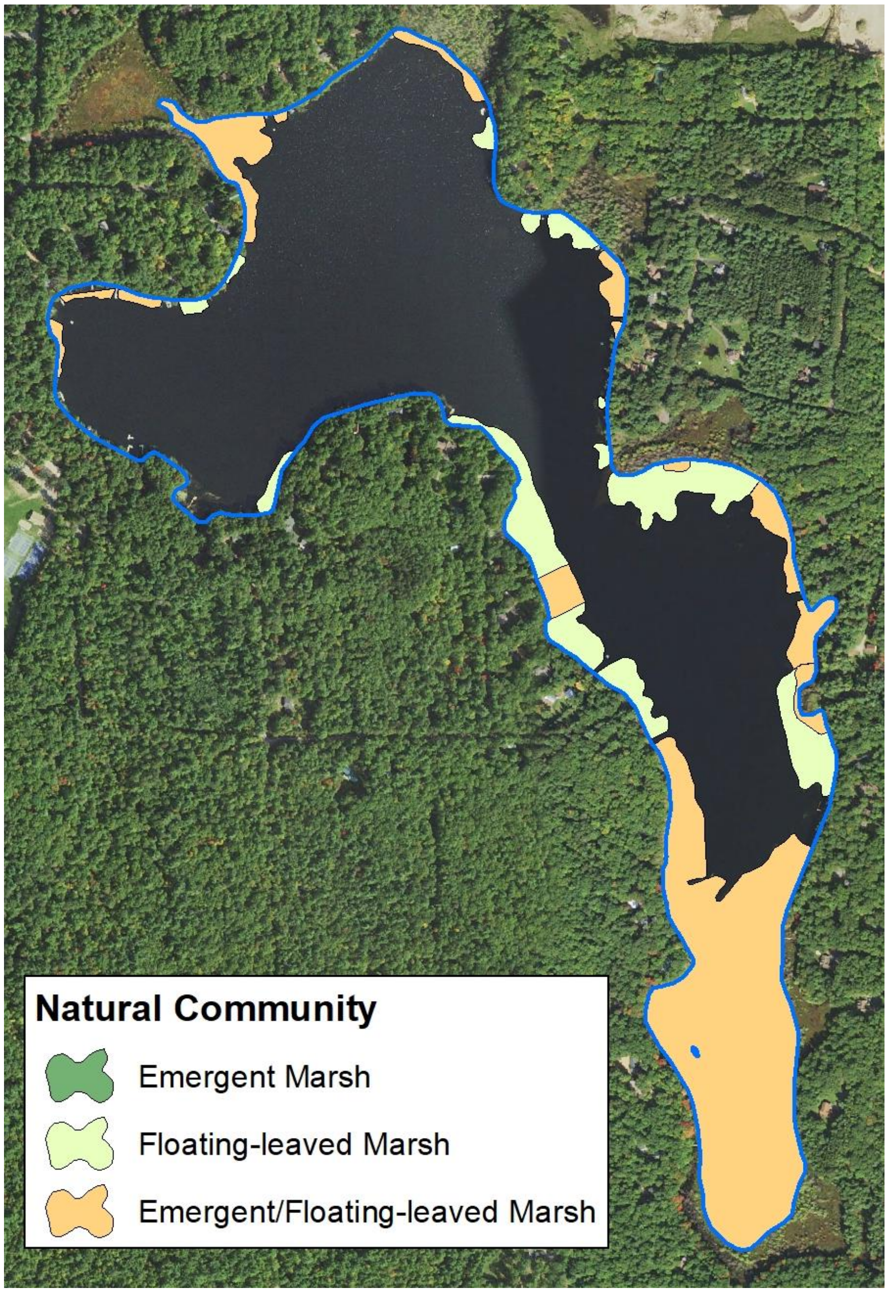


Figure 3.5-7. Towanda Lake 2018 emergent and floating-leaf plant communities. Species composition of these communities can be found on Map 6.

Non-Native Aquatic Plants in Towanda Lake

Reed Canary Grass (*Phalaris arundinacea*)

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach three to six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelands.

Reed canary grass is difficult to eradicate; at the time of this writing there is no efficient control method. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic. Chemical applications are difficult because the plant is found in moist environments, and many herbicides are harmful to aquatic organisms.

At this time, populations are not excessive, though it is recommended that continued monitoring of reed canary grass takes place. During the community mapping survey of Towanda Lake in 2018, Onterra ecologists mapped occurrences of reed canary grass along the northern shoreland of the lake with sub-meter GPS technology. The spatial data has been provided to the Vilas County GIS Department and is also displayed on Map 6 of this report.

3.6 Aquatic Invasive Species in Towanda Lake

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

Table 3.6-1. AIS present within Towanda Lake

Type	Common name	Scientific name	Location within the report
Plants	Reed Canary Grass	*Phalaris arundinacea*	Section 3.5 – Aquatic Plants
Invertebrates	Chinese Mystery Snail	*Cipangopaludina chinensis*	Section 3.6 - Aquatic Invasive Species
	Banded Mystery Snail	*Viviparus georgianus*	Section 3.6 - Aquatic Invasive Species

Figure 3.6-1 displays the seven aquatic invasive species that Towanda Lake stakeholder survey respondents believe are in Towanda Lake. Only the species present in Towanda 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

Aquatic Animals

Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

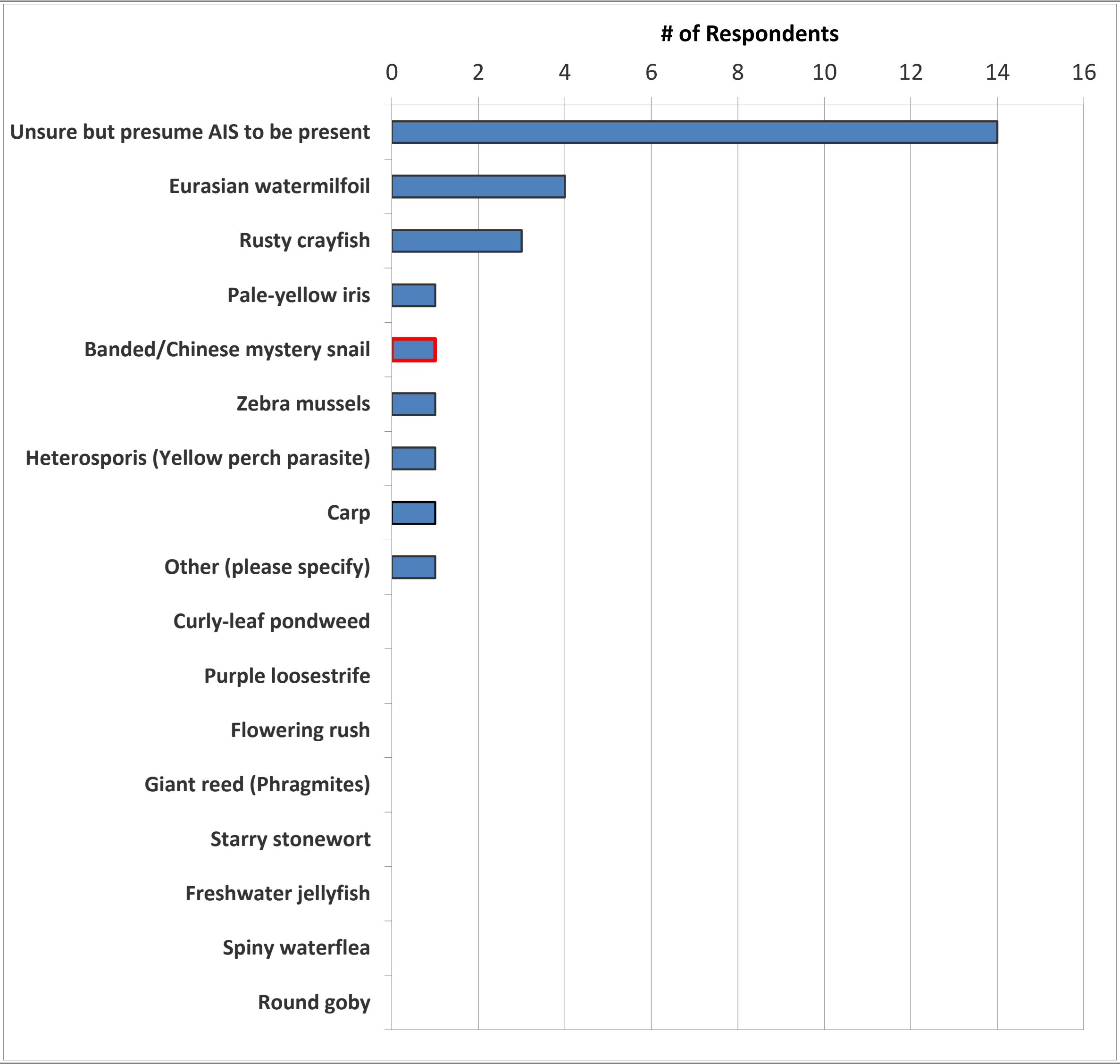


Figure 3.6-1. Towanda Lake stakeholder survey responses to which aquatic invasive species they believe are present in Towanda Lake. A red outline indicates species which have been verified in Towanda Lake.

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 numerous fisheries biologists overseeing Towanda Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Steve Gilbert (WDNR 2019 & GLIFWC 2018).

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

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

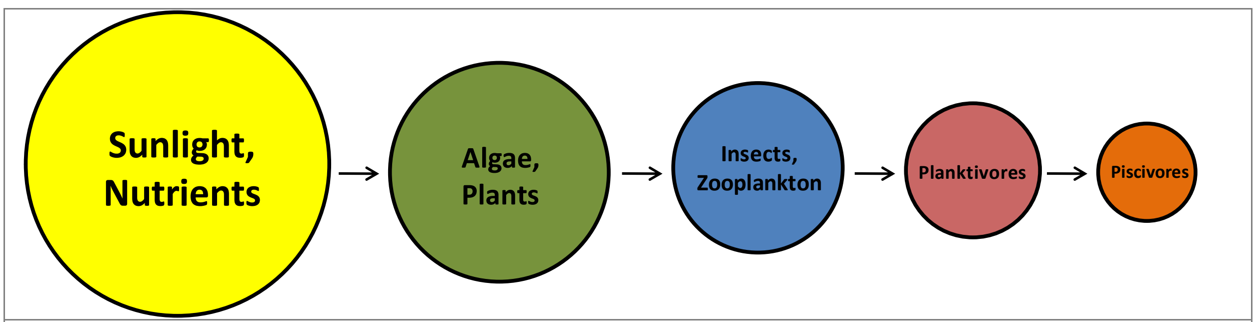


Figure 3.7-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Towanda 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 Towanda Lake should be able to support an appropriately 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.

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

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Panfish	9	Dependent on species	Dependent on species	Dependent on species
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish

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

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. Towanda Lake has been stocked from 1972 to 2017 with walleye and muskellunge (Table 3.7-2).

Photograph 3.7-2. Fingerling Muskellunge.

Future stocking efforts of walleye will likely be consistent following Towanda Lakes' inclusion in the Wisconsin Walleye Initiative. The Initiative was made possible by the governor's office, Department of Natural Resources and statewide partners to maintain the walleye population in Wisconsin's lakes and improve walleye fisheries in lakes capable of sustaining the sportfish (WDNR 2014). Lakes chosen to be included are selected based upon anticipated fingerling survival, natural reproduction opportunities, public access, tribal interest (for ceded territory lakes) and potential impacts to tourism (WDNR 2014). Stocking rates are randomly assigned to chosen lakes and stocked every other year to avoid competing year classes. Beginning in 2013 and odd years thereafter Towanda Lake was selected to receive the stocking rate of 10 extended growth walleye/acre as funding allows (WDNR 2013).

Table 3.7-2. Stocking data available for Towanda Lake (1972-2017).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1974	Walleye	Unspecified	Fingerling	4,860	3
1976	Walleye	Unspecified	Fingerling	6,675	3
1981	Walleye	Unspecified	Fingerling	7,320	3
1983	Walleye	Unspecified	Fingerling	6,000	2
1986	Walleye	Unspecified	Fingerling	6,000	3
1988	Walleye	Unspecified	Fingerling	7,205	2.5
1990	Walleye	Unspecified	Fingerling	7,930	3
1991	Walleye	Unspecified	Fingerling	3,056	2
1992	Walleye	Unspecified	Fingerling	3,143	3
1993	Walleye	Unspecified	Fingerling	7,722	2
1995	Walleye	Unspecified	Fingerling	7,530	1.9
2001	Walleye	Unspecified	Small Fingerling	7,300	1.3
2005	Walleye	Mississippi Headwaters	Large Fingerling	1,460	7.1
2013	Walleye	Mississippi Headwaters	Large Fingerling	1,459	7.1
2015	Walleye	Mississippi Headwaters	Large Fingerling	1,390	7.7
2017	Walleye	Mississippi Headwaters	Large Fingerling	1,391	3.8
1972	Muskellunge	Unspecified	Fingerling	700	7
1977	Muskellunge	Unspecified	Fingerling	300	9
1984	Muskellunge	Unspecified	Fingerling	300	11

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water and ice) was the second important reason for owning property on or near Towanda Lake (Question #15). Figure 3.7-2 displays the fish that Towanda Lake stakeholders enjoy catching the most, with walleye and bluegill/sunfish being the most popular. Approximately 74% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.7-3). Approximately 74% of respondents who fish Towanda 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).

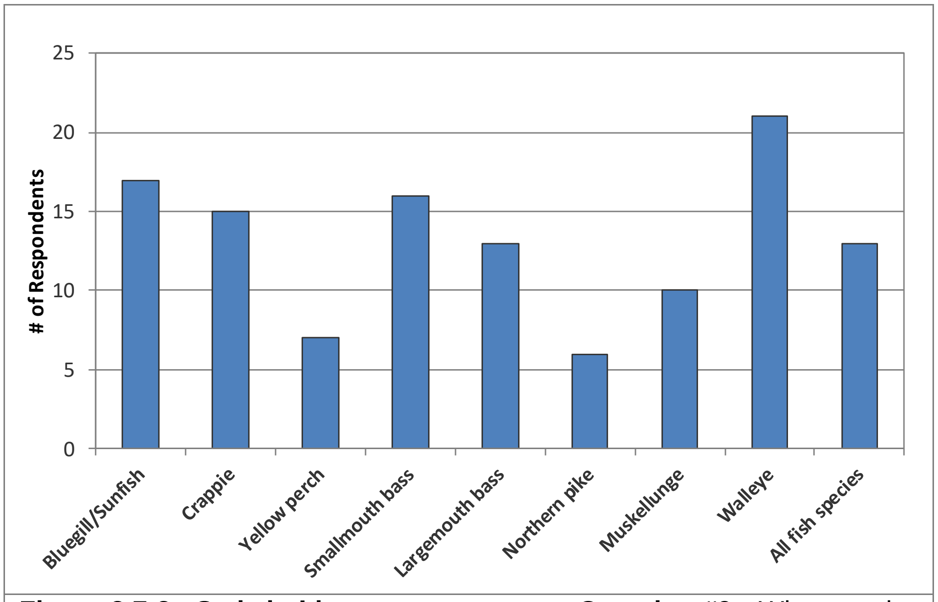


Figure 3.7-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Towanda Lake?

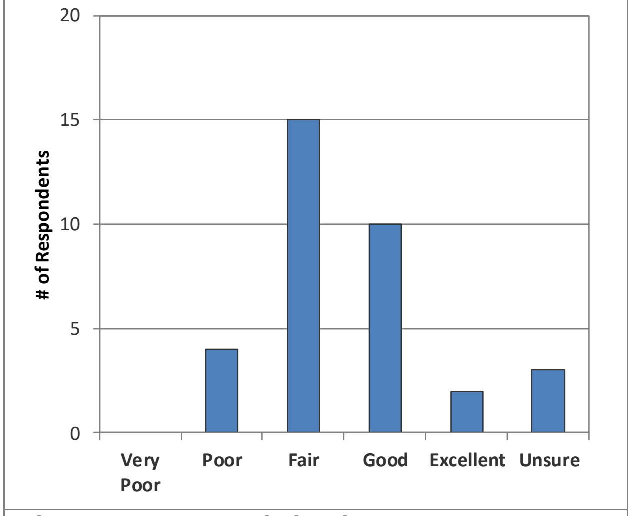


Figure 3.7-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Towanda Lake?

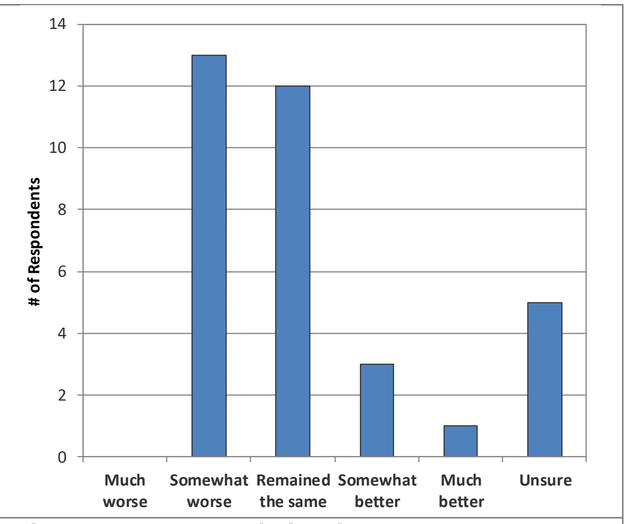


Figure 3.7-4. Stakeholder survey response Question #11. How has the quality of fishing changed on Towanda Lake since you started fishing the lake?

Fish Populations and Trends

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

Gamefish

The gamefish present on Towanda Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye and bluegill/sunfish on Towanda Lake (Figure 3.7-2). However, Towanda Lake is also known for harboring a Class A2 and category 1 muskellunge population. This means Towanda Lake is capable of providing consistent angling action with the potential of trophy muskellunge while being self-sustained through natural reproduction (WI Muskellunge Waters 2018).

Towanda Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.7-5). Towanda Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through high efficiency methods. By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

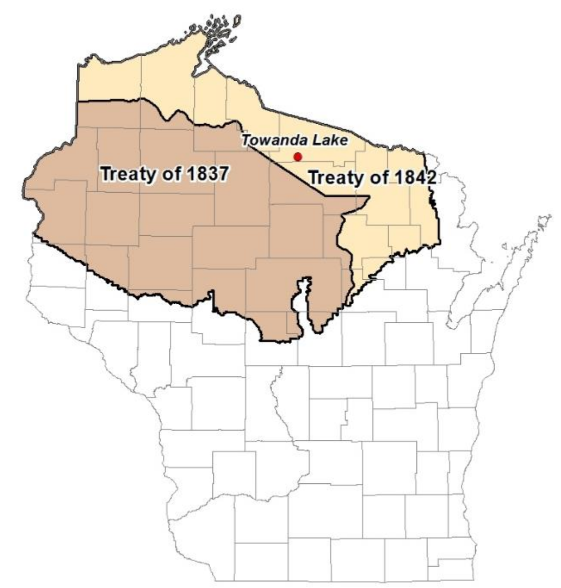


Figure 3.7-5. Location of Towanda Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Tribal members may harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Spearfishing of a particular species ends once the declared harvest is reached in a given lake. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

While within the ceded territory, Towanda Lake has not experienced a spearfishing harvest. A small quota for walleye and muskellunge harvest has been listed for Towanda Lake in recent years; however, no spearing efforts have been undertaken. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for both walleye and muskellunge.

Towanda 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 2018, 80% of the substrate sampled in the littoral zone of Towanda Lake were soft sediments, 15% was composed of sand and 5% were composed of rock sediments.

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 2006). 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 Towanda Lake's coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.7-3). 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 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

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

Fishing Regulations

Regulations for Towanda Lake fish species as of May 2018 are displayed in Table 3.7-4. 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 3.7-4. WDNR fishing regulations for Towanda Lake (As of May 2019).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth	5	14"	June 15, 2019 to March 1, 2020
Smallmouth bass	Catch and Release	-	May 4, 2019 to June 14, 2019
Largemouth bass	5	14"	May 4, 2019 to June 14, 2019
Muskellunge and hybrids	1	40"	May 25, 2019 to November 30, 2019
Northern pike	5	None	May 4, 2019 to March 1, 2020
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 4, 2019 to March 1, 2020
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 3.7-6. 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

The next survey is scheduled for fall 2019 and the next comprehensive survey by the WDNR is planned for 2027.

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 Towanda Lake ecosystem.
2) Collect sociological information from Towanda Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.
3) Using the information above, create a realistic and implementable management plan for Towanda Lake.

The three objectives were fulfilled during the project and have led to a good understanding of the Towanda Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

Overall, Towanda Lake is considered a healthy waterbody with a diverse plant community, good water quality, and a variety of habitat types to support fish and wildlife. Towanda is a seepage lake, so groundwater is constantly moving through the lake; essentially, the water levels in Towanda Lake are a reflection of the area's water table level.

Little land area drains to Towanda Lake, but those areas that do drain to the lake, mostly support cover types that export very little phosphorus and sediments to waterways. In fact, 50% of the landcover in the Towanda watershed is in forest and wetlands, the two landcover types that export the least amount of pollutants. While developed properties only occupy about 11% of the lake's watershed, they account for about 18% of the lake's annual phosphorus load. Septic systems account for about half of that level, so combined, the shoreland properties produce a little over a quarter of the annual phosphorus input. The total annual load to the lake is about 112 pounds, so between the runoff from developed properties and potential septic inputs, there is only about 30 pounds, but there is potential for more development on the lake and of course more inputs; therefore, minimizing impervious surfaces and shoreland runoff, along with maintaining a natural shoreland buffer area, is important in keeping Towanda Lake's good water quality.

Towanda Lake has a healthy, but abundant aquatic plant community. The lake supports two species listed as special concern in the state and no exotic plant species were located during the multiple surveys completed in 2018. Compared to other lakes in the area and in the state, Towanda's plant community is of higher diversity and of higher floristic quality. Both of these matrices indicate the overall good health of the waterbody.

Much of Towanda Lake is shallow and those shallow areas support an abundant plant population composed primarily of submersed and floating-leaf species. In the far southern area of the lake, the population is so abundant it creates nuisance conditions which impedes boat navigation. The areas supporting dense plant populations can also exhibit higher sedimentation rates brought on by incomplete decomposition of aquatic vegetation.

In some situations, the shallow depth and high plant biomass can lead to difficulties in navigation. Dredging is often brough up as a solution, but it is seldom feasible due to cost. Hydraulic dredging, which is the most common form of lake dredging, entails the pumping of sediments out of the lake to a field with a system of dykes that allows the sediment to settle out and the water to return to the lake. Lake sediments are removed at an average cost of about $15/yd^3 of sediment. As an example, removing one foot of sediment from an acre of lake bottom would cost approximately $24,200. Dredging that areas 3-feet deeper would cost nearly $75,000. Further, state grants are not available to fund dredging projects of this type. So, in most cases, dredging is not a feasible option.

Mechanical harvesting, if performed correctly, is an environmentally sound method for relieving nuisance conditions brought on by dense aquatic plant populations. A WDNR permit is required and harvesting is typically limited to areas 3-feet or deeper. Harvesting can be completed with a mechanical harvester owned by the lake group or by contracted harvester. In either case, cost is often the limiting factor in determining if harvesting is a good option for a lake. The TLA will be investigating the feasibility of mechanical harvesting on Towanda Lake as described in the implementation plan.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Towanda Lake Association Planning Committee and ecologist/planners from Onterra. It represents the path the TLA 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 Towanda 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: Protect and Improve the Ecological Health of Towanda Lake

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	TLA Board of Directors
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 is currently being completed annually by Towanda 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. The TLA currently monitors the deep hole site as a part of the advanced CLMN program. This includes collecting Secchi disk transparency and sending in water chemistry samples (chlorophyll-a, and total phosphorus) to the Wisconsin State Laboratory of Hygiene 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). It will be the Board of Directors responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples each year.

Action Steps:

1. Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
2. CLMN volunteer and/or TLA Board of Directors facilitate new volunteer(s) as needed.
3. Coordinator contacts Sandra Wickman (715.365.8951), or appropriate WDNR staff, to acquire necessary materials and training for new volunteer(s).

Management Action: Continue participation in LoonWatch Program.

Timeframe: Continuation of current effort.

Facilitator: TLA Board of Directors

Description: LoonWatch is a program of the Sigurd Olson Environmental Institute (SOEI), of Northland College in Ashland, WI. The program's primary objective is to protect common loons and their aquatic habitats through education, monitoring, and research. The program relies on volunteer Loon Rangers as its primary tool to collect data on loons in northern Wisconsin. Each Loon Ranger attends a training session in the spring and collects data throughout the summer. The record when loons arrive, whether they nested or not, and if so, how many chicks were produced. They also record potential threats to the nest site. Loon Rangers also help protect loons by educating other lake users and encouraging them not to encroach upon loons on nests or on the lake.

Towanda Lake has had an active Loon Ranger for many years and intends to continuation its participation in the program. The TLA Board of Directors will assure that a volunteer is available and trained to continue the LoonWatch program on Towanda Lake each year.

Action Steps:

1. Trained Loon Ranger collects data and report results to SOEI and to association members during annual meeting.
2. Loon Ranger and/or TLA Board of Directors facilitate new volunteer(s) as needed.
3. Coordinator contacts Erica LeMoine (715.682.1220), or appropriate SOEI staff, to acquire necessary materials and training for new volunteer(s).

Management Action: Monitor Towanda Lake water levels.

Timeframe: Begin 2021

Facilitator: TLA Board of Directors

Description: The North Lakeland Discovery Center assists many lake groups in Vilas County with the monitoring of lake water levels. This includes the purchase of a suitable staff gauge, annual installation of the gauge, and tracking of levels over time. The TLA will contact the North Lakeland Discovery Center (see Table 5.0-1) to enlist in their water level monitoring program. Cumulative results will be presented and discussed at the Towanda Lake Association annual meeting and listed in the association newsletter.

Action Steps: See above.

Management Action:	Educate stakeholders on the importance of shoreland condition, shoreland restoration, and proper shoreland stewardship on Towanda Lake.
Timeframe:	Begin 2021
Possible Grant:	Healthy Lakes Initiative Grant
Facilitator:	TLA Board of Directors
Description:	As discussed in the Shoreland Condition Section (3.3), 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. 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 TLA members through a variety of educational opportunities, including newsletter articles, direct emailing/mailing of informational material, and presentations at the association's annual meeting. Informational topics will include shoreland restoration resources, like the WDNR Healthy Lake Initiative grants described below, 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. Vilas County and the UW-Extension Lakes Program (see Table 5.0-1) are excellent sources of information, articles, and presenters. 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. More advanced projects that require advanced engineering design may seek alternative funding opportunities and assistance through Vilas County, which has been active in shoreland restorations for nearly two decades.

The WDNR Healthy Lakes Initiative Grant Program:

- 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
- Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap)
- Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances
- Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide
- Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
- Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available

Action Steps:

See description above.

Management Action: Increase understanding of Towanda Lake fisheries among riparians and increase important fish habitat within Towanda Lake.

Timeframe: Initiate 2020

Facilitator: TLA Board of Directors

Description: Towanda Lake is a relatively productive system with excellent capacity and habitat diversity to produce a high-quality fishery. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Many anglers assume that a lake's fishery can be 'forced' to its potential through stocking efforts. This is not the case in any lake as habitat availability, existing fish populations, level and make up of forage fish populations, and of course angler pressure, are critical to reaching and maintaining fishery potential. A primary objective of this action is to initiate frequent and productive communications with WDNR fisheries personnel to; 1) provide information regarding Towanda Lake's fishery potential to association members, 2) assure that the TLA is doing what it can to aid local fisheries staff in performing their duties, and 3) that the WDNR staff understands the goals and concerns of the TLA regarding Towanda's fishery. Ultimately, this will lead to a productive and effective stocking program on Towanda Lake.

Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation, shore-fishing, or swimming. Or, which is the case in some areas of Towanda Lake, the area adjacent to the shoreline a wetland that does not support large tree growth, so there is little natural CWH in those areas. Naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail.

The WDNR's Healthy Lakes Initiative Grant allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.

- 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
- Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
- Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
- Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
    - The landowner would need to commit to leaving the area un-mowed
    - The landowner would need to implement a native planting (also cost share through this grant program available)
- Coarse woody habitat improvement projects require a general permit from the WDNR
- Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:

1. Recruit facilitator(s) from TLA membership.
2. Facilitator(s) contacts WDNR Lakes Coordinator and WDNR Fisheries Biologist to gather information on initiating and conducting coarse woody habitat projects.
3. The TLA will encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Management Goal 2: Increase the TLA's Capacity to Manage Towanda Lake, Communicate with Lake Stakeholders, and Facilitate Partnerships with Other Management Entities

<u>Management Action:</u> Promote lake protection and enjoyment through stakeholder education

Timeframe: Continuation of current efforts

Facilitator: TLA Board of Directors

Description: Education represents an effective tool to address many lake issues and misconceptions among riparian property owners. The TLA currently communicates with its members primarily through special mailings and at the association annual meeting. The primary objective of this action is to increase the association's capacity to communicate and inform its members and other riparians about important lake issues and topics. To meet this objective, the TLA will develop and maintain a website, refine and advertise a current Facebook Group, develop an association email address list, and create a newsletter that will be distributed in hardcopy and electronic formats depending on the needs of the recipients. The Facebook Group will be an important media for getting information out to association members and an excellent method to bring followers to the association website for more information. All of these mediums allow for communication with association members, but increasing the level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings.

The TLA Board of Directors will also investigate the applicability of using a closed group app such as Nextdoor to share information with Towanda Lake riparians.

Depending on support within the TLA, the Board of Directors may create a standing committee (e.g. Education and Communication Committee) with an annual budget to implement these activities.

The TLA 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.

Example Educational Topics

- History of Towanda Lake
- Specific topics brought forth in other management actions
- Aquatic invasive species identification
- Basic lake ecology
- Sedimentation

- Boating safety (promote existing guidelines, Lake Use Information handout)
- Shoreline habitat restoration and protection
- Noise and light pollution
- Fishing regulations and overfishing
- Minimizing disturbance to spawning fish
- Recreational use of lakes

Action Steps:

See description above.

Management Action: Increase Towanda Lake Association membership.

Timeframe: 2021

Facilitator: TLA Board of Directors

Description: Many lake groups reach a plateau in their membership levels because any lake resident that would respond to typical written requests to join the organization have already done so. To overcome this recruitment barrier, the TLA will complete door-to-door and dock-to-dock contacts with non-member households. This will be an organized effort beginning with current board members contacting their non-member neighbors. The program will then expand to other households around the lake.

An important part of this action will be discovering the potential membership level that is available on Towanda Lake. This will be completed in first action step below.

Once the membership has reached its maximum potential, the TLA will investigate the interest among its members in creating an online and/or hardcopy membership contact list.

Action Steps:

1. Utilizing a lake property parcel map, the Board of Directors will create a current membership map showing all member and non-member households. Vilas County Land Information Department can assist by creating a parcel map for Towanda Lake.
2. Board members and other active association members will first speak to their neighbors that are not members. The program will then branch out to other areas of the lake. Recruiters will be equipped with TLA information and membership forms. Importantly, information regarding volunteer opportunities will be a part of the TLA information.
3. As contacts are made, those initiating the contact will report back to a Director that is tracking progress on the map. Notes would be added to the map indicating if no contact has been made after several attempts, the owners are not interested, there is follow-up necessary, the household will be joining, ect.

Management Action: Continue TLA's involvement with other entities that have responsibilities in managing (management units) Towanda Lake.

Timeframe: Continuation of current efforts

Facilitator: TLA Board of Directors

Description: The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation.

It is important that the TLA actively engage with all management entities to enhance the association's 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 Table 5.0-1

Action Steps:

See guidelines in Table 5.0-1.

Table 5.0-1 Management Partner List.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Arbor Vitae, WI	Town Chairman (Frank Bauers, 715.356.6820, townofav@frontier.com)	Oversees ordinances, funding, and other items pertaining to town	As needed.	May be contacted regarding ordinance questions, and for information on community events.
North Lakeland Discovery Center	Executive Director (John Heusinkveld, 715.543.2085, john@discoverycenter.net) Water Program Coordinator (Emily Heald, 715.543.2085, water@discoverycenter.net)	Educates and inspires connection to the natural state of the Northwoods	As needed.	Project sponsor. Direct resource for AIS education and monitoring needs, operates aquatic education programs and assists with volunteer recruitment.
Vilas County Land and Water Conservation Department	Lake Conservation Specialist (Mariquita (Quita) Sheehan, 715.479.3721, mashee@co.vilas.wi.us)	Oversees conservation efforts for lake grants and projects.	Twice a year or more as needed.	Contact for shoreland remediation/restoration techniques and cost-share procedures, wildlife damage programs, education and outreach documents.
	Lake Conservation Specialist (Cathy Higley, 715.479.3738, cahigl@co.vilas.wi.us)	Oversees AIS monitoring and education activities county-wide.	Twice a year or more as issues arise.	AIS training and ID, monitoring techniques, CBCW training, report summer activities.

Table 5.0-1 Management Partner List. (con't)

Partner	Contact Person	Role	Contact Frequency	Contact Basis
University of Wisconsin Extension Office	Lakes Specialist (Pat Goggin, 715.365.8943, Patrick.Goggin@wisconsin.gov)	Provides guidance for lakes, shoreline restoration, and outreach/education.	As needed.	Contact for shoreland remediation/restoration techniques, outreach/education.
Great Lakes Indian Fish and Wildlife Commission	General (715.682.6619)	Resource management within Ceded Territory	As needed.	Collaborate on lake related studies, AIS management, inform of meetings, etc.
Vilas County Lakes & Rivers Association (VCLRA)	President (Tom Ewing, president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partner in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Wisconsin Department of Natural Resources	Fisheries Biologist (Eric Wegleitner, 715.356.5211 Ext. 246 eric.wegleitner@wisconsin.gov)	Manages the fish populations and fish habitat enhancement efforts.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937)	Oversees management plans, grants, all lake activities.	As needed.	Information on planning/AIS projects, grant applications or to seek advice on other lake issues.
	Environmental Grant Specialist (Jill Sunderland, 715.635.4167)	Oversees financial aspects of grants.	As needed.	Information on grant financials and reimbursement, CBCW grant applications.
	Conservation Warden (Matt Meade, 715.329.0615)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity, include fishing, boating safety, ordinance violations, etc.
	Trout Lake Station staff (Susan Knight and Carol Warden 715.356.9494)	Conducts lake research on multiple levels	As needed.	Can be contacted for identification or consultation on AIS.
	Citizen Lake Monitoring Network (Sandy Wickman – 715.365.8951, sandra.wickman@wisconsin.gov)	Provides information, training, and equipment for CLMN volunteers.	As needed.	Contact of information regarding CLMN program, including training, equipment, and data entry into SWIMS

Table 5.0-1 Management Partner List. (con't)

Partner	Contact Person	Role	Contact Frequency	Contact Basis
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	Those interested 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.
Vilas County Sheriff Dept.	1.800.472.7290 or 715.479.4441 non-emergency, 911 emergencies only.	Perform law enforcement duties to protect lakes, especially pertaining to compliance with boating safety rules.	As needed.	Contact regarding suspected violations pertaining to boating safety rules on the lake.

Management Goal 3: Prevent Aquatic Invasive Species Introductions to Towanda Lake

Management Action: Begin Clean Boats Clean Waters watercraft inspections at Towanda Lake public access location.

Timeframe: 2021

Facilitator: TLA Board of Directors

Potential Grant: WDNR AIS-Clean Boats Clean Waters Grant (https://dnr.wi.gov/lakes/cbcw/)

Description: Towanda Lake is a somewhat popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The goal is to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of AIS spread.

Action Steps:

1. Assure that the TLA membership is prepared to contribute the necessary volunteer hours. To utilize a WDNR CBCW grant, the lake group must commit to at least 200 hours of watercraft monitoring.
2. Contact Vilas County Lake Specialist for general information on grant application and training possibilities.

Management Action: Design and install customized AIS and lake information kiosk at Towanda public boat landing.

Timeframe: 2022

Facilitator: TLA Board of Directors

Potential Grant: Small-Scale AIS-Education, Prevention, and Planning Grant

Description: Some lake groups in Wisconsin have designed and installed AIS and lake information kiosks at the public landings providing access to their lake. Found Lake, North and South Twin Lakes, and Little Arbor Vitae Lakes are examples in Vilas County. The kiosks are designed to be flexible in the information they display. Often the lake group posts information regarding AIS prevention, specific lake rules, information about the lake and the lake group, and special event information.

Action Steps:

1. Obtain permission from Town of Arbor Vitae to place sign at town landing. Also, determine best placement of sign for snow removal and road maintenance.
2. Design sign and determine information that will be posted. SeaGrant, WDNR, and UW-Extension Lakes Program are excellent resources for AIS messaging.
3. Determine costs and grant needs.

Management Action:	Coordinate annual volunteer monitoring for Aquatic Invasive Species on Towanda Lake.
Timeframe:	Begin 2022
Facilitator:	TLA Board of Directors
Description:	In lakes without Eurasian watermilfoil and other submersed invasive species like curly-leaf pondweed, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. One way in which lake residents can spot early infestations of AIS is by conducting "Lake Sweeps" on their lake. During a lake sweep, volunteers monitor the entire area of the system in which plants grow (littoral zone) at least twice annually in search of non-native plant species. This program uses an "adopt-a-shoreline" approach where volunteers are responsible for surveying specified lengths of the shoreline. During recruitment of volunteers, it is important to emphasize that they will receive training and that they are not expected to be able to identify the numerous types of plants that are in the lake. They will be trained to recognize specific aquatic invasive plant species, like Eurasian watermilfoil, curly-leaf pondweed, purple loosestrife, and pale-yellow iris. It is also important for the volunteers to know that they are not responsible for making the final identification. If suspect plants are located, an expert from Vilas County or the WDNR office in Woodruff can inspect the specimen and determine if it is an AIS. The Vilas County Lakes Specialist (see Table 5.0-1) can provide excellent training that will include the best time of year to complete the surveys, identification tips for the target AIS, and methods to collect specimens and mark areas of the lake that may require further investigation by professionals.
Action Steps:	
1.	TLA board member contacts Vilas County Lake Specialist to obtain preliminary information regarding number of volunteers needed and tentative dates for training.
2.	TLA Board of Directors presents program to membership and recruits volunteers.
3.	Training session is conducted and program begins.
4.	Program activities are summarized and volunteers are recognized in newsletter and at TLA annual meeting.

Management Action:	Initiate rapid response plan following detection of AIS in Towanda Lake.
Timeframe:	If/When Necessary
Facilitator:	TLA Board of Directors
Description:	If volunteer or professional surveys locate a suspected new AIS within Towanda Lake, the location would be marked (e.g. GPS, maker buoy) and a specimen would be taken to the WDNR Lake Coordinator (Kevin Gauthier), or to the Vilas County Land Conservation Department for verification. If the suspected specimen is indeed a non-native species, the WDNR will fill out an incident form and develop a strategy to determine the population level within the lake. The lake would be professionally surveyed, either by agency personnel or a private consulting firm during that species' peak growth phase. If the AIS is a NR40 prohibited species (i.e. red swamp crayfish, starry stonewort, hydrilla, etc.), the WDNR may take an active role in the response. If the AIS is a NR40 restricted species (i.e. purple loosestrife, curly-leaf pondweed, etc.), the TLA would need to reach out to a consultant to develop a formal monitoring and/or control strategy. The WDNR would be able to help financially by issuing an AIS-Early Detection and Response Grant. This grant program is non-competitive and doesn't have a specific application deadline, but is offered on a first-come basis to the sponsor of project waters that contain new infestations (found within less than 5% of the lake and officially documented less than 5 years from grant application date). Currently this program will fund up to 75% percent of monitoring and control costs, up to $20,000.
Action Steps:	
	See description above

Management Action:	Conduct periodic quantitative vegetation monitoring on Towanda Lake.
Timeframe:	Point-Intercept Survey every 3-5 years, Community Mapping every 7-10 years
Possible Grant:	Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning in <$10,000 category.
Facilitator:	TLA Board of Directors
Description:	As part of the ongoing AIS prevention program, a whole-lake point-intercept survey will be conducted at a minimum once every 3-5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Towanda Lake. A point-intercept survey was conducted on Towanda Lake in 2018; therefore, the next point-intercept survey will be completed between 2021 and 2023, depending on the need by the TLA.

In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Towanda Lake, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on Towanda Lake in 2018 as a part of this management planning effort. The next community mapping survey will be completed between 2025 and 2028.

Action Steps:

See description above.

Management Goal 4: Assure Safe and Pleasurable Recreational Opportunities on Towanda Lake for All Users

Management Action:	Conduct a mechanical harvesting feasibility study.
Timeframe:	2021 and beyond
Facilitator:	TLA Board of Directors
Description:	The southern lobe of Towanda Lake has dense aquatic vegetation growth consisting of native submersed and floating-leaf species. The dense vegetation makes motorized and non-motorized boat navigation difficult to impossible. The TLA will assess the potential of using a mechanical harvester to restore navigation to the southern area of the lake and other problem areas should they develop in the future. The TLA supports the reasonable and environmentally sound actions to facilitate navigability on Towanda 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. A preliminary mechanical harvesting plan design is included as Map 8. This is a working plan developed to provide access to properties that had piers in place during the summer of 2012. If mechanical harvesting is found to be feasible, additional property owners may install piers and request to be included in the harvesting plan. The financial feasibility of harvesting on Towanda Lake is likely the biggest hurdle. Even with the distance to the boat landing for unloading harvested plants, the harvesting displayed on Map 8 would likely take approximately 3 hours. A typical cost for contracted mechanical harvesting is about $200/hr. There is also a mobilization fee of $500 to $1000, so at that rate and a three-hour work day, the potential cost to the association could be $1,100 to $1,600 to complete the harvesting. The cost may be more because the contractor may charge a minimum per day fee." Mechanical harvesting of any sort requires a WDNR permit. As described in the Action Steps, discussions with the WDNR regarding permit needs should be the first step in determining the feasibility of mechanical harvesting on Towanda Lake. Harvesting permits from the WDNR can be issued for up to a period of 5 years when operating under an approved aquatic plant management plan.

	For the period to be covered by the application, maps as prepared in support of the current aquatic plant management plan should be submitted as part of the permit application.
Action Steps:	1. Contact WDNR regarding permitting needs, several months or more, in advance of applying for permit (see Table 5.0-1). 2. Contact two or more mechanical harvesting contactors for cost estimates. 3. Determine fiscal feasibility of completing mechanical harvesting.

Management Action:	Update the Towanda Lake Association 'Gentlemen's Agreement'.
Timeframe:	2021
Facilitator:	TLA Board of Directors
Description:	The TLA developed a written 'Gentlemen's Agreement' to clearly state acceptable recreational practices on Towanda Lake. The Board of Directors will update the agreement to include additional concerns and provide it to the riparian property owners of Towanda Lake.
Action Steps:	See description above

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Towanda Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by TLA members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall and winter. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

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

	Spring		June	July		August	Fall		Winter	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**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	■									

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Towanda 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

A survey for curly-leaf pondweed was completed on Towanda Lake during a June 20, 2018 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 Towanda 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 11-12, 2018. A point spacing of 39 meters was used resulting in approximately 373 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Towanda 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 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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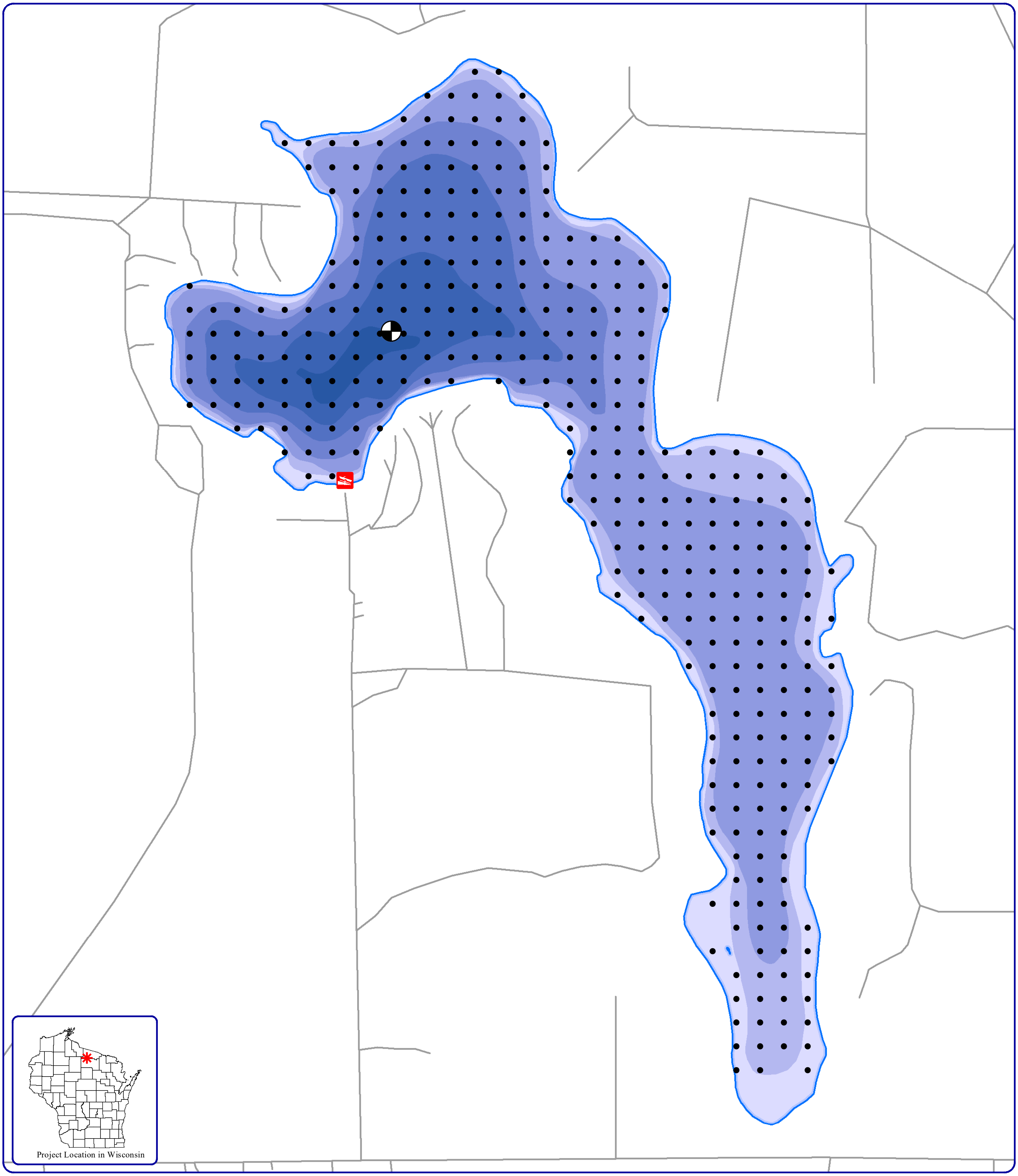


N
W E
S

675
Feet

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

Sources:
Roads and Hydro: WDNR
Map Date: December 5, 2017
Filename: Towanda_location_proposal.mxd

Legend

Towanda Lake - 139 acres
WDNR Definition

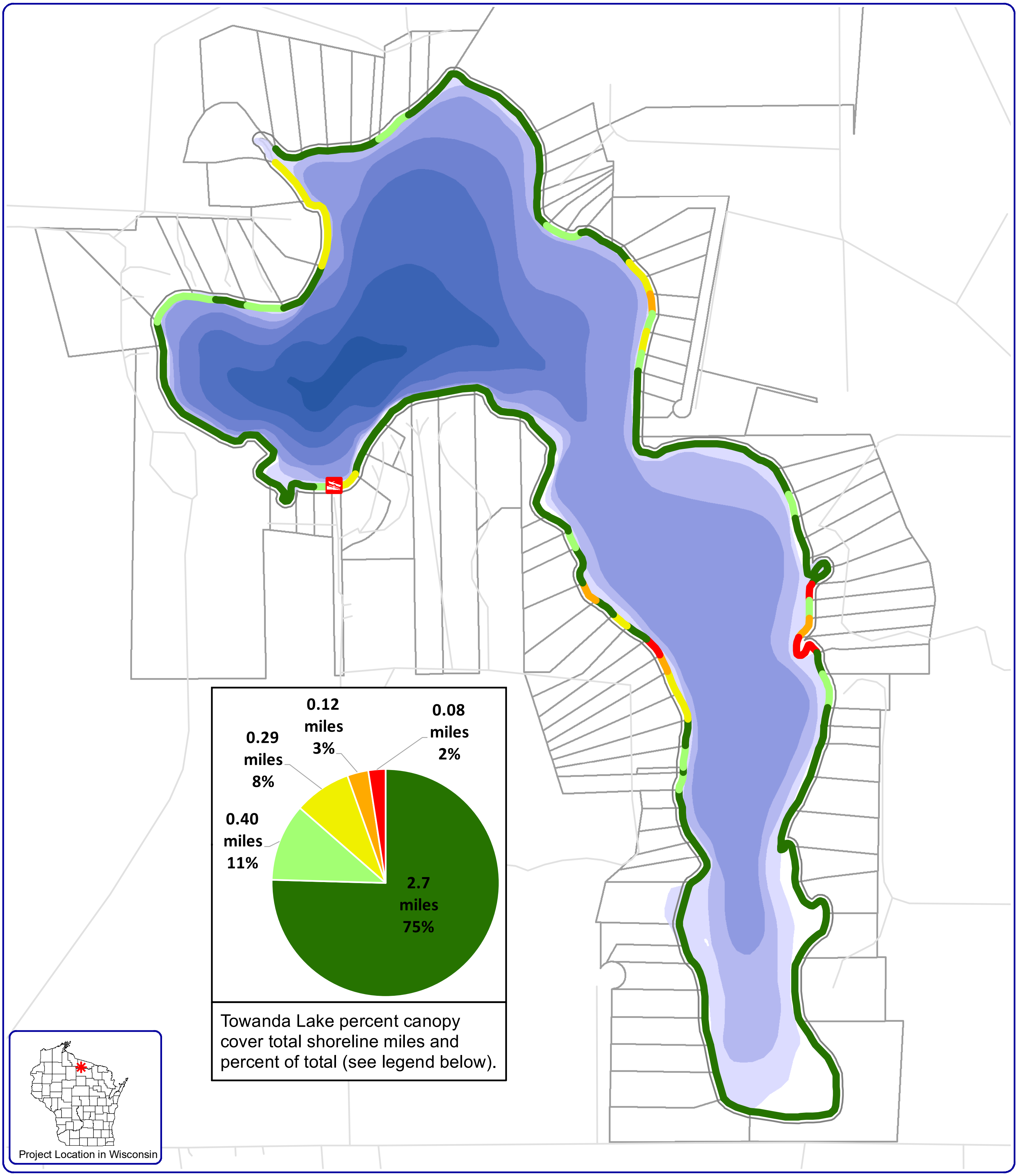
Point-intercept Sample Location
39 meter points, 373 points

Public Access

Water Quality Site

Map 1
Towanda Lake
Vilas County, Wisconsin

Project Location & Lake Boundaries



N W E S

1,150

Feet

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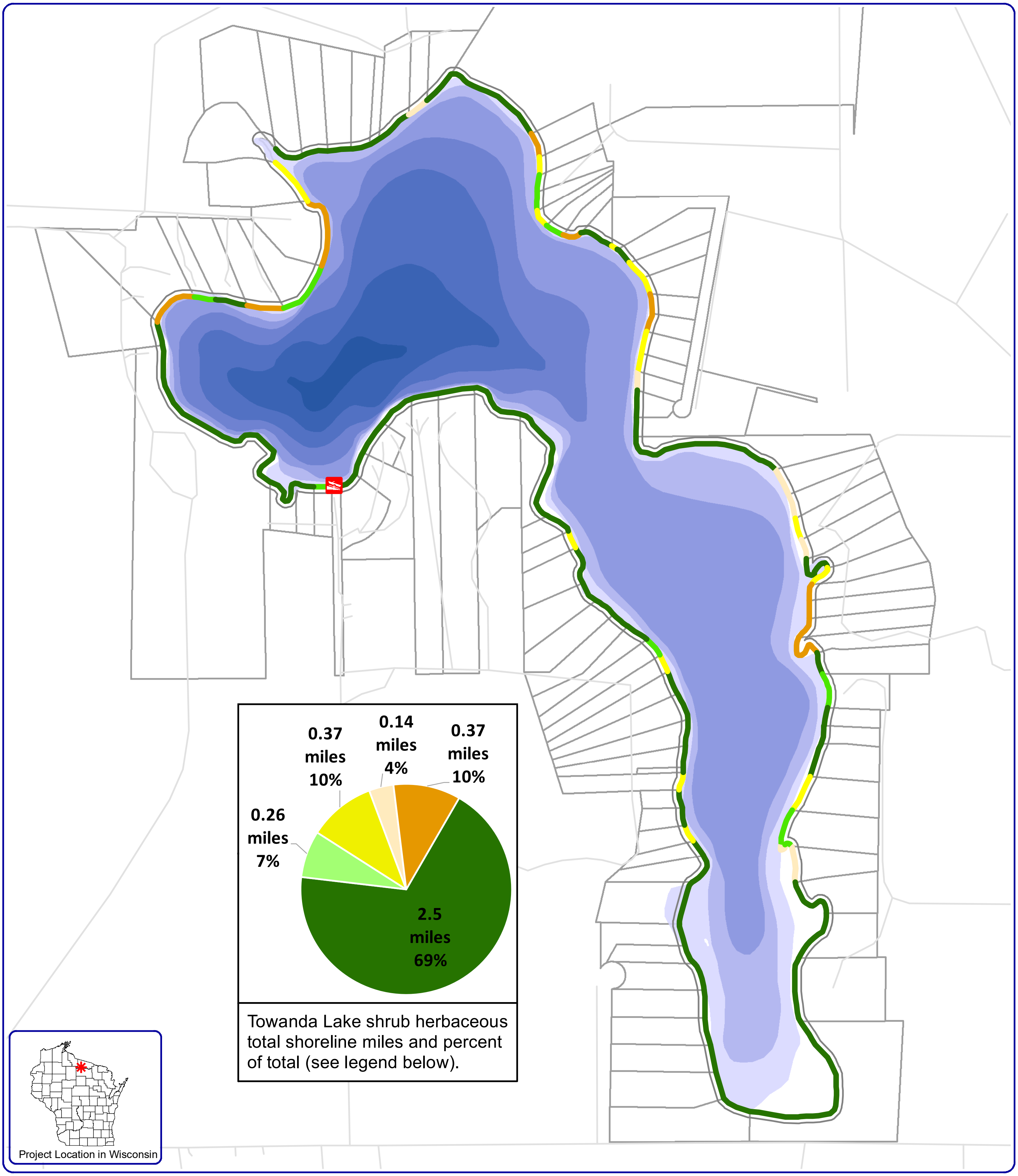
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Map date: August 30, 2019 JMB
Filename: Towanda_SA_Canopy_2019.mxd

Legend

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

Map 2
Towanda Lake
Vilas, Wisconsin
Percent Canopy Cover



1,150
Feet

Legend

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

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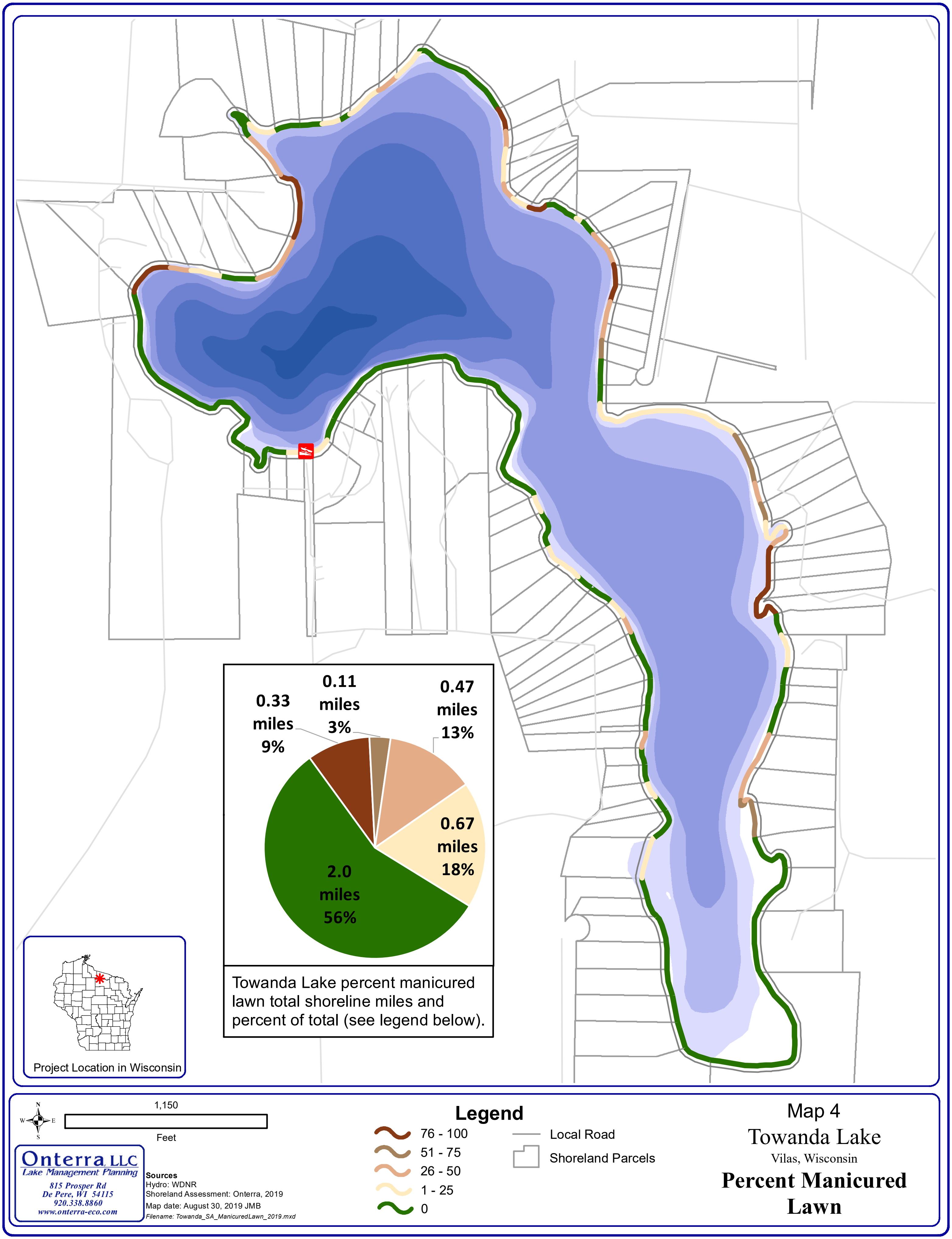
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Map date: August 30, 2019 JMB
Filename: Towanda_SA_ShrubHerbaceous_2019.mxd

Map 3
Towanda Lake
Vilas, Wisconsin
Percent Shrub Herbaceous


0.33 miles 9%
0.11 miles 3%
0.47 miles 13%
0.67 miles 18%
2.0 miles 56%
Towanda Lake percent manicured lawn total shoreline miles and percent of total (see legend below).
Project Location in Wisconsin
N
W
E
S
1,150
Feet
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Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
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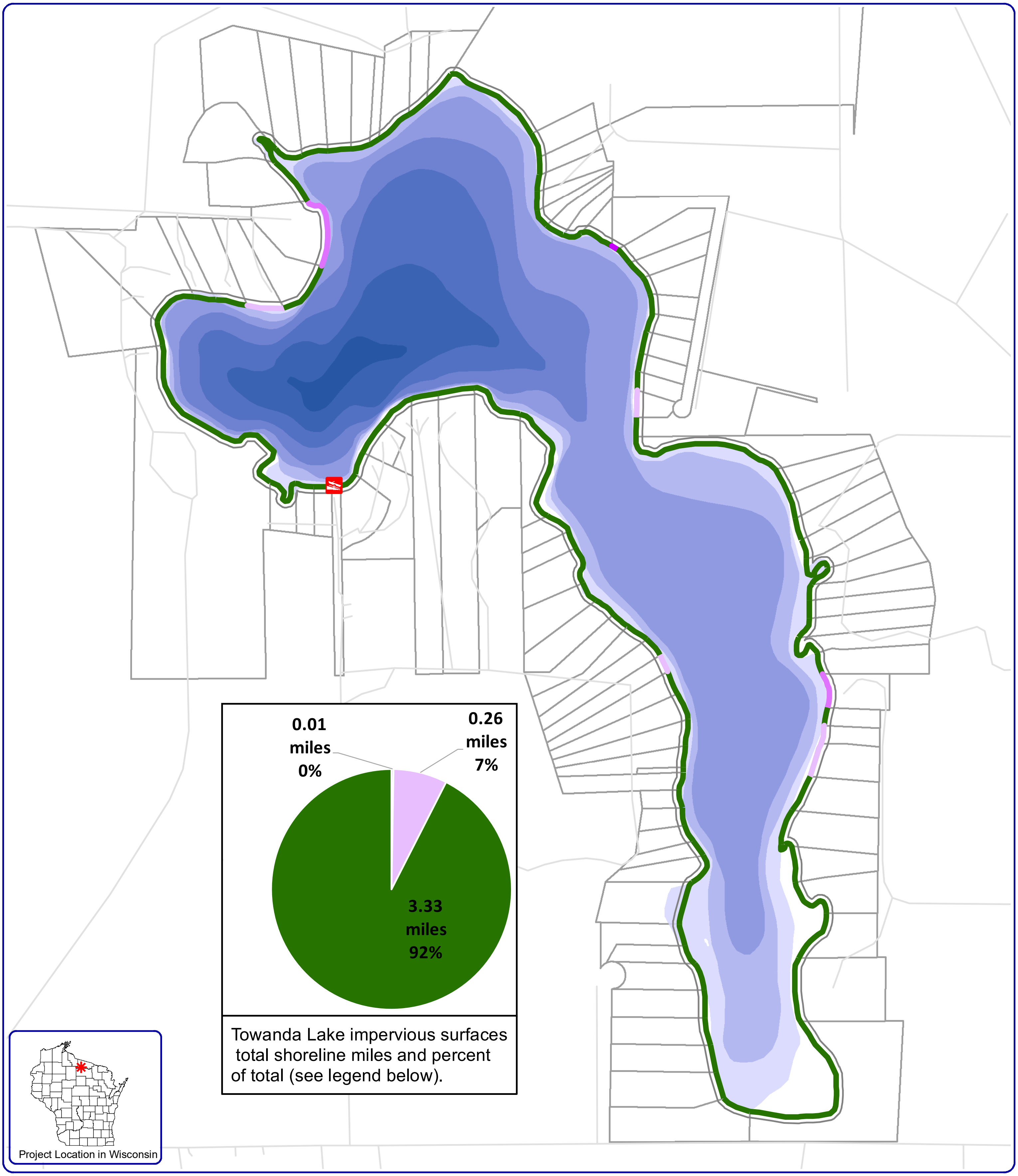
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Map date: August 30, 2019 JMB
Filename: Towanda_SA_ManicuredLawn_2019.mxd
Legend
76 - 100
51 - 75
26 - 50
1 - 25
0
Local Road
Shoreland Parcels
Map 4
Towanda Lake
Vilas, Wisconsin
Percent Manicured Lawn



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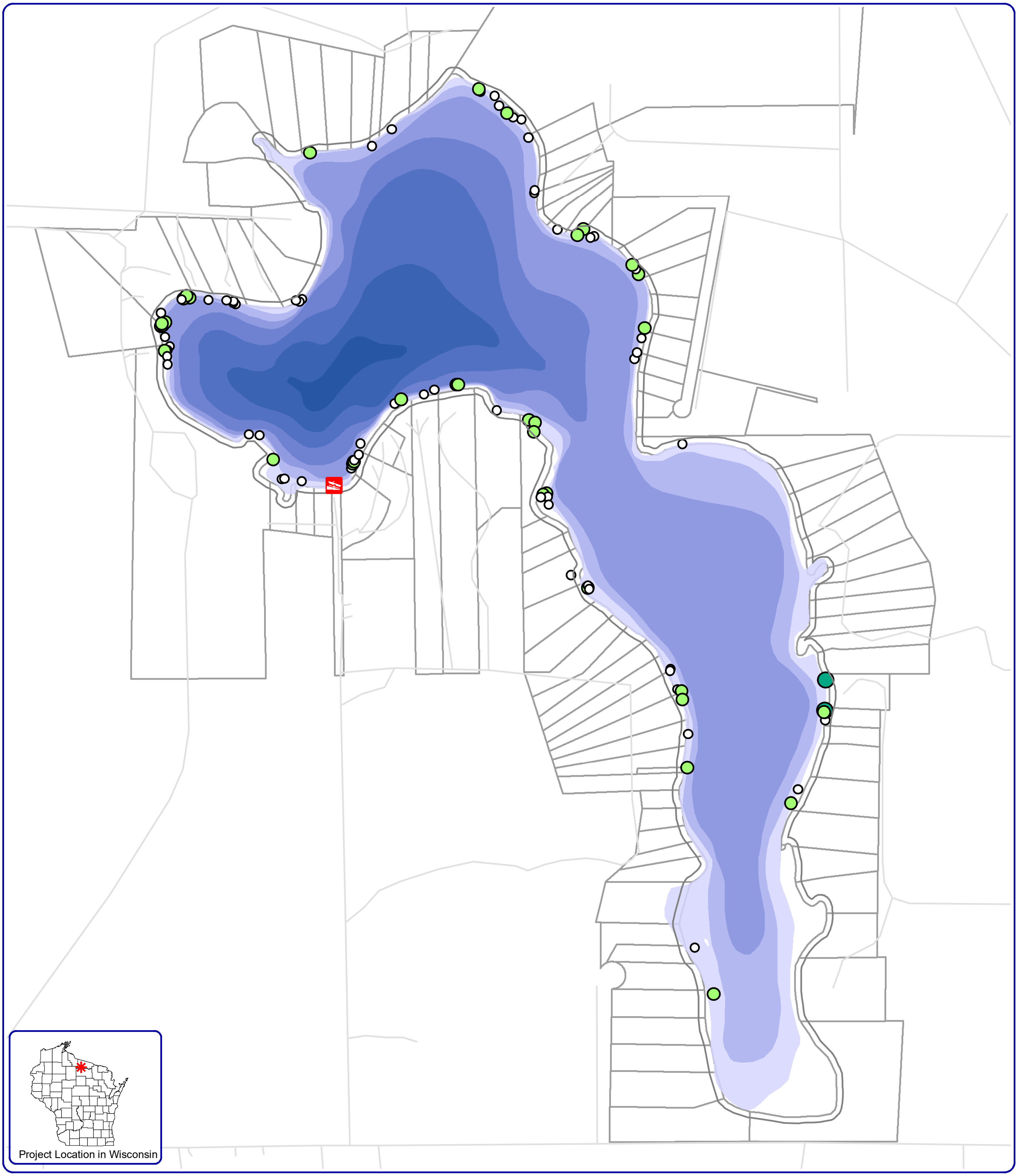
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Map date: August 30, 2019 JMB
Filename: Towanda_SA_Impervious_2019.mxd

Map 5
Towanda Lake
Vilas, Wisconsin
Percent Impervious Surfaces



1,150

Feet

Legend

- No Branches
- Some Branches
- Full Canopy
- Local Road
- Shoreland Parcels

Map 6
Towanda Lake
Vilas, Wisconsin
Coarse Woody Habitat

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815 Prosper Rd
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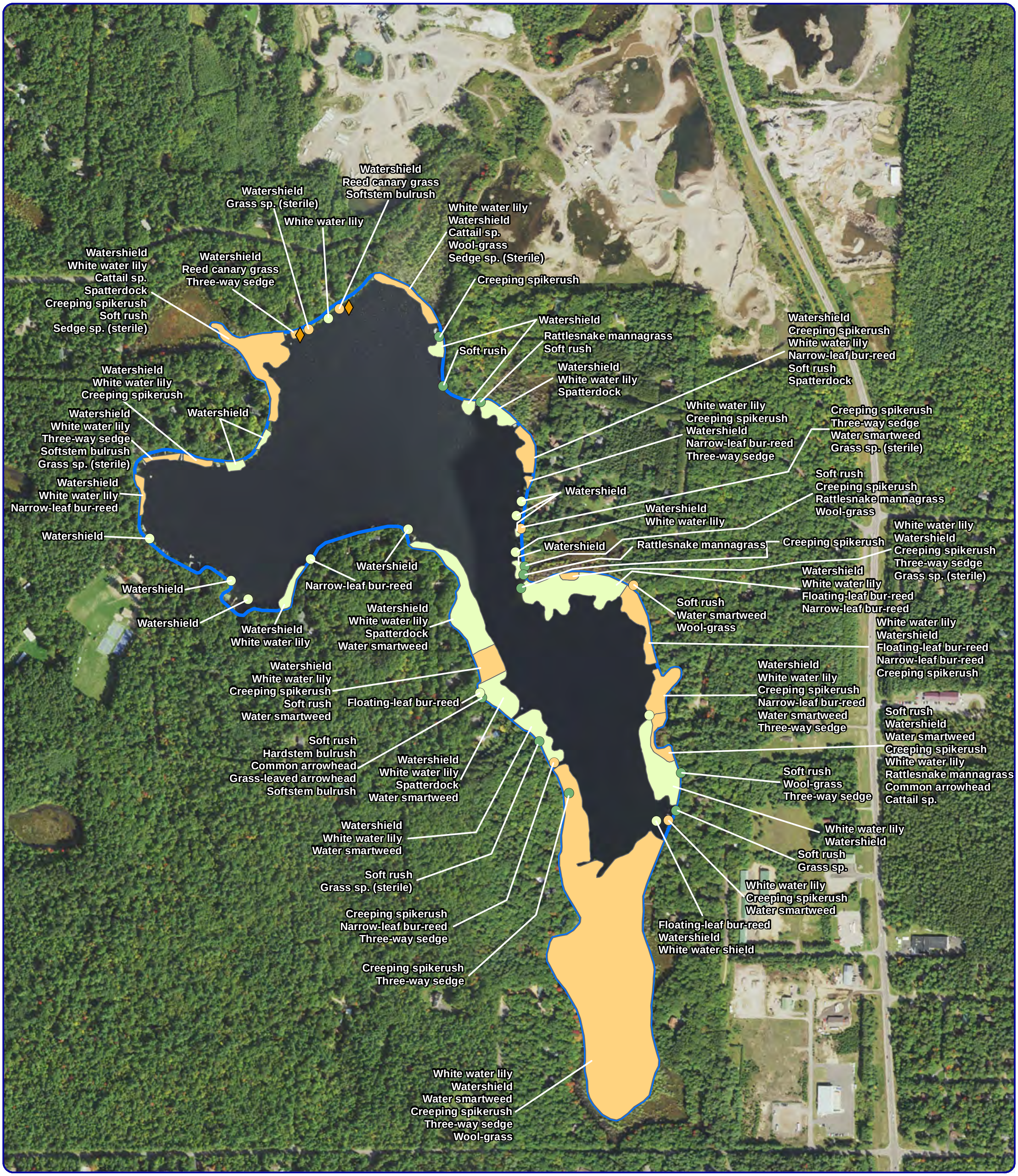
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Map date: August 30, 2019 JMB
Filename: Towanda_CWH_2019.mxd



N
W E
S

1,300

Feet

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Lake Management Planning

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920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: Month Day, Year Initals
Filename: *Towanda_Comm_2018.mxd*

Project Location in Wisconsin

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Reed Canary Grass

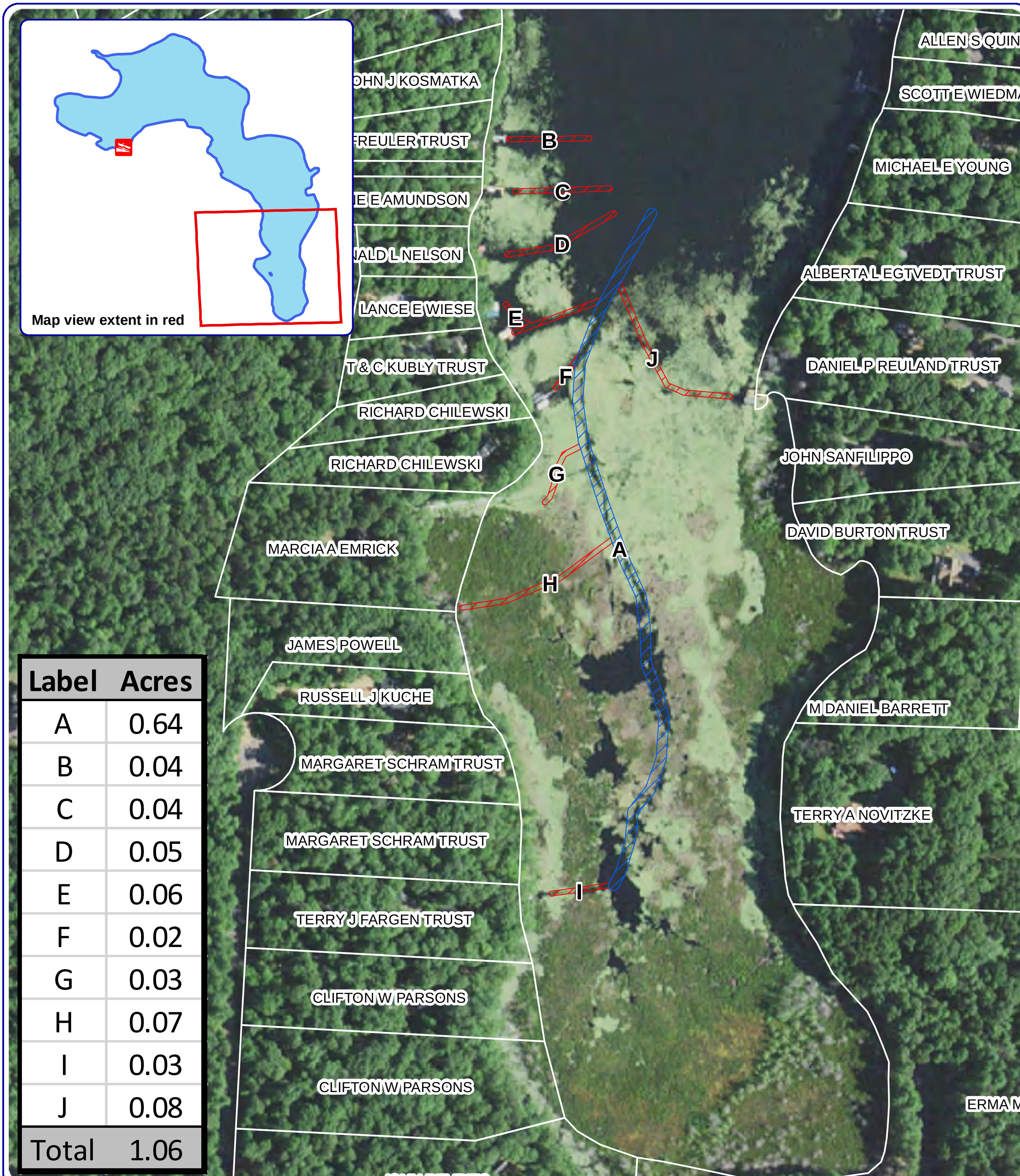
Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 7

Towanda Lake

Vilas County, Wisconsin

Aquatic Plant Communities



Label	Acres
A	0.64
B	0.04
C	0.04
D	0.05
E	0.06
F	0.02
G	0.03
H	0.07
I	0.03
J	0.08
Total	1.06

N W E S

250
Feet

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

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: November 20, 2019 TWH
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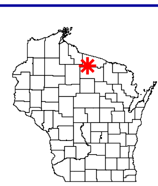

Project Location in Wisconsin

Legend

Mechanical Harvesting Lanes

10' Harvesting Lanes

20' Harvesting Lanes

Map 8
Towanda Lake
Vilas County, Wisconsin
Preliminary Mechanical Harvesting Locations