Waterford Waterway

Racine County, Wisconsin

Comprehensive Management Plan

February 2020

Sponsored by:

Waterford Waterway Management District

WDNR Grant Program

LPL-1664-18 & LPL-1665-18

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Onterra LLC
Lake Management Planning

Waterford Waterway

Racine County, Wisconsin

Comprehensive Management Plan

February 2020

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Funded by: Waterford Waterway Management District
Wisconsin Dept. of Natural Resources
(LPL-1664-18 and LPL-1665-18)

Acknowledgements

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

Waterford Waterway Planning Committee

Barbara Baron	Don Baron	Mike Waghorn
Steve Larry	Gary Bluemel	Paul Kling
Ted Derse	Dave Spurlock	Janet Dickinson
Richard Bondar	Dan Schultz	Greg Horeth

Wisconsin Dept. of Natural Resources

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1.0 INTRODUCTION

The Waterford Waterway contains Tichigan Lake, Waterford Lake, Conservancy Bay and the Fox River channel summing 1,229 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program (NAIP*) collected in June 2015. The Waterford Waterway has a maximum depth of 63 feet in Tichigan Lake. This system has a relatively large watershed when compared to the size of the waterway. The Waterford Waterway has an abundance of plants with 22 native plant species, of which coontail and common waterweed are the most common. Five exotic plant species are known to exist in the Waterford Waterway. Prior to this study reports have been completed on the Waterford Waterway in 1993, 2003, 2011, 2012 and 2016.

Field Survey Notes

The Waterford Waterway system has very high plant growth with the most abundant species being native communites. While much of the shoreline is developed, large areas of natural shoreline exist on the system's many islands and in Conservancy Bay.

Photograph 1.0-1 Waterford Waterway, Racine County

Lake at a Glance – The Waterford Waterway

Morphology	
Acreage	1,229
Maximum Depth (ft)	63
Vegetation	
Number of Native Species	22
Threatened/Special Concern Species	None
Exotic Plant Species	EWM, CLP, pale yellow iris, purple loosestrife
Simpson's Diversity	0.78
Average Conservatism	5.4
Water Quality	
Trophic State	Highly Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	186:1

The primary citizen-based organization leading management activities on the Waterford Waterway is the Waterford Waterway Management District (WWMD). The studies included within the current management planning project document the present state of the native and exotic plant populations, compare them to previous occurrences, and use this information to develop a plan for future management of exotic populations. Additionally, the WWMD sought to examine their lake in a holistic manner, understanding the ecosystem and better protecting it from future threats. Shoreland and fish habitat assessment results educate riparian property owners about healthy shorelines and how they may be able to improve their property through BMPs and/or habitat improvements. A stakeholder survey was circulated to assess the needs and concerns of all property owners. Finally, water quality data and analysis collected through a concurrent USGS study was integrated into this project.

2.0 STAKEHOLDER PARTICIPATION

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

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. The WWMD posted all planning meetings as open to the public.

Aquatic Plant Management Meeting

On December 14, 2017, prior to the beginning of this grant-funded project, the WWMD hosted an aquatic plant management informational meeting. The meeting was facilitated by Onterra staff members, Tim Hoyman, Eddie Heath, and Brenton Butterfield. While the meeting was not officially a part of the management planning project and no in-kind time was recorded for either of the grants funding the plan development, the meeting included information specifically about the upcoming project. Onterra's presentation included general information about aquatic plant management, including the differences between nuisance plant control and AIS control, limitations of herbicide spot treatments, and an overview of many aquatic plant management techniques commonly used in Wisconsin. The presentation also included specific information about a Eurasian watermilfoil mapping survey completed by Onterra that fall and past management activities that occurred on the waterway in the last decade or so. Finally, a nuisance aquatic plant management and monitoring strategy for 2018 was described in detail.

Project Wrap-up Meeting

On August 21, 2019, the WWMD held a special meeting regarding the completion of the Waterford Water Management Planning Project. During the meeting, Tim Hoyman presented the highlights of the many studies that had been completed on the waterway since 2017. Detailed information regarding Waterford Lake water quality and the advantages/disadvantages of different types of water level drawdowns was included as well. Tim also answered many questions about the system and its past and current management. An outline of the draft management plan was also integrated within his presentation.

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 three meetings were open to the planning committee and public. The planning committee members were supplied with the draft report sections prior to the first meeting and much of the time of the first two meetings was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of that time was to fortify a solid understanding of the Waterford Waterway among the committee members. The second half of Planning Meeting II and all of Planning Meeting III was concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

On March 12, 2019, Tim Hoyman of Onterra met with the Waterford Waterway Planning Committee for 3.5 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of the meeting included the water quality studies, the watershed assessment, and aquatic plant surveys completed on the waterway as a part of this project and others. The meeting ended with a specific discussion of water level drawdown as management tool on the Waterford Waterway.

Planning Committee Meeting II

On April 4, 2019, Tim Hoyman reconvened with the Planning Committee for 3 hours. The meeting started with a discussion regarding the shoreland assessment survey, coarse woody habitat survey, and fisheries information compiled for the waterway. A review of the study results from the previous meeting was completed before the committee began discussion the challenges facing the Waterford Waterway and the Waterford Waterway Management District. By the end of the meeting, the committee had assembled long list of challenges and had begun discussions of how the management plan may address them.

Planning Committee Meeting III

On April 25, 2019, Tim Hoyman reconvened with the Planning Committee for another 2 hours to complete the discussion started at the end of the previous meeting. At the conclusion of this meeting, the Planning Committee had assembled an outline of management goals and appropriate management actions to meet those goals. That outline was the framework utilized to create the full Implementation Plan found in Section 5.

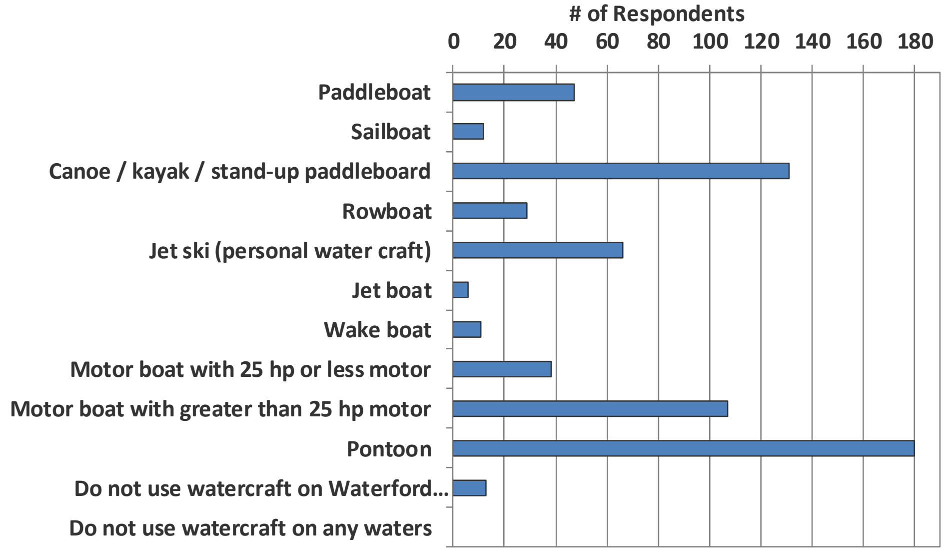
Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to all district members around the Waterford Waterway. The survey was designed by Onterra staff, the WWMD Planning Committee and reviewed by a WDNR social scientist. During December 2018, the eleven-page, 42-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 WWMD volunteer for analysis. Twenty-nine 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 that use and care for the Waterford Waterway. The majority of stakeholders (75%) live on the waterway year-round, while 10% utilize their property as a seasonal vacation home and 5% as a seasonal residence. 26% of stakeholders have owned their property between zero to five years, and 23% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect 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 the Waterford Waterway (Question 17). Paddleboats were also a popular option. On the narrow portions of the Waterford Waterway, 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 20, several of the top recreational activities on the lake involve boat use. Although boat traffic was listed as a factor potentially impacting the Waterford Waterway in a negative manner (Question 28), it was ranked 6th on a list of stakeholder's top concerns regarding the lake (Question 29).

Question 17: What types of watercraft do you currently use on Waterford Waterway?



Question 20: Please rank up to three activities that are important reasons for owning your property on or near Waterford Waterway.

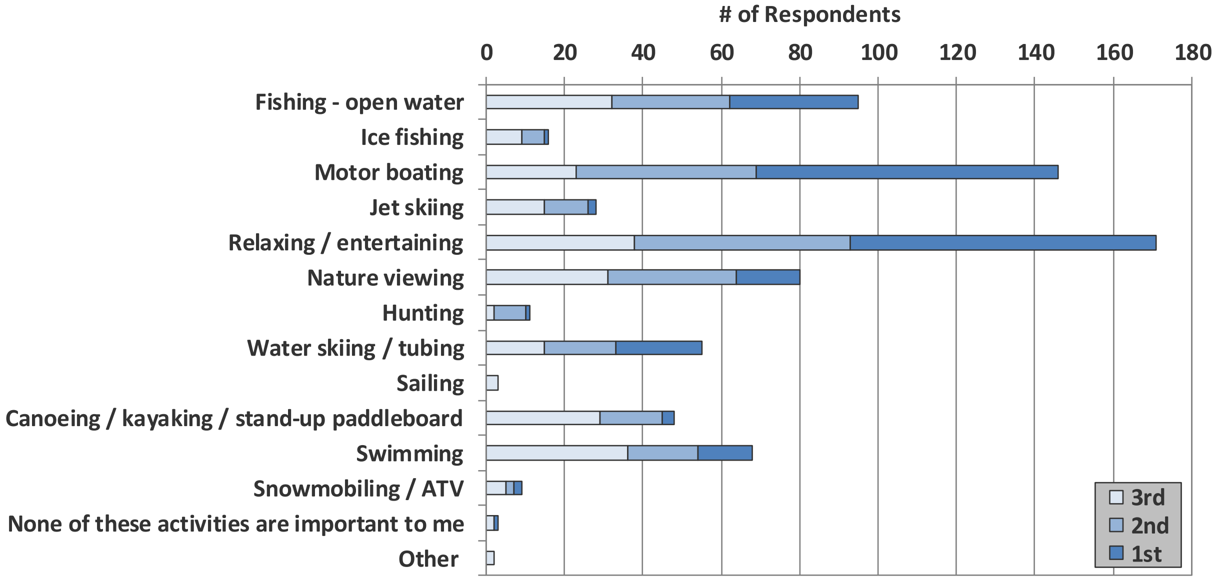


Figure 2.0-1. Select survey responses from the Waterford Waterway Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 28: To what level do you believe these factors may be negatively impacting Waterford Waterway?

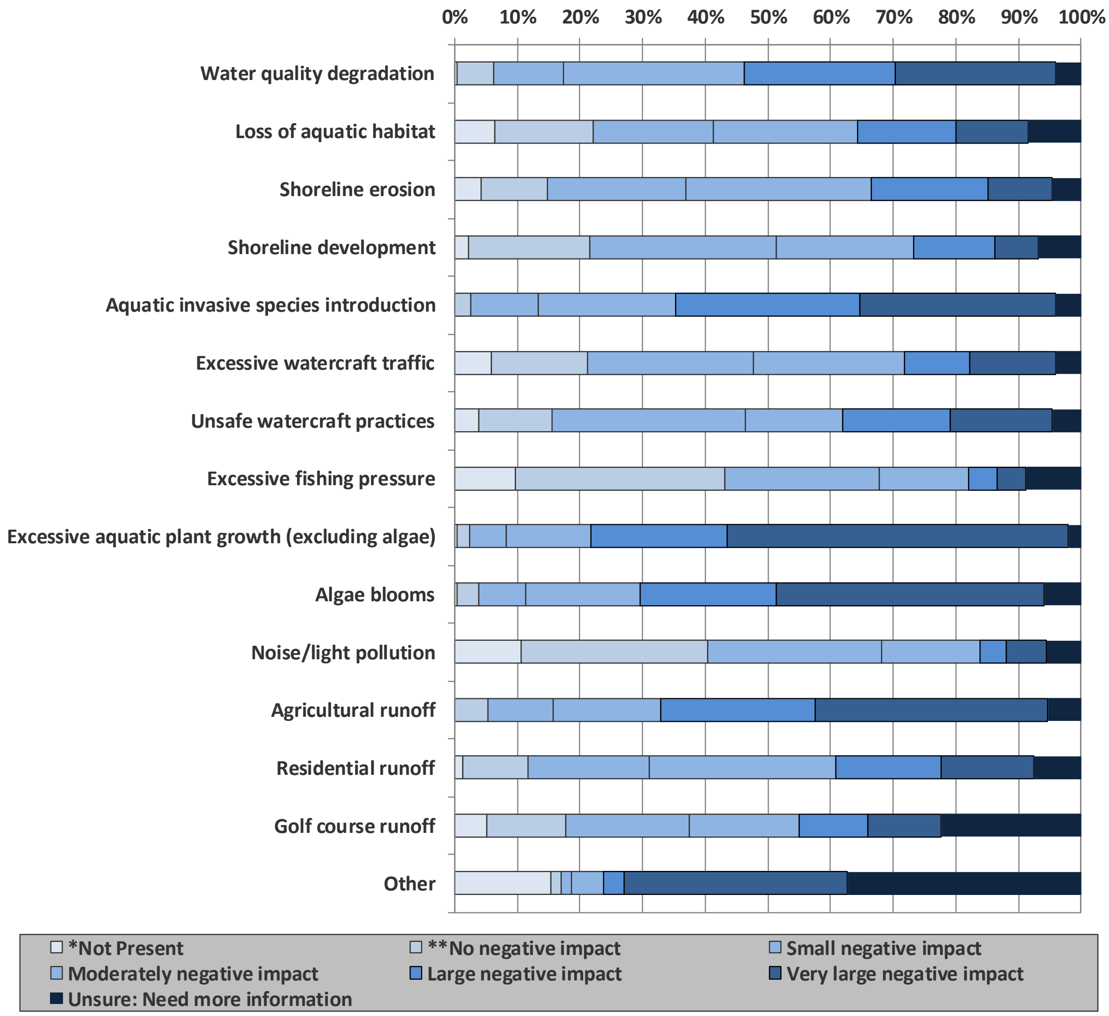


Figure 2.0-2. Select survey responses from the Waterford Waterway Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Question 29: Please rank your top three concerns regarding Waterford Waterway.

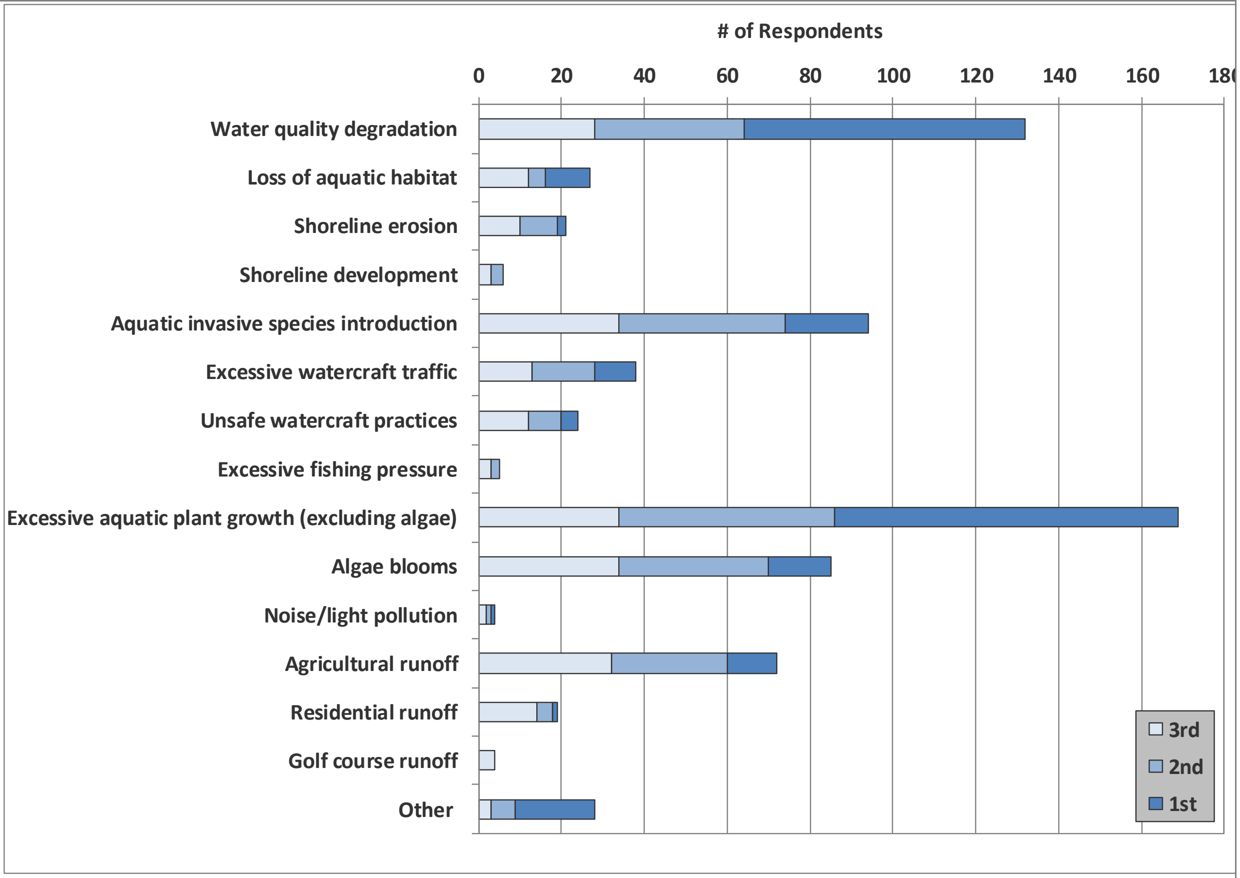


Figure 2.0-3. Select survey responses from the Waterford Waterway Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

On July 3, 2019, a draft of the full Implementation Plan was provided to the Planning Committee for review. Feedback was received from the committee on July 20, 2019 and integrated within the plan. That version of the plan was presented to the general public during the August 21, 2019 Wrap-up Meeting and included in the Official First Draft of the management plan provided to the WDNR for review on November 15, 2019 following approval of that draft by the WWMD Board of Commissioners on November 12, 2019. WDNR comments were received on December 4, 2019 and integrated into the Official Second Draft of the plan that was provided to the WDNR on January 21, 2020. Two minor comments were provided by the WDNR via email on February 18, 2020 and discussed via a phone conversation the following day. Those comments were integrated within the Official Third Draft that was provided to the WWMD Board of Commissioners for their final approval. Appendix H. contains WDNR comments and Onterra responses. The final plan was approved by the WWMD Board of Commissioners on February 22, 2020.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Tichigan 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 Tichigan 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 quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, 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 process 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 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 2013A) 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 Tichigan 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, 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, Tichigan Lake is classified as a deep headwater drainage lake (category 3 on Figure 3.1-1).

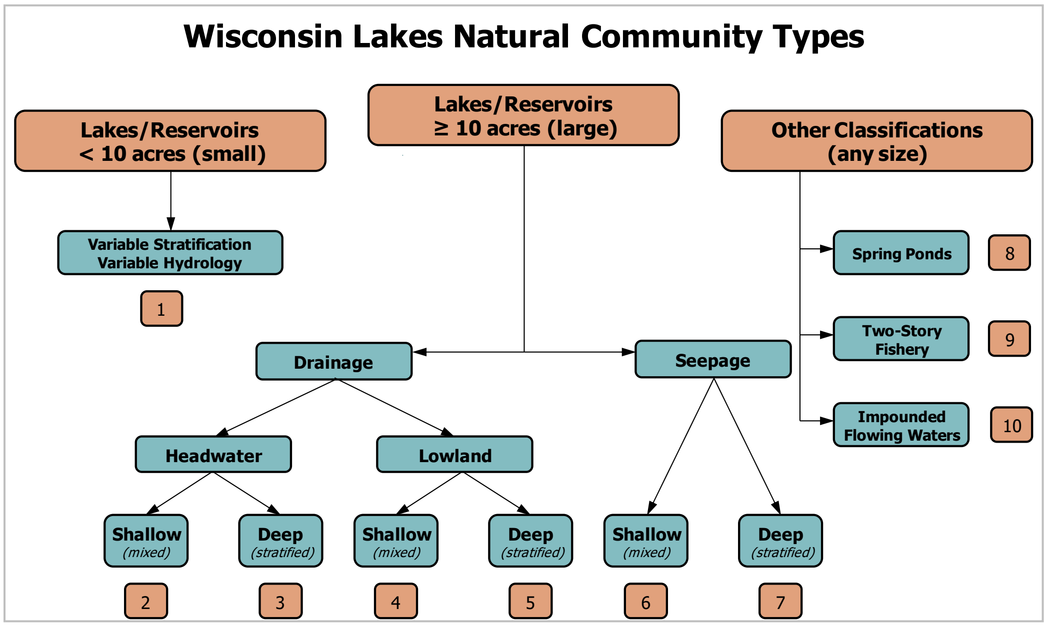


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Tichigan Lake is within the North Central Hardwood Forests (NCHF) ecoregion.

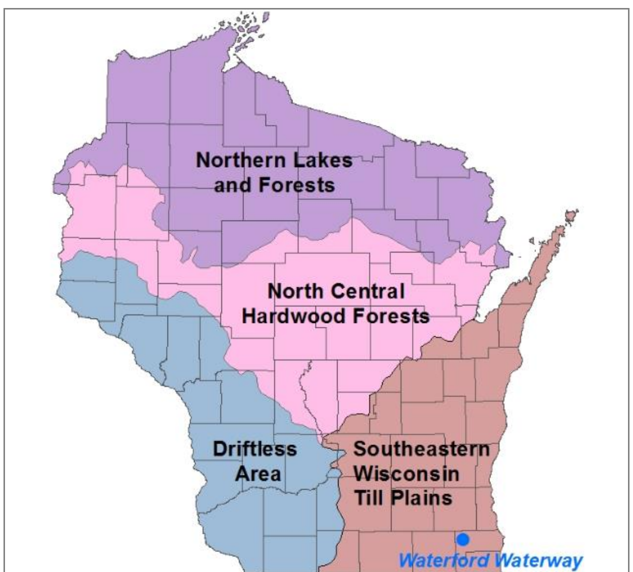


Figure 3.1-2. Location of the Waterford Waterway within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2018 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 Tichigan and Waterford lakes and the Fox River near Waterford Lake are displayed in Figures 3.1-3 - 3.1-19. 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.

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

Waterford Waterway Water Quality Analysis

The Waterford Waterway is a 1,228-acre impoundment, including Buena, Waterford, and Tichigan lakes, of the Fox River in Racine County, WI. The Town of Waterford surrounds the system, which is retained by the Waterford Dam. Tichigan Lake was a natural lake before the dam was placed on the Fox River but its lake level was raised by the dam. It is likely Buena and Waterford lakes were wetlands prior to the placement of the dam. The water quality of all of these lakes is strongly influenced by the Fox River which drains a large watershed above the system.

Variable amounts of water quality data are available for three sites in the Waterford Waterway and are discussed below. The site at the Tichigan Lake's deep hole has the most data. This site has been primarily sampled through the WDNR Citizens Lake Monitoring Network (once known as the Self-Help Lake Monitoring Program) since 1994. Waterford Lake has limited data, primarily collected by consultants since 2016. The Fox River channel near the channel to Waterford Lake, was sampled as a part of this project only in 2018. Tichigan Lake is considered a deep, stratified, lowland drainage lake while Waterford Lake is a shallow, lowland drainage lake, and the Fox River near the connecting channel with Waterford Lake is a shallow, lowland drainage lake. Currently, the Fox River and Tichigan Lake are on the Wisconsin 303(d) list as impaired due to phosphorus and polychlorinated biphenyls (PCBs).

Tichigan Lake Water Quality Analysis

Tichigan Lake Long-term Trends

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. For Tichigan Lake, Wisconsin DNR staff, volunteers from Tichigan Lake, and Onterra staff have been collecting some of these parameters for most years since 1988, building a continual dataset that will yield valuable information on Tichigan Lake's water quality through time. For Waterford Lake and the Fox River channel near Waterford Lake data has only been collected in 2018.

Total Phosphorus

Near-surface total phosphorus data from Tichigan Lake are available from 1973 and 1974 and annually from 1994 to 2018. The values for 1973 and 1974 are considerably higher (equal to or greater than 100 µg/L) than concentrations measured since 1993. Since these values differ so much from the concentrations in the last 25 years they will not be discussed further. Average summer total phosphorus concentrations ranged from 21 µg/L in 1996 to 69 µg/L in 2011 (Figure 3.1-3). The weighted summer average total phosphorus concentration is 41 µg/L, which falls into the *fair* category for Wisconsin's deep lowland drainage lakes. The lake's weighted summer average total phosphorus concentration is greater than both the median value for other deep lowland drainage lakes in the state and the median value for all lake types within the SWTP ecoregion.

As discussed in the previous section, internal nutrient loading is a process by which phosphorus (and other nutrients) are released from sediments when bottom waters become devoid of oxygen (anoxic). Internal nutrient loading is more prevalent in deeper lakes which experience summer stratification or in shallow lakes that are highly productive where high rates of decomposition deplete oxygen near the sediment-water interface. To determine if internal nutrient loading of phosphorus is occurring in a stratified lake, phosphorus concentrations are measured near the bottom in the deepest part of the lake. In lakes which experience high levels of internal nutrient loading, the near bottom phosphorus concentrations are significantly higher than those measured near the surface.

Figure 3.1-4 displays near-surface and near-bottom total phosphorus concentrations collected from Tichigan Lake in 1973-75, 1994-98, 2004, 2016, and 2018. As illustrated, in every year except during winter and spring turnover, the near-bottom total phosphorus concentration is much higher than the values measured near the surface. This indicates that phosphorus is being released from bottom sediments into the hypolimnion. Although some internal loading is occurring, it is unclear how much this contributes to the total phosphorus budget. In some years, Tichigan's water quality is strongly influenced by water entering the lake from the Fox River, which is typically high in phosphorus and may make the internal load negligible.

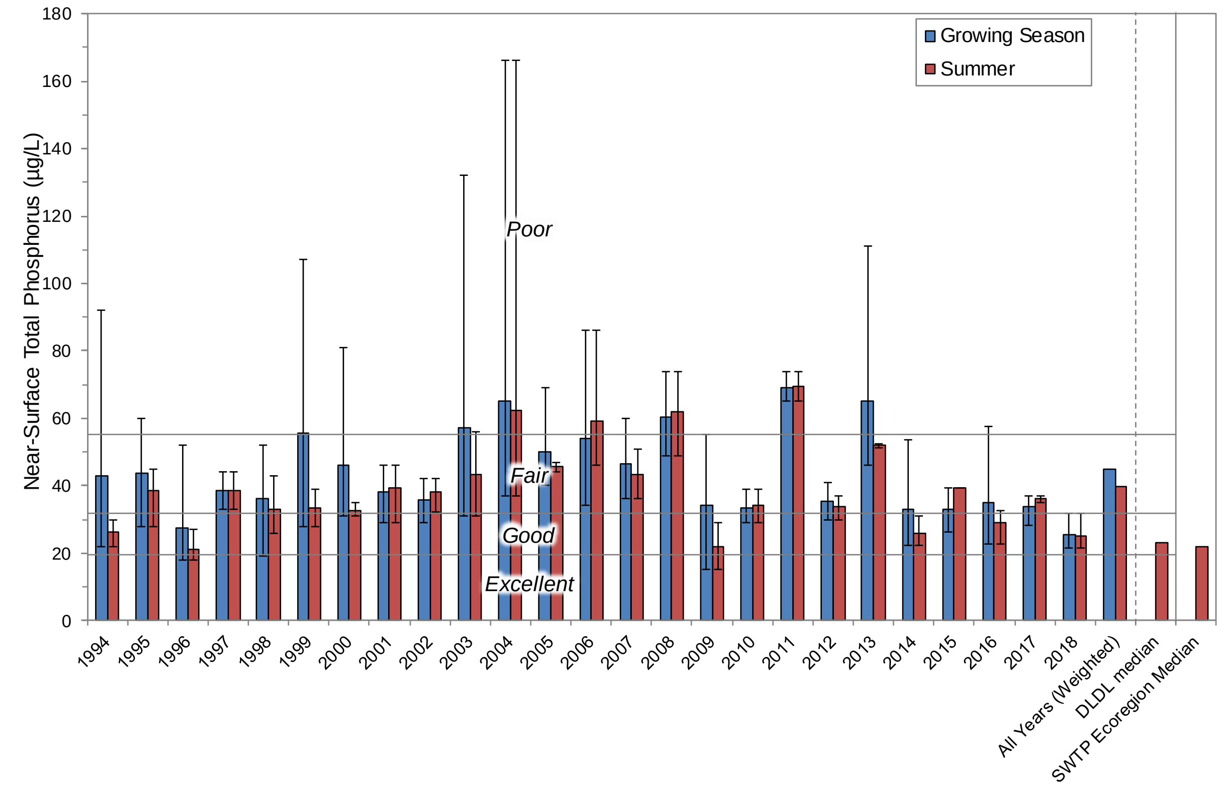


Figure 3.1-3. Total phosphorus concentrations in Tichigan Lake, state-wide deep lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

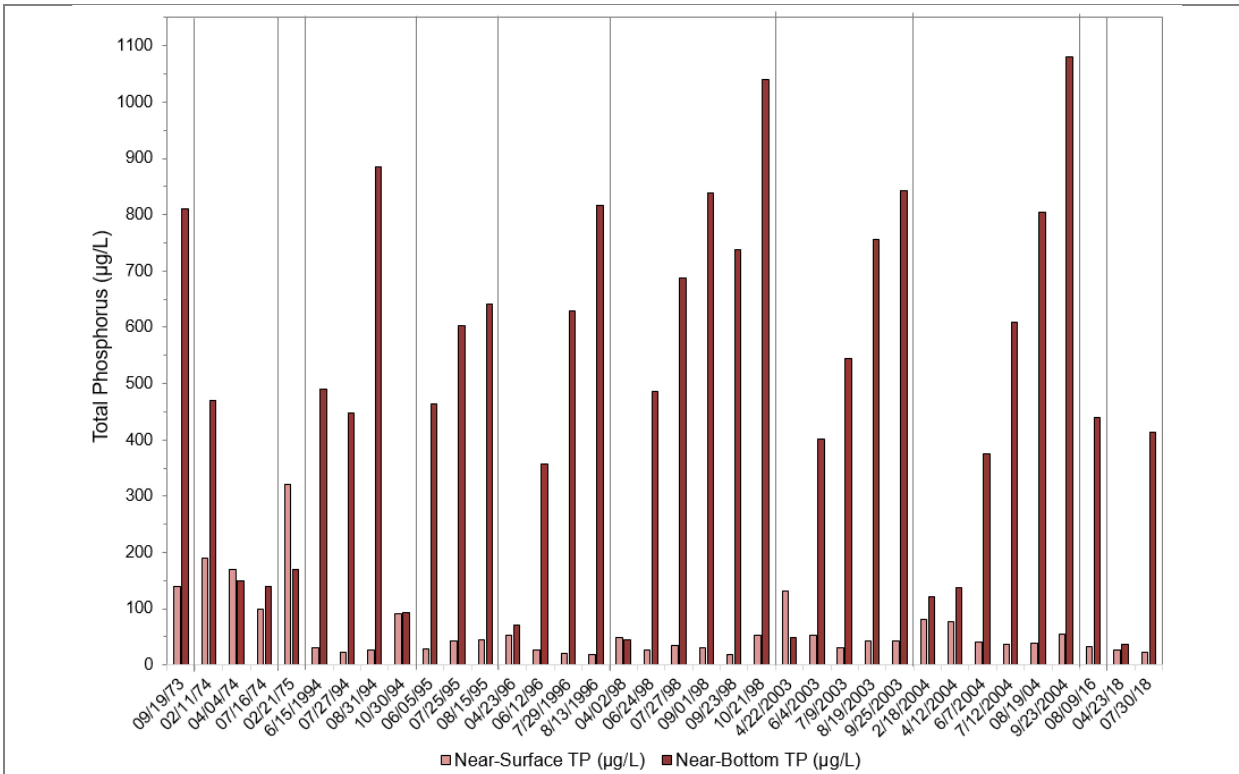


Figure 3.1-4. Tichigan Lake near-surface and near-bottom total phosphorus concentrations. All concentrations are actual values, not averages.

The Fox River does not flow directly through Tichigan Lake, but the river still has a significant impact on Tichigan's water quality. As an example, gage heights (water levels) at the Waterford Dam during the spring and summer of 2018 were examined in conjunction with phosphorus concentrations in the Fox River during the same timeframe. The close proximity of Tichigan Lake to the dam means that level fluctuations at the dam, with some delay, indicate similar fluctuations in Tichigan's water levels.

If water levels remain the same for extended periods of time, very little water, if any, water from the Fox River would make its way into Tichigan Lake; however, due to natural precipitation events, the water levels in the Fox River, and thus in Tichigan Lake, fluctuate to some level constantly. During the spring and summer of 2018, it was not uncommon to see water levels fluctuate by 0.3 feet over a few days. On June 28, 2018, the water level in the Fox River increased by 0.2 feet. Around that same time period, Tichigan Lake's level increased by roughly 0.2 feet as well and the primary source of that increase was Fox River water. The phosphorus concentration in the river channel on that date was measured at 144 µg/L, meaning that roughly 22 lbs. of phosphorus was added to Tichigan Lake during the event and likely quickly taken up by algae. While some of the phosphorus is returned to the river when levels recede, much of it stays in the lake due to biological uptake and settling.

Chlorophyll-α

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algal growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within a lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton, which feed on algae, also influence algal abundance.

Chlorophyll-*a* data are available annually for Tichigan Lake from 1993 through 2018 (Figure 3.1-5). Average summer chlorophyll-*a* concentrations ranged from 4 µg/L in 2009 to 85 µg/L in 2011. The weighted summer average total chlorophyll-*a* concentration was 18 µg/L and falls into the *fair* category for Wisconsin's deep lowland drainage lakes and indicates that Tichigan Lake's chlorophyll-a concentrations are higher than the median value for deep lowland drainage lakes in the state and is higher than the median value for all lake types within the SWTP ecoregion.

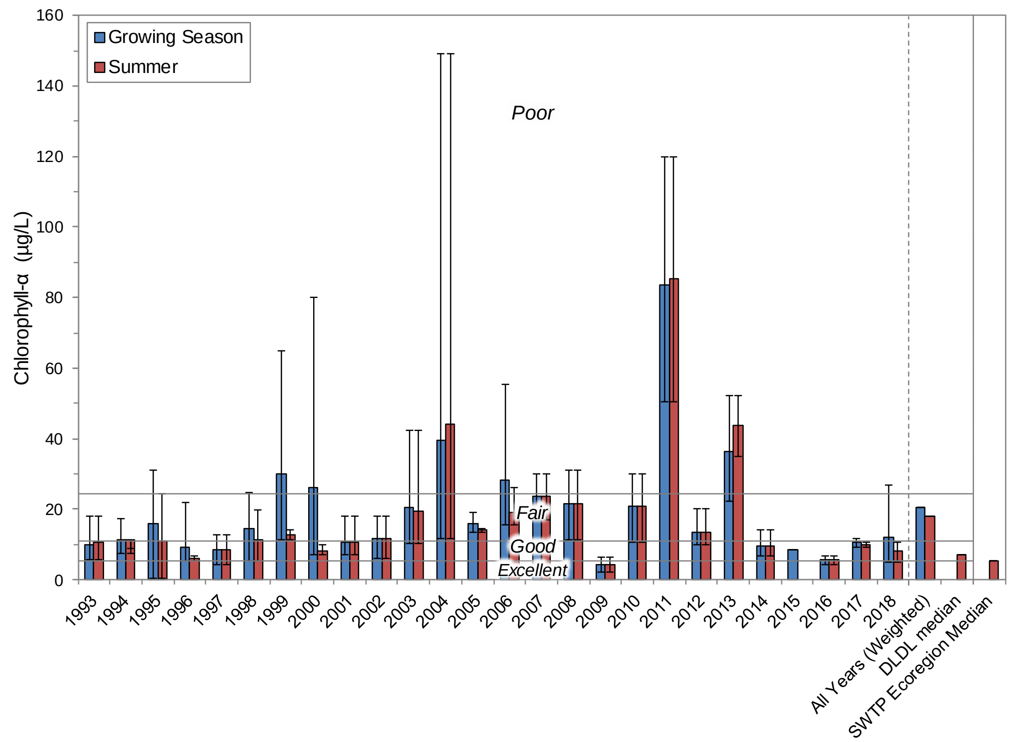


Figure 3.1-5. Chlorophyll-*a* concentrations in Tichigan Lake, state-wide deep lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water Clarity

Secchi disk transparency data are available from Tichigan Lake for 1973-74 and annually from 1988 to 2018, except for 1991 and 2015 (Figure 3.1-6). Average summer Secchi disk depths ranged from 2.0 feet in 1974 and 2.1 in 2011 to 10.9 feet in 2009. The weighted summer average Secchi disk depth was 5.4 feet and falls into the *good* category for Wisconsin's deep lowland drainage lakes. The lake's weighted summer average Secchi disk depth is worse than the median values for deep lowland drainage lakes in the state and for all lake types within the SWTP ecoregion. The poor water clarity in 1973 and 1974 supports the high phosphorus concentrations reported in those years. During the period 1989-2001 water clarity was generally in the *good* category while it was in the *fair* category during the period 2002-2008. Since 2008 water clarity has been more variable ranging from the *excellent* to the *poor* categories.

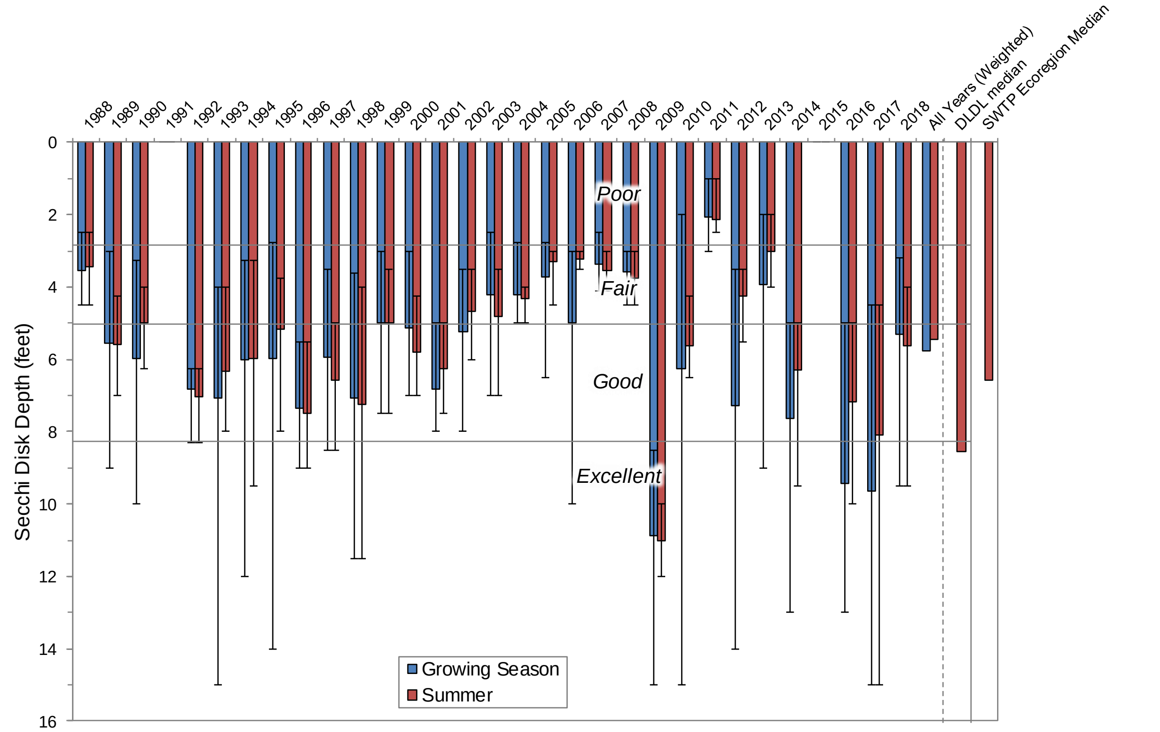


Figure 3.1-6. Secchi disc transparency depths in Tichigan Lake, state-wide deep lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Tichigan Lake

Using midsummer nitrogen and phosphorus concentrations from Tichigan Lake, a nitrogen:phosphorus ratio of 37:1 was calculated. This finding indicates that Tichigan 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.

Tichigan Lake Trophic State

Figure 3.1-7 contains the weighted average Trophic State Index (TSI) values for Tichigan Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-a, and Secchi disk transparency data collected as part of this project with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved compounds in the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The TSI values for Secchi disk transparency, chlorophyll-*a*, and total phosphorus concentrations are in the eutrophic range (Figure 3.1-7). The TSI was best in 2009 when it was in the mesotrophic range. The trophic state of Tichigan Lake is worse than other deep, lowland drainage lakes as well as lakes of all types in the SWTP ecoregion.

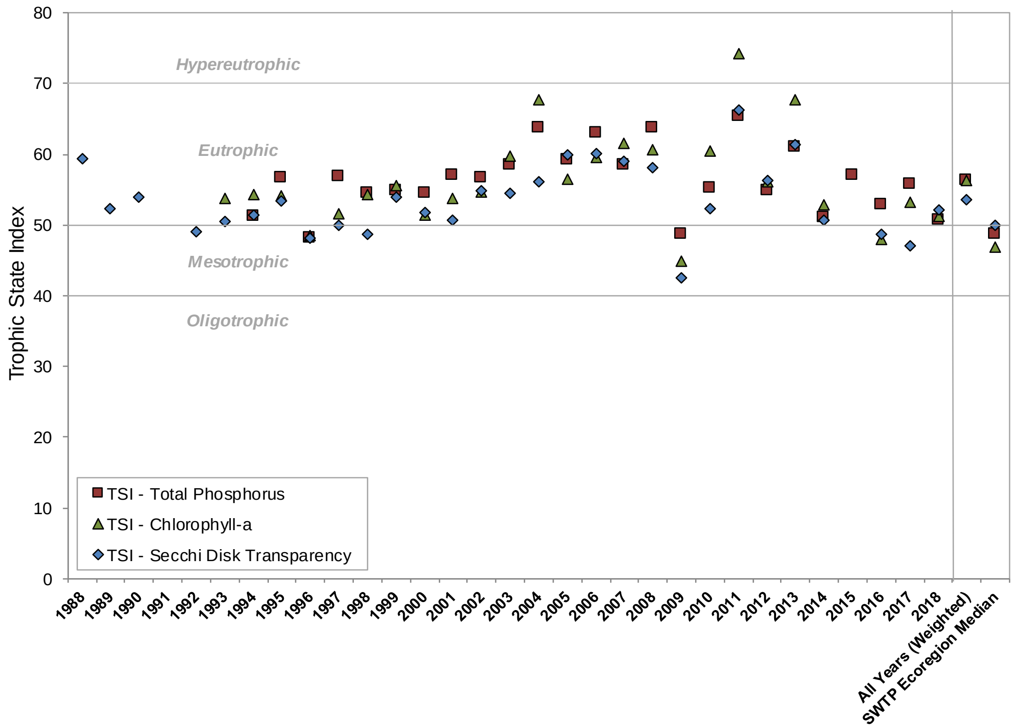


Figure 3.1-7. Tichigan Lake, state-wide class 5 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Tichigan Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Tichigan Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-8. Tichigan 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 Tichigan 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.

By the end of June much of the water column was devoid of dissolved oxygen. Only depths shallower than 15 feet contained enough oxygen to support fish. The long and extensive period of anoxia results in phosphorus being released from the bottom sediments as shown in Figure 3.1-4.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. As shown in Figure 3.1-8, the lake was completely mixed by mid-November.

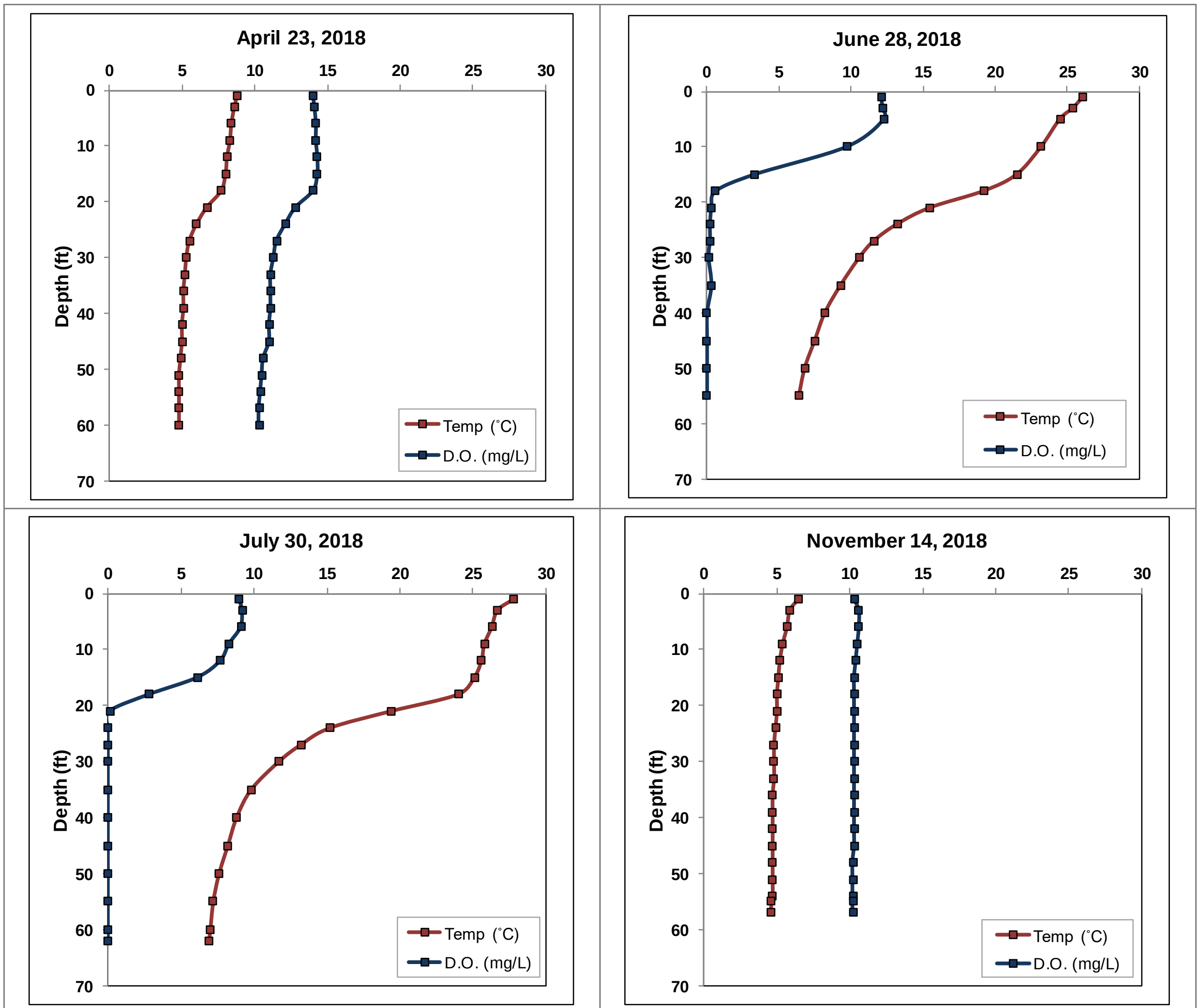


Figure 3.1-8. Tichigan Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Tichigan 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 Tichigan 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 and softwater 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 Tichigan Lake was found to be alkaline with a value of 8.5, and falls just within the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Tichigan Lake was measured at 204 mg/L (as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Tichigan Lake's pH of 8.4 falls inside of this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Tichigan Lake was found to be 55.5 mg/L, falling well into the optimal range for zebra mussels.

Zebra mussels (*Dreissena polymorpha*) are small bottom dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. 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.

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

Waterford Lake Water Quality Analysis

Waterford Lake Long-term Trends

Water quality samples were collected from Waterford Lake as well as in the Fox River near the outlet of the lake in 2018. These samples were used to assess the water quality conditions at each site as well as assess whether conditions were significantly different between the two sites. If conditions in the river are significantly better than the lake then it might be possible to improve conditions in the lake by augmenting the water in the lake with water from the Fox River.

Total Phosphorus

Near-surface total phosphorus data from Waterford Lake are available for 2016-2018. Phosphorus concentrations were relatively high in 2018 with the average summer concentration being 88.4 µg/L which places the lake in the *fair* category (Figure 3.1-9). The growing season concentration was 114.6 µg/L, which is in the *poor* category. Much of this elevated phosphorus likely enters the lake from the Fox River and not the nearshore area around the lake. The mean summer concentration is much higher than other shallow, lowland lakes and much higher than all lake types in the SWTP ecoregion.

In order to determine if internal loading via sediment release from the deeper water, near bottom samples were collected at the same time the surface samples were collected. Concentrations in the near bottom sample were very similar to concentrations near the surface indicating that there likely is no significant internal loading from the sediments (Figure 3.1-10).

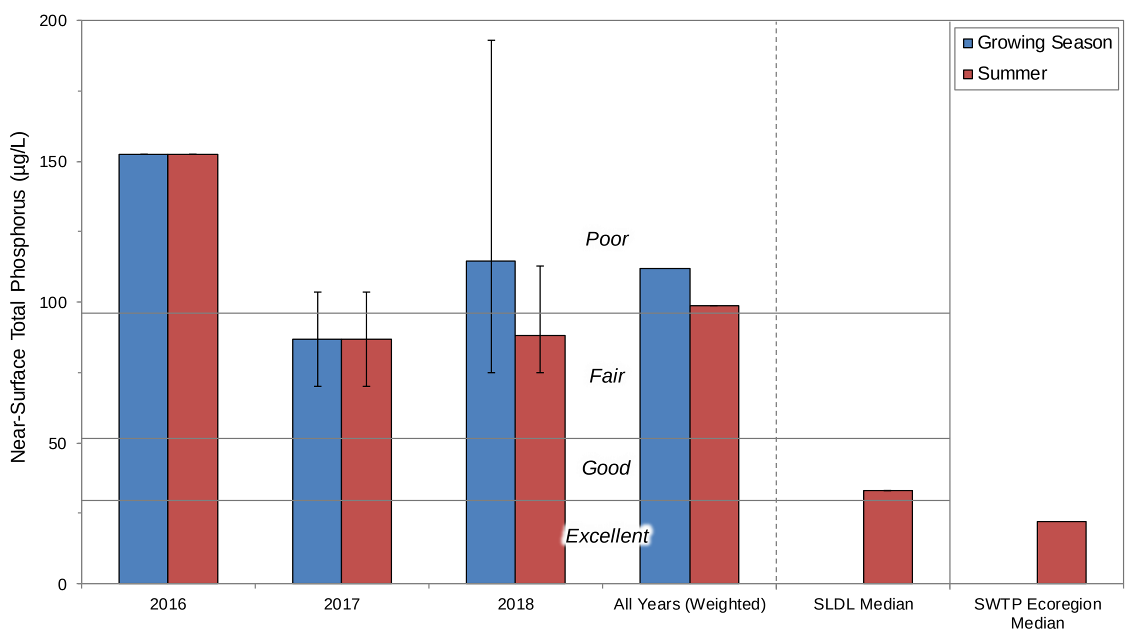


Figure 3.1-9. Total phosphorus concentrations in Waterford Lake, state-wide shallow, lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

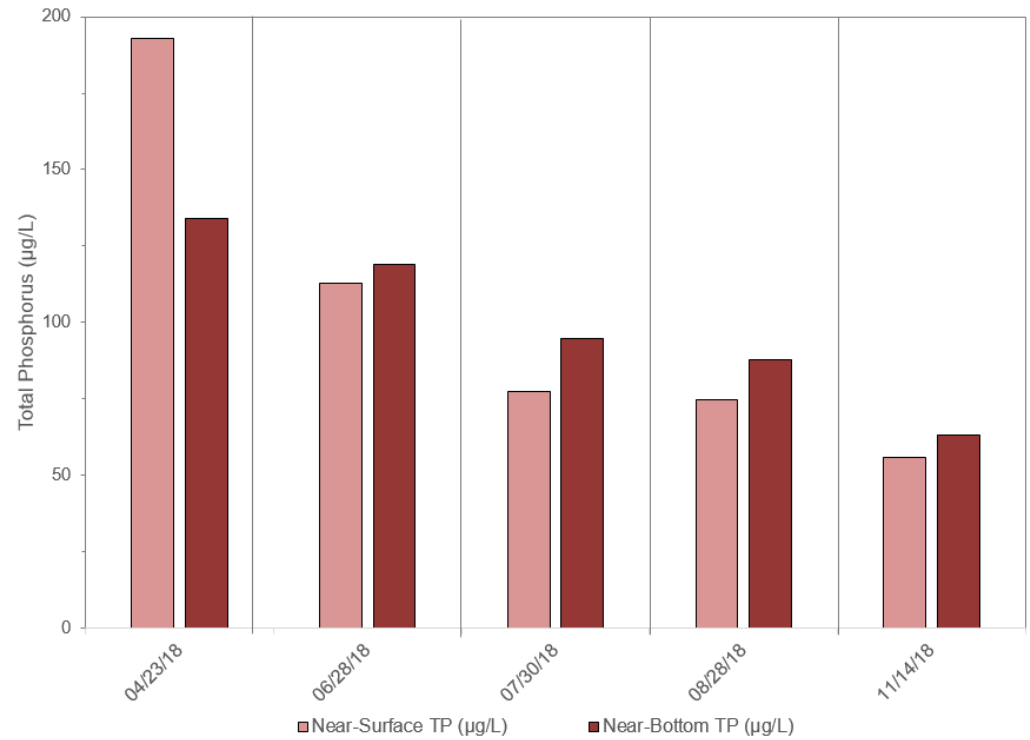


Figure 3.1-10. Waterford Lake near-surface and near-bottom total phosphorus concentrations. All concentrations are actual values, not averages.

During 2016 and 2017, the WWMD explored the use of lanthanum, sold under the trade name of Phoslock by SePro, Inc., to reduce internal phosphorus loading in Waterford Lake in the hopes of reducing algae blooms as well. Alum (aluminum-sulfate) is a more commonly used compound to minimize internal loading of phosphorus from bottom sediments. Lanthanum and the aluminum in alum, bind redox available phosphorus within the sediments and prevent it from recycling back into the water column. Because alum is a more commonly utilized product and has a proven track record, the WWMD was curious about potential costs of completing a properly dosed alum treatment on Waterford Lake.

Sediment cores were taken and analyzed from three sites in Waterford Lake to estimate how much of the type of phosphorus that can move from the sediments into the overlying water (redox-available phosphorus) is available. The cores were collected on April 23, 2018 and sent to the lab of William James at University of Wisconsin-Stout for analysis of the sediment. The sediment cores were sectioned into 1 cm intervals for the top 6 cm and then 2 cm intervals to 12 cm. The amount of loosely bound phosphorus and iron phosphorus were determined in each slice. These are the forms of sediment phosphorus that are likely to be released into the water column during anoxic conditions.

By knowing how much available phosphorus is in the sediments, the proper dosage of alum can be determined. Typically, the amount of phosphorus in the upper 10 cm is used to calculate the dosage. Experience has shown if the major sources of external phosphorus are small, an alum treatment is often effective for 10 to 20 years. For Waterford Lake, during high flow events in the Fox River, water and sediment enters Waterford Lake. This sediment would be expected to cover the alum layer and render it ineffective over time. Because the longevity is expected to be less than what is usually the case in other lakes, only the sediment phosphorus in the upper 5 cm was considered in calculating the amount of alum to add. By only including the phosphorus in the upper 5 cm of the sediments, the cost is greatly reduced. It was estimated the cost to treat Waterford Lake would be $30-35,000. If the amount of phosphorus in the upper 10 cm were used in the calculation the cost would likely exceed $120,000. The longevity of the alum treatment in Waterford Lake is difficult to estimate because the frequency or extent of high flows in the Fox River that will occur is unknown.

Modeling completed as a part of this project indicated that internal loading is not significant compared to the amount of phosphorus that enters the lake from the Fox River and the lake's watershed; therefore, a Phoslock or alum treatment would not work to reduce algal blooms in Waterford Lake. This subject is discussed in more detail in the Watershed Section 3.2.

Chlorophyll-a

Chlorophyll-*a* results are only available for 2018. Concentrations were quite high and variable. The mean summer concentration was 66 µg/L which places the lake in the *poor* category (Figure 3.1-11). Concentrations were highest in the spring and the fall when concentrations exceeded 150 µg/L. The summer mean concentrations was considerably higher than the median value for other shallow lowland drainage lakes and all lake types in the SWTP ecoregion.

Water Clarity

The mean summer Secchi disc transparency in Waterford Lake in 2018 was 1.7 feet which places the lake on the border between *poor* and *fair* categories Figure 3.1-12). The worst water clarity was in the spring and the fall when chlorophyll-*a* concentrations were the highest. The worst water clarity was measured on April 23, 2018 when it was 1.2 feet. The water clarity in Waterford Lake is much worse than the median value for other shallow, lowland drainage lakes and also much worse than all lake types in the SWTP ecoregion.

Limiting Plant Nutrient of Waterford Lake

Using summer nitrogen and phosphorus concentrations from Waterford Lake, a nitrogen:phosphorus ratio of 14:1 was calculated. This finding indicates that Waterford Lake is at times phosphorus limited and other times nitrogen limited. Although most lakes in Wisconsin are phosphorus limited, when algal levels are as high as they are in Waterford Lake, nitrogen limitation can occur.

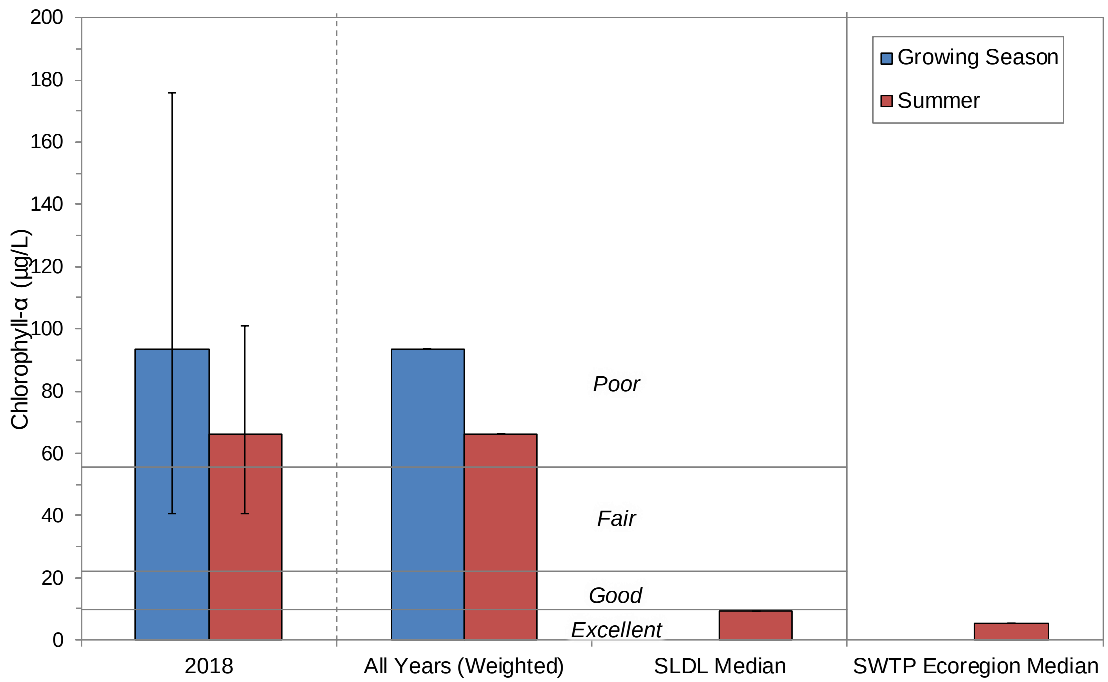


Figure 3.1-11. Chlorophyll-*a* concentrations in Waterford Lake, state-wide shallow, lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Figure 3.1-12. Secchi disc transparency depths in Waterford Lake, state-wide shallow lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Waterford Lake Trophic State

Figure 3.1-13 contains the weighted average Trophic State Index (TSI) values for Waterford Lake. These 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 assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved compounds in the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The TSI value places the lake on the border between eutrophic and hypereutrophic categories. This is trophic level is much worse than other shallow lowland drainage lakes as well as all lake types in the SWTP ecoregion.

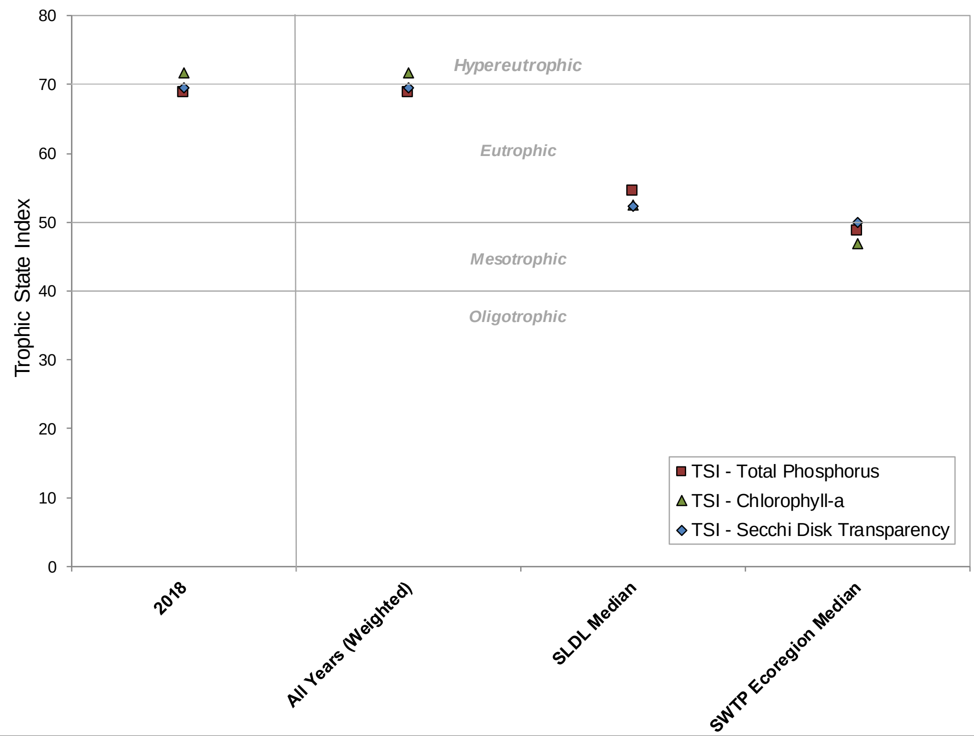


Figure 3.1-13. Waterford Lake, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Waterford Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Waterford Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-14. Waterford Lake is *polymictic*, meaning the lake frequently mixes throughout the ice free season. Dissolved oxygen levels in the upper 3 feet of the water column often exceeded 100% saturation because of the high algal levels. As the algae photosynthesize, they produce oxygen. In Waterford Lake the productivity was high enough during the day that equilibrium could not be maintained with the atmosphere. In April the oxygen levels exceeded the capacity of the meter (22 mg/L) to accurately measure the oxygen levels. There was always some oxygen recorded in the near bottom waters further indicating the lake is polymictic.

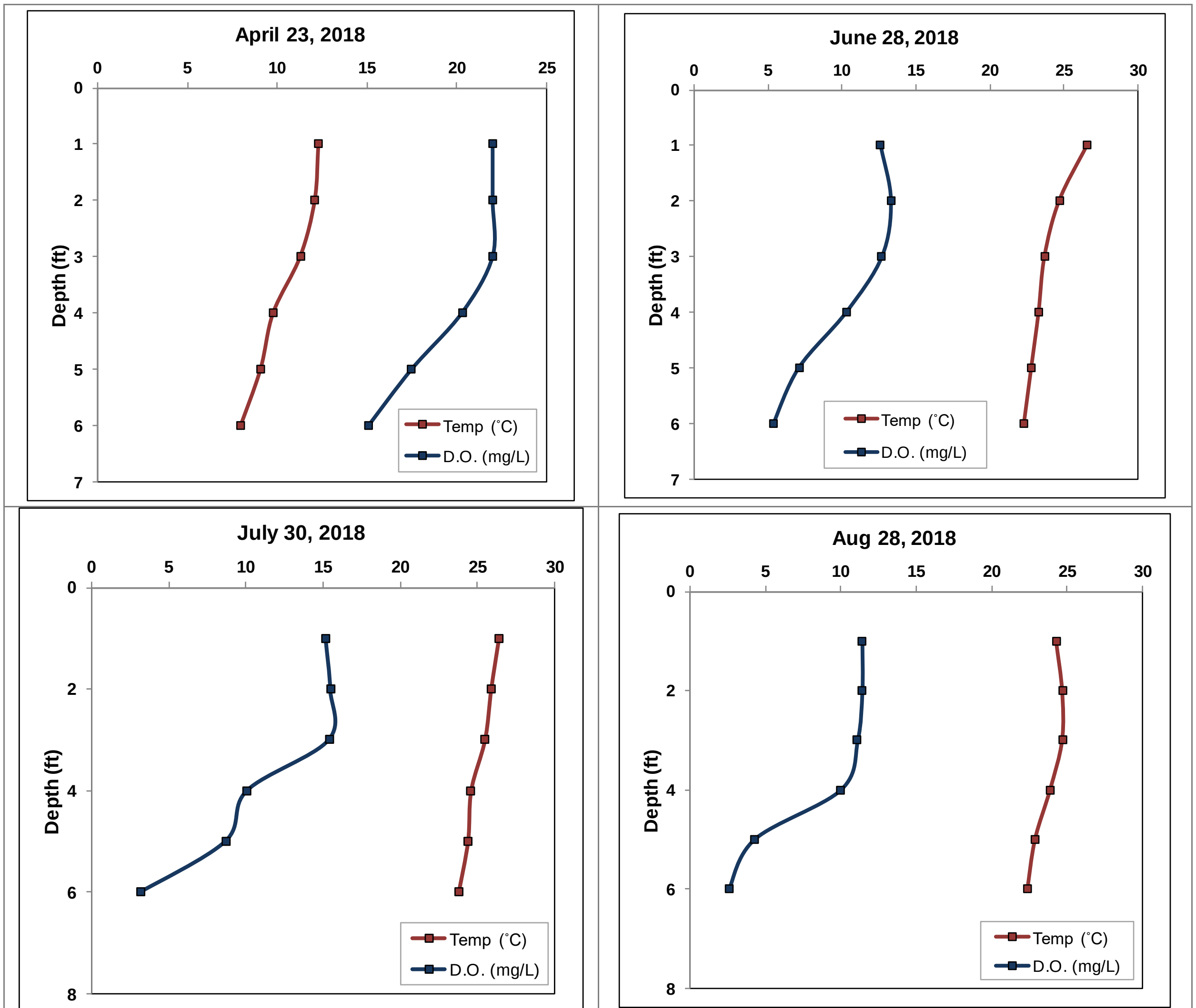


Figure 3.1-14. Waterford Lake dissolved oxygen and temperature profiles. Surface dissolved oxygen levels on April 23 were higher than the 22 °C shown but this was the maximum value the meter was able to display.

Additional Water Quality Data Collected at Waterford 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. While pH, alkalinity, and calcium were collected for Tichigan Lake, only pH was collected in Waterford Lake. 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 and softwater lakes. The pH of the water in Waterford Lake was found to be alkaline with a value of 9.1. This value is somewhat higher than many other Wisconsin lakes but reflects the high algal productivity that occurs in the lake. During photosynthesis, the algae remove CO_2 from the water which is an acid thus raising the lake's pH.

Fox River Channel Water Quality Analysis

Fox River Channel Long-term Trends

Water quality samples were collected from the Fox River near the connection with Waterford Lake in 2018 (Photograph 3.1-2). These samples were used to assess the water quality conditions at the site as well as assess whether conditions were significantly different between the two sites. If conditions in the river are significantly better than the lake then it might be possible to improve conditions in the lake by augmenting the water in the lake with water from the Fox River.

Total Phosphorus

Near-surface total phosphorus data from the Fox River are only available for 2018. Phosphorus concentrations were relatively high with the average summer concentrations being 110 µg/L which places the lake in the *fair* category (Figure 3.1-15). The early summer concentration was even higher, being 144 µg/L. The mean summer concentration is much higher than the median value for shallow, lowland drainage lakes throughout the state and much higher than all lake types in the SWTP ecoregion.

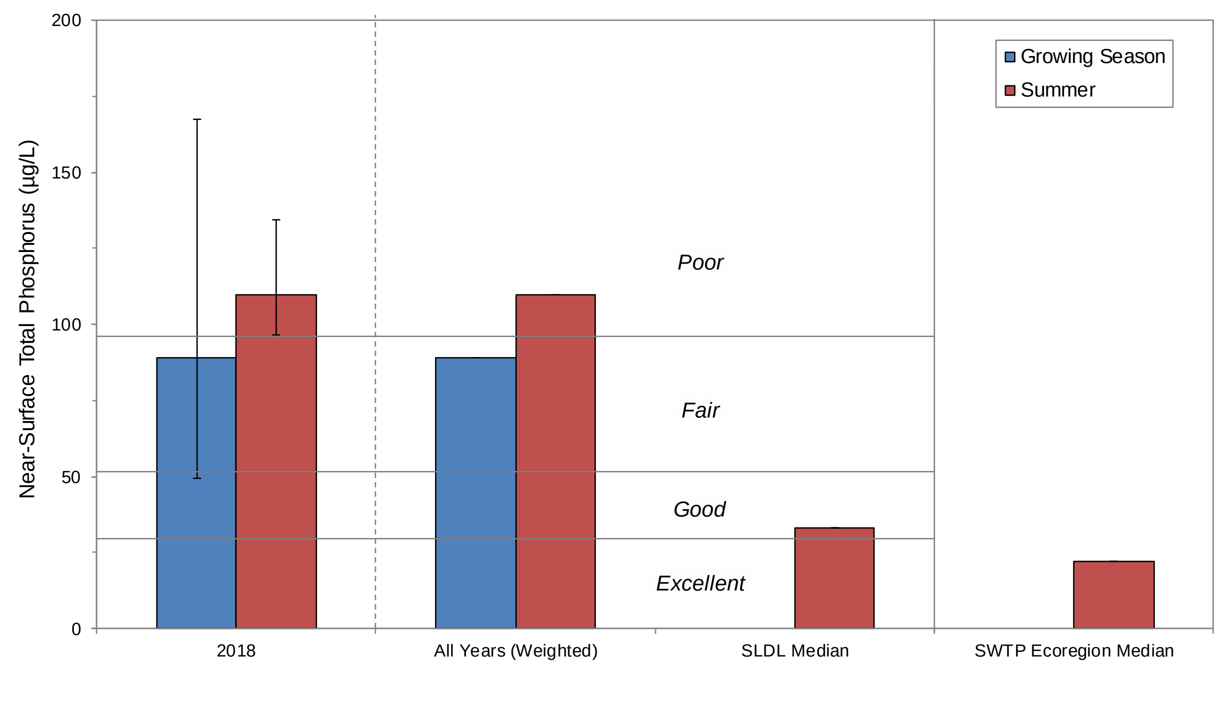


Figure 3.1-15. Total phosphorus concentrations in the Fox River, state-wide shallow, lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-a

As with phosphorus, chlorophyll-*a* results are only available for 2018. Concentrations were quite high and extremely variable. The mean summer concentration was 67 µg/L which places the river channel in the *poor* category (Figure 3.1-16). Concentrations were highest in June and July when concentrations were near 100 µg/L but in August and November they were less than 4 µg/L. The concentrations in the first half of the summer are the result of the high phosphorus concentrations. The much lower concentrations in August and November reflect the high flow rate of the river following periods of heavy rain. The increased flow essentially dilutes the resident algal populations and restricts algal growth. The summer mean concentrations was considerably higher than the median value for shallow, lowland drainage lakes and all lake types in the SWTP ecoregion.

Water Clarity

The mean summer Secchi disc transparency in the Fox River in 2018 was 2.4 feet which places the river in the *fair* category Figure 3.1-17). The worst water clarity was at the end of the July when the Secchi transparency was 1.8 feet and the best was in November when it was 5.9 feet. The water clarity in the Fox River is worse than the median value for shallow, lowland drainage lakes throughout the state and also worse than all lake types in the SWTP ecoregion.

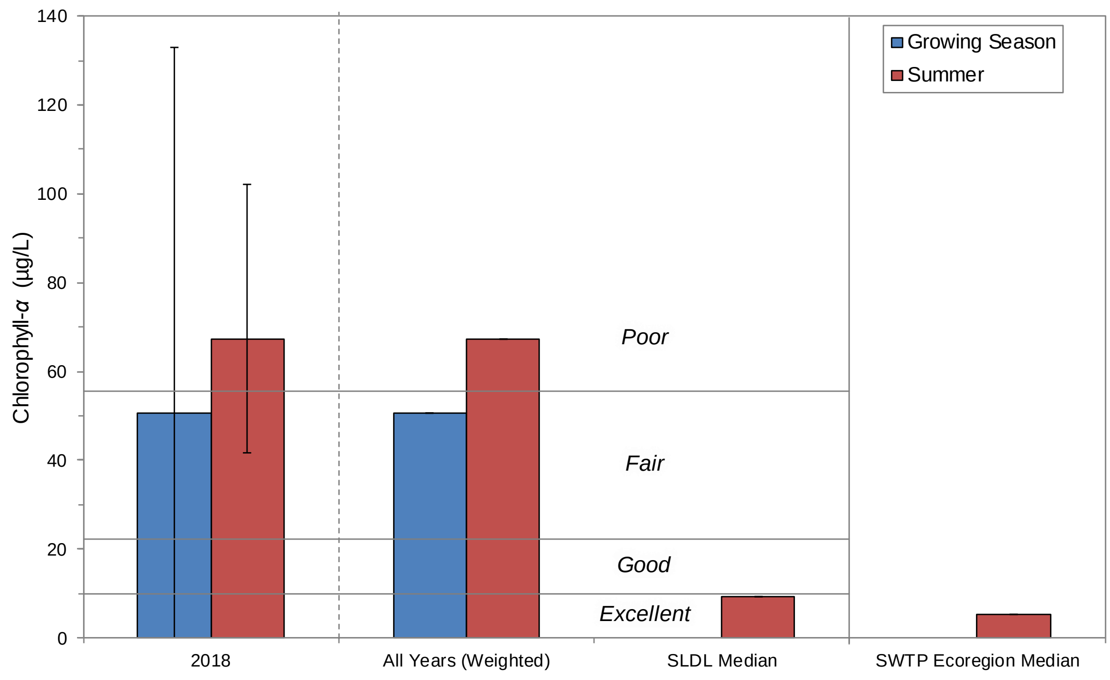


Figure 3.1-16. Chlorophyll-*a* concentrations in Fox River, state-wide shallow, lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

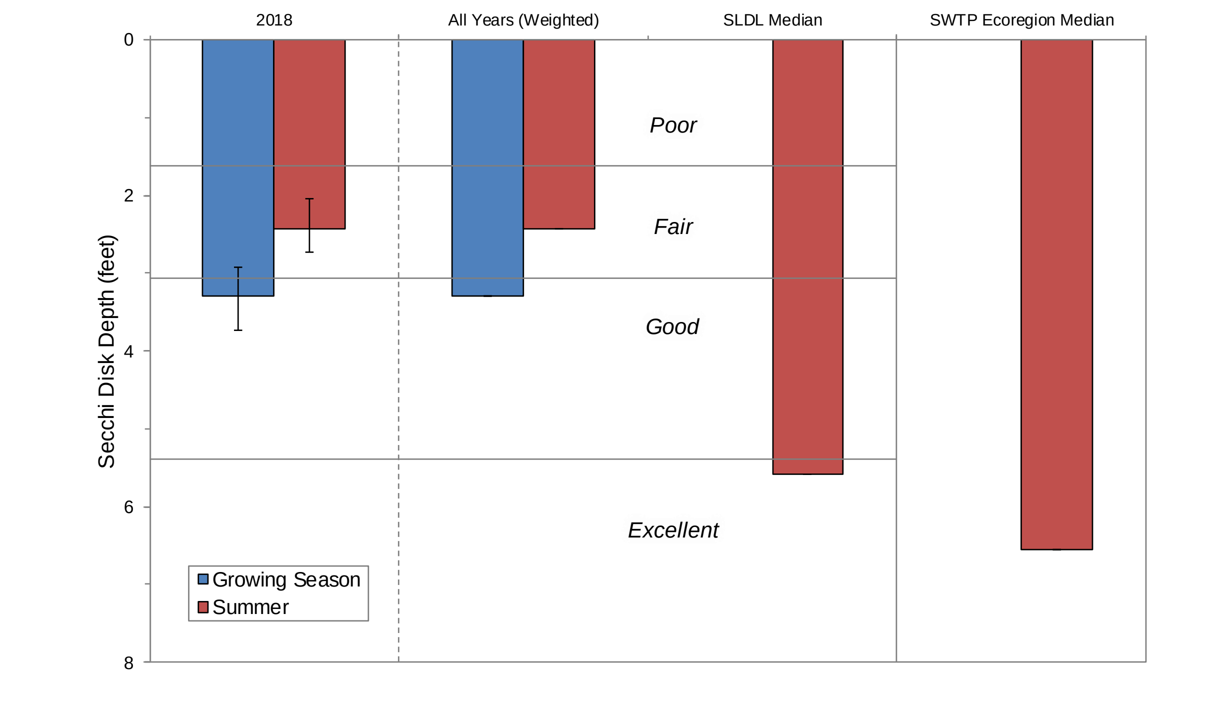


Figure 3.1-17. Secchi disc transparency depths in the Fox River, state-wide shallow lowland drainage lakes, and regional lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Fox River

Using summer nitrogen and phosphorus concentrations from the Fox River, a nitrogen:phosphorus ratio of 18:1 was calculated. This finding indicates that the river is at times phosphorus limited and other times nitrogen limited. Although most lakes in Wisconsin are phosphorus limited, when algal levels are as high as they are at times in the Fox River, nitrogen limitation can occur.

Fox River Trophic State

Figure 3.1-18 contains the weighted average Trophic State Index (TSI) values for the Fox River. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-a, and Secchi disk transparency data collected as part of this project with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved compounds in the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The TSI values place the river on the border between eutrophic and hypereutrophic categories. This trophic level is much worse than shallow lowland drainage lakes throughout the state as well as all lake types in the SWTP ecoregion.

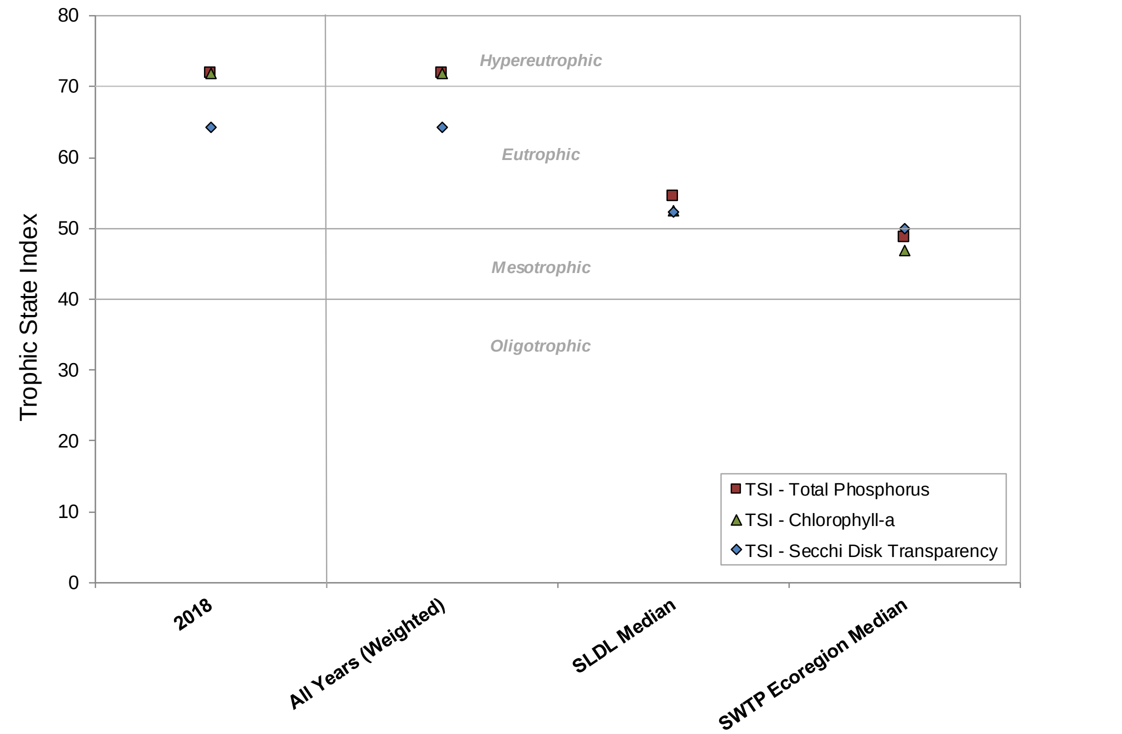
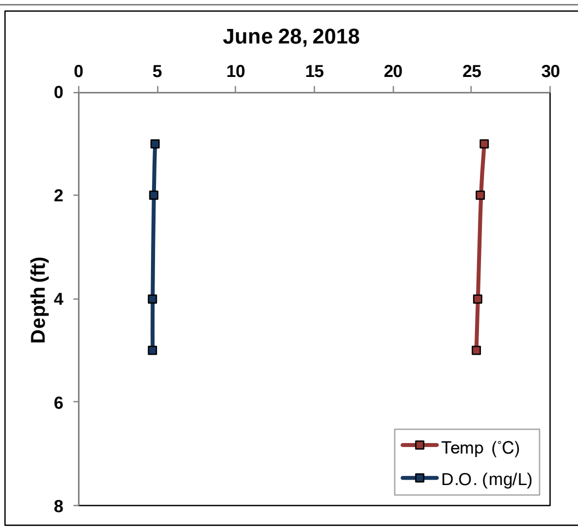
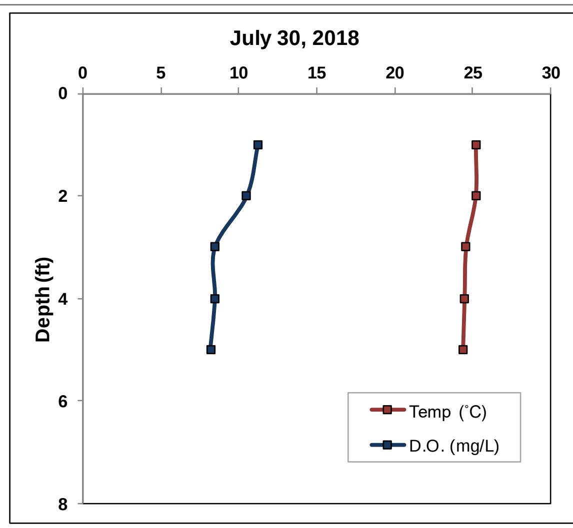


Figure 3.1-18. Fox River Channel, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Fox River

Dissolved oxygen and temperature were measured during water quality sampling visits to the Fox River by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-19. The Fox River at this site is *polymictic*, meaning the river frequently mixes throughout the ice free season. Even though the water depth at this site is similar to the depth in nearby Waterford Lake, temperature and oxygen levels at the top and bottom of the river site are more similar than the lake. This is because the lake is more isolated from wind than the river and there is always a significant current in the river which keeps it mixed.





Onterra LLC
Lake Management Planning

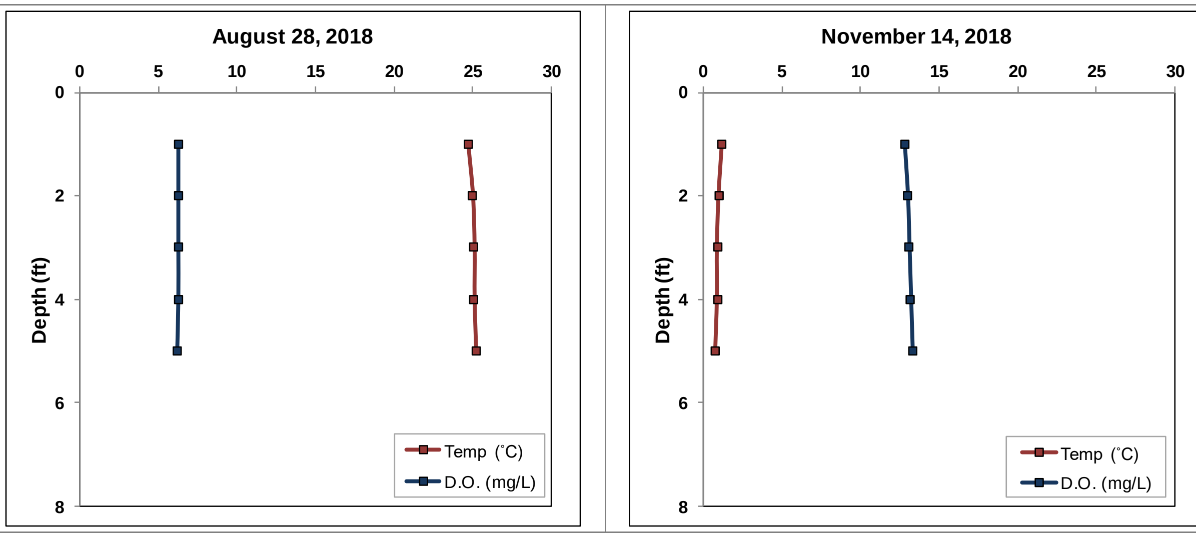


Figure 3.1-19. Fox River dissolved oxygen and temperature profiles. The river was always mixed with oxygen levels and temperatures being similar at the top and bottom of the water column.

Comparison of Water Quality of Waterford Lake and the Nearby Fox River

The reason for sampling the Fox River near the connecting channel with Waterford Lake in 2018 was to explore the possibility of augmenting the movement of water from the river through the lake to improve the water quality of the lake. At the present time there is some movement of water from the river into the lake via a channel under Riverside Road. Figure 3.1-20 shows a comparison of total phosphorus, chlorophyll-*a*, and Secchi disc transparency for the summer months and November. During the period June-August, phosphorus concentrations were always higher in the river compared with the lake. Chlorophyll-*a* values were higher or similar to the lake in June and July but they were much lower in the river in August and November. Water clarity was usually better in the river compared with the lake.

It is likely that concentrations in the river are, at least partly, controlled by water flow. During periods of high flow, chlorophyll-*a* may be suppressed as the high flow reduces the ability of algae to grow and also during high flow more non-algal turbidity may be in the river water which would reduce the amount of light available for algal growth. Based upon the data available in 2018, there is not a significant difference between the water quality in the river and that in Waterford Lake. Based on the 2018 data, it does not appear that increasing the flow of water from the river into Waterford Lake would improve the lake's water quality or reduce the incidence of algal blooms.

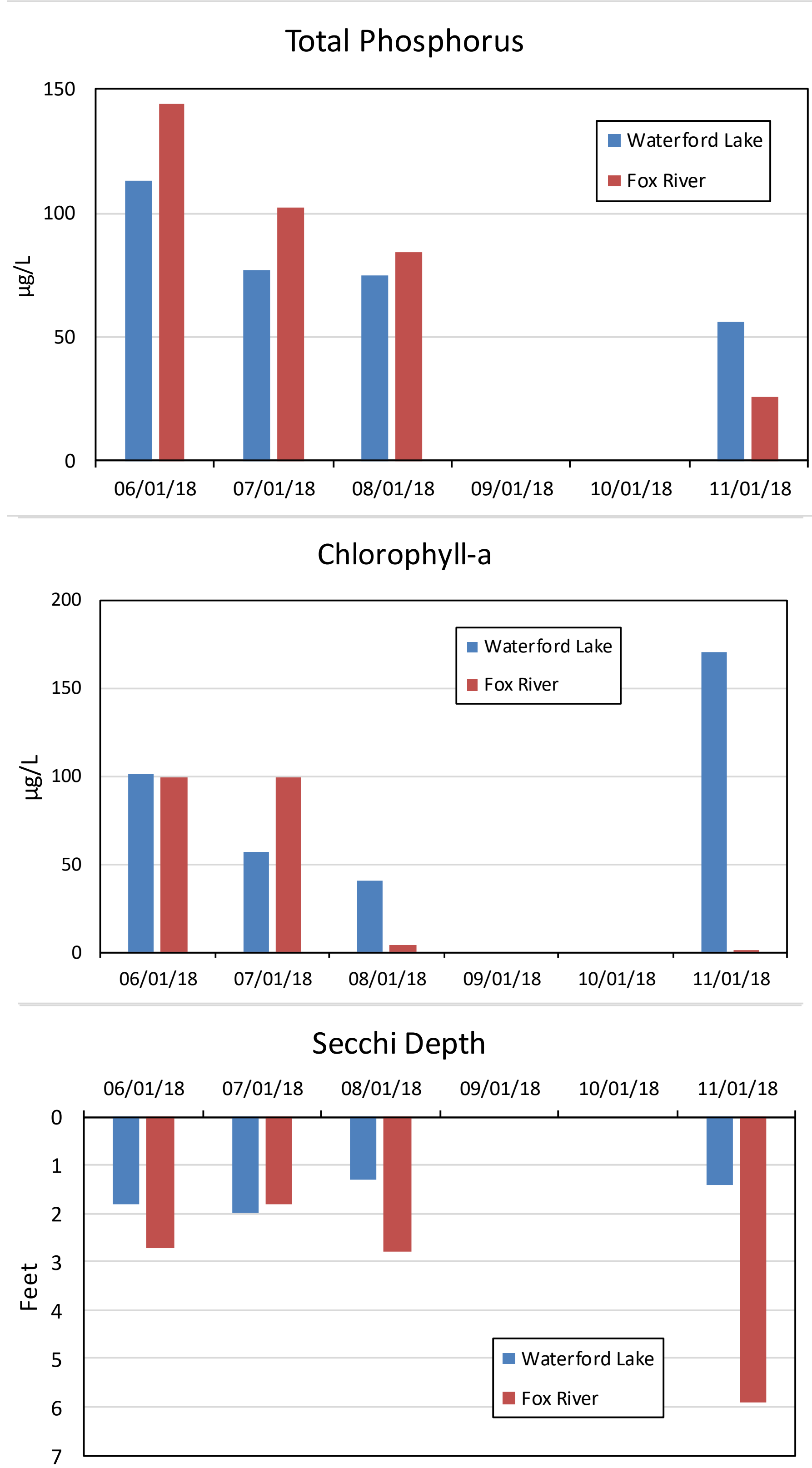


Figure 3.1-20. Comparison of trophic parameters between Waterford Lake and the Fox River near the outlet channel of the lake.

Onterra LLC
Lake Management Planning

Stakeholder Survey Responses to Waterford Waterway 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. Figures 3.1-8 and 3.1-9 display the responses of members of the Waterford Waterway stakeholders to questions regarding water quality and how it has changed over their years visiting the Waterford Waterway.

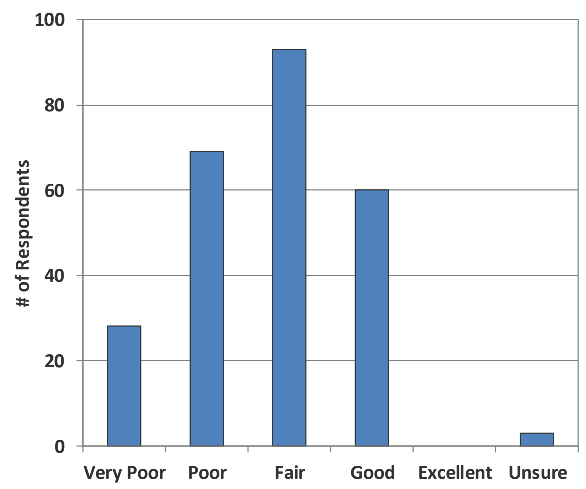


Figure 3.1-21. Stakeholder survey response Question #21. How would you describe the current water quality of Waterford Waterway?

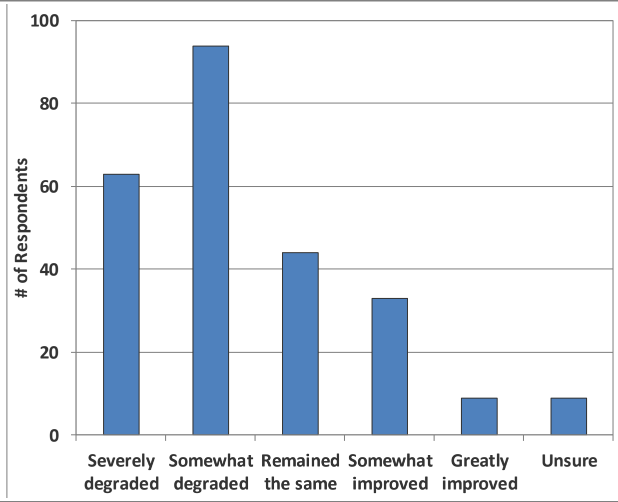


Figure 3.1-22. Stakeholder survey response Question #22. How as the water quality changed in Waterford Waterway since you first visited the lake?

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

A reliable and cost-efficient method of creating a general picture of a watershed's 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.

The impounded area known as the Waterford Waterway receives the vast majority of its water from the approximately 356 sq. mi. watershed that drains towards the Waterford Dam, including the water draining through Buena, Tichigan, and Waterford lakes (Map 2). The Waterford Waterway includes approximately 1,229 surface water acres; therefore, approximately 186 acres of land drain to each acre of the impoundment. That is an incredibly high watershed to lake area ratio. Based upon landcover data derived from 2011 satellite imagery (NLCD – Fry et. al 2011), the impoundment itself accounts for 1% of the watershed, while roughly 28% of the land is used for row crop agriculture, 23% is in pasture/grass, 17% is forested, 12% is in wetlands, 12% is developed as rural residential areas, and the remaining 7% are in medium- and high-density urban development. Waterford Waterway is a complicated system comprised of essential three lakes and a large, impounded area of the Fox River. While it is somewhat considered as a single system for the development of this plan, it is definitely is much more complicated; therefore WiLMS, would likely not provide an accurate assessment of the phosphorus entering the impoundment as a whole. However, modeling the two primary watersheds separately; the one draining primarily through the Fox River and entering the impoundment at the north end of Conservancy Bay, and the watershed draining into Tichigan Lake, does provide some insight to the impact the surface drainage has on these systems.

Figure 3.2-1 depicts the landcover types found in the drainage basin entering the Waterford Waterway primarily through the Fox River. To be clear and as shown in Map 2, it is the Waterford Waterway watershed, excluding Tichigan Lake watershed. As with the full watershed, the largest components are row crop agriculture (28%), pasture/grass (23%), forested (17%), wetlands (12%), and rural residential areas (12%). The remaining areas are in medium- (5%) and high-density urban development (2%) and the impounded waters (1%). Figure 3.2-2 shows the modeled contribution that each of those landcover types makes to the overall annual phosphorus load of just over 89,000 lbs (44.5 tons). It is interesting to note that while row crop agriculture occupies just over a quarter of the watershed area, it accounts for over 60% of the phosphorus load. Further, forested areas account for 17% of the landcover, but only contribute 4% of the load.

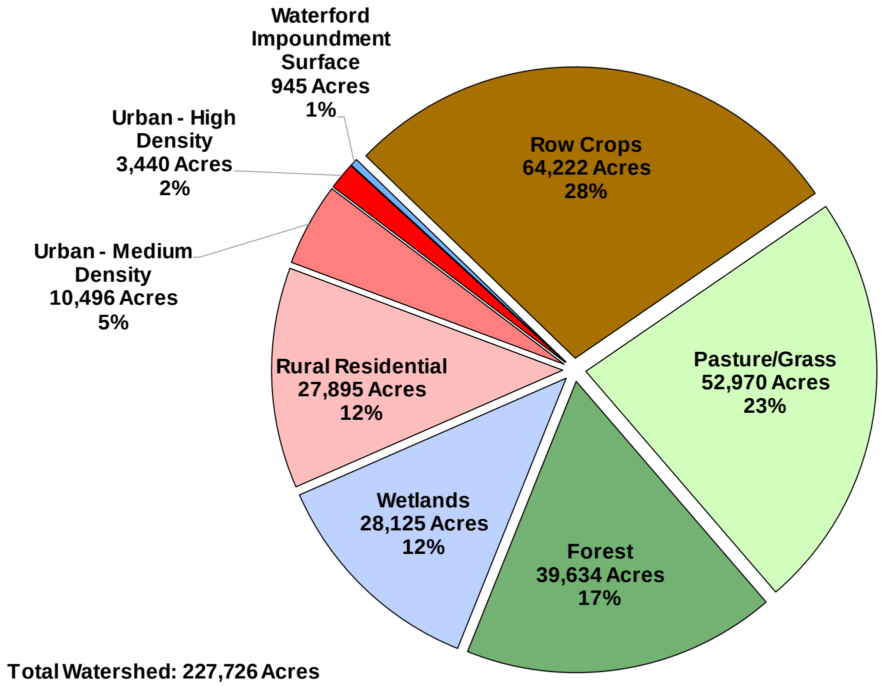


Figure 3.2-1. Waterford Waterway watershed, excluding Tichigan Lake watershed, land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

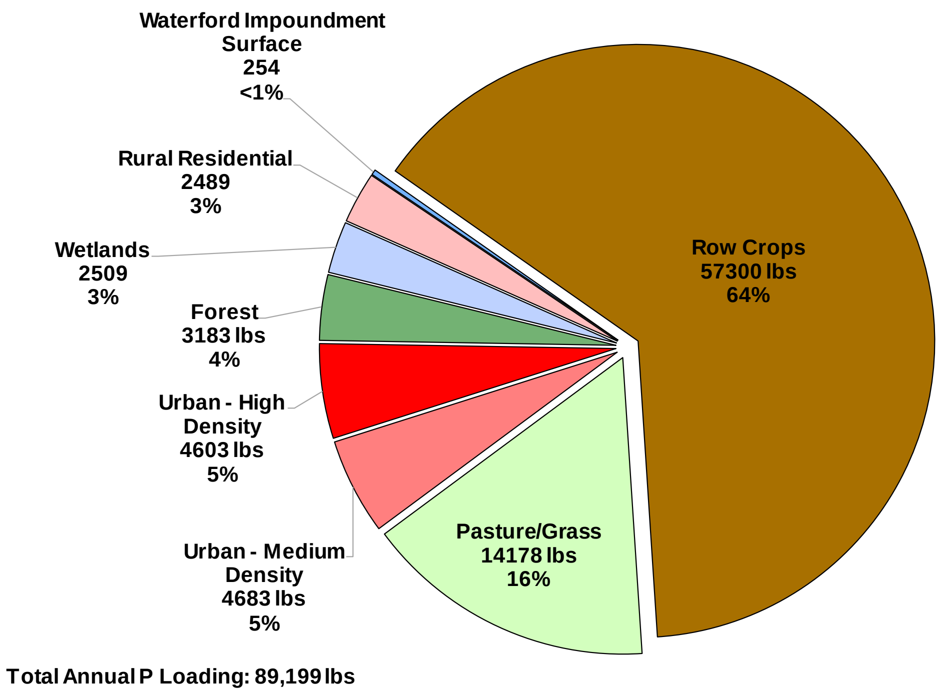


Figure 3.2-2. Waterford Waterway watershed, excluding Tichigan Lake watershed, phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

It must be noted that adding 44.5 tons of phosphorus to a waterbody is incredibly high, but because the waterway this drainage basin feeds is primarily riverine in nature, it does not have the same impacts on the biology of the system, especially considering aquatic plants, that it would if it were added to a lake of the same acreage. This is because the massive watershed replaces the water within the system (not including Tichigan Lake in this case), approximately once in every seven days. Systems with a flushing rate faster than 14 days, like rivers, typically are not able to build tremendous algal populations. However, this portion of the Waterford Waterway includes many backwater areas, like Buena Lake, Fowlers and Elm Island bays, and Waterford Lake. These areas do not necessarily have the flushing rates likely seen in the main channel, but to some extent, are impacted by the tremendous phosphorus load entering the system from the watershed as described near the end of this section for Waterford Lake.

Tichigan Lake's direct watershed encompasses an area of approximately 1,570 acres, yielding a small watershed to lake area ratio of approximately 5.5:1 (Map 2). In other words, approximately 5.5 acres of land drain to every one acre of Tichigan Lake. Approximately 23% of Tichigan Lake's watershed is composed of pasture/grass, 22% of row crops, 18% of the lake's surface, 16% of rural residential areas, 15% of forest, 3% of medium urban density, 3% of wetlands, and less than 1% of urban high density (Figure 3.2-3, left). Under natural conditions, Tichigan Lake would be estimated to have a water flushing rate of 0.22 times per year, which means that water would remain in the lake about 4.5 years before leaving. However, as explained below, since the creation of the Waterford Impoundment, the Fox River now impacts Tichigan's hydrology as well as its chemistry.

Tichigan Lake is connected to the Fox River by a fairly wide channel. It is very likely that at times water flows from the river into the lake. A circa 1980 study was conducted by the former Office of Inland Lake Renewal to estimate if a significant amount of water enters the lake from the river. At that time, it was estimated that when the river is at higher stages, water does flow from the river into the lake and this was indeed a significant source of phosphorus in some years (D. Knauer, personal communication). The option of installing gates was explored to prevent the inflow of river water but the structures were never installed.

In 2018, phosphorus samples were collected from the Fox River at Bridge Road which just upstream of Tichigan Lake as well as near where the culvert connecting Waterford Lake with the river, which is downstream of Tichigan Lake. The channel which connects Tichigan Lake with the Fox River allows water to flow between the two water bodies. Since water seeks its own level, when the level of the river rises water flows from the river into the lake. The USGS maintains a station on the Fox River at the Waterford Dam to measure the water level of the river. During the period February through October there were numerous times when the river level rose (Figure 3.2-4). In 2018, the phosphorus concentration of the river water for most of the summer was very high. It is likely that when the water level of the river rises, water flows from the river into the lake. Conversely when the level of the river falls, water flows from the lake into the river. In 2018 phosphorus concentrations were determined in the river five times. Based upon the height the river rose, the phosphorus concentration in the river, and the area of Tichigan Lake, the amount of phosphorus entering the lake from the river was estimated for the period of February through October. A specific example for a single event can be found in the Tichigan Lake water quality discussion (Section 3.1).

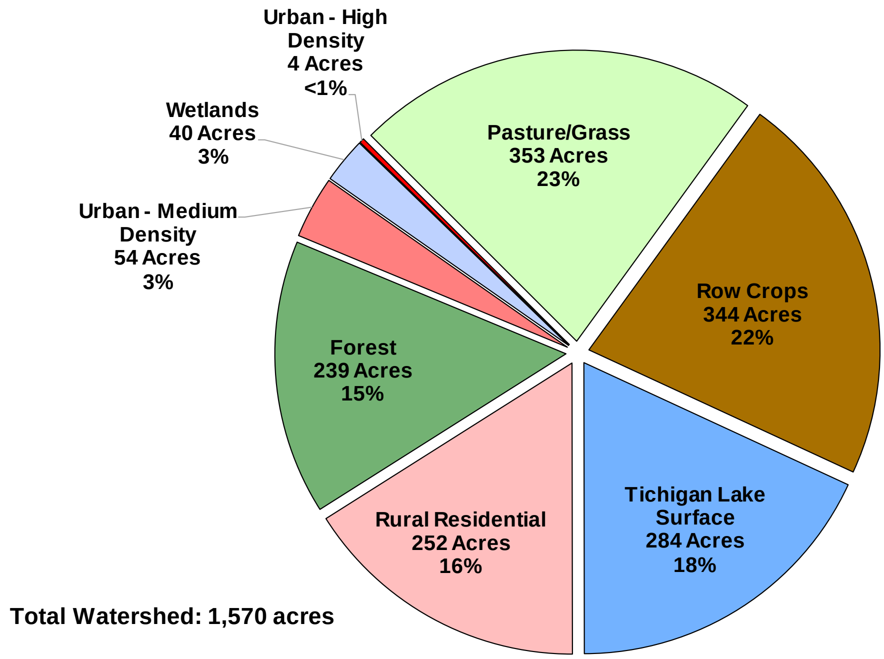


Figure 3.2-3. Tichigan Lake watershed, land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

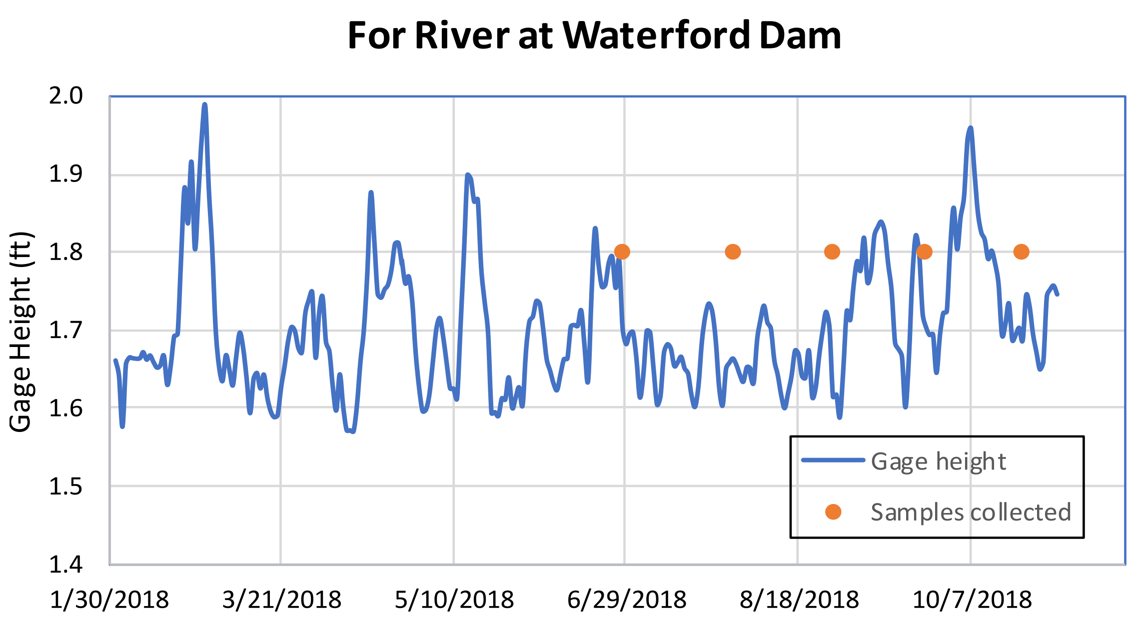


Figure 3.2-4. The gage height of the Fox River at the Waterford Dam and dates when phosphorus samples were collected from the river. There were a number of times when the river level rose which would cause water to enter the lake from the river.

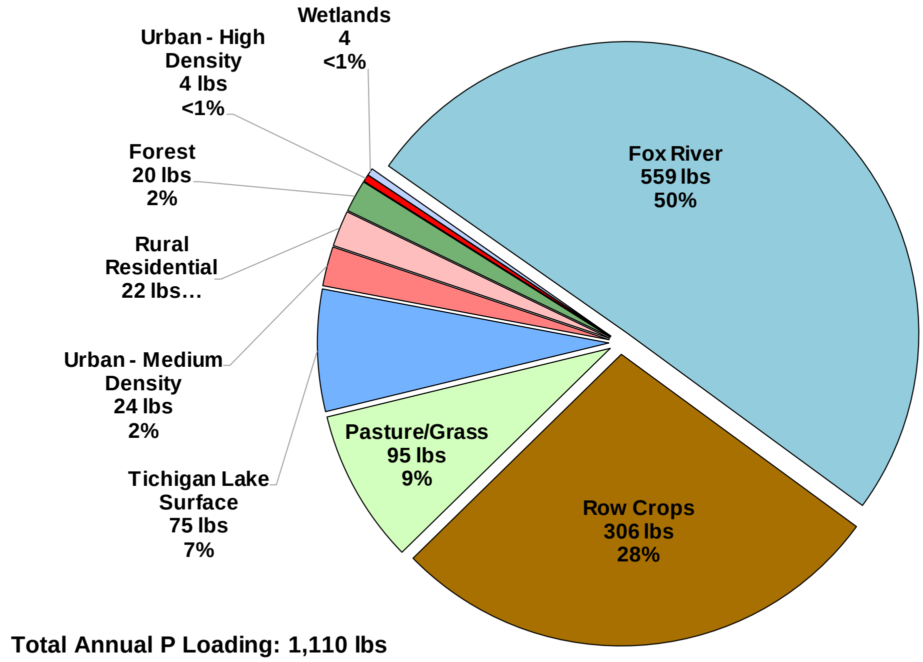


Figure 3.2-5. Tichigan Lake external phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Utilizing the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Tichigan Lake's watershed. In 2018 it is likely that a significant amount of phosphorus entered the lake from the Fox River (Figure 3.2-2). It is estimated that this contributed 50% of the annual phosphorus load. The land uses of row crops and pasture/grass where the next largest contributors to the phosphorus load.

It is likely that the amount of phosphorus entering the lake from the Fox River is considerably variable from year to year. In years with low flows it is likely very little river water enters the lake. In years with higher flows much more water enters the lake from the river. This is likely why phosphorus levels in the lake are so variable from year-to-year (Figure 3.1-3).

The sources of phosphorus to Waterford Lake are 1) the watershed immediately around the lake, 2) precipitation falling on the lake, 3) internal loading from the lake sediments, and 4) input from the Fox River through the culvert under Riverside Road.

The watershed around Waterford Lake is 32 acres and entirely residential. Since the landuse is moderately developed residential, a runoff coefficient of 0.45 pounds/acre was used. Water that falls on the 5-acre lake surface. The precipitation contains dust and other particles which contain phosphorus. Also, dust falls on the lake even when there is no precipitation. The coefficient used for the phosphorus falling on the lake surface is 0.27 lbs/ac.

It is likely that some phosphorus is released from the lake sediments when the bottom waters are devoid of oxygen (anoxic). When Onterra staff sampled the lake in 2018 there was always some oxygen in the deepest waters, but it is likely anoxia occurs at times, especially during nighttime and on days when there is minimal wind. Because Onterra staff did not directly observe anoxia when phosphorus samples were collected it is difficult to know exactly how much internal loading of phosphorus occurs. We know from the sediment study that was conducted to determine how much alum should be used in the lake, which is discussed below, that there is considerable phosphorus in the sediments. For this study we used a phosphorus release rate of 13 mg/m^2/day, which is on the high end of what is reported in the literature.

The culvert which connects Waterford Lake with the Fox River allows water to flow between the two water bodies. Since water seeks its own level, when the level of the river rises water flows from the river into the lake. The USGS maintains a station on the Fox River at the Waterford Dam to measure the water level of the river. During the period February through October there were numerous times when the river level rose (Figure 3.2-4). In 2018, the phosphorus concentration of the river water for most of the summer was very high. It is likely that when the water level of the river rises, water flows from the river into the lake. Conversely, when the level of the river falls, water flows from the lake into the river. In 2018 phosphorus concentrations were determined in the river five times. The samples in June, July, and August were collected in the river near the culvert from Waterford Lake. The samples in September and October where collected where Bridge Road crosses the Fox River. Based upon the height the river rose, the phosphorus concentration in the river, and the area of Waterford Lake, the amount of phosphorus entering the lake from the river was estimated for the period of February through October.

As shown in Table 3.2-1, the amount of phosphorus that enters Waterford Lake from the immediate watershed, on the lake surface, and from internal loading on an annual basis is 19 pounds. The amount of phosphorus that enters the lake from the Fox River is 8 pounds. This contributes at least 30% of the total phosphorus load for the year. Some years would be higher and some years would be lower. The importance of the river as a source of phosphorus is also supported by comparing the phosphorus concentration in the lake with the concentration in the river, as discussed in the Water Quality Section 3.1 During 2018, the concentrations are similar in both sites and when the concentrations in the river decline, they also are lower in the lake.

Table 3.2-1. Estimated annual phosphorus input to Waterford Lake from sources other than the Fox River.

Source	Annual Input (lbs)	Annual Input (%)
Watershed	14	52%
Lake surface	1	5%
Lake sediments	3	13%
Fox River	8	30%
Total	**27**	**100%**

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) 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 3.3-1. Example of coarse woody habitat in a lake.

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

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin 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 (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 3.3-2. Example of a biolog restoration site.

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

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

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 area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

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

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

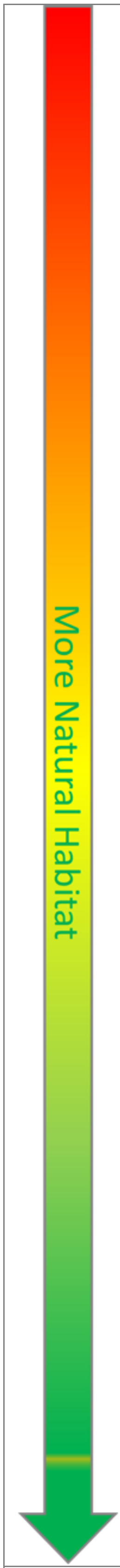
- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.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

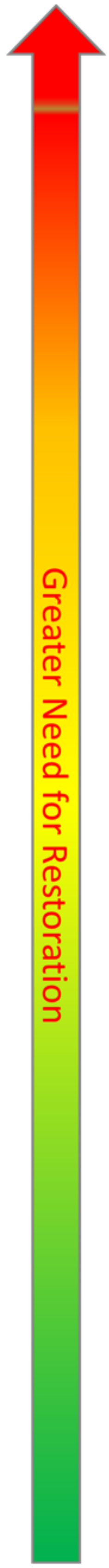
Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake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

The Waterford Waterway Shoreland Zone Condition

Shoreland Development

The Waterford Waterway's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.





Urbanized: This type of shoreline has essentially no natural habitat. Areas that are mowed or unnaturally landscaped to the water's edge and areas that are rip-rapped or include a seawall would be placed in this category.

Developed-Unnatural: This category includes shorelines that have been developed, but only have small remnants of natural habitat yet intact. A property with many trees, but no remaining understory or herbaceous layer would be included within this category. Also, a property that has left a small (less than 30 feet), natural buffer in place, but has urbanized the areas behind the buffer would be included in this category.

Developed-Semi-Natural: This is a developed shoreline that is mostly in a natural state. Developed properties that have left much of the natural habitat in state, but have added gathering areas, small beaches, etc within those natural areas would likely fall into this category. An urbanized shoreline that was restored would likely be included here, also.

Developed-Natural: This category includes shorelines that are developed property, but essentially no modifications to the natural habitat have been made. Developed properties that have maintained the natural habitat and only added a path leading to a single pier would fall into this category.

Natural/Undeveloped: This category includes shorelines in a natural, undisturbed state. No signs of anthropogenic impact can be found on these shorelines. In forested areas, herbaceous, understory, and canopy layers would be intact.

Figure 3.3-1. Shoreland assessment category descriptions.

On the Waterford Waterway, the development stage of the entire shoreland was surveyed during fall of 2018, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

The Waterford Waterway has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 13.8 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 12.7 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Waterford Waterway shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

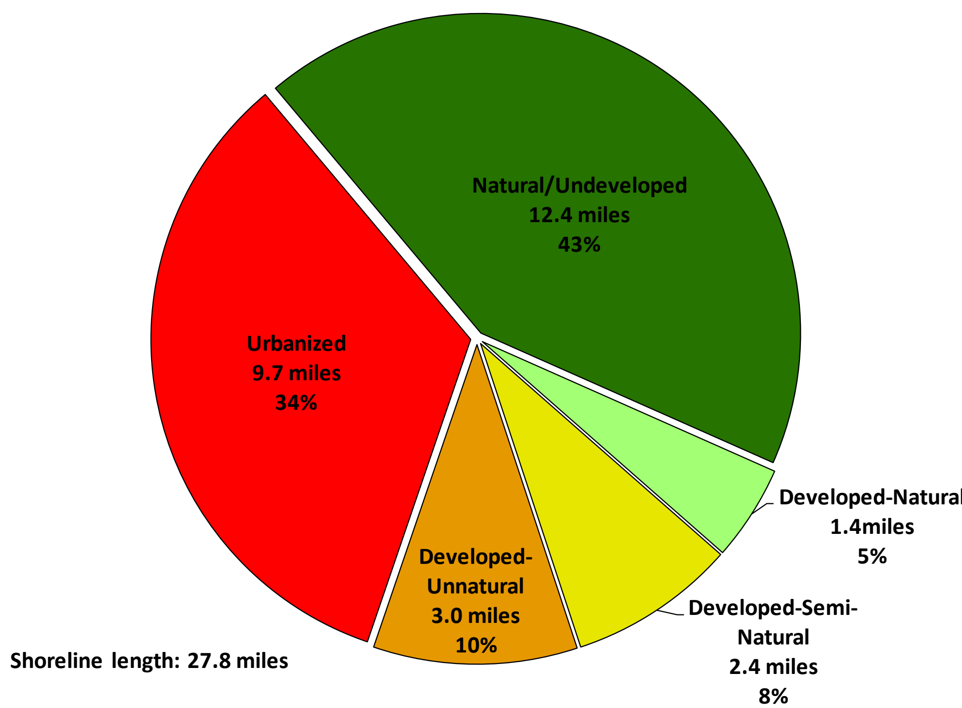


Figure 3.3-2. The Waterford Waterway shoreland categories and total lengths. Based upon a fall 2018 survey. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

The Waterford Waterway was surveyed in 2018 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 167 total pieces of coarse woody habitat were observed along 28.9 miles of shoreline, meaning that the Waterford Waterway has approximately 6 coarse woody habitat structures per mile of shoreline. Locations of coarse woody habitat are displayed on Map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

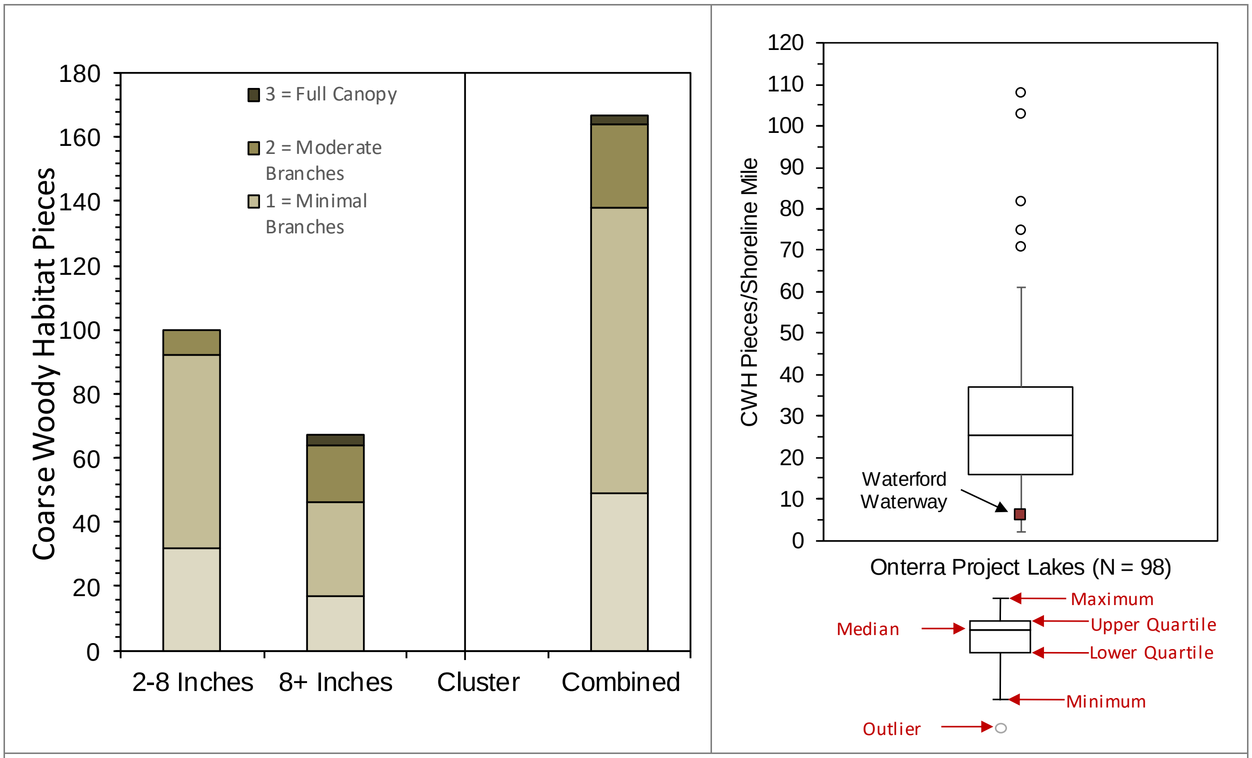


Figure 3.3-3. The Waterford Waterway coarse woody habitat survey results. Based upon a fall 2018 survey. Locations of the Waterford Waterway coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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

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

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

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

Aquatic Plant Management and Protection

Important Note:
Even though some of these techniques are not applicable to Waterford Waterway, 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 Waterford Waterway 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 3.4-2. 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.

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

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,000 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,000 when DASH (Diver Assisted Suction Harvest) technology is used. Additional disposal, travel, and permitting fees may also apply.

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

Bottom Screens

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

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

Please note that this is general information related to drawdowns. More information can be found specific to the Waterford Waterway in vegetation results sections.

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 3.4-3. Mechanical harvester.

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

Cost

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $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 3.4-4. 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. Table 3.4-1 provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

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

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

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

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

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

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

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

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

The use of any aquatic herbicide poses environmental risks to non-target plants and aquatic organisms. The majority of available toxicity data has been conducted as part of the EPA product registration process. These laboratory studies are attempted to mimic field settings, but can underestimate or overestimate the actual risk (Faribrother and Kapuska 1996). Federal and state pesticide regulations and strict application guidelines are in place to minimize impacts to non-target organisms based on the organismal studies. The use of aquatic herbicides includes regulatory oversight and must comply with the following list:

- Labeled and registered with U.S. EPA's office of Pesticide Programs;
- Registered for sale and use by the Department of Agriculture, Trade, and Consumer Protection (DATCP);
- Permitted by the Wisconsin Department of Natural Resources (WDNR); and
- Applied by a DATCP-certified and licensed applicator

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. • Herbicide selection and application timing can provide a degree of selectivity towards the target plant. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

Advantages	*Disadvantages*
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations 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 emergent or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Waterford Waterway; 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 Waterford Waterway. 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 Waterford Waterway, 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 Waterford Waterway to be compared to other lakes within the region and state.

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

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species where 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. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018). 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 Waterford Waterway is compared to data collected by Onterra and the WDNR Science Services on 77 lakes withn the Southeast Wisconsin Till Plain 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 or watershield. The emergent and floating-leaf aquatic plant communities in Waterford Waterway were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Aquatic Plant Survey Results

During the aquatic plant surveys completed on Waterford Waterway in 2018, a total of 19 species of plants were physically sampled during the point-intercept survey. Additional species that were observed during the survey but not physically sampled on the survey rake are considered *incidental* species. An incidentally-located species means the plant was not directly sampled on the rake during the point-intercept survey, but was observed in the lake by Onterra ecologists and was recorded/collected. The majority of incidentally-located plants typically include emergent species growing along the lake's margins and submersed species that are relatively rare within the lake's plant community. Incidental species observed in 2018 included spatterdock (*Nuphar variegata*), cattail (*Typha* sp.), water willow (*Decodon verticillatus*, softstem bulrush (*Schoenoplectus tabernaemontonii*), reed canary grass (*Phalaris arundinacea*), and giant bur-reed (*Sparganium eurycarpum*).

In past surveys on Waterford Waterway, horned pondweed, flowering rush, slender naiad, common bladderwort and northern watermilfoil have been documented. It is likely that these species are present in the system, however they were not observed in the course of the 2018 surveys likely due to relatively low abundance in the system.

Table 3.4-2 displays the aquatic plant species that were identified in Waterford Waterway (not including Conservancy Bay) during the 2012 and 2018 point-intercept surveys and does not include incidentally located species or other historically present species.

Table 3.4-2. Aquatic plant species located in Waterford Waterway during 2012 & 2018 point-intercept surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2012 Stantec	2018 Onterra
FL	*Nuphar variegata*	Spatterdock	6	X	
	Nymphaea odorata	White water lily	6	X	X
Submergent	*Chara spp.*	Muskgrasses	7		X
	Ceratophyllum demersum	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic/Invasive	X	X
	Najas guadalupensis	Southern naiad	7		X
	Potamogeton gramineus	Variable-leaf pondweed	7		X
	Potamogeton nodosus	Long-leaf pondweed	5		X
	Potamogeton pusillus	Small pondweed	7		X
	Potamogeton crispus	Curly-leaf pondweed	Exotic/Invasive	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6		X
	Ranunculus aquatilis	White water crowfoot	8		X
	Stuckenia pectinata	Sago pondweed	3	X	X
	Vallisneria americana	Wild celery	6		X
	Zannichellia palustris	Horned pondweed	7	X	
FF	*Lemna turionifera*	Turion duckweed	2		X
	Lemna trisulca	Forked duckweed	6		X
	Lemna minor	Lesser duckweed	5	X	X
	Wolffia spp.	Watermeal spp.	N/A	X	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

2018 Point-Intercept Survey Results

Map 1 displays the sampling points that were included within the 2018 point-intercept survey as a part of the planning project. The 2018 point-intercept survey was completed by Onterra ecologists on August 27-29 and included 1,162 sampling points (63-meter resolution) spaced out over the entire system. The 2018 survey was a replication of all of the point-intercept locations that were sampled during a 2012 survey with the exception of Conservancy Bay which was not sampled in 2012 but was added to the 2018 survey.

Prior to the adoption of the currently utilized point-intercept grid sampling methodology developed by the WDNR in 2010, a transect-based aquatic plant survey was often utilized. A transect aquatic plant survey was completed in 2003 on Waterford Waterway and found sparse aquatic plants in the system with coontail being the most commonly found aquatic plant present in about half of the sites (SEWRPC, 2012). The methodologies between transect based survey and grid-based survey differ substantially and are not typically comparable. The 2012 SEWRPC *Aquatic Plant Management Plan Update Report* discusses the two survey methods in greater detail and draws comparisons between the 2003 transect survey and the 2012 grid-based survey. The 2003 survey will not be directly compared to the 2018 point-intercept survey in the following analysis due to the differing sampling methodologies.

A custom point-intercept survey grid was sampled annually between 2010 & 2016 as a part of an aquatic plant management program led by Wisconsin Lake & Pond Resource, LLC at the time. These surveys used a sampling pattern that differs from the WDNR 63-meter grid that was used for the point-intercept surveys in 2012 and 2018. Although these surveys likely served the purpose of monitoring the active management that was occurring on the system at the time, they are not directly comparable to the surveys completed in 2012 and 2018 that used the WDNR 63-meter grid. The *2016 Aquatic Plant Management Report* by WLPR noted that coontail and common waterweed were the most dominant aquatic plant species and contributed the most to the nuisance conditions.

Scientists from DNR Research surveyed Tichigan Lake in 2007 as part of the Environmental Protection Agency National Lakes Assessment with a different point resolution of 50 meters. The results of the 2007 data will be compared to the results from 2012 and 2018 when a 63-meter sampling resolution was used. The results from the 2018 Conservancy Bay point-intercept survey are analyzed independently. The remaining sampling points in the system outside of Tichigan Lake and Conservancy Bay are compared between 2012 and 2018 and include the Fox River Channel as well as the locally known Buena Lake.

In order to make comparisons to previous surveys completed in 2007 and 2012, within the following analysis, the point-intercept survey results are broken into three sections: Conservancy Bay (2018 only), Tichigan Lake (2007, 2012 & 2018), and the Waterford Waterway including the Fox River and Buena Lake (2012 & 2018). These three datasets are displayed on Map 1.

Conservancy Bay Point-Intercept Survey Results

A point-intercept survey was completed on Conservancy Bay for the first time in 2018 as a part of the management planning project to allow for a quantitative assessment of the aquatic plant community. During the survey, shallow water coupled with dense, surface matting vegetation limited the navigability of the field crew resulting in 187 of the sampling points being designated as non-navigable or terrestrial and not surveyed (Figure 3.4-1). Of the 173 points that were visited during the survey, nearly 90% contained vegetation. Coontail was present on 87.7% of the sampling points, with common waterweed being located on 54.4% (Figure 3.4-2).

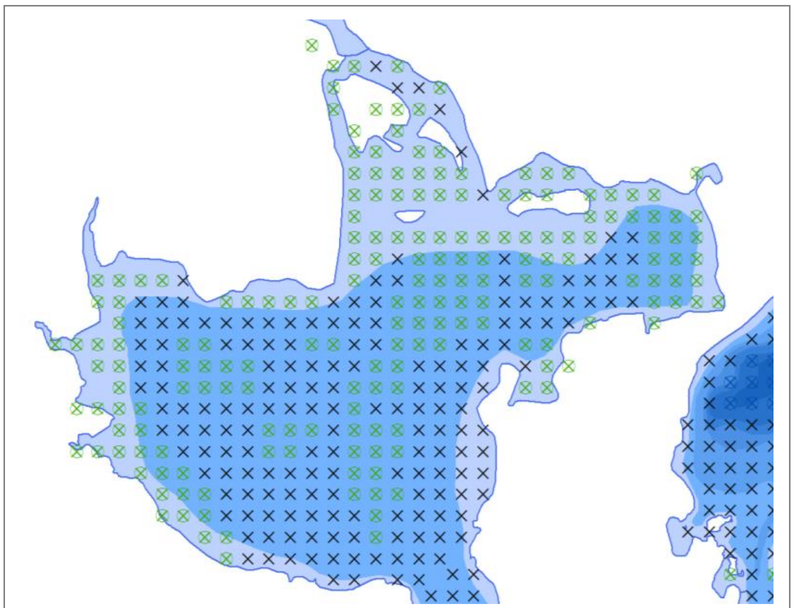


Figure 3.4-1. Conservancy Bay 2018 Point-Intercept Survey Locations. Black X represents points that were sampled, green symbol represents points that were unreachable and therefore not sampled.

Eurasian watermilfoil was the third most frequently encountered plant in Conservancy Bay with a littoral occurrence of 17.0%. Free floating plants were common in the Bay and included forked, lesser, and turion duckweed as well as watermeal. Other submersed native species in Conservancy Bay included water stargrass, flat-stem pondweed, sago pondweed, and white-water crowfoot. White water lily and curly-leaf pondweed were also sampled in low frequencies.

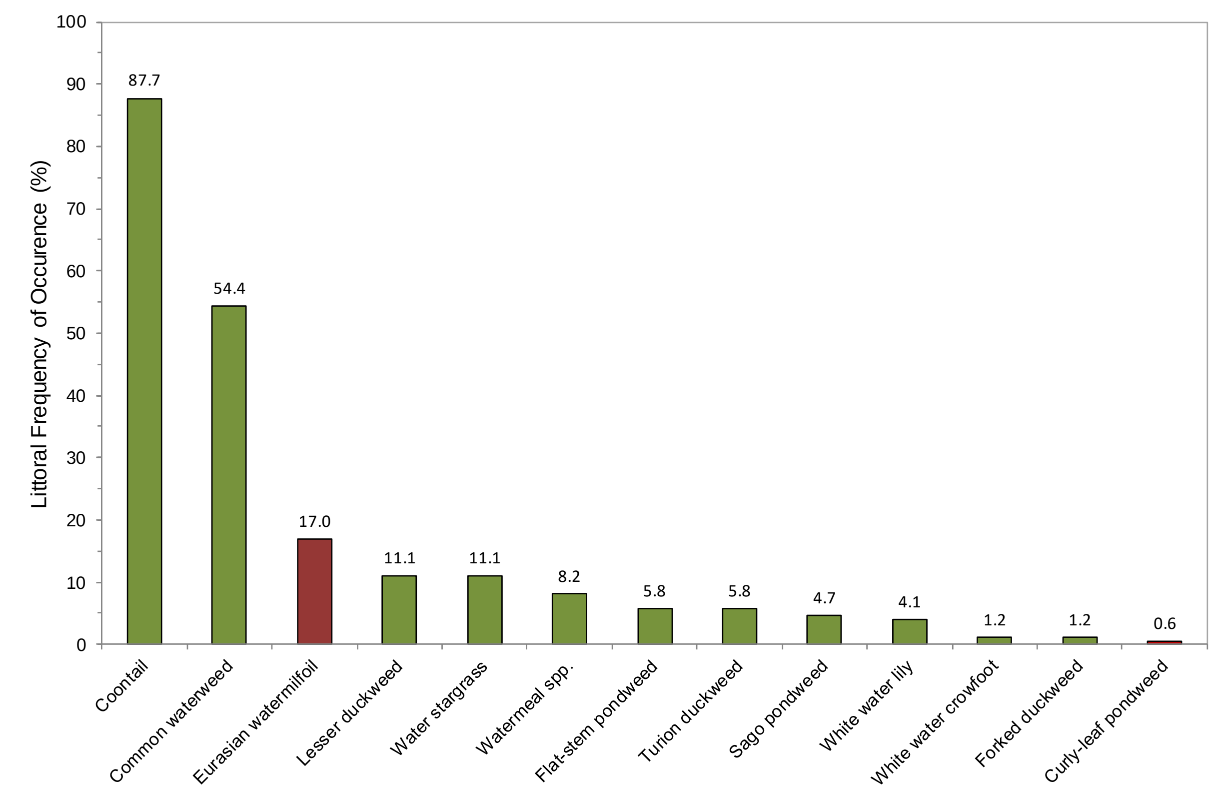


Figure 3.4-2. Conservancy Bay 2018 aquatic plant littoral frequency of occurrence. (n=173)

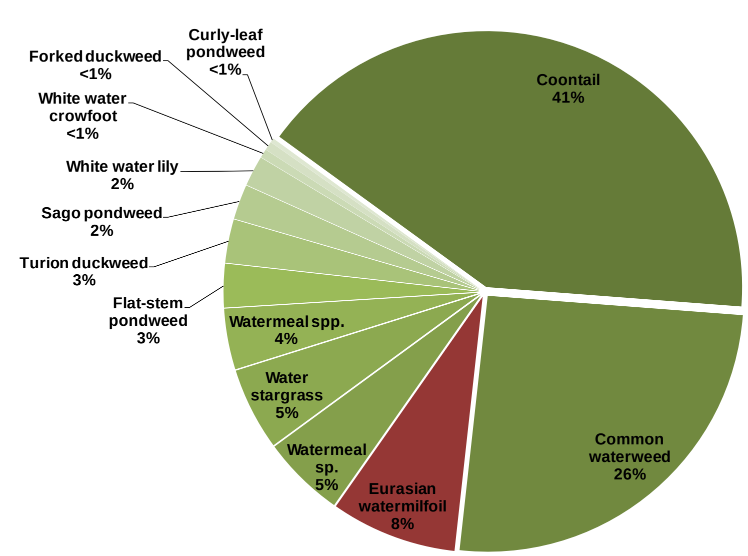


Figure 3.4-3. 2018 relative frequency of occurrence of aquatic plants in Conservancy Bay. Created using data from 2018 point-intercept survey.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at 87.7% of the sampling locations in Conservancy Bay in 2018, its relative frequency of occurrence was approximately 41%. Explained another way, if 100 plants were randomly sampled from

Conservancy Bay, 41 of them would be coontail. Looking at relative frequency of occurrence (Figure 3.4-3), 67% of the aquatic plant community is dominated by coontail or common waterweed which yields lower species diversity.

Fox River and Buena Lake Point-Intercept Survey Results

The point-intercept sampling locations <u>outside of</u> Conservancy Bay and Tichigan Lake are evaluated below and consist of 518 total sampling points (Map 1). These same sampling points were surveyed during the 2012 point-intercept survey and are compared to the 2018 survey. During the 2018 survey, 413 of the sampling sites were visited of which 261 points contained aquatic vegetation. The sampling points that were not visited included points that were in non-navigable areas of the system. A total of 16 native aquatic plant species and two non-native species were located during the survey. The most commonly encountered plant species in the Fox River and Buena Lake portion of the Waterford Waterway was coontail (53.9%) and common waterweed (35.2%) (Figure 3.4-4). The littoral frequency of occurrence of EWM was 12.6%. Free floating plants were commonly sampled and included watermeal, lesser duckweed, forked duckweed, and turion duckweed. Native species that were present in at least 2% of the sampling points included white water lily, water stargrass, flat-stem pondweed and sago pondweed (Figure 3.4-4).

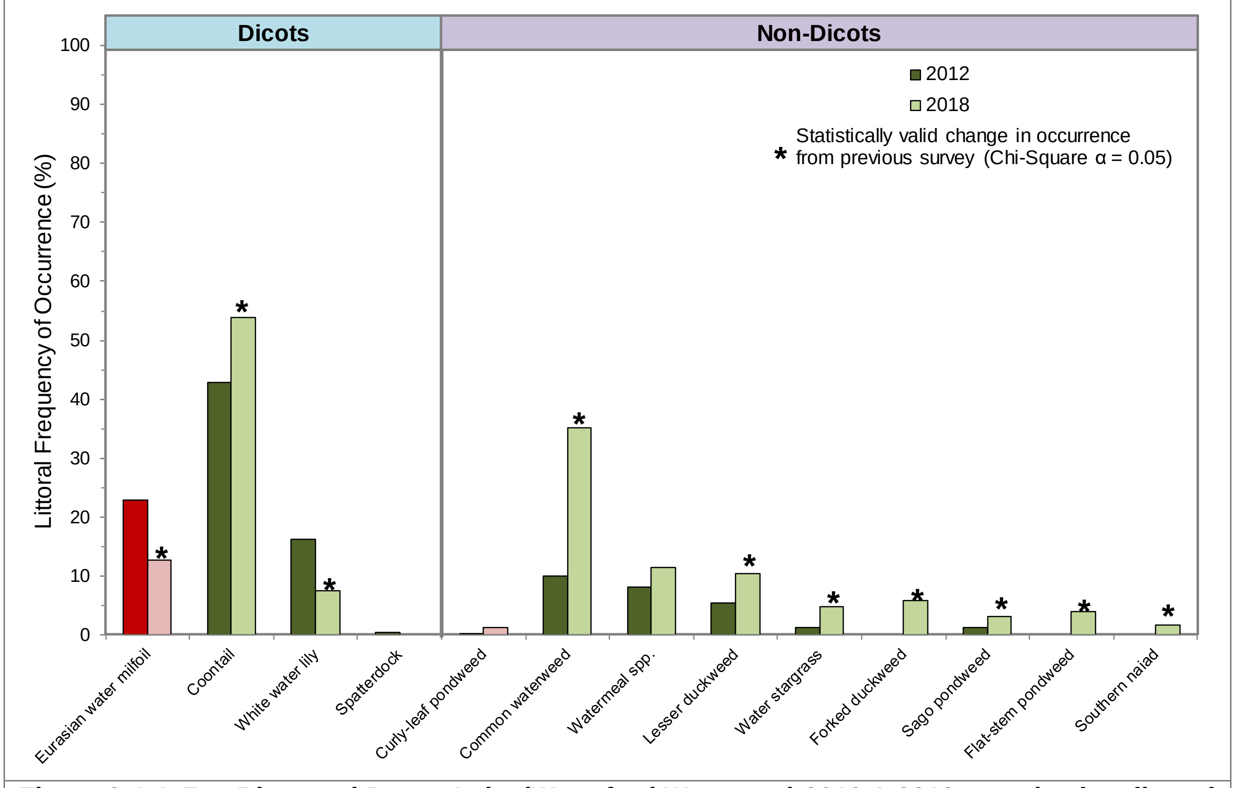


Figure 3.4-4. Fox River and Buena Lake (Waterford Waterway) 2012 & 2018 aquatic plant littoral frequency of occurrence. Created using data from 2012 Stantec & 2018 Onterra whole-lake point-intercept surveys

The calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The native aquatic plant species located on the rake during the point-intercept surveys from 2012 and 2018 and their conservatism values were used to calculate the FQI for each year. Native plant species richness was 15 in 2018 compared to eight in 2012 (Figure 3.4-5). The 2018 plant species richness falls at the median values for other lakes within the SWTP ecoregion and below the median value for lakes throughout Wisconsin. The FQI value of 20.9 for the aquatic plant community of the Fox River and Buena Lake section of the Waterford Waterway falls just below the median for lakes within the SWTP ecoregion (21.1) but below the median for lakes throughout Wisconsin (27.2).

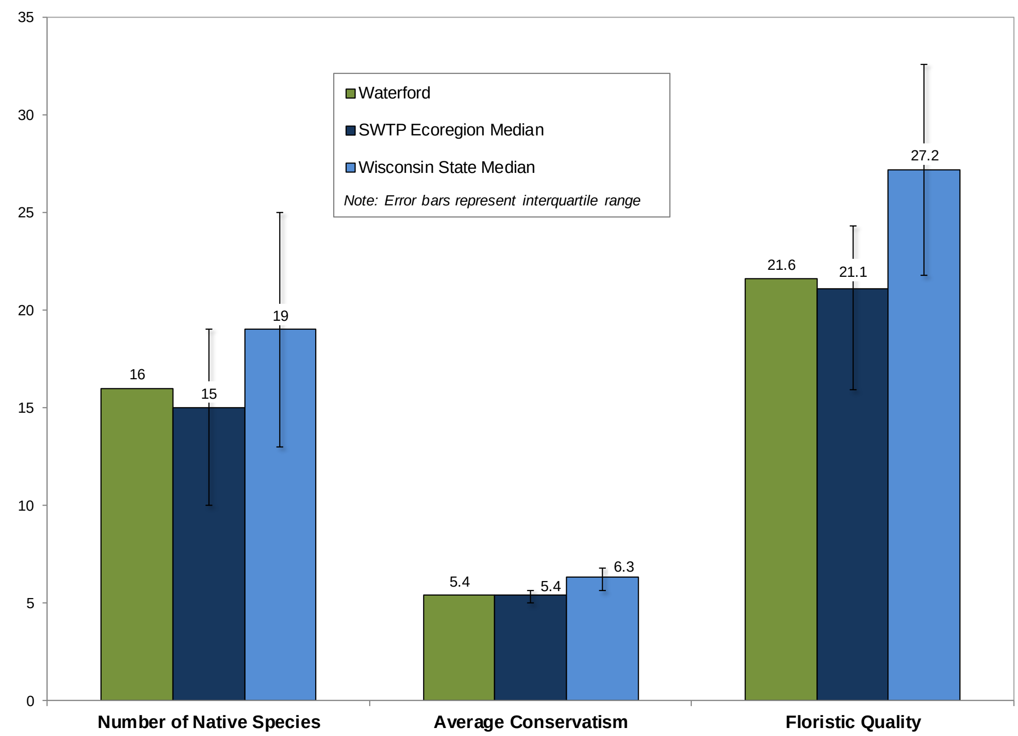


Figure 3.4-5. Fox River & Buena Lake (Waterford Waterway) Floristic Quality Assessment. Created using data from 2012 Stantec & 2018 Onterra whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data. Analysis follows Nichols 1999.

The relative frequency of occurrence showed that coontail and common waterweed combine to dominate approximately 58% of the plant community (Figure 3.4-6).

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 the Waterford Waterway's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the Southeastern Wisconsin Till Plains (SWTP) Ecoregion. Using the data collected from the 2018 whole-lake point-intercept surveys, the Fox River and Buena Lake's aquatic plant species diversity was 0.80. The species diversity value of 0.80 falls just below the median value for lakes within the SWTP ecoregion.

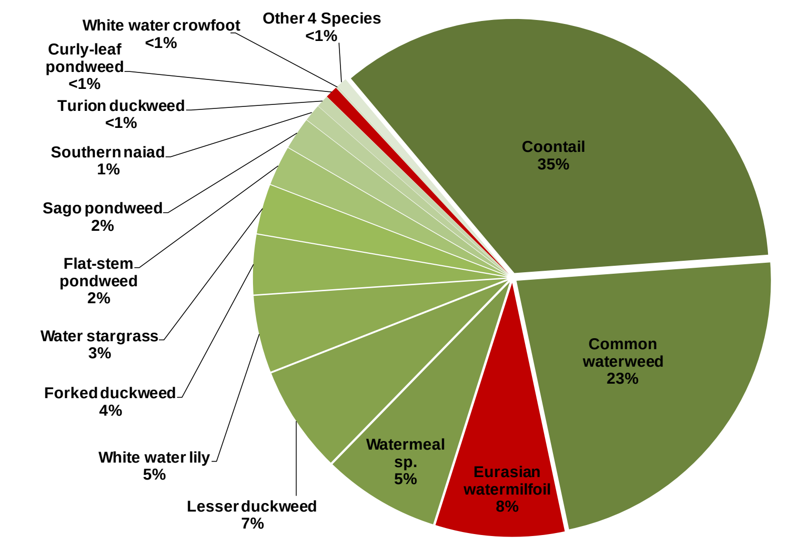


Figure 3.4-6. 2018 Relative Frequency of Occurrence of Aquatic Plants in the Fox River & Buena Lake of the Waterford Waterway. Created using data from 2018 point-intercept survey.

Tichigan Lake Point-Intercept Survey Results

Figure 3.4-7 displays the littoral frequency of occurrence for aquatic plants in Tichigan Lake from the 2018 point-intercept survey. Coontail was the most frequently encountered species in Tichigan Lake in 2018 with a littoral frequency of occurrence of 57.5%. Common waterweed (14.4%) was the second most frequently encountered species and southern naiad (10.2%) was the third most encountered species (Figure 3.4-7).

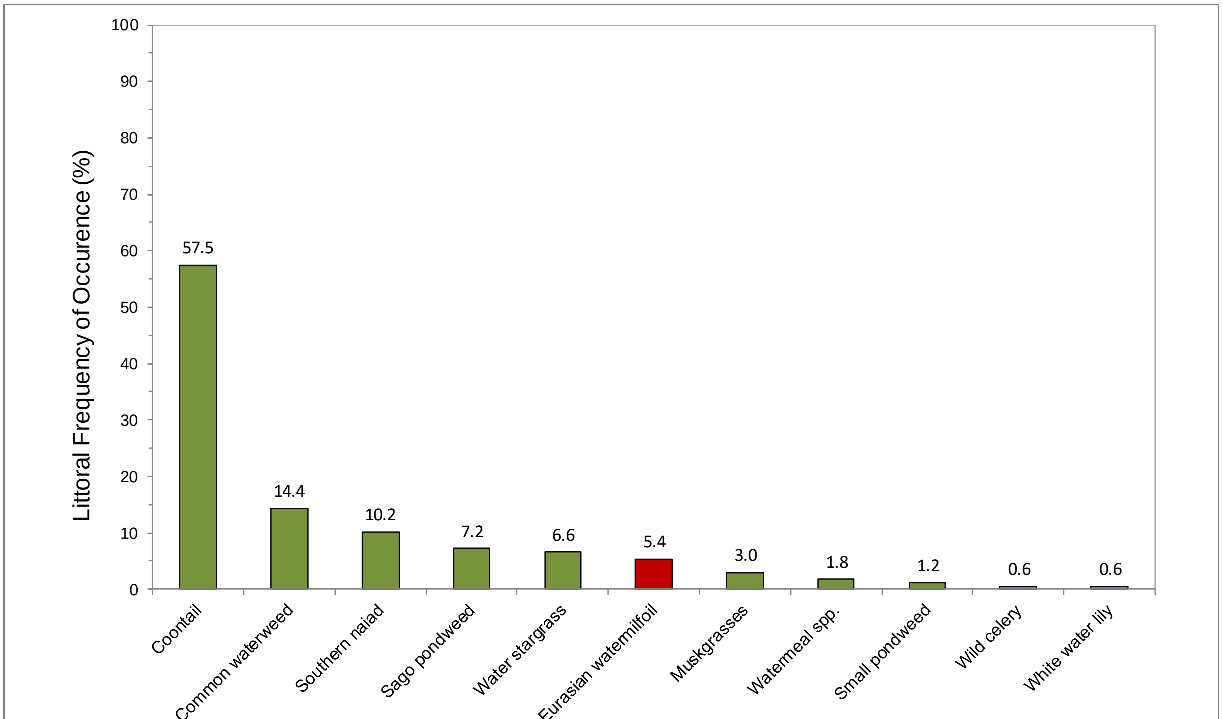


Figure 3.4-7. Tichigan Lake 2018 aquatic plant littoral frequency of occurrence. Data from Onterra 2018 Point-Intercept Survey 2018 n=167**.**

The littoral frequency of aquatic plants in the 2018 survey are compared to the surveys that were completed in 2007 by the WDNR and 2012 by Stantec in Figure 3.4-8. The littoral frequency of occurrence for EWM was 5.4% in 2018, compared to 17.8% in 2012 and 0% in 2007. The occurrences of coontail, common waterweed, sago pondweed and southern naiad were all higher in 2018 than the previous survey in 2012.

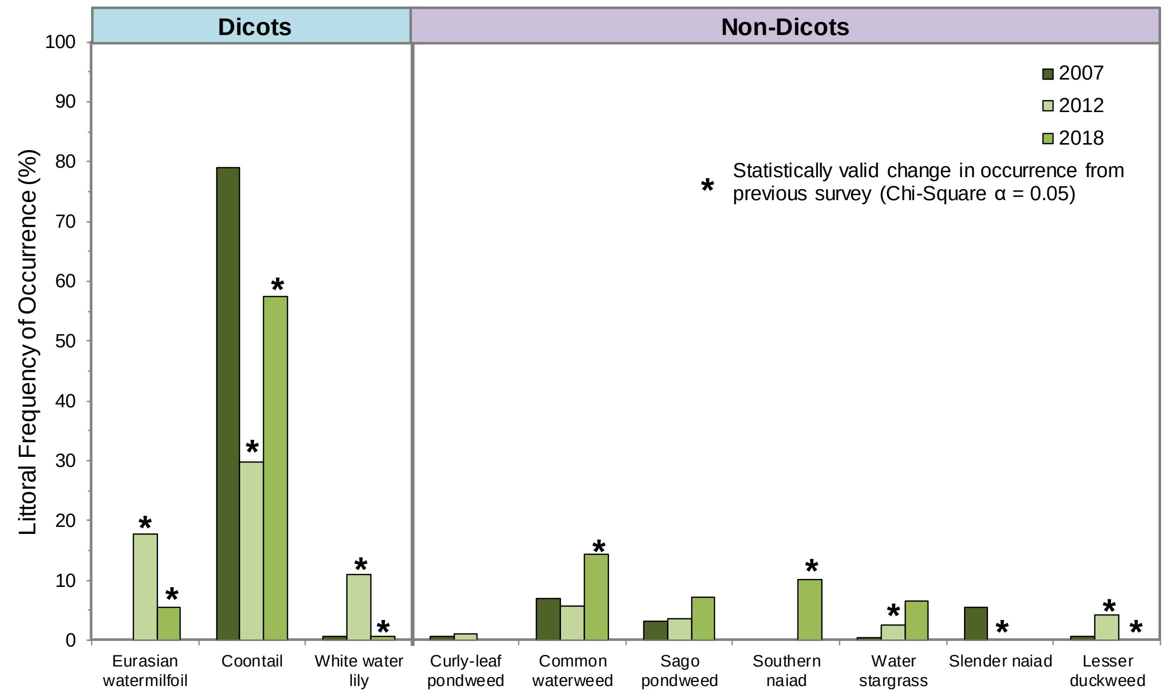


Figure 3.4-8. Tichigan Lake 2007, 2012 & 2018 aquatic plant littoral frequency of occurrence. Created using data from 2012 Stantec & 2018 Onterra whole-lake point-intercept surveys

The average species conservatism was 5.3 in 2018 compared to 4.9 in 2007 and 4.6 in 2012 (Figure 3.4-9). In each year the average conservatism has been below the ecoregion and state medians. The calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The native aquatic plant species located on the rake during the point-intercept surveys from 2007 to 2018 and their conservatism values were used to calculate the FQI for each year. Native plant species richness was 11 in 2018 compared to eight in 2007 and 2012 (Figure 3.4-9). The average native plant species richness falls below the median values for other lakes within the SWTP ecoregion and below the median value for lakes throughout Wisconsin. The floristic quality of Tichigan Lake was 17.7 in 2018 which is below the ecoregion average of 21.1 and well below the state average of 27.2 (Figure 3.4-9).

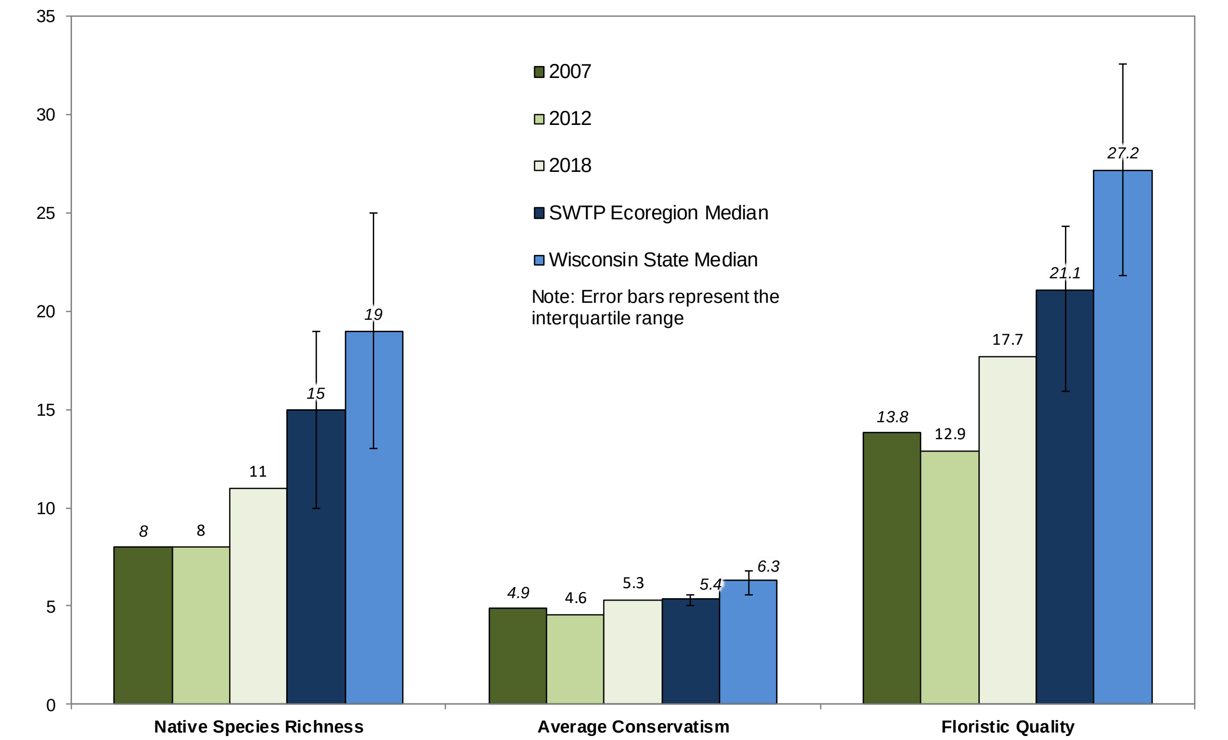
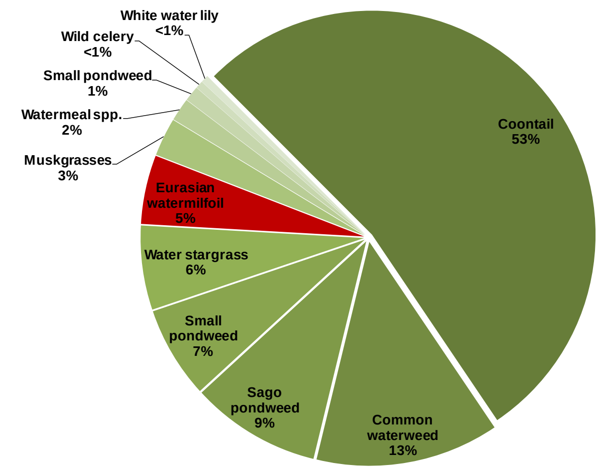


Figure 3.4-9. Tichigan Lake Floristic Quality Assessment. Created using data from 2007 WDNR, 2012 Stantec & 2018 Onterra whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data. Analysis follows Nichols 1999.

Looking at relative frequency of occurrence (Figure 3.4-10), Tichigan Lake's aquatic plant community is dominated by coontail (53%) which yields a lower species diversity. Four other native species including common waterweed, sago pondweed, small pondweed and water stargrass comprise an additional 35% of the relative frequency in Tichigan Lake.

Using the data collected from the 2007, 2012 and 2018 whole-lake point-intercept surveys, Tichigan Lake's aquatic plant species diversity ranged from 0.44 in 2007, to 0.82 in 2012 (Figure 3.4-11). The diversity index value was 0.68 in 2018. The species diversity value of 0.68 falls below the median value for lakes within the SWTP ecoregion, indicating low species diversity for this region.



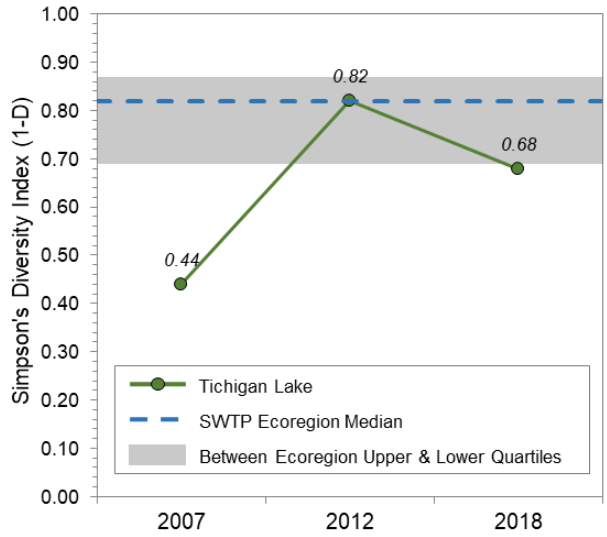


Figure 3.4-10. 2018 relative frequency of occurrence of aquatic plants in Tichigan Lake. Created using data from 2018 point-intercept survey.	**Figure 3.4-11. Tichigan Lake Simpson's Diversity Index.** Created using data from 2007, 2012 & 2018 whole lake-lake point intercept surveys.

Summary of Point-Intercept Survey Results

Plant species which tend to flourish in higher nutrient conditions are dominant in Waterford Waterway, including coontail, common waterweed, and white-water lily.

Coontail, arguably the most common aquatic plant in Wisconsin, was the most frequently encountered aquatic plant in surveys completed on Conservancy Bay, Tichigan Lake and the Waterford Waterway-Fox River section in 2018. The left viewing frame on Map 5 displays the total rake fullness values for point-intercept survey locations where coontail was sampled in the 2018 survey. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in waterbodies with higher nutrients and lower water clarity. Coontail has the capacity to form dense beds which mat on the surface and was observed matting on the surface in portions of the system during 2017 and 2018. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and helps to improve water clarity.

Common waterweed, the second-most frequently-encountered aquatic plant in the 2018 point-intercept surveys, is an aquatic plant species with a wide distribution across North America, and like coontail obtains the majority of its nutrients directly from the water. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies with higher nutrients. Like coontail, it can tolerate the low light conditions found in eutrophic systems better than many other aquatic plant species. For these reasons, common waterweed has competitive advantages over other aquatic plant species that favor its growth in productive systems. Common waterweed was observed to be contributing to nuisance plant conditions on Waterford Waterway during 2017-2018. The right viewing frame on Map 5 displays the total rake fullness values for point-intercept survey locations where common waterweed was sampled in the 2018 survey.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, water levels, changes in clarity, herbivory, competition, and disease among other factors. Certain native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants

The quality of the plant community is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the system. The 2018 community map indicates that approximately 428.7 acres of the Waterford Waterway contains floating-leaf plant communities while another 35.2 acres contain emergent or floating-leaf and emergent communities (Table 3.4-3 and Maps 6 & 7). Several native floating-leaf and emergent species were located on the Waterford Waterway in 2018, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft. The vast majority of the floating-leaf plant community is comprised of white-water lily with a few isolated areas of spatterdock. The emergent community on the system is dominated by cattail and water willow.

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

Table 3.4-3. Waterford Waterway acres of plant community types. Created from August 2018 community mapping survey.

Community Type	Acres
Emergent	34.9
Floating-Leaf	428.7
Floating-Leaf & Emergent	0.3
Total	**463.9**

Non-native Plants in Waterford Waterway

During the 2018 surveys on the Waterford Waterway, six non-native plants were identified and include Eurasian watermilfoil, curly-leaf pondweed, flowering rush, pale-yellow iris, purple loosestrife and reed canary grass. Each of these species are discussed further within this section. 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 (EWM)

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-12). 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 sometimes 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. In some situations, Eurasian watermilfoil integrates itself into the native plant community without causing wide-scale ecological impacts nor impacts to human uses of the lake.

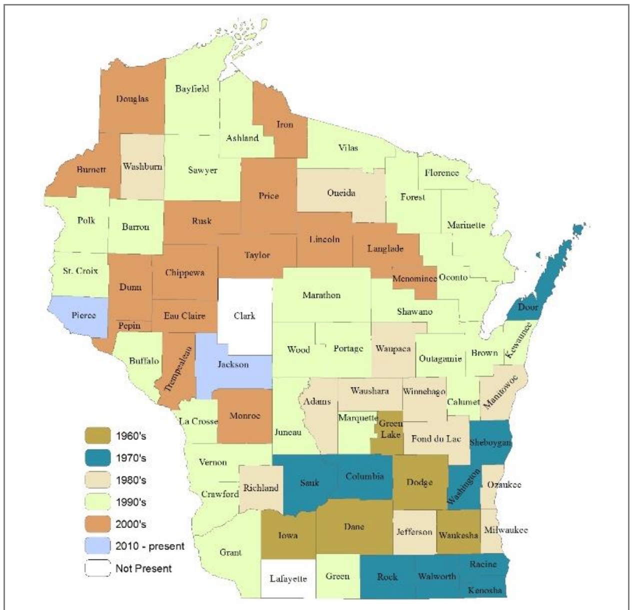


Figure 3.4-12. Spread of Eurasian watermilfoil within WI counties. Source: WDNR

The Eurasian watermilfoil population in the Waterford Waterway, and its management, is discussed in more detail later in the Aquatic Plant Management Strategy in Waterford Waterway section.

Curly-leaf pondweed (CLP)

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. But like Eurasian watermilfoil, the impacts of curly-leaf pondweed in a lake may be minimal, especially in northern and northeastern Wisconsin.

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.

Early-season treatments completed in past years have targeted curly-leaf pondweed throughout the Waterford Waterway; however, the primary goal has not been to reduce the population on a system-wide basis, but instead to reduce biomass in recreation areas. Curly-leaf pondweed typically begins dying back naturally by early July, minimizing its impact on recreation during the growing season.

To allow for an accurate assessment of untreated curly-leaf pondweed densities during 2018, curly-leaf pondweed was not specifically targeted for treatment in 2018. The CLP population throughout the Waterford Waterway was mapped during a June 2018 Early-Season AIS survey (ESAIS). The results of the survey are displayed on Map 8 and show that CLP is widespread in the system with the population consisting of isolated occurrences or *highly scattered* or *scattered* colonies. No areas of CLP were found to be of dominant or greater densities during 2018 and CLP was not observed to be a large contributor to nuisance conditions in the system.

CLP Management Strategy

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced in one year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Traditionally a control strategy for an established CLP population includes 5-7 years of treatments of the same area to deplete the existing turion bank within the sediment (Jones et al 2012, Johnson et al. 2012). In practice, it is unclear how many years CLP turions can remain viable and therefore the number of consecutive years treatments are required is unknown.

Johnson et al. (2012) investigated 9 midwestern lakes with established CLP populations that received five consecutive annual large-scale endothall treatments to control CLP. The greatest reductions in CLP frequency, biomass, and turions was observed in the first 2 years of the control program, but continued reductions were observed following all five years of the project. These lakes contained CLP for numerous years before the whole-lake treatment program began, likely containing a robust turion bank in the sediment. When treatments ceased after five years, CLP populations continued to be present indicating that five years was insufficient to fully exhaust the sediment turions. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.

The WWMD has not followed the strategy described above in past years. As discussed, they have treated small areas around the system which kills that year's growth, but does not treat the population as a whole and reduce occurrence in the long-term. This is important in how the WWMD decides to control CLP in the future. As described above, CLP basically occurs within the entire waterway, so it would be unrealistic to believe that system-wide population control could be met by completing large-scale, likely whole-system, CLP treatments for 7 or more years. The cost would be tremendous at hundreds of thousands of dollars per year, and the ecological harm would be astounding. If a bay or large area of one of the lake basins were to become inundated with CLP for multiple years, completing repeated, large-scale treatments may be appropriate to reduce that area's population. However, the navigation lane treatments described above do work to control CLP well and provide access to open areas of the system; therefore, that strategy should be the primary choice for the WWMD.

Flowering Rush

Flowering rush (*Butomus umbellatus*) is an invasive aquatic plant that is native to Europe (Photograph 3.4-5). This perennial plant flowers in late summer to early fall. It ranges in size from 1-5 feet, generally growing it shallow water, though it can be found growing submersed in up to 10 feet. Like other non-native invasive plants, flowering rush displaces native aquatic and wetland plants and can alter ecosystem functions.

Photograph 3.4-5. Flowers, stem, and colony of flowering rush, a non-native invasive wetland plant. Photo credit Onterra.

The district has facilitated herbicide applications and hand-harvesting of flowering rush within the system. In 2017, a total of 2.0 acres of flowering rush were treated with imazapyr (Habitat®) and imazamox (Clearcast®) on August 29-30.

Flowering rush was not located during Onterra's 2018 surveys.

Pale Yellow Iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photo 3.4-6). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. A few occurrences of pale-yellow iris were observed growing in the Waterford Waterways system in 2018 and are displayed on Map 7.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*), like yellow garden loosestrife, is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental (Photo 3.4-7). This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Populations of purple loosestrife were observed along many areas of the shoreline in Waterford Waterway (Maps 6 & 7).

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly.

Photograph 3.4-6. Pale-yellow iris in shoreland area. Photo credit Onterra.

Photograph 3.4-7. Purple loosestrife in a shoreland area. Photo credit Onterra.

Reed Canary Grass

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 shorelines.

Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. 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. Reed canary grass was located along the Fox River just south of Tichigan Lake in 2018 and is likely present elsewhere around the shores of the Waterford Waterway (Map 6). A specimen of suspected reed canary grass was collected from Waterford Waterway in 2018 and sent to the UW- Stevens Point Herbarium where it was positively identified.

Aquatic Plant Management Strategy in Waterford Waterway

There is a long history of aquatic plant management on Waterford Waterway dating back to at least the 1950's when WDNR records are available. Historically the aquatic plant management has been focused on providing relief from nuisance conditions that impede navigability in the system. In more recent years (approximately 2004-present), the WWMD has used several methods to control nuisance levels of exotic and native species; including herbicide treatments to clear navigation lanes, the use of diver assisted suction harvesting (DASH) and small excavators, also to clear navigation lanes, and specific treatments aimed at reducing curly-leaf pondweed and Eurasian watermilfoil. The district has also facilitated herbicide applications and hand-harvesting of flowering rush within the system.

Over time the WWMD has attempted to use Best Management Practices (BMP's) to manage aquatic plants in the system. The BMP's change over time as greater understanding of any given management technique is studied and evaluated. Practices that were once a common management technique, such as small <2-acre treatments with systemic herbicides, have become less common in recent years as greater understanding of the limitations of these strategies have been determined.

The following sections will evaluate the aquatic plant management activities that took place during 2018. The activities associated with the aquatic plant management strategy included basin-wide herbicide treatments that targeted nuisance EWM populations, navigation lane herbicide treatments, and DASH harvesting, and are evaluated below. Additional information related to the applicability of mechanical harvesting and water level drawdown as management techniques is also included although these techniques have not been historically used to manage aquatic plants in Waterford Waterway.

Aquatic Invasive Species Management Strategies

During the strategic Planning Committee meetings, Onterra will discuss three broad potential AIS population management goals for consideration including a recommended action plan to help reach each of the goals. The following paragraphs provide brief overview of these potential options.

Let Nature Take its Course: In some instances, the AIS population of a lake may plateau or reduce without conducting active management. Some lake groups decide to periodically monitor the AIS population, typically through an annual or semi-annual point-intercept survey, but do not coordinate active management (e.g. hand-harvesting or herbicide treatments). This requires that the riparians tolerate the conditions caused by the AIS, acknowledging that some years may be problematic to recreation, navigation, and aesthetics. Individual riparians may choose to hand-remove the AIS (primarily referring to EWM) within their recreational footprint, but the lake group would not assist financially or assist with securing permits. In some instances, the lake group may select this management goal, but also set an AIS population threshold or "trigger" where they would revisit their management strategy if the population reached that level.

Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with AIS populations, that may be to manage the AIS population at a reduced level with the perceived goal to allow the lake to function as it had prior to AIS establishment. It must also be acknowledged that some lake managers and natural resource regulators question whether that is an achievable goal.

In early AIS populations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. If conducted properly, large-scale management can reduce AIS populations for several years, but will not eradicate it from the lake. Subsequent smaller scale management (e.g. hand-harvesting or spot treatments) is typically employed to slow the rebound of the population until another large-scale effort is likely required again. Typically, complete rebound of an EWM population following a large-scale control action is 4-6 years, with quicker rebound on some lakes and longer control observed on others. Large-scale control efforts, especially using herbicide treatments, can be impactful of some native plant species as well as carry a risk of environmental toxicity. Some argue that the impacts of the control actions may have greater negative impacts to the ecology of the system than if the AIS population was not managed.

Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with the AIS population on their lake is the reduced recreation, navigation, and aesthetics compared to before AIS became established in their lake. Particularly on lakes with large AIS populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve the navigability within the lake. In order to reach this goal, a strategic network of common use lanes and riparian spokes through AIS colonies are maintained by either professional hand-harvesting or mechanical harvesting (i.e. weed cutting machine). On lakes with surface matted or near surface matted AIS in high navigation corridors, mechanical harvesting may be able to temporarily remove the top few feet of AIS of select areas whereas herbicide spot treatments may provide an entire season of nuisance relief.

2018 Nuisance AIS Management Program

Using sub-meter GPS technology, EWM locations were mapped in early fall during 2017 and 2018 by using either 1) point-based or 2) area-based methodologies. Point-based techniques were applied to EWM locations that were considered to be *small plant colonies* (< 40 feet in diameter), *clumps of plants*, or *single or few plants*. Large colonies (> 40 feet in diameter) are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*.

In 2017, approximately 700 acres of the Waterford Waterway was found to contain EWM; however, 96% of this area was delineated as having either *scattered* or *highly scattered* EWM. At these lower densities, EWM does not cause significant recreational interference and likely has little to no measurable ecological impact, therefore; no active management was directed at these populations in Waterford Waterway during 2018. Approximately 25 acres or 4% of the littoral area containing EWM was delineated with a density rating of *dominant* or greater in 2017. These areas of EWM of higher density have the potential to cause recreational interference and also likely impart negative ecological impacts. The 2017 late-season AIS survey indicated three areas in the Waterford Waterway where EWM was found to dominate the nearby plant community, including Elm Island Bay and two areas in Tichigan Lake. These areas were proposed for herbicide treatment in 2018 as basin-wide applications at lower doses with the expectation of a longer exposure time.

Eurasian watermilfoil was not managed at a population level in Waterford Waterways in 2018 as the majority of the population was of relatively low densities. Instead, select areas where EWM was creating *dominant* colonies and nuisance conditions were considered for management as a part of a nuisance control strategy outlined above.

Onterra staff completed a spring visit to Waterford Waterways on 4-23-18 to complete other components of the planning project and to make observations of the stage of plant growth in the proposed treatment areas. It was determined that the majority of the EWM in the system was not yet actively growing and water temperatures during this visit were in the mid 40's.

On May 10, 2018, Onterra staff returned to the system and completed the Pre-treatment Confirmation and Refinement Survey. The purpose of this survey was to evaluate the sites that were preliminarily proposed for treatment that targeted EWM specifically. The twelve sites that were on the preliminary treatment strategy were evaluated in terms of EWM abundance and growth stage. The average depths and extents of the treatment areas were refined and confirmed during the survey. Near surface water temperatures were between 65-66°F at the time of the survey. Eight of the 12 preliminary sites did not have significant populations of EWM and were removed from the final strategy. Ultimately, four sites were included on the final AIS treatment strategy and included targeting 35.9 acres with a combination treatment of 2,4-D and endothall (Map 9).

Onterra staff completed the late-summer EWM peak-biomass survey on October 15-16, 2018. The late-Summer AIS Survey is a meander-based survey where all areas of the waterway are visually inspected for the presence of EWM.

The survey extents included all navigable littoral areas of the Waterford Waterways system. The results of the survey are displayed on Map 10. A total of approximately 238 acres of EWM were mapped during the survey of which the majority was composed of relatively low-density colonies consisting of highly scattered (34 acres) or scattered plants (190 acres). It must be noted that during the 2018 survey, many areas in Conservancy Bay were inaccessible by boat due to heavy nuisance levels of native plants; therefore, comparing the 2017 acreages to that of the 2018 acreages is not fully appropriate. At the densities found in 2018, EWM imparts little negative ecological impacts on the system as native plants are able to grow along with EWM in most locations. Approximately 14 acres were designated as dominant in density and no areas were mapped as either highly dominant or surface matting. Some areas in the system were non-navigable at the time of the survey, particularly Conservancy Bay, and EWM is known to be present in similarly low densities in these locations based on previous surveys.

Figures 3.4-13 and 3.4-14 highlight the four 2018 AIS treatment areas in Waterford Waterway where the left frame shows the late-summer 2017 (pre-treatment) EWM mapping results and the right frame displays the late-summer 2018 (post-treatment) EWM mapping results.

Site A-18 (Tichigan): Site A-18 in the southeast part of Tichigan Lake was treated with 2,4-D and endothall in spring of 2018 to control EWM (Map 9). Navigation lane treatments occurred on several occurrences during the summer (Map 11). Professional DASH harvesting efforts also took place in the site during 2018 and included over 68 hours of effort and 19,450 pounds of harvesting vegetation (Map 12). In 2017, the small bay was characterized by an area of highly dominant EWM and scattered EWM with a small surface matted area on the north side of the bay. After the herbicide treatments and DASH harvesting, the late-summer 2018 survey showed the bay contains scattered or dominant EWM plants throughout the treated area (Figure 3.4-13)

Site B-18 (Tichigan): Site B-18 on the southwest side of Tichigan Lake was treated with 2,4-D and endothall in spring 2018 to control EWM. Prior to treatment, the site contained a large area of highly dominant EWM plants. No additional navigation lane treatments or DASH harvesting occurred in the site during the growing season. After treatment, the EWM population was reduced in much of the site to include an area of scattered plants as well as point-based occurrences including a small plant colony and several single or few plants (Figure 3.4-13).

Site E-18 (Tichigan): Site E-18 encompasses the northern end of Tichigan Lake where scattered EWM was mapped throughout the area in late 2017. Following the 25.0 acres AIS treatment with 2,4-D and endothall, several nuisance navigation lane treatments also occurred during the growing season (Map 11). After the treatments, the late-summer 2018 survey indicated a reduction in area of the scattered colony, however an area of highly scattered or scattered EWM remained present in the shallower extents of the treated area (Figure 3.4-13).

Site C-18 (Elm Island Bay): The entirety of Elm Island Bay was treated with 2,4-D and endothall in spring 2018 for EWM control purposes. Navigation lane treatments also occurred in portions of the Bay during 2018 that targeted EWM as well as native plants that were contributing to the nuisance conditions (Map 11). The late-summer 2017 survey indicated large areas of dominant, highly dominant or surface matted EWM present in the site. The late-summer 2018 survey indicated that EWM remained present in much of the site, however the majority of the population consisted of highly scattered to scattered densities (Figure 3.4-14).

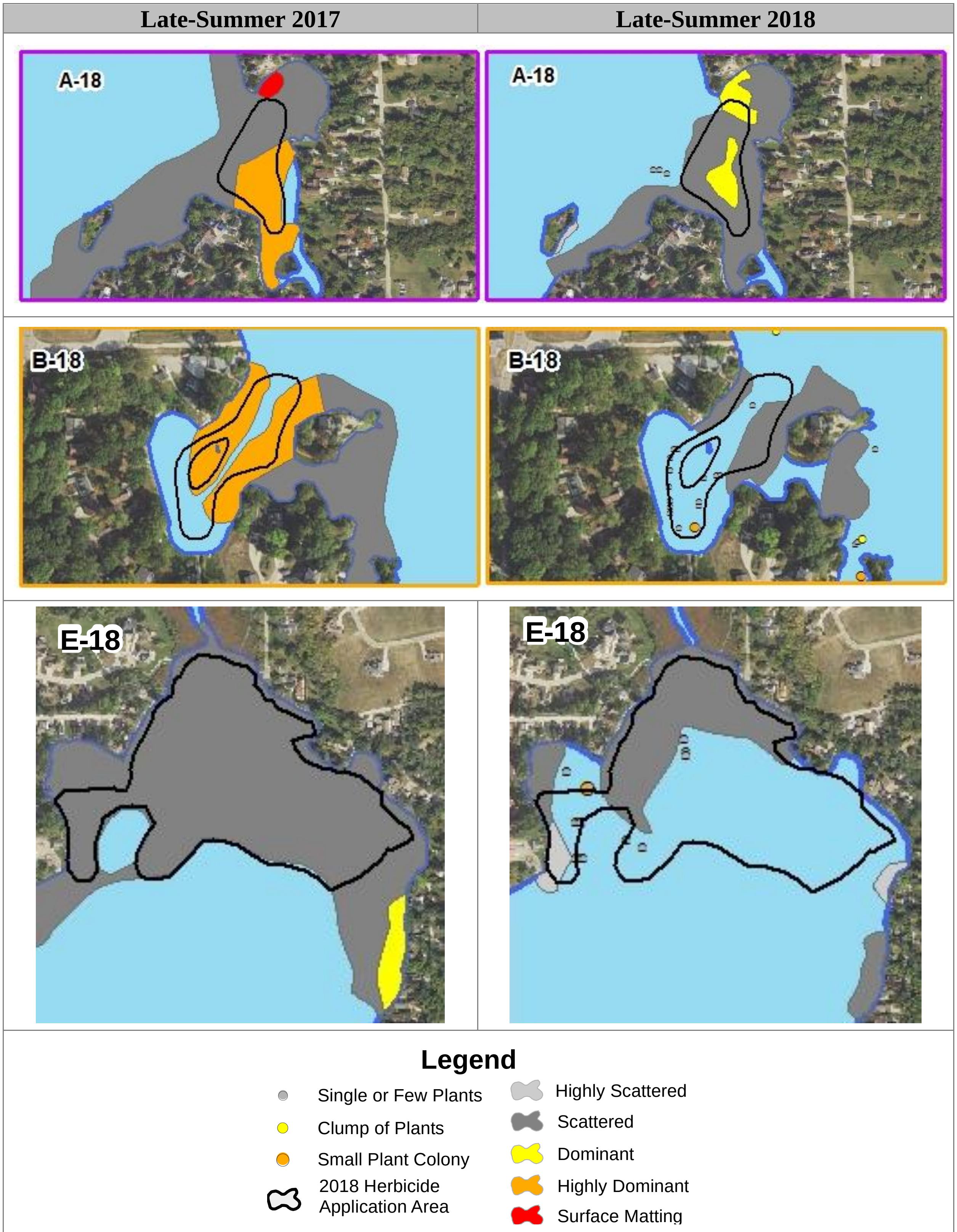


Figure 3.4-13. EWM population from late-summer 2017 (pre-treatment) and late-summer 2018 (post-treatment) for sites A-18, B-18 & E-18 in Tichigan Lake of the Waterford Waterway.

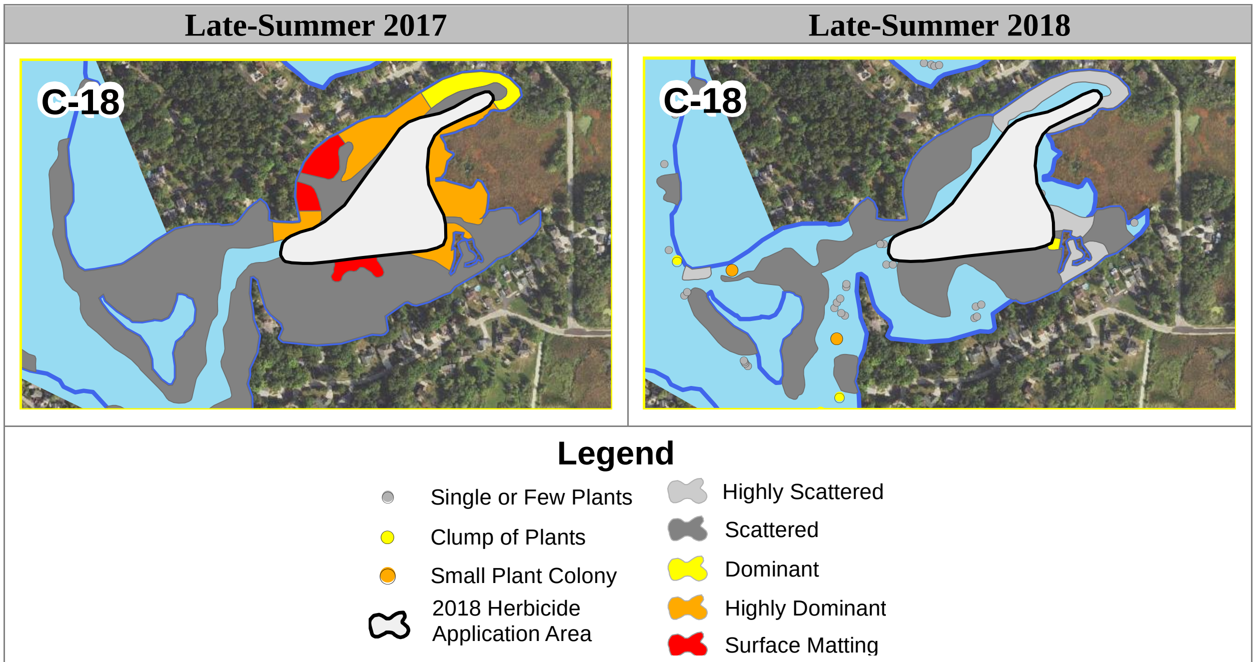


Figure 3.4-14. EWM population from late-summer 2017 (pre-treatment) and late-summer 2018 (post-treatment) for site C-18 in Elm Island Bay of the Waterford Waterway.

Nuisance Aquatic Plant Management Strategy: Navigation Lanes

Common navigation lanes have been maintained through a variety of herbicide treatments in recent years. The areas requiring treatment change from year-to-year and even within the same growing season. During 2018, all of the previously treated areas from 2010-2017 were surveyed to determine nuisance plant levels and need for treatment. Onterra staff surveyed these areas before and after treatments, throughout the 2018 growing season, to not only determine the need for treatment, but also to better understand the tolerance levels of riparian property owners and the efficacy of the treatments. During each navigation lane survey, each lane was categorized into one of three different designations:

- ***Current Nuisance*** – Aquatic plants are currently at nuisance levels.
- ***Anticipated Nuisance*** – Aquatic plants are not currently at nuisance levels, but likely will be in a week to two weeks.
- ***No Nuisance*** – Very little plant growth in the area, no treatment needed at this time.

Following each navigation lane assessment, all lanes that were described as either '*current nuisance*' or '*anticipated nuisance*' were included in the treatment strategy. During 2018, navigation lanes were treated with a slurry of herbicides, including flumioxazin (0.125 ppm), diquat (0.245 ppm), and copper (0.111 ppm). This mixture of herbicides showed improved results in 2017 over mixtures utilizes in previous years.

Navigation lanes assessments were conducted by Onterra staff on five occasions during the 2018 growing season. The first of these visits occurred on May 10 and the navigation treatment strategy was later updated following a May 31st assessment. A total of four navigation lane treatments occurred in 2018 and are listed on Table 3.4-4. An updated permit map was created for each navigation lane treatment. The majority of the nuisance navigation lanes required just one treatment during the growing season, however some lanes were treated two, three or all four times (Map 11). Onterra staff also completed navigation lane assessments on June 29, July 30, and August 31. After each of these assessments, the lanes designated for treatment were determined and spatial data was provided to the applicator.

The navigation lane treatment program in 2018 was fairly similar to the previous year in that four applications occurred and costs were similar.

Table 3.4-4. Navigation Lane Treatment Summary from 2017 and 2018 on Waterford Waterway.

2017 Navigation Lane Herbicide Treatments			
	Date	Acres Treated	Cost
Treatment #1	5/22/2017	12.5	8412
Treatment #2	6/21+26/2017	12.5	9062
Treatment #3	7/20/2017	6.25	4561
Treatment #4	8/25/2017	4	3229
Totals		35.25	25264

2018 Navigation Lane Herbicide Treatments			
	Date	Acres Treated	Cost
Treatment #1	6/4+7/2018	25.5	14825
Treatment #2	7/12/2018	15	5555
Treatment #3	8/8/2018	6.8	3662
Treatment #4	9/10/2018	3.75	2187
Totals		51.05	26229

Nuisance Aquatic Plant Management Strategy: DASH & Mechanical Removal Lanes

In recent years, the WWMD has utilized diver assisted suction harvesting (DASH) as a method to open common navigation lanes in densely vegetated areas. The DASH harvesting has been used to provide relief from nuisance plant conditions that are caused by species such as lily pads that may not be well controlled by the herbicide control program. Plants that typically grow later in the growing season or are in shallow waters where herbicide control has either not been effective or was not applicable have also been targeted for professional hand-harvesting removal efforts.

Typically, DASH utilizes a pump system to convey vegetation harvested by scuba divers through hoses to a barge. The divers remove the plants by hand, feed the vegetation into a hose, and the harvested materials are filtered out through a series of sieve trays and/or mesh bags. This methodology has been used to remove exotic plant species, especially EWM, from lakes throughout Wisconsin for nearly a decade. On the Waterford Waterway, divers are not utilized due to water depth. Instead, several harvesters are wading in the water ahead of the pump barge as they remove plants. The plants are fed into the vacuum hoses for delivery to the boat deck and later disposed at designated sites.

The APMC and district members believe that this methodology works well and provides longer lasting results than lanes created by herbicide treatments, although it is much slower, and on an acre-by-acre comparison, more expensive. In early 2017 a two-year WDNR mechanical harvesting permit was issued that expired at the end of October 2018. A DASH contractor worked 280 hours in 2017 to clear lanes in just over 4 acres of the Waterford Waterway. A total of approximately 103,800 pounds of aquatic plants were harvested from nine sites during DASH operations in 2017. In 2018, a professional hand-harvesting contractor worked 232 hours with DASH and 22 hours hand-harvesting aquatic vegetation from 10 locations around the Waterford Waterway. A total of approximately 72,750 pounds of vegetation were removed from 6.45 acres of the permitted areas (Map 12)

Aquatic Plant Management: Conventional Mechanical Harvesting

The WWMD has investigated the use of conventional, cutter-style mechanical harvesting on the Waterford Waterway during several planning efforts in the past decade; however, no specific recommendations were made. Many Wisconsin lake groups successfully manage nuisance levels of aquatic vegetation through lake group-owned or contracted mechanical harvesting. The primary factor typically limiting the use of a mechanical harvester is water depth. Most operators will not harvest in less than three feet of water due to difficulty in maneuvering the equipment and the amount of sediment that is resuspended in these areas. Map 13 displays areas of the waterway that typically support water depths of 3-feet or greater. While a harvester may be able to operate in 3 feet of water, other factors, such as plant density, obstructions, distance to offload site, and intermingled shallow areas, must be considered to the applicability of conventional mechanical harvesting.

During a Late-June 2018 visit to the system, Onterra staff met with a representative of the WWMD to conduct a site tour visit within Tichigan Lake to evaluate the applicability of operating a mechanical harvester. From this visit, it was determined that certain areas in Tichigan Lake where adequate water depths allow, may be suitable for mechanical harvesting to alleviate nuisance aquatic plant growth. Most areas of Tichigan Lake that exhibited nuisance plant growth however, were in shallow waters less than approximately three feet of depth which makes mechanical harvesting in these areas difficult or even impossible.

A preliminary mechanical harvesting plan was developed during 2018 that could serve to alleviate nuisance aquatic plant conditions in Tichigan Lake (Map 14). However, before any action was implemented in 2018, the vegetation in Tichigan Lake naturally declined to levels that no longer caused nuisance conditions in most of the lake and no further steps were taken.

Aquatic Plant Management: Water level Drawdown

The term “water level drawdown” or “drawdown” can mean many things in lake management. Actually, in Wisconsin and elsewhere, there are many types of drawdowns used to managed certain aspects of the lake environment. There are winter drawdowns that typically last from just after Labor Day to spring. Some lakes have been exposed to summer drawdowns, while other to drawdowns lasting a year or more. The timing and longevity of a drawdown are important in meeting the goal of the action. Common goals for drawdowns in lake management (not dam maintenance or shoreline/near-shore modification) are AIS control, native plant restoration/enhancement, and sediment decomposition/consolidation. The latter, often called ‘sediment compaction’ refers to the actual chemical and physical change in sediment brought on by oxidation, not just drying out (dehydration) of the sediments.

To achieve substantial sediment decomposition/consolidation, the drawdown period must include significant bottom sediment exposure during much of the growing season – typically an entire summer. Very little, if any water depth gain is made through this process during the cold temperatures of a winter drawdown.

Native plant restoration and enhancement, mostly seen in the emergent plant community, must also include exposure of bottom sediments during the warm growing season months. It is during this exposure that native emergents are able to establish and expand within the lake. No native plant enhancement results directly from a winter drawdown; however, as discussed below, a ‘good’ winter drawdown may heavily impact AIS plants; therefore, native submergents may rebound because of less competition from non-native plants.

Eurasian watermilfoil has been shown to be impacted greatly by winter drawdowns in several lakes in Wisconsin and other temperate areas. As alluded to above, it must be a 'good' winter drawdown where cold and dry conditions exist throughout much of the winter. If the sediment is exposed due to the drawdown, but kept hydrated by deep snow or winter rains, the impacts to Eurasian watermilfoil will likely not meet expectations. In fact, an incomplete or poor winter drawdown has been shown to exasperate the Eurasian watermilfoil problem in some cases.

Curly-leaf pondweed, in most cases, is also impacted by winter drawdown. In some cases, no change was found to occur. Several native submergent plants are also reduced following drawdown, while some so no impact, and others increase. The response of floating-leaf species has been variable to drawdowns. Tubers can be resilient to desiccation and freezing. White water lily has been found to expand following some drawdowns

Table 3.4-5 shows the most common submergent aquatic plant species present in Waterford Waterway and how the population of these species have changed in previous studies on other Wisconsin lakes with *year pre-drawdown* and *year after* post-drawdown monitoring. The three most dominant aquatic plant species found in the Waterford Waterway in 2018, (coontail, common waterweed, and Eurasian watermilfoil) have been found to exhibit statistically valid decreases in littoral frequency of occurrence following winter drawdowns on other monitored drawdown projects completed on Little Muskego Lake, Soo Lake and Musser Lake (Figure 3.4-15)

Table 3.4-4. Submersed Aquatic Plants Present in Waterford Waterway and their Responses to Water level Drawdowns. Soo Lake and Musser Lake data from Onterra point-intercept surveys, Little Muskego Lake data from WDNR.

Waterford Waterway Submergent Plant Community		**Drawdown Response**		
Scientific Name	**Common Name**	**Little Muskego**	**Soo**	**Musser**
Ceratophyllum demersum	Coontail	↓	↓	↓
Elodea canadensis	Common waterweed	↓	↓	↓
Myriophyllum spicatum	Eurasian watermilfoil	↓	↓	
Stuckenia pectinata	Sago pondweed	↓		
Najas guadalupensis	Southern naiad	↓		
Potamogeton crispus	Curly-leaf pondweed			↓
Ranunculus aquatilis	White water crowfoot			NC
Heteranthera dubia	Water stargrass	NC		
Potamogeton zosteriformis	Flat-stem pondweed		↓	
Chara spp.	Muskgrasses	↓		
Vallisneria americana	Wild celery	↓	↓	NC
Potamogeton gramineus	Variable-leaf pondweed			
Najas flexilis	Slender naiad	↑	↑	
Utricularia vulgaris	Common bladderwort		NC	NC
Zannichellia palustris	Horned pondweed			

There has been much talk about completing a winter drawdown on the Waterford Waterway since 2017. Some of the information and discussions have been factual, while some have not. For instance, the waterway would see little benefit, or possibly no benefit, in the terms of water depth increase due to sediment decomposition/consolidation brought on by a winter drawdown. Further, as described above, there would not be substantial restoration to the native plant community. There are many impacts, some positive and some negative, that must be weighed in making the decision to perform a winter drawdown on the Waterford Waterway.

The vegetation surveys completed as a part of this project and early projects as well, have shown that Eurasian watermilfoil and curly-leaf pondweed are <u>not</u> the primary species causing the navigational issues on the Waterford Waterway. These species are not typically found to be at nuisance levels on a lakewide basis until they reach a littoral frequency of occurrence of 30% or more and maintain that level for greater than a single season. Coontail and common waterweed are by far the dominate plants in the system causing the issue; therefore, at current levels, AIS control should not be a reason for completing a winter drawdown. Studies completed on other lakes completing winter drawdowns have shown reductions in both coontail and common waterweed following winter drawdowns, but sufficient data do not exist to determine how long the impact would last.

Winter drawdowns typically include refilling during the spring when water flows are typically the greatest. Spring flows to the Waterford Waterway contain the highest phosphorus levels of the year; therefore, the impact of that high concentration must be considered in the water quality of Tichigan and Waterford lakes. Considering a 5-foot drawdown, the surface area of each lake, and an average spring phosphorus concentration of 140 µg/L in the Fox River Channel (it was 144 µg/L during late June 2018), phosphorus loading to the two waterbodies would be very high during the refill. In fact, an estimate of 540 lbs. of phosphorus would be added to Tichigan Lake, which is approximately half of its annual load, while 18 lbs. would be added to Waterford Lake which is over 63% of the lake's estimated annual load. In both cases, the incredible increase in phosphorus load during the beginning of the growing season could spur algal blooms that would last the entire summer. The load could be reduced by about a third if the refill was completed later in the summer when river inputs were less, but recreation would be loss during those months and the refill would be slower.

Some riparians see a drawdown event as an opportunity to complete nearshore dredging and shoreline modification. A shorter drawdown period would be needed to complete these actions, but the affects on phosphorus loading during the refill must still be considered. The lowest concentrations of phosphorus in the Fox River occur in fall. Samples collected during late October 2018 had a phosphorus concentration of 40 µg/L. Utilizing a 5-foot drawdown during that time, as an example, would add approximately 154 lbs. of phosphorus to Tichigan Lake. While that is about 10% of the annual phosphorus load to the lake, the event would occur during cold water temperatures, substantially reducing the chance of an algal bloom and much of the phosphorus would settle to the bottom during the winter, so the impact during the following growing season would likely be minimal.

Stakeholder Survey Responses regarding Aquatic Vegetation within Waterford Waterway

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. Questions related to aquatic plant management activities were included in the survey and Figures 3.4-15 through 3.4-17 highlight a few of these topics. When asked to rank their top three concerns regarding Waterford Waterway, the top choice among the respondents was *excessive aquatic plant growth* (Figure 3.4-15). The majority of the survey respondents are supportive or moderately supportive of using herbicides or DASH to manage AIS and native aquatic plants on Waterford Waterway (Figure 3.4-16 & 3.4-17).

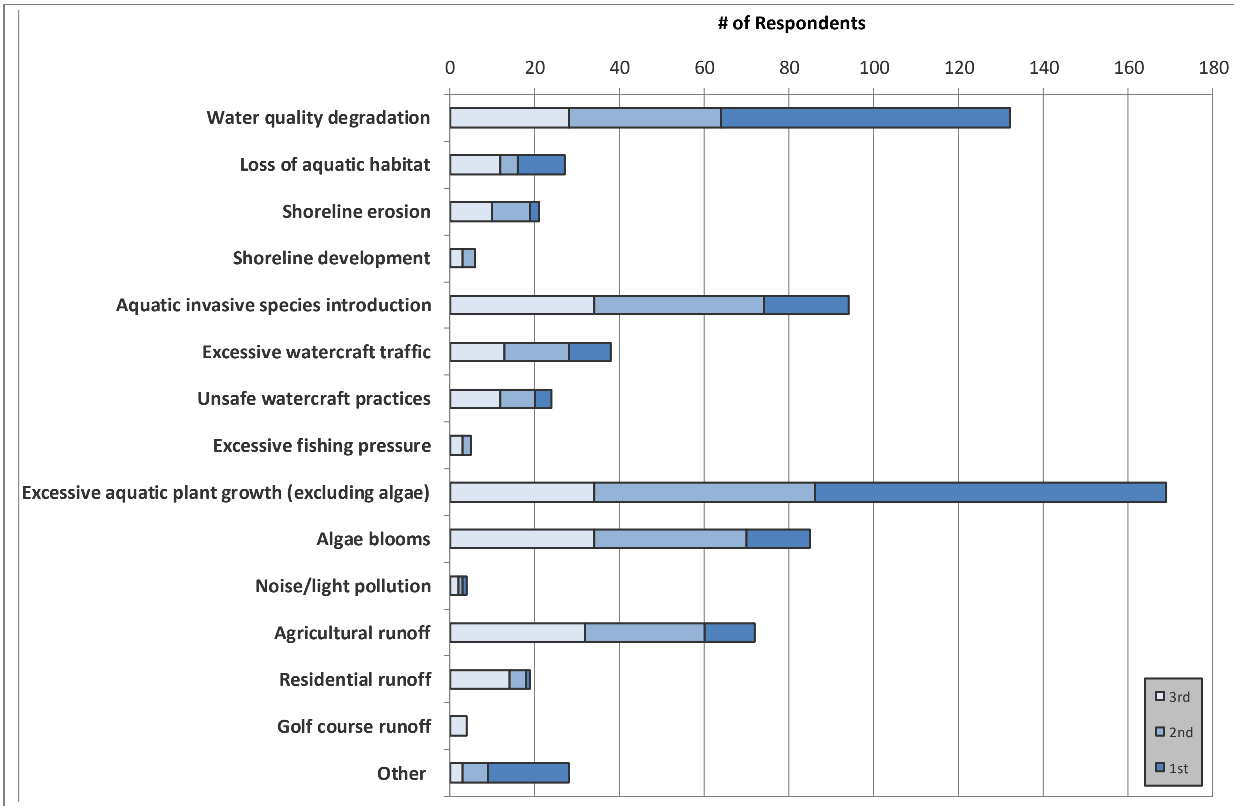


Figure 3.4-15. Stakeholder survey response Question #29. From the list below, please rank your top three concerns regarding Waterford Waterway, with 1 being your greatest concern.

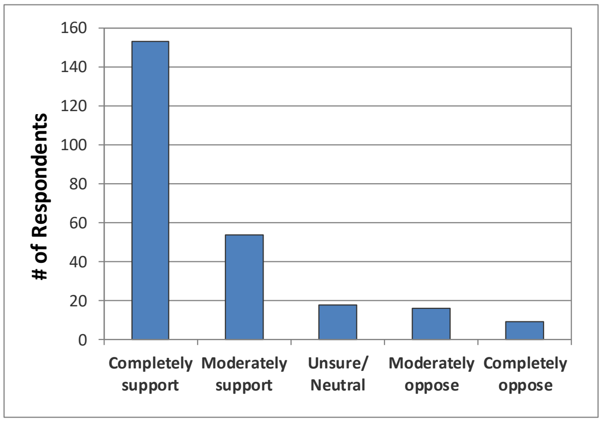


Figure 3.4-16. Stakeholder survey response Question #34. What is your level of support or opposition for future aquatic herbicide use to target AIS and nuisance aquatic plants in Waterford Waterway?.

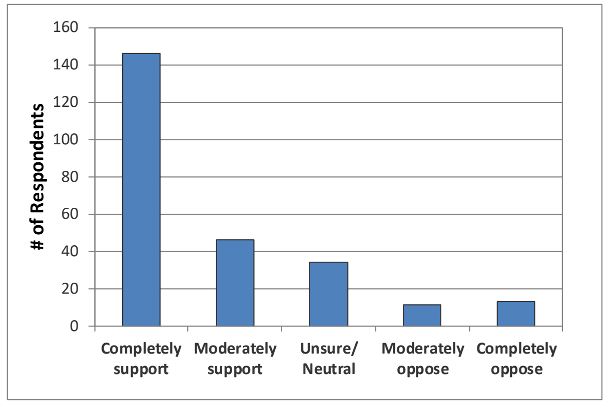


Figure 3.4-17. Stakeholder survey response Question #37. What is your level of support or opposition for using DASH to target nuisance aquatic plant growth in Waterford Waterway?

3.5 Aquatic Invasive Species in Waterford Waterway

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

Table 3.5-1. AIS present within Waterford Waterway

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
	Flowering rush	*Butomus umbellatus*	Section 3.4 – Aquatic Plants
	Purple Loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
	Pale-yellow Iris	*Iris pseudacorus*	Section 3.4 – Aquatic Plants
	Reed canary grass	*Phalaris arundinacea*	Section 3.4 – Aquatic Plants
Invertebrates	Zebra mussel	*Dreissena polymorpha*	Section 3.1 – Water Quality
Fish	Common carp	*Cyprinus carpio*	Section 3.5 –AIS in Waterford Waterway

Figure 3.5-1 below displays the 15 aquatic invasive species that Waterford Waterway stakeholders believe are in Waterford Waterway. Only the species present in Waterford Waterway are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species 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

Common Carp

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

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

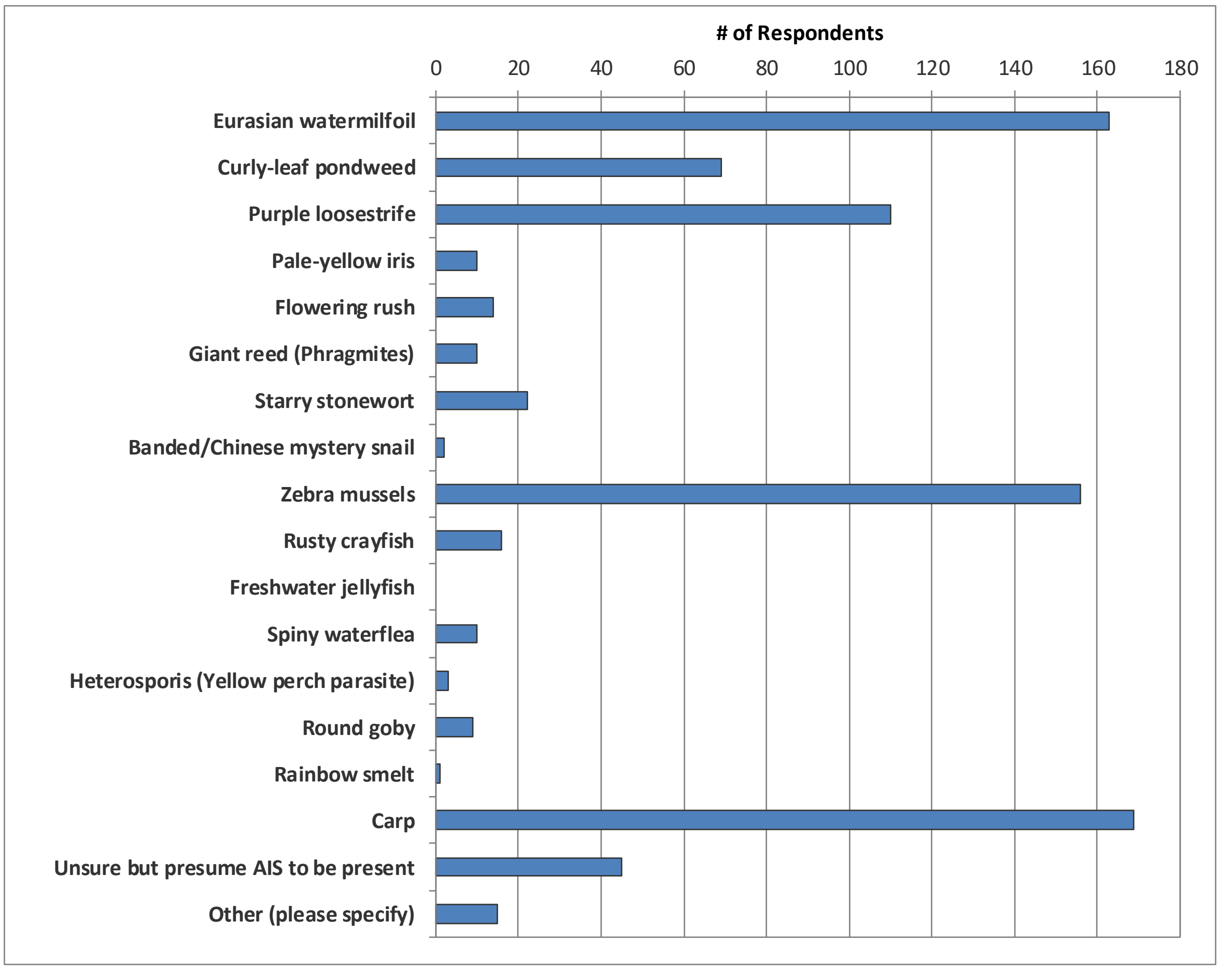


Figure 3.5-1. Stakeholder survey response Question #27. Which aquatic invasive species do you believe are in Waterford Waterway?

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing the Waterford Waterway. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) and personal communications with DNR Fisheries Biologist Luke Roffler (WDNR 2019).

The Waterford Waterway Fishery

Energy Flow of a Fishery

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

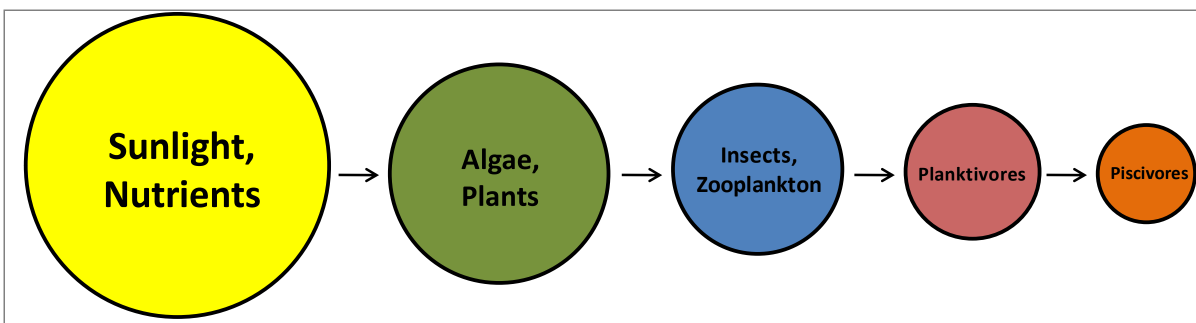


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, the Waterford Waterway is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means the Waterford Waterway should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past WDNR surveys of the Waterford Waterway include common carp (*Cyprinus carpio*), freshwater drum (*Aplodinotus grunniens*), gizzard shad (*Dorosoma cepedianum*), longnose gar (*Lepisosteus osseus*), shortnose gar (*Lepisosteus platostomus*), and the quillback (*Carpiodes cyprinus*).

Additionally, the Waterford Waterway harbors the following fish species on the Wisconsin Natural Heritage Working List which contains all species known or suspected to be rare in the state (WDNR NHI List, 2016). The lake chubsucker (*Erizyzon sucetta*) is a special concern species in Wisconsin due to a restricted range, few populations, recent declines or other factors. Its global status, however, is considered secure and at a very low risk for extinction. The river redhorse (*Moxostoma carinatum*) is a threatened species in Wisconsin due to a restricted range, steep declines, severe threats or other factors. Its global status is at a low risk of extinction due to an extensive range with many populations. The starhead topminnow (*Fundulus dispar*) is an endangered species in Wisconsin due to a restricted range, steep declines, severe threats or other factors. Its global status is at a low risk of extinction due to an extensive range with many populations. All of these imperiled species prefer habitat in river systems, the lake chubsucker and starhead topminnow specifically prefer dense vegetation provided in the Waterford Waterway.

Table 3.6-1. Gamefish present in the Waterford Waterway with corresponding biological information (Becker, 1983).

Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Trout (*Salmo trutta*)	18	October - December	Large streams to small spring-fed tributaries with gravel bottom	Aquatic invertebrates, terrestrial insects, worms, fish, and crayfish
Bullhead (*Ameiurus*)	6	Dependent on species	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Amphipods, insect larvae and adults, fish, detritus, algae
Channel Catfish (*Ictalurus punctatus*)	15	May - July	Dark cavities or crevices, rock ledges, beneath tree roots	Fish, insects, other invertebrates, seeds, plant materials
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
White Bass (*Morone chrysops*)	8	Late April - June	Running water of streams, windswept shorelines, sand, gravel, or rock	Crustaceans, insect larvae and other invertebrates, and fish
White Crappie (*Pomoxis annularis*)	13	May - June	Within 10 m from shore, over hard clay, gravel, or roots	Crustaceans, insects, small fish
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

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

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

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


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

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Tichigan Lake has been stocked from 1972 to 2018 with muskellunge, northern pike, brown trout, smallmouth bass and walleye (Tables 3.6-2-4).

Photograph 3.6-2. Fingerling Muskellunge.

Future stocking efforts of walleye will be consistent following Tichigan 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 2014 and even years thereafter Tichigan Lake was selected to receive a stocking rate of 5 extended growth walleye/acre as funding allows (WDNR 2013).

Table 3.6-2. Stocking data available for northern pike in the Waterford Waterway (1972-2018).

Stocking Location	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Tichigan Lake	1991	Northern Pike	Unspecified	Fingerling	2,000	8
Tichigan Lake	1992	Northern Pike	Unspecified	Fingerling	2,260	8
Tichigan Lake	1993	Northern Pike	Unspecified	Fingerling	2,352	8.6
Tichigan Lake	1994	Northern Pike	Unspecified	Fingerling	1,123	7.7
Tichigan Lake	1995	Northern Pike	Unspecified	Fingerling	2,260	8.5
Tichigan Lake	1999	Northern Pike	Lake Puckaway	Large Fingerling	2,260	7.2
Tichigan Lake	2001	Northern Pike	Lake Puckaway	Large Fingerling	3,000	7.6
Tichigan Lake	2005	Northern Pike	Unspecified	Large Fingerling	1,129	8.5
Tichigan Lake	2011	Northern Pike	Unspecified	Yearling	1,191	17.2
Tichigan Lake	2013	Northern Pike	Mud Lake - Madison Chain of Lakes	Large Fingerling	1,793	10
Tichigan Lake	2015	Northern Pike	Mud Lake - Madison Chain of Lakes	Small Fingerling	2,350	3
Tichigan Lake	2017	Northern Pike	Mud Lake - Madison Chain of Lakes	Small Fingerling	2,429	2.32
Fox River (Bridge Rd)	2018	Northern Pike	-	-	22,500	1.3

Table 3.6-3. Stocking data available for walleye in the Waterford Waterway (1972-2018).

Stocking Location	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Tichigan Lake	1972	Walleye	Unspecified	Fingerling	16,800	4
Tichigan Lake	1974	Walleye	Unspecified	Fingerling	20,000	3
Tichigan Lake	1976	Walleye	Unspecified	Fingerling	44,715	3
Tichigan Lake	1978	Walleye	Unspecified	Fingerling	11,040	4
Tichigan Lake	1981	Walleye	Unspecified	Fingerling	44,000	3.6
Tichigan Lake	1982	Walleye	Unspecified	Fry	2,000,000	
Tichigan Lake	1984	Walleye	Unspecified	Fingerling	47,000	3
Tichigan Lake	1985	Walleye	Unspecified	Fingerling	40,130	3
Tichigan Lake	1986	Walleye	Unspecified	Fry	1,100,000	1
Tichigan Lake	1989	Walleye	Unspecified	Fingerling	67,170	2.5
Tichigan Lake	1991	Walleye	Unspecified	Fingerling	26,231	3
Tichigan Lake	1995	Walleye	Unspecified	Fingerling	28,300	2.8
Tichigan Lake	1997	Walleye	Unspecified	Large Fingerling	25,275	2.7
Tichigan Lake	2000	Walleye	Unspecified	Small Fingerling	113,230	1.7
Tichigan Lake	2002	Walleye	Mississippi Headwaters	Small Fingerling	48,650	1.9
Tichigan Lake	2006	Walleye	Rock-Fox	Small Fingerling	39,620	2
Tichigan Lake	2010	Walleye	Rock-Fox	Small Fingerling	9,765	1.7
Tichigan Lake	2012	Walleye	Rock-Fox	Small Fingerling	39,620	1.52
Tichigan Lake	2014	Walleye	Rock-Fox	Large Fingerling	1,392	7.35
Fox River (Bridge Rd)	2014	Walleye	-	-	22,500	1.3
Fox River (Bridge Rd)	2015	Walleye	-	-	570	7
Tichigan Lake	2016	Walleye	Rock-Fox	Large Fingerling	1,395	6.2
Fox River (Bridge Rd)	2016	Walleye	-	-	556	7
Fox River (Bridge Rd)	2017	Walleye	-	-	540	7
Fox River (Bridge Rd)	2017	Walleye	-	-	1,872	3.1
Tichigan Lake	2018	Walleye	Unspecified	Large Fingerling	1395	6.2
Fox River (Bridge Rd)	2018	Walleye	-	-	726	7

Table 3.6-4. Stocking data available for brown trout, smallmouth bass and muskellunge in the Waterford Waterway (1979-2016).

Stocking Location	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Tichigan Lake	1979	Brown Trout	Unspecified	Fingerling	500	7
Tichigan Lake	1982	Brown Trout	Unspecified	Yearling	700	
Tichigan Lake	1987	Brown Trout	Unspecified	Yearling	2,100	9
Tichigan Lake	2000	Brown Trout	St. Croix	Yearling	700	9
Fox River (Bridge Rd)	2014	Smallmouth Bass	-	-	22,500	1.3
Fox River (Bridge Rd)	2018	Smallmouth Bass	-	-	540	5
Fox River (Bridge Rd)	2016	Muskellunge	-	-	175	11

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water) was the third important reason for owning property on or near the Waterford Waterway (Question #20). Figure 3.6-2 displays the fish that the Waterford Waterway stakeholders enjoy catching the most, with bluegill/sunfish, largemouth bass and northern pike being the most popular. Approximately 78% of these same respondents believed that the quality of fishing on the lake was either fair or good (Figure 3.6-3). Approximately 56% of respondents who fish the Waterford Waterway believe the quality of fishing has remained the same or is somewhat worse since they first started to fish the lake (Figure 3.6-4).

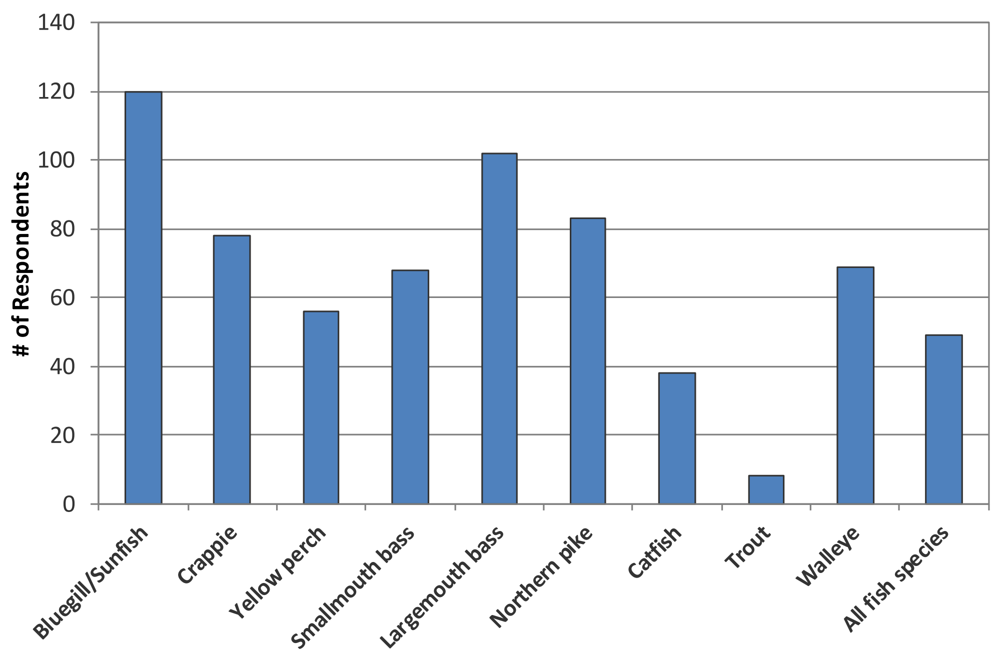


Figure 3.6-2. Stakeholder survey response Question #14. What species of fish do you like to catch on Waterford Waterway?

Figure 3.6-3. Stakeholder survey response Question #15. How would you describe the current quality of fishing on Waterford Waterway?

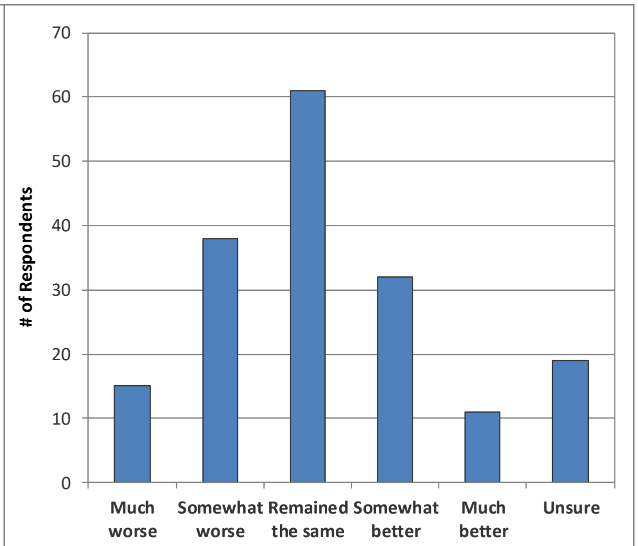


Figure 3.6-4. Stakeholder survey response Question #16. How has the quality of fishing changed on Waterford Waterway since you have started fishing the lake?

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 the Waterford Waterway represent different population dynamics depending on the species but overall harbors an excellent and diverse fishery (Roffler 2017). The results for the stakeholder survey show landowners prefer to catch largemouth bass on the Waterford Waterway (Figure 3.6-2). Brief summaries of gamefish with fishable populations in the Waterford Waterway are provided based off of the report submitted by WDNR fisheries biologist Luke Roffler following the fisheries survey completed from 2014 - 2017.

Walleyes are a valued sportfish in Wisconsin Lakes. The Waterford Waterway, however, has a high walleye abundance particularly when compared to other lakes in the region (Roffler 2017). Size structure was also good with an average length of 17.8 inches. From 1972 to 2018 3,100,000 fry, 276,160 small fingerlings and 377,715 large fingerling walleyes have been stocked in the Waterford Waterway (Table 3.6-2). The walleye population estimate after the 2017 sampling was 4.3 adult walleye per acre which is greater than most lakes in the area.

Largemouth bass are also considered abundant with a strong size structure (average length of 14 inches) in the Waterford Waterway. In 2014 and 2018 22,500 small fingerlings and 540 large fingerlings were stocked, respectively (Table 3.6-4).

Northern Pike are considered relatively abundant in the Waterford Waterway. Size structure was very good with an average length of 25.1 inches. Northern pike are considered an important predatory fish in the system keeping panfish and rough fish numbers under control (Roffler 2017).

Channel Catfish are considered the most abundant top predator in the Waterford Waterway system. Size structure was very strong (average length 18.8 inches) and several catfish were observed during the 2017 survey which were larger than the maximum length during the 2014 survey.

Panfish

The panfish present on the Waterford Waterway also represent different population dynamics depending on the species. The results for the stakeholder survey show anglers prefer to catch bluegill/sunfish on the Waterford Waterway (Figure 3.6-2). Brief summaries of panfish with fishable populations in the Waterford Waterway are provided based off of the WDNR fisheries survey completed in 2014 to 2018 (Roffler 2017).

Bluegill and yellow perch were both relatively infrequent on the Waterford Waterway, however, size structure was strong for these species.

Black crappie and pumpkinseed were also captured during the surveys and also had strong size structures.

The Waterford Waterway 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, 85% of the substrate sampled in the littoral zone of the Waterford Waterway was soft sediments, 13% was composed of sand and 2% 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). A fall 2018 survey documented 167 pieces of coarse woody along the shores of the Waterford Waterway, resulting in a ratio of approximately 6 pieces per mile of shoreline. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how The Waterford Waterway's coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

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

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

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

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 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 (WDNR 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 Waterford Waterway Management District, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for the Waterford Waterway.

Fishing Regulations

Regulations for Tichigan and Buena Lakes fish species as of March 2019 are displayed in Table 3.6-5. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-5. WDNR fishing regulations for Tichigan and Buena Lakes (As of March 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 bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 5, 2018 to December 31, 2018
Northern pike	2	26"	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	18"	May 5, 2018 to March 3, 2019
Catfish	10	None	Open All Year
Bullheads	Unlimited	None	Open All Year
Rock, yellow, and white bass	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. As mentioned in the Water Quality Section 3.1, Tichigan Lake and the Fox River are currently impaired by PCBs. More information can be found at: https://dnr.wi.gov/topic/Fishing/consumption/specialmap.html. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-5. 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 3.6-5. 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/)

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Waterford Waterway ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil and curly-leaf pondweed.
3) Determine the extent, dominant species involved, and possible remedies to nuisance aquatic plants within the system.
4) Collect sociological information from Waterford Waterway stakeholders regarding their use of the waterway and their thoughts pertaining to the past and current condition of the system and its management.

The four objectives were fulfilled during the project and have led to a good understanding of the Waterford Waterway ecosystem, the folks that care about the system, and what needs to be completed to make the system the best it can be.

The section below is intentionally written to include minimal data and be general in terms of the information being discussed. Much more detailed information regarding the results of the studies completed and the data compiled as a part of this project can be found in Sections 1-4. The reader is encouraged to read those sections and use them as a reference as needed.

For the most part, the Waterford Waterway is a manmade system. It is true that Tichigan Lake existed prior to the construction of the Waterford Dam, but like the wetlands that now make up Buena Lake and Conservancy Bay, Tichigan Lake has been totally altered from a natural ecosystem. The construction of the Waterford Dam created a situation where the Illinois Fox River has an unnatural influence on Tichigan Lake and the waterbodies now called Buena Lake and Conservancy Bay. The most obvious influence is that what where floodplain wetlands likely naturally occurred, there are now shallow lakes. The influence on Tichigan Lake is not as apparent, but due to the consistent, unnaturally increased water levels brought on by the dam, river water frequently enters Tichigan Lake and as a result, impacts the lake's water quality profoundly. Prior to the dam, Fox River water likely did not flow into the lake or only did during the most extreme flooding events.

As described in the Watershed Section 3.2, the land area draining to the Waterford Waterway is about 356 sq. mi. or roughly 227,840 acres. The Waterford Waterway is approximately 1,229 acres, meaning that 186 acres of land drains to each acre of waterway. A watershed to lake area ratio of 186:1 is exceptionally large. A tremendous amount of water drains through the Waterford Waterway from its large watershed. This is important to consider in the management of the Waterford Waterway. The unnaturally large watershed delivers an unnaturally large amount of nutrients to the waterbody. Considering the Waterford Waterway as a whole, the primary nutrient of concern is phosphorus because it is the limiting nutrient and thus controls plant growth. Those high phosphorus loads foster very high plant production within the system. That plant production shows itself in the form of high vascular plant biomass and frequent algae blooms.

As presented in the Water Quality Section 3.1, Tichigan Lake's water quality fluctuates greatly from year-to-year between what is considered good to poor for a drainage lake. The lake is considered highly productive because of high phosphorus and chlorophyll-a concentrations. The lake also exhibits nuisance levels of aquatic plant growth and occasional filamentous algae blooms. Analysis of the Tichigan Lake watershed indicates that approximately half of the phosphorus that enters the lake originates from the Fox River. As elaborated on in both the Water Quality and Watershed Sections, water from the Fox River is able to enter Tichigan due to the natural fluctuation in the system's water level during the year.

As mentioned above, Tichigan Lake, as well as other areas of the Waterford Waterway, experience occasionally heavy filamentous algae blooms. Filamentous algae are a group of simple plants that consist of individual algal cells that grow in a filament (string). Most lakes have some filamentous algae growing in them, but they often go unnoticed because they grow on the bottom of the lake in shallow areas where light is available. They primarily draw their nutrients from the sediment. If sufficient light and heat is available, the filamentous matts can become thick, trapping gasses from decomposition in the sediment and oxygen from photosynthesis. With enough gas, the mats can be lifted from the bottom and float to the surface where they wash up on vascular vegetation. This can be unsightly and produce noxious odors. Unfortunately, this is a symptom of a nutrient rich system and little can be done to predict or prevent the blooms.

Water quality data were also examined for Waterford Lake. The lake is considered to have poor water quality exhibited by very high phosphorus levels, high chlorophyll-a concentrations, and recently frequent blue-green algae blooms. Other areas of the waterway have been documented to experience blue-green algae blooms as well. The conditions leading to blue-green algae blooms are complicated, but most involve high nutrient levels and warm water temperatures.

The WWMD asked that Onterra explore the possibility that internal nutrient recycling in Waterford Lake was elevating the phosphorus levels and causing blue-green algae blooms. As discussed in the Watershed Section 3.2, nutrient modeling for Waterford Lake indicates that internal phosphorus loading accounts for only 13% of the lake's total phosphorus budget. However, much like Tichigan Lake, the Fox River accounts for about 30% and the watershed around the lake accounts for about 52%. The remaining 5% is direct input to the lake surface through atmospheric deposition.

As mentioned in the beginning of this section, the Fox River has an overwhelming impact on the water quality of the Waterford Waterway. Modeling of the Waterford Waterway watershed, <u>not</u> including the land draining to Tichigan Lake, indicates that about 44.5 tons of phosphorus enters the waterway from that drainage basin. Of course, the vast majority of that enters via the Fox River. Roughly 64% of that load originates from agricultural row crops in the drainage basin. A natural conclusion to reduce the phosphorus load to the system is to reduce the impact of agricultural row crops. In a natural lake system with a typical watershed to lake area ration of 20:1 or less, that would likely produce good results. However, in the case of the Waterford Waterway, the sheer size of the watershed overrides the impact of land cover type. For example, scenario modeling indicates that if one-half of the row crop agriculture in the watershed was returned to forested cover, the best type of cover because it exports the least amount of phosphorus per acre, the phosphorus load would only be reduced to approximately 31.6 tons, which would still make the Waterford Waterway a highly productive waterbody and any improvements to water quality would likely go unnoticed by the human eye.

Several plant studies were completed on the Waterford Waterway during 2017 and 2018. These surveys were used to document native and non-native (exotic) aquatic plant species in the waterway. The surveys found that the aquatic plant community for the waterway is of moderate ecological value and indicative of an over productive, unnatural system. The surveys also documented that nuisance levels of plant growth occur in many parts of the system, but aquatic invasive species (AIS) are not the culprits causing the nuisance. In fact, two native species, coontail and common waterweed, dominate the community and bring about most of the navigational difficulties. Past studies completed on the waterway since 2007 have also documented that coontail and common waterweed were the dominant species during those years as well. Monitoring of navigation lane treatments utilizing herbicides during the 2018 growing season found that the treatments work well at providing riparians with access to open water. The Implementation Plan found in Section 5.0 below contains district actions in investigating other methods of nuisance relief on the Waterford Waterway.

Near the end of the Aquatic Plant Section 3.4, there is an extended discussion regarding water level drawdowns and their use on lakes and impoundments. There are several types and variations of water level drawdown used by lake managers throughout the US and world, but none are a silver-bullet for controlling any one plant or improving lake ecology. Each has its own advantages and disadvantages. Specific to the Waterford Waterway, a winter drawdown during a cold and dry winter would likely reduce the two primary AIS of concern on the waterway, Eurasian watermilfoil and curly-leaf pondweed. However, the surveys completed before this project and during this project confirmed that these two species are not an issue on the waterway. In some localized areas, they may cause an issue, but in vast majority of areas, the native species, coontail and common waterweed are causing the nuisance conditions. While the levels of curly-leaf pondweed and Eurasian watermilfoil fluctuate annually, the Waterford Waterway does not have an AIS problem at this time.

Studies completed on other Wisconsin lakes before and after winter drawdowns indicate that coontail and common waterweed may be reduced by a good winter drawdown. However, data do not exist indicating how long that impact would last. Modeling and calculations performed as a part of this project indicated that if a 5-foot winter drawdown on the Waterford Waterway completed, that the water entering Tichigan Lake from the Fox River during the spring refilling would add upwards of 500 lbs. of phosphorus to the lake in a matter of days. That would equate to a 50% addition to the lake's typical annual phosphorus load. This could result in heavy algae blooms on the lake throughout the summer following the drawdown. A similar scenario would likely occur in Waterford Lake as well.

The implementation plan that follows in Section 5.0 outlines the actions the WWMD will take to meet the goals it has set for the management of the Waterford Waterway. The plan takes into account that while the Waterford Waterway experiences certain symptoms brought on by its large watershed, there are methods and strategies that can be used to treat those symptoms and make the Waterford Waterway the best it can be for the people that care for it and utilize it as a valuable resource for a variety of recreational opportunities, including one of the best fisheries in Southern Wisconsin.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the WWMD Planning Committee and ecologist/planners from Onterra. It represents the path the WWMD will follow in order to meet their lake management goals and the district mission:

Maintain, protect, and improve the quality of the Waterford Waterway, its fisheries, its watershed, and boundaries; while maintaining the highest possible quality of living experience for its residents.

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 Waterford Waterway 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 the Waterford Waterway

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	This action was started in spring 2019.
Facilitator:	APM Committee Chair
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. The Waterford Waterway's current planning effort suffered because of a lack of water quality data available to substantiate or dispel lake user comments regarding worsening water quality in the lake. In the past two decades, the only substantial water quality collections have been completed as a part of the district's management planning efforts, which is far too infrequent to allow for long-term trends analysis. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. The WWMD volunteers would be trained to monitor the deep hole site as a part of the advanced CLMN program. This includes collecting Secchi disk transparency and sending in water chemistry samples (chlorophyll-a, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The samples are collected once during the spring and three times during the summer. It is important to note that as a part of this program, the data collected are automatically added to the

WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

It will be the Board of Commissioner's responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples each year.

Sampling Sites on Waterford Waterway

Tichigan Lake Deep-hole Site. Station ID: 523122. Used by Citizens Lake Monitoring Network (CLMN) volunteers currently.

Waterford Lake Center of Lake. Station ID: 10050715. This site's station ID was set up (requested to WDNR) for the planning project. Only data collected during the planning project are currently available.

Fox River Fox River (Waterford Waterway) – Near Channel to Waterford Lake. Station ID: 10051229. This station was set up for the planning project. Only data collected during the planning project are currently available. This represents the water quality of the Waterway just above the dam in the main channel.

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Conservancy Bay Fox River (Waterford Waterway) – Middle of Conservancy Bay. Station ID: *Not Created*. This is a proposed station for use by the WWMD volunteer water quality monitor and would represent water quality data of the Waterway near the mouth of the Fox River as it enters the Waterway.

The WDNR may not be able to include all of these sites within the CLMN program; therefore, the WWMD will consider paying for the analysis at the Wisconsin State Laboratory of Hygiene (WSLH) following the CLMN sampling regime. One large advantage of using the WSLH is that the data are automatically loaded into the WDNR statewide database, Surface Water Integrated Management System (SWIMS). The data are then available to anyone through that system and easily accessible in future planning activities. The WWMD has an account set up with the lab currently.

Wisconsin State Laboratory of Hygiene
http://www.slh.wisc.edu/
Wisconsin State Laboratory of Hygiene
2601 Agriculture Drive, PO Box 7904
Madison, WI 53718
(800) 442-4618

Action Steps:

1. Trained CLMN volunteer(s) collects data and report results to WDNR and to district members during annual meeting and on WWMD website.

2. CLMN volunteer and/or WWMD Board of Commissioners facilitate new volunteer(s) as needed
3. Coordinator contacts Rachel Sabre (Rachel.Sabre@wisconsin.gov 262-574-2133) to acquire necessary materials and training for new volunteer(s)

Management Action: Conduct AIS population control utilizing herbicide spot treatments and winter drawdowns

Timeframe: Begin 2019

Facilitator: WWMD Board of Commissioners

Possible Grant: AIS or Small-Scale Planning Grants for monitoring.

Description: Earlier management plans and AIS Grant projects simply called for the control of AIS (EWM and CLP) in the Waterford Waterway. The only real limitation to the acreage treated each year was the funding level acceptable to the district members. A great deal has been learned about the effective use of herbicides to battle AIS in the past decade. This is especially true regarding the characteristics of spot treatments that lead to effective results beyond seasonal control. This management plan utilizes current best management practices regarding the use of herbicides in spot treatment scenarios, taking into account the size of the treatment and susceptibility of dilution due to flow and surrounding, untreated waters.

The EWM and CLP populations were surveyed during 2017 and 2018 and found to throughout much of the lake, but in limited occurrences. At this level, neither is causing recreational or ecological issues. While the WWMD has completed CLP treatments in the past, those treatments were not completed in a manner that would manage the plant on a population scale by repeatedly treating the same areas with the aim of reducing the sediment turion base. Based upon surveys completed as a part of this project and those completed earlier, it is believed that the CLP population in the system has typically been low and in areas where it is dense, the acreages are small. Further, CLP dies back naturally in the system by early-July and navigation lane treatments successfully control it. Until CLP occurrences are documented to have increased significantly in density and area, the WWMD will not consider controlling the exotic in a manner that would meet typical CLP population control guidelines. Those guidelines and additional information regarding CLP can be found in the Curly-leaf pondweed sections of Section 3.4

The strategy described below targets EWM, which was documented to be at 5.4% (2018 frequency of occurrence (FOO)). In general, the intent of the spot treatments would be to keep the EWM population below the 30% FOO that would initiate discussions regarding a winter drawdown.

Herbicide Spot Treatment

If the following trigger is met, the WWMD would initiate pretreatment monitoring and begin discussions, regarding conducting herbicide spot treatments:

Colonized (polygons) areas of dominant EWM where a sufficiently large treatment area can be constructed to hold concentration and exposure times.

The minimum area would be approximately 3 acres which would need to be targeted with herbicides that require short exposure times (diquat, florpyrauxifen-benzyl [ProcellaCOR™]) or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). Larger areas (>5 acres) or sites in protected parts of the lake are to be targeted with an herbicide spot treatment, more traditional systemic herbicides like 2,4-D may be appropriate and considered. If populations exceed spot-treatment thresholds, large-scale herbicide strategies may be given consideration.

Depending on the herbicide chosen and the size of the herbicide treatment area, the WDNR may require specific GPS mapping of treatment areas, as opposed to a conglomeration of point-intercept points, and/or herbicide concentration monitoring as a part of the permit conditions.

In late-winter, an herbicide applicator firm would be selected and a conditional permit application would be applied for from the WDNR. The herbicide treatment would occur when surface water temperatures are roughly below 60°F and active growth tissue is confirmed on the target plants. A pretreatment survey, a week or so prior to treatment, would be used to finalize the permit, potentially with adjustments, and dictate approximate ideal treatment timing.

Overall, the WWMD will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen. Any financial cost will first be approved by the WWMD Board of Commissioners.

Winter Water Level Drawdown

Winter water level drawdowns are widely known to control EWM if desiccation and/or freezing of sediments occurs in areas that EWM occupies. Still, winter level drawdown also has negative aspects, like the loss of certain native species, short-term impacts to the fishery, and of course the loss of winter recreational opportunities. Therefore, the WWMD elects to only consider utilizing a winter water level drawdown if and when the EWM population is very high as evidenced by a FOO of 30% or greater. Please see the following action regarding periodic vegetation monitoring on the Waterford Waterway.

Action Steps:

1. Perform periodic vegetation monitoring as outlined in this management plan.
2. Utilizing local professional assistance and WDNR expertise, assess potential need for herbicide spot treatments based upon examining dense areas of EWM in late-summer and utilizing thresholds described above.
3. If areas are thought to meet the thresholds, an herbicide applicator should be contacted to assess the areas, create a strategy, submit a permit application, and perform the treatment.
4. If the most recent point-intercept survey indicates a 30% EWM FOO, the district board should discuss the issue and contact the WDNR for guidance and permit needs.

Management Action:	Conduct periodic quantitative vegetation monitoring on the Waterford Waterway.
Timeframe:	Point-Intercept Survey every 3-5 years, Community Mapping every 7-10 years, AIS mapping surveys as needed.
Possible Grant:	Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning Grant in <$10,000 category.
Facilitator:	WWMD Board of Commissioners
Description:	As part of the ongoing AIS and nuisance vegetation management 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 the Waterford Waterway. A point-intercept survey was conducted on the Waterford Waterway in 2018; therefore, the next point-intercept survey will be completed between 2020 and 2023, depending on the level or anticipated need of AIS management being completed. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in the Waterford Waterway, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on the Waterford Waterway in 2018 as a part of this management planning effort. The next community mapping survey will be completed between 2025 and 2028. There is a potential for AIS to expand in both density and area more rapidly than can be effectively monitored with the periodic point-intercept surveys; therefore, the WWMD will hire consultants to complete meander-based mapping surveys as needed.
Action Steps:	See description above.

Management Action:	Educate riparian stakeholders on the importance of shoreland condition on the Waterford Waterway.
Timeframe:	Initiate 2020
Facilitator:	WWMD Board of Commissioners
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. Approximately 44% of the Waterford Waterway's shoreline is considered completely urbanized or developed unnatural (Figure 3.3-2). This limits shoreland habitat, but it also reduces natural buffering of shoreland runoff and allows nutrients to enter the lake. However, 48% of the Waterford Waterway's shoreline remains as undeveloped and natural; therefore, this action is aimed at not only conducting shoreland restorations on developed property on those that need it, but also to educate shoreland property owners about the importance of protecting existing shorelines that are in natural or near-natural states to keep the Waterford Waterway healthy. If shoreland property owners are interested in restoring their shorelands, information regarding an appropriate WDNR Grant program is below. As a part of implementing this management plan, the WWMD will be creating and utilizing electronic and hardcopy methods of communication with the district members. One of the educational topics that will be visited frequently will be about the importance of healthy and natural shorelands and what property owners can do to make sure their properties are not impacting the lake's ecological health. The UW-Extension Lakes Program at UW Stevens Point publishes *Lake Tides*, a newsletter for people interested in healthy lakes, for over a decade. The articles are searchable and useable in lake group newsletters. They can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/resources/newsletter/default.aspx 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, potentially through Racine County and/or the Fox River Commission.

- 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.

<u>Management Action:</u> Continue to support Southeastern Wisconsin Fox River Commission's efforts in the Waterford Waterway and its drainage basin.

Timeframe: Continuation of current effort.

Possible Grant: Determined on project method and goals.

Facilitator: WWMD Board of Commissioners

Description: The Southeastern Wisconsin Fox River Commission (SEWFRC) was created in 1997 by the State of Wisconsin in response to community concerns over issues in the Illinois-Fox River system. Conducting an engineering study to determine areas for selective dredging, including selective shallow areas of the impounded area of the Waterford Waterway, and formulating an operating plan for the Waterford Dam, with a winter drawdown level and possible automation of the Waterford Dam using upstream sensors were the primary charges of the commission and are described within Section 33.59 of the Wisconsin Statutes creating the SEWFRC.

The WWMD supported the development of the commission's plan (SEWRPC 2011) and has also supported the implementation of that plan. The WWMD will continue those efforts as they have a direct benefit on the quality of the Waterford Waterway and those waterbodies downstream of it.

As a part of the SEWFRC implementation of its plan, several areas around the Waterford Waterway were mapped as high-concern areas for erosion. Work has been completed on many of the areas. In 2016, with the assistance of Graef Engineering, the WWMD updated the *key locations* (See Appendix G). These priority areas will be investigated for further restoration beginning with Site No. 3 at Hwy 164 and Pine Lane. This concentrated flow area is thought to have significant impacts on the northern portion of Tichigan Lake, although no scientific studies have been completed to truly test not only the concentration of sediment and phosphorus entering the lake, but also load, which requires flow determination as well. This area will be studied to determine the actual amounts of these pollutants so remediation actions can be determined or the concerns of the WWMD can be put to rest.

In 2020, the WWMD will reassess these areas and update the map and table found in Appendix G to guide future efforts of the WWMD.

Action Steps:

See description above.

<u>Management Action:</u> Enhance the Waterford Waterway fishery through proper stocking and coarse woody habitat additions.

Timeframe: Initiate 2020

Facilitator: WWMD Board of Commissioners

Description: The Waterford Waterway is a highly productive system with excellent capacity that currently supports 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 through habitat enhancement and possibly stocking. 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 the Waterford Waterway's fishery potential to district members, 2) assure that the WWMD 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 WWMD regarding the system's fishery. Ultimately, this will lead to an appropriate and effective stocking program on the Waterford Waterway.

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 regarding portions of the Waterford Waterway's shoreline, prior to the lake being created, the area was a wetland that did not support large tree growth, so there is little natural coarse woody habitat (CWH). However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of CWH 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 from Planning Committee or Board of Commissioners to direct this initiative. One of the WWMD standing committees may also be able to complete this task.
2. Facilitator contacts WDNR Lakes Coordinator and WDNR Fisheries Biologist to gather information on current stocking efforts, future stocking efforts and regarding initiating and conducting coarse woody habitat projects on the Waterford Waterway.
3. The WWMD will encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites for future projects.
4. The WWMD promotes a better understanding of the lake's fishery and its capacity via educational topics included in electronic and hardcopy communications with district members.

Management Goal 2: Assure Open Water Recreational Opportunities on the Waterford Waterway

Management Action:	**Conduct nuisance plant treatments using herbicides on an as-needed basis in common use areas of the Waterford Waterway.**
Timeframe:	Continuation of an effort trialed and refined in 2018 with an updated navigation lane map.
Potential Grant:	Not applicable
Facilitator:	WWMD Board of Commissioners
Description:	As described Section 3.4 Subheading: Nuisance Aquatic Plant Management: Navigation Lanes, the Waterford Waterway supports nuisance levels of native aquatic plants that interfere with recreational use, including boating, swimming, and fishing. The majority of areas of the Waterford Waterway supporting nuisance vegetation are not appropriate for mechanical harvesting utilizing a traditional cutter-style harvester because of shallow water or obstructions, such as near piers or in narrow channels. To alleviate the nuisance brought on by abundant vegetation in these areas, the WWMD will utilize herbicide treatments as needed and approved by the department. The areas displayed on Map11 will be considered for treatments each year by the WWMD and represented in an herbicide treatment permit application to the WDNR in early spring. These areas may be treated multiple times in a single season, under a single herbicide treatment permit. A member of the WWMD will inspect these lanes throughout the open water season and guide treatments based upon need. Need for treatment will not be determined by inspecting a large area, such as a bay, from a distance, but on more of a lane-by-lane basis. The WWMD volunteer will provide the determinations to the applicator and the WDNR following the inspections utilizing the same or similar designations of *current nuisance*, *anticipated nuisance*, and *no nuisance*, as is described in the Aquatic Plan Section 3.4 under the sub-heading "Nuisance Aquatic Plant Management Strategy: Navigation Lanes". The dosing strategy used in 2018 and documented to have produced good results, consisted of a mixture of diquat (0.245 ppm), copper (0.111 ppm) and flumioxazin (0.125). This dosing regime is considered the current best management practice (BMP) for this strategy. Overtime, as different herbicides are developed or different species of plants become an issue or do not continue to pose issues, the WWMD will update the strategy with guidance supplied by the WDNR and applicator. As the strategy integrates new herbicides, additional monitoring may be required as a part of WDNR permitting.

Note: As described in the following action, the WWMD will investigate the use of a roller-type harvester for control of some of these areas in the future.

Action Steps:

See description above.

Management Action:	**Utilize mechanical harvesting in appropriate portions of the system to provide riparian access to open water areas of the Waterford Waterway**
Timeframe:	2019
Potential Grant:	Wisconsin Waterways Commission Grant for purchase of new harvesting equipment.
Facilitator:	WWMD Board of Commissioners
Description:	The WWMD understands the importance of native aquatic vegetation within the Waterford Waterway. However, nuisance aquatic plant conditions exist in much of the system, primarily caused by loosely-rooted vegetation (coontail, common waterweed, southern naiad), floating matts of filamentous algae, limited floating-leaf species, and AIS such as EWM and CLP.

The WWMD supports the reasonable and environmentally sound actions to facilitate navigability on the Waterford Waterway. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns and fishing. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than necessary.

This management action covers three types of mechanical harvesting, 1) Diver-assisted suction harvesting (DASH), 2) Conventional mechanical harvesting with cutter-style harvesting equipment, and 3) roller-style harvesting (Silver Mist Eco Harvester)

Mechanical harvesting of any sort requires a WDNR permit. 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. The maps should reference the areas proposed for harvesting (e.g., Map 13 and 14), as well as DASH (e.g. Map 12). Additionally, language describing the harvesting method should be included. (For instance, “In areas where native plants are harvested, the cutter bar would be operated no closer than one foot to the bottom. In no cases would the harvester be run in depths shallower than three feet."

The following typical mechanical harvesting permit conditions, detailed below, will be adhered to on the Waterford Waterway:

1) Only areas with documented nuisance levels of aquatic plants will be harvested.
2) Mechanical harvesting will not begin, in any given year, prior to June 1st.
3) Harvesting schedule will be available upon request. The WDNR Water Resources Biologist may schedule and conduct an on-site supervision of harvesting activities.
4) Only areas contained within the method's respective permit map will be harvested without an additional permit from the WDNR.
5) A copy of the current harvesting permit will be kept onboard the equipment at all times. All operators will read and understand the limitation and conditions of the aquatic plant management plan and harvesting permit before they harvest aquatic plants.
6) All harvesting shall not disturb the lake bed sediments of the Waterford Waterway.
7) All aquatic plants harvested will be removed immediately from the system. Disposal of plant material occur only areas specified within the permit and in accordance with county and local regulations. Plant material will not be disposed of in wetlands.
8) All mechanical harvesting records will be maintained and readily available to the WDNR upon request. An annual report summarizing harvesting activities will be provided each year by November 1. The report shall include a map of areas harvested, the total acres harvested, and the total amount of plant material removed from the waterbody.

The WDNR oversees the management of aquatic plants on inland lakes. The manual cutting and raking of native aquatic plant species within a 30-foot-wide area containing a pier, boatlift, or swim raft is exempt from a state permit provided that the cut plants are removed from the lake. However, the use of mechanized or mechanical devices requires a WDNR permit.

<u>DASH Harvesting</u>

Navigation lane maintenance has been completed with DASH for the past several years on the Waterford Waterway. More information regarding this method can be found in Section 3.4 Subsection: Nuisance Aquatic Plant Management Strategy: DASH & Mechanical Removal Lanes. Utility and placement are determined based upon water depth, plant species, and accessibility by watercraft. Map 12 displays areas slatted for DASH in 2018 and can be viewed as example areas applicable to this method. Each year, the WWMD will determine areas applicable to DASH and update the mechanical harvesting permit specific to this method

<u>Conventional Mechanical Harvesting</u>

Additional information regarding this method can be found in the beginning of Section 3.4 and in Subsection: Aquatic Plan Management: Conventional Mechanical Harvesting.

As a part of this management planning project, areas suitable for conventional mechanical harvesting were determined depending on depth of water within the Waterford Waterway. Those results are displayed on Map 13. While areas outside of Tichigan Lake may be applicable to conventional mechanical harvesting based upon water depth, the WWMD is only considering this method's use on Tichigan Lake as a part of this management plan. Other areas may be developed in the future, but would rely on guidance and permitting by the WDNR before implemented. Map 14 displays potential areas of Tichigan Lake that may be considered for conventional mechanical harvesting based upon need and cost. Only areas with WWMD-documented levels of nuisance plant growth impeding watercraft navigation will be considered for this method. The WWMD understands that a minimum acreage would need to be harvested in a single year to allow the action to be cost-effective. That minimum acreage is likely around 4 acres depending on current costs and availability of harvesting contractors.

<u>Roller-Style Mechanical Harvesting</u>

Silver Mist Aquatic Services of Waupaca, WI has developed a small, dual-paddlewheel propelled, mechanical harvester that utilizes an expanded metal barrel to pull aquatic plants out of the water. The manufacturer claims it can be used in water as shallow as 10"; however, that is likely a minimum requirement for operation, but not for effective, ecologically-sound operation. Still, it is likely that the harvester can be used in shallower areas than a conventional mechanical harvester.

WWMD members will investigate the use of a harvester of this type in the Waterford Waterway and present their findings to the District Board of Commissioners and the WDNR. If the inquiry determines the harvester may be applicable for use in the waterway, the navigation lanes historically controlled herbicide treatments (Map 11) would be considered first for this method.

It should be noted that this method of harvesting actually utilizes the pulling of aquatic plants from the sediments; as opposed to cutting, as utilized in conventional mechanical harvesting. For that reason, the WDNR has correctly limited the use of this method statewide because cutting is less environmentally harmful that pulling (or tearing) the plants out of the sediment. Still, this method may have less environmental impact over continued herbicide use in the current navigation lanes. There may also be cost benefits if the district owns the equipment and employs the operators.

Action Steps:

See description above.

Management Action: **Continue to investigate feasibility of sediment dredging in Waterford Waterway to facilitate navigation.**

Timeframe: Continuation of current effort.

Potential Grant: Unknown

Facilitator: WWMD Board of Commissioners

Description: As described in the 5th action of Goal 1, was created in 1997 by the State of Wisconsin in response to community concerns over issues in the Illinois-Fox River system. One of the primary purposes of creating the commission was to conduct an engineering study to determine areas for selective dredging, including selective shallow areas of the impounded area of the Waterford Waterway. This action was first explored by the Southeastern Wisconsin Regional Planning Commission in a report commissioned by the WWMD and completed in 2012. Later in 2012, the WWMD contracted with Graef Engineering of Milwaukee to begin the process of creating a dredging plan, including the completion of state-required sediment analysis, and the development of a permit application to dredge. The sediment investigation report was completed in July 2013 and the application for dredging followed in May 2016. Detailed documents can be found on the WWMD website.

In 2018, with the assistance of Graef, the WWMD developed a pilot project aimed at investigating operational parameters needed to develop the full-scale dredging project that would include removal of waterway bottom sediments, drying of those sediments, and ultimately the spread of those sediments on farm fields for soil nutrient augmentation. The primary objective of the pilot program is to define the logistics required to complete the entire 500,000 cubic yard dredging project at a greatly reduced cost.

The WWMD will support the implementation of the pilot project (Phase I of Waterford Waterway Ecosystem Restoration and Rehabilitation Project), which received approval from the WDNR and the US Army Corps of Engineers to spread 7,000 to 9,000 cubic yards of dredged and dewatered sediment on farm fields owned by the WDNR.

Action Steps:

See description above.

Management Goal 3: Improve District Member Interest and Involvement

Management Action: Use information to promote lake protection and enjoyment through stakeholder education

Timeframe: 2020

Facilitator: WWMD Board of Commissioners

Description: Education represents an effective tool to address many lake issues. The WWMD currently maintains a district webpage and Facebook group. The district has also considered publishing periodic newsletters and mailing them to all district members. The webpage the district currently maintains is a very useful repository for district information; including meeting minutes and announcement, general district information, and educational materials; however, it requires that the interested individual check back for updates periodically; therefore, it is not reliable for disseminating information quickly. Facebook utilizes a newsfeed to display the information posted by 'friends' and groups the user follows. Facebook is excellent for groups, like the WWMD, to get short bits of information out to those that follow the district Facebook group. This can include announcements, pictures, short videos, and links to websites. Links to websites are useful because they allow the district to keep their followers informed regarding updates and additions made to the WWMD webpage. The disadvantage to utilizing Facebook is that it requires users to have a subscription, which is free, and check their newsfeed regularly. Email is another useful form of electronic communication that allows the district to disseminate news quickly at low cost. Emails can contain short informational pieces, pictures, and links to information on the web.

The WWMD will work to build followers of the district Facebook group and to obtain email addresses of district members. However, so district members to not have access to the internet, so very important information will be provided as a part of the announcement of the annual district meeting.

Example Educational Topics for Webpage, email, and Facebook

- Specific topics brought forth in other management actions

- Aquatic invasive species identification
- Basic lake ecology
- Sedimentation
- Boating safety (promote existing guidelines)
- Shoreline habitat restoration and protection
- Noise and light pollution
- Fishing regulations and overfishing
- Minimizing disturbance to spawning fish
- Recreational use of the lake

Action Steps:

See description above.

Management Goal 4: Improve the Capacity of the Waterford Waterway Management District to Effectively Manage the Waterford Waterway

Management Action:	Participate in annual Wisconsin Lakes Partnership Convention.
Timeframe:	Annually
Facilitator:	WWMD Board of Commissioners
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and districts. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/district. The WWMD will sponsor the attendance of 1-3 district members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of commissioners regarding topics that may be applicable to the management of the Waterford Waterway and operations of the WWMD. The attendees will also create a summary in the form of a webpage article and if appropriate, update the district membership at the annual meeting.

Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/convention/default.aspx.

Action Steps:

See description above.

Management Action: Continue WWMD's involvement with other entities that have responsibilities in managing (management units) the Waterford Waterway

Timeframe: Continuation of current efforts

Facilitator: WWMD Board of Commissioners

Description: The waters of Wisconsin belong to everyone and therefore the objective 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 WWMD actively engage with all management entities to enhance the district'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 the table below:

Action Steps:

See guidelines in Table 5.0-1.

Table 5.0-1 Management Partner List.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Waterford Village	Village Clerk (Rachel Ladewig 262.534.3980 ext. 223)	The Waterford Waterway falls within this village.	Once a year, or more as issues arise.	Village staff may be contacted regarding ordinance reviews or questions, and for information on community events
Town of Waterford	Town Clerk (Tina Mayer, t.mayer@townofwaterford.net, 262.534.2350)	The Waterford Waterway falls within this township.	Once a year, or more as issues arise.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Southeastern Wisconsin Fox River Commission	Commission Chairman (Dean Falkner falknerd@aol.com)	Oversees projects which improve the Illinois Fox River basin	As needed.	Update on projects on or near the Waterford Waterway.

Table 5.0-1 Management Partner List continued.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Southeastern Wisconsin Regional Planning Commission	Executive Director (Kevin Muhs 262.953.4288 or kmuhs@sewrpc.org)	To address environmental issues within the counties they serve.	As needed.	Resource for reports completed on or near the Waterford Waterway and to seek advice on lake or watershed issues.
Racine County Highway Department	Highways and Parks Superintendent (David Prott, david.proott@racinecounty.com)	Maintains nearby highways	As needed	Contact to discuss highway runoff concerns.
Racine County Land Conservation Department	County Conservation (262.886.8440)	Oversees conservation efforts for land and water projects.	Continuous as it relates to lake and watershed activities	Can aid with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Travis Motl – travis.motl@wisconsin.gov, 920.387.7873)	Manages the fishery of the Waterford Waterway.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Heidi Bunk, heidi.bunk@wisconsin.gov, 262.574.2130)	Oversees management plans, grants, all lake activities.	Continuous as it relates to lake management activities	Information on updating a lake management plan or to seek advice on other lake issues including AIS management.
	Aquatic Plant Management Coordinator (Craig Helker – craig.helker@wisconsin.gov 262.884.2357)	Oversees aquatic plant management plans and management activities.	Continuous as it relates to aquatic plant management activities	Provides guidance and regulatory oversight regarding AIS and native nuisance plant management.
Wisconsin Lakes	Eric Olson, Director and Lakes Specialist (715.346.2192) Paul Skawinski, Citizens Lake Monitoring Network Educator (715.346.4853)	Provide general information regarding lakes and lake districts. Assist in CLMN training and education.	As needed.	The UW-Ext Lakes Program is a resource for educational materials and guidance regarding lakes, lake monitoring, and the operations of lake management districts.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in the Waterford Waterway (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on Tichigan and Waterford Lakes 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 WWMD 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.

Tichigan Lake

	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	■									

Waterford Lake

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	■	■	■	■	■	■	■	■	■	■		
Dissolved Phosphorus	■	■	■	■	■	■	■	■	■	■		
Chlorophyll - *a*	■		■		■		■		■			
Total Nitrogen	■	■	■	■	■	■	■	■	■	■		
True Color												
Laboratory Conductivity												
Laboratory pH												
Total Alkalinity												
Hardness												
Total Suspended Solids												
Calcium												

♦ 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.

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

Waterford Lake Sediment Core Collection and Analysis

Three sediment cores were collected from Waterford Lake on April 23, 2018. The methodology used is described within the Waterford Lake total phosphorus discussion in the Water Quality Section 3.1.

Watershed Analysis

The watershed analysis began with an accurate delineation of the Waterford Waterway'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) Detailed WiLMS output data can be found in Appendix D.

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on the Waterford Waterway during a June 28, 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 the Waterford Waterway to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on August 29, 2018. A point spacing of 63 meters was used resulting in approximately 860 points. Aquatic plant data entry worksheets showing total rake fullness values for each species at each sampling location can be found in Appendix E.

Community Mapping

During the species inventory work, the aquatic vegetation community types within the Waterford Waterway (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.

2017 - 2019 Treatment Monitoring

The methodology used to monitor the 2017 - 2019 herbicide treatments is included within the results section under the heading: *Treatment Monitoring.*

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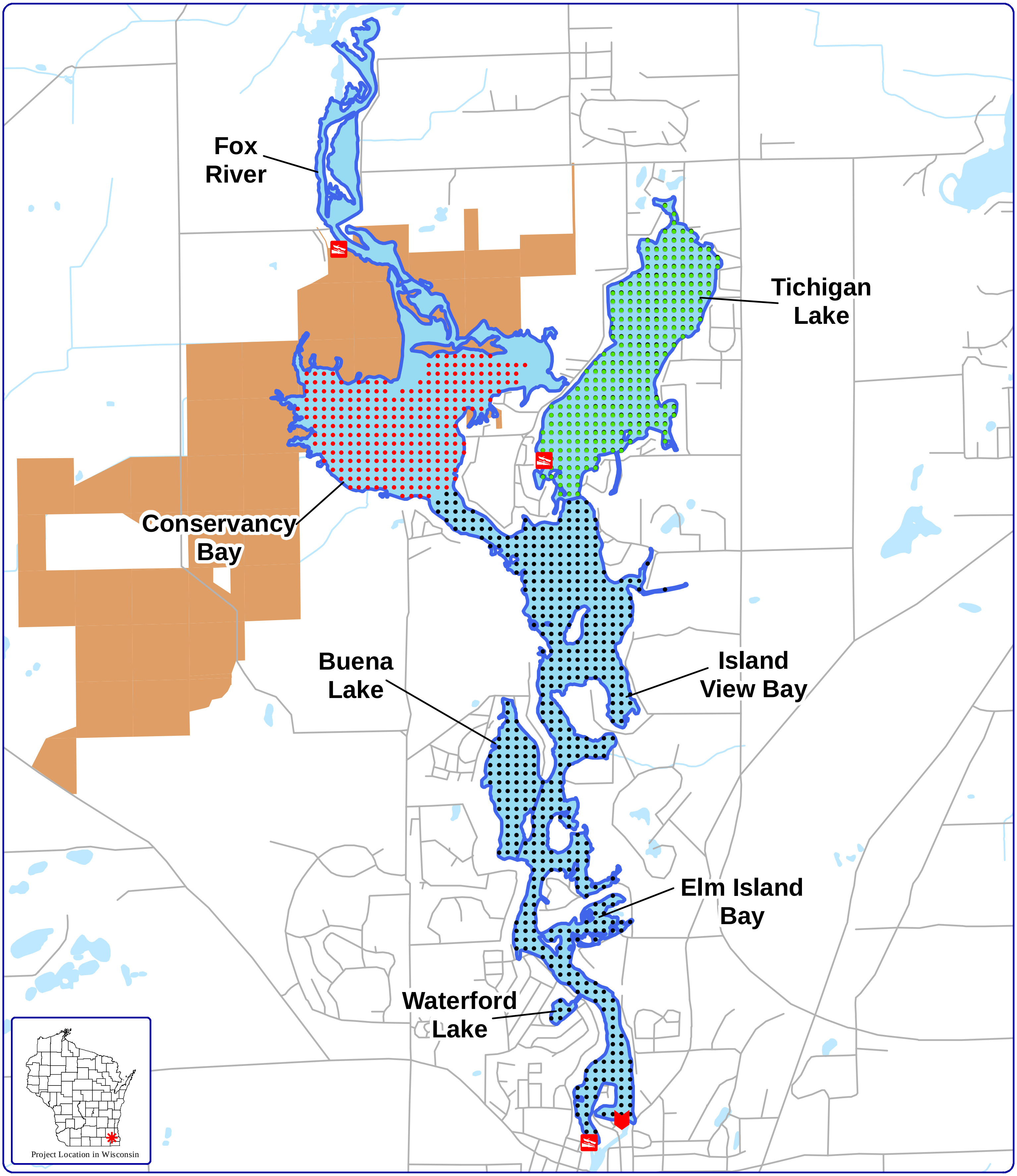


N
W E
S
2,900
Feet

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: November 27, 2017
Filename: Waterford_Project_Proposal.mxd

Legend

Waterford Impoundment
WDNR Definition, 1,228 acres

WDNR Managed Lands

Public Access

Dam Location

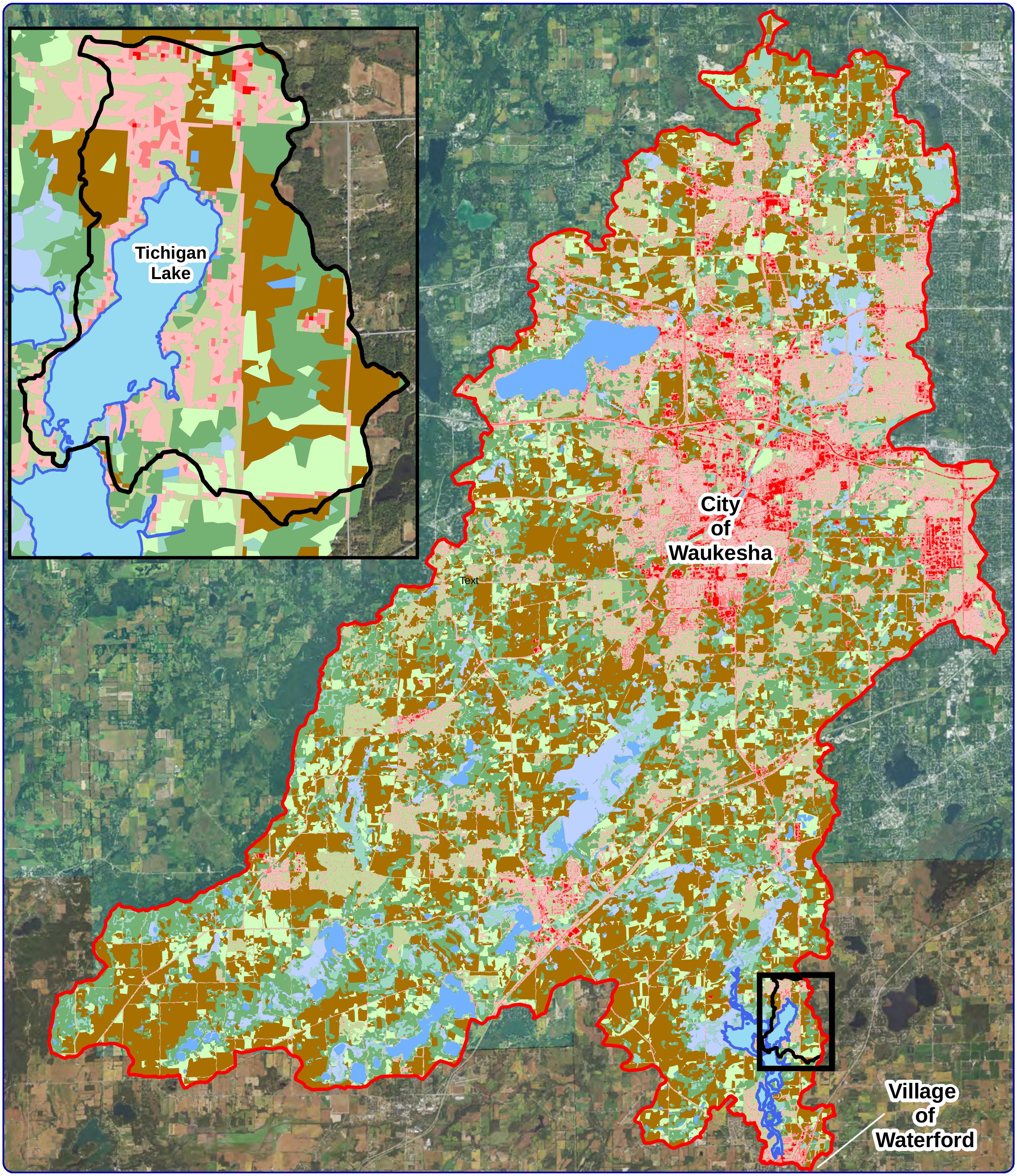
Tichigan Lake Point-Intercept Sample Location
63 meter points, 284 total points

Waterford Waterway Point-Intercept Sample Location
63 meter points, 518 total points

Conservancy Bay Point-Intercept Sample Location
63 meter points, 360 total points

Map 1
Waterford Waterway
Racine County, Wisconsin

Project Location & Lake Boundaries



N W E S

3,100
Feet

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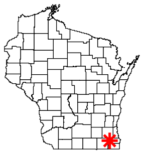
Sources:
Hydro: WDNR
Orthophotography: NAIP 2017
Land Cover: NLCD, 2011
Watershed Boundaries: Onterra, 2019

Map Date: March 6, 2019 AMS
File Name: Waterford_WS_2018

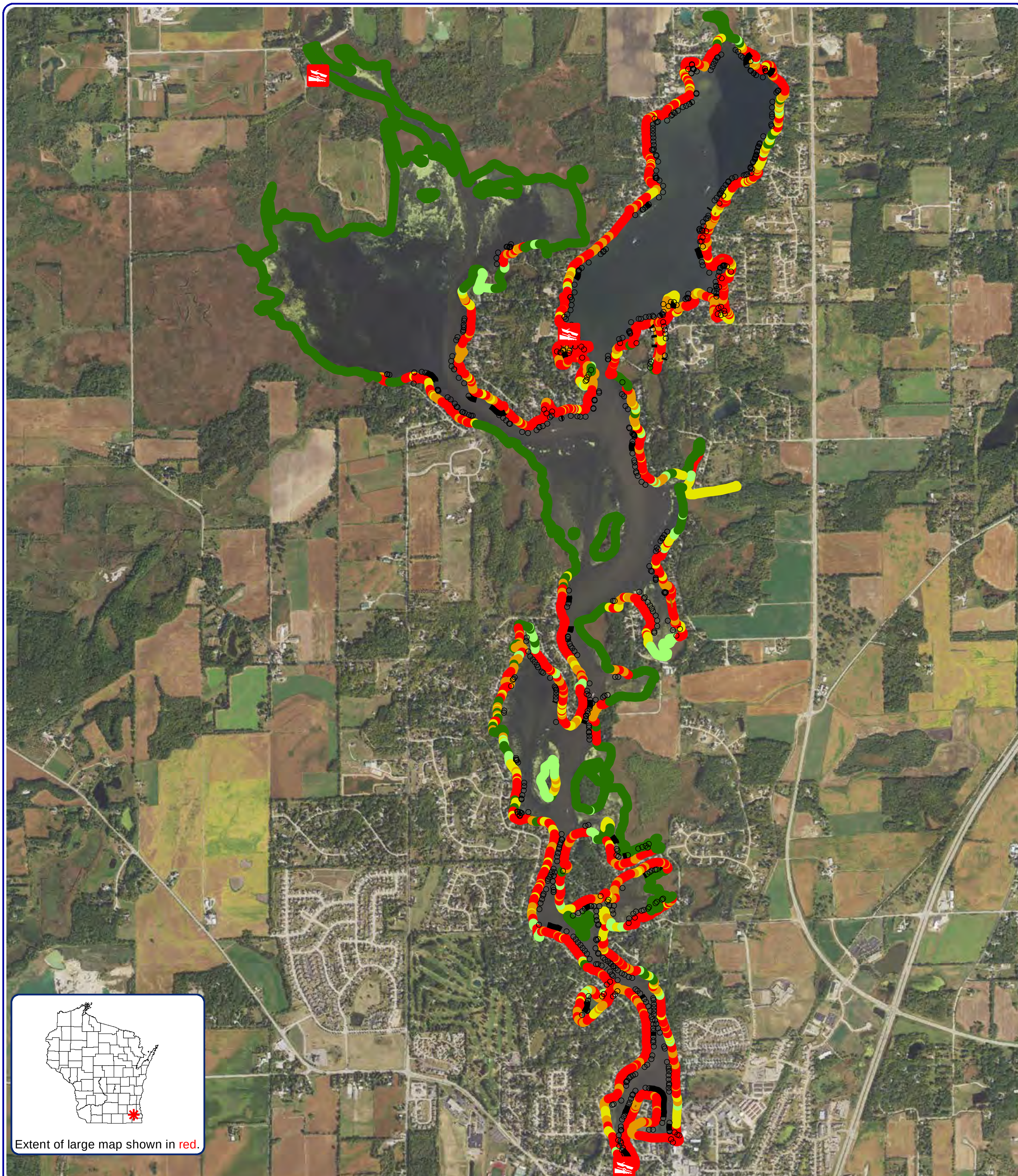


Legend

- Forest
- Forested Wetlands
- Pasture/Grass
- Open Water
- Wetland
- Tichigan Lake Watershed Boundary
- Row Crop Agriculture
- Rural Open Space
- Rural Residential
- Urban - High Density
- Urban - Medium Density
- Waterford Waterway Watershed Boundary

Map 2
Waterford Waterway
Racine County, Wisconsin

Watershed Boundaries & Land Cover Types



N
W E
S
2,200
Feet

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Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: November 20, 2018 AMS
Filename: Waterford_SA_Oct18.mxd

Legend

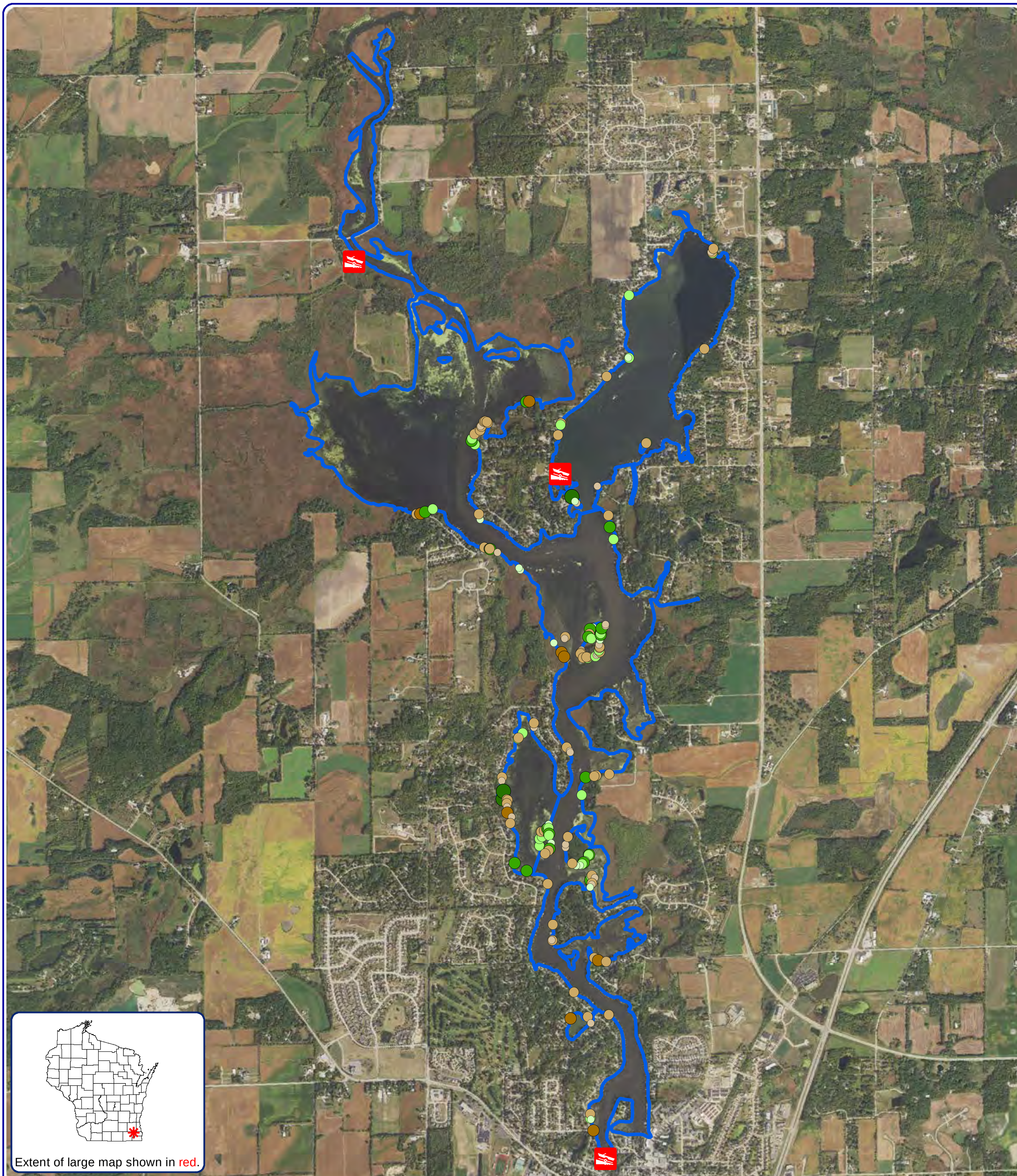
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall Modifier

- Masonary/Wood Seawall
- Rip-Rap

Map 3
Waterford Waterway
Racine County, Wisconsin

2018 Shoreland Condition Assessment



3,000

Feet

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy

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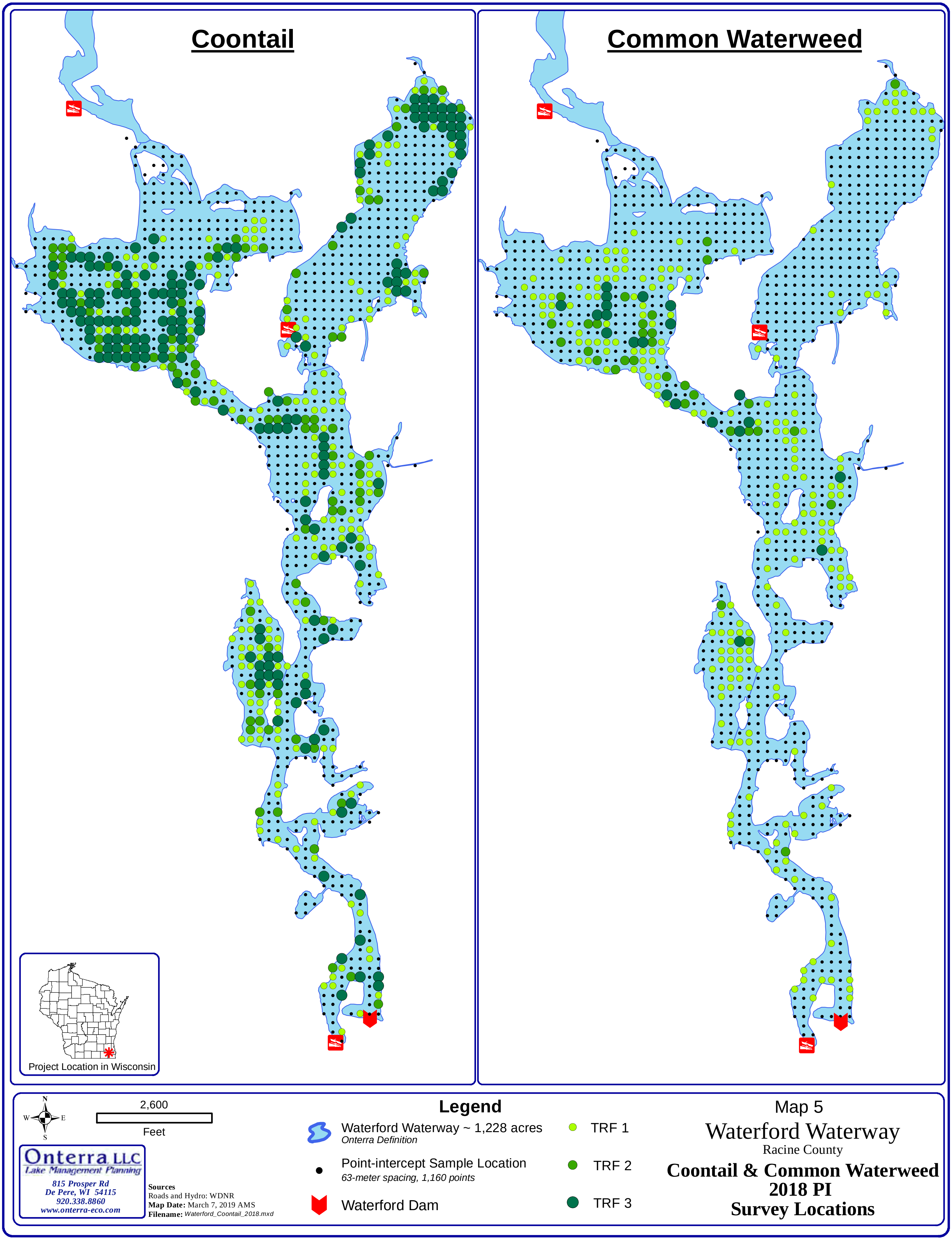
Sources
Hydro: WDNR
CWH Survey: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: November 20, 2018 AMS
Filename: Waterford_CWH_Oct18.mxd

Map 4
Waterford Waterway
Racine County, Wisconsin

2018 Coarse Woody Habitat Results


Coontail
Common Waterweed
Project Location in Wisconsin
N
W
E
S
2,600
Feet
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Lake Management Planning
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De Pere, WI 54115
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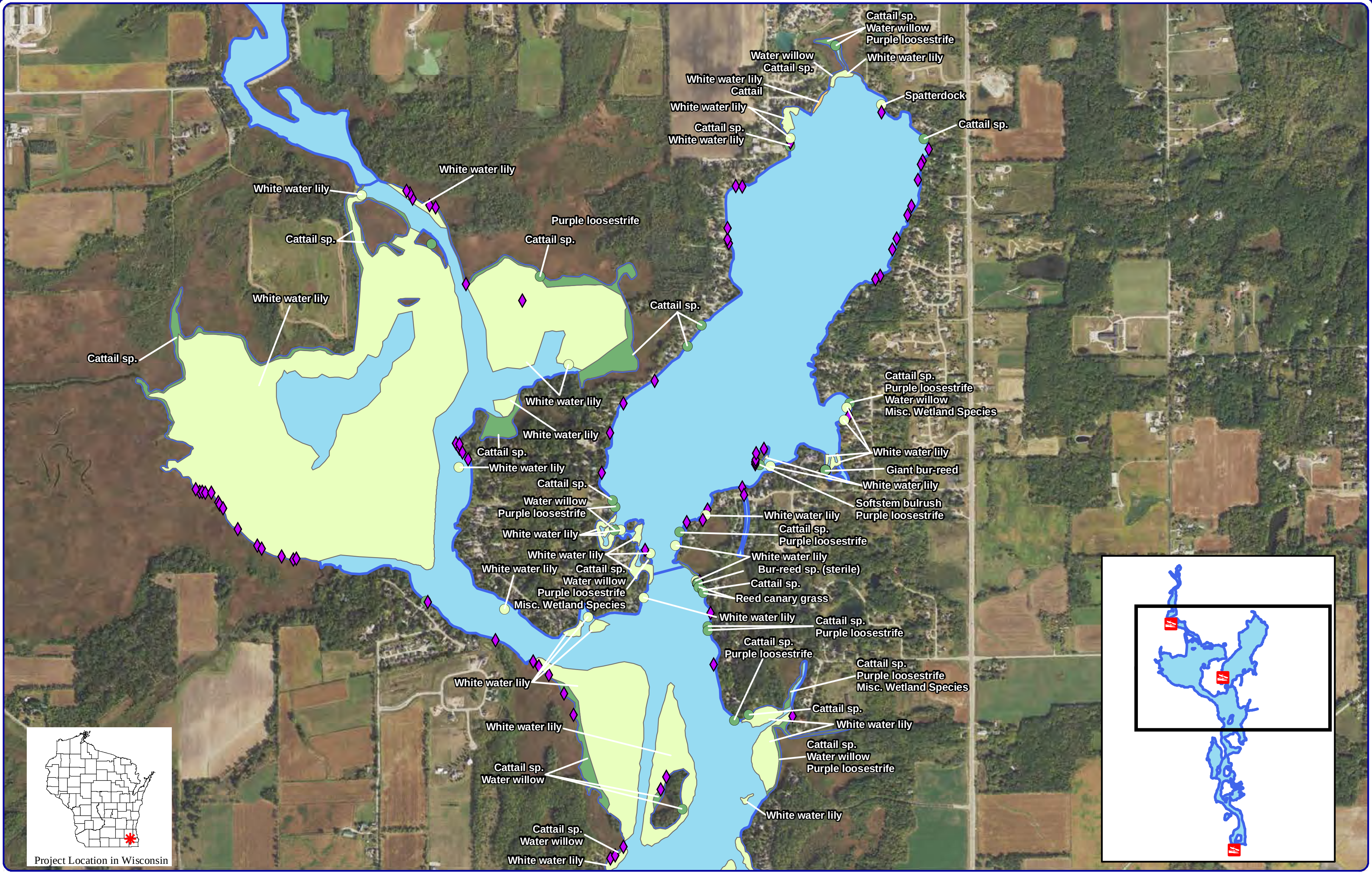
Sources
Roads and Hydro: WDNR
Map Date: March 7, 2019 AMS
Filename: Waterford_Coontail_2018.mxd
Legend
Waterford Waterway ~ 1,228 acres
Onterra Definition
Point-intercept Sample Location
63-meter spacing, 1,160 points
Waterford Dam
TRF 1
TRF 2
TRF 3
Map 5
Waterford Waterway
Racine County
Coontail & Common Waterweed
2018 PI
Survey Locations



N
W E
S

1,400

Feet

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Purple Loosestrife

Large Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

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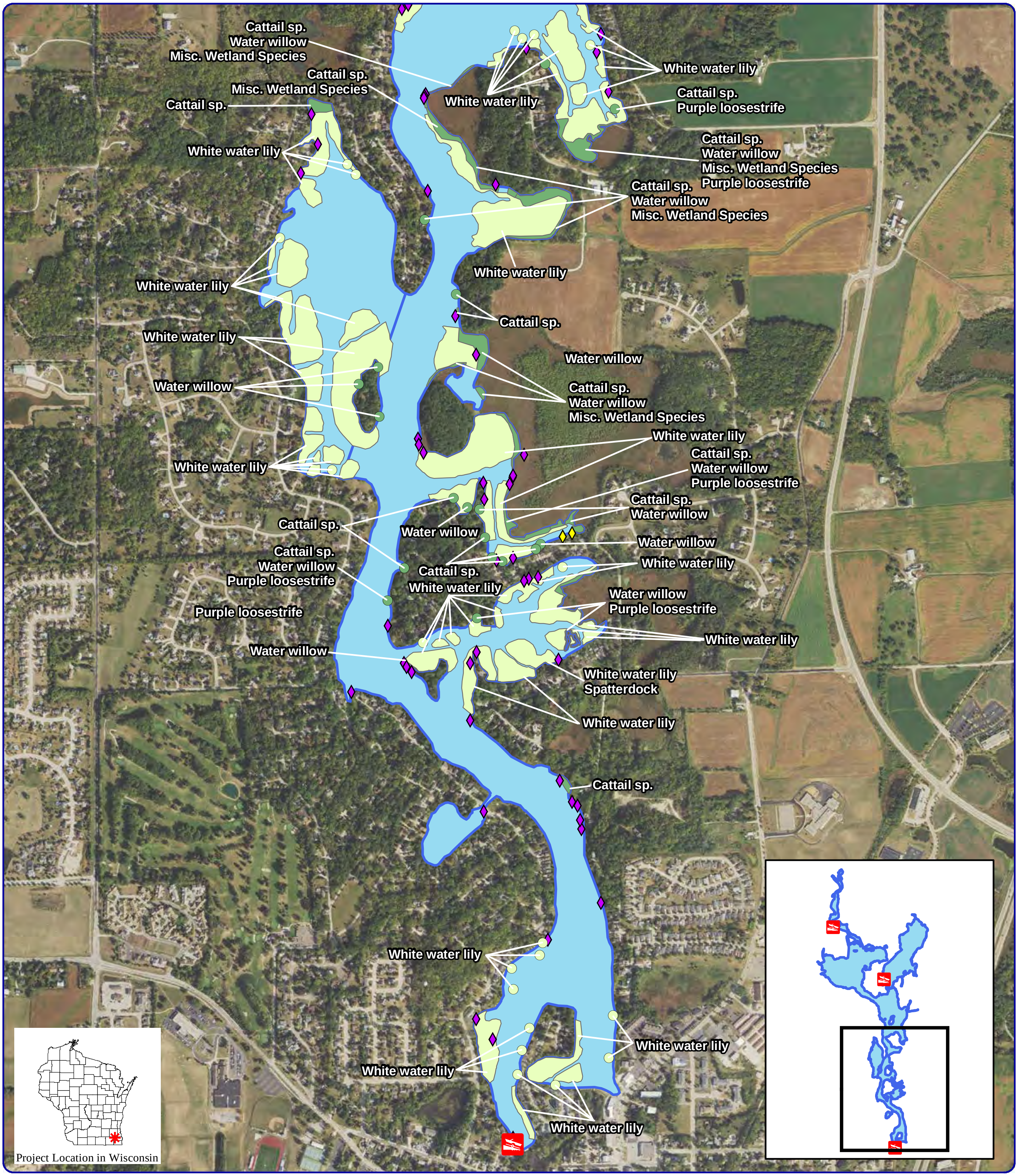
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: January 21, 2019 AMS
Filename: Waterford_Comm_2018_North.mxd

Map 6

Waterford Waterway-North
Racine County, Wisconsin

Aquatic Plant Communities



Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife
- Pale-yellow Iris

Large Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

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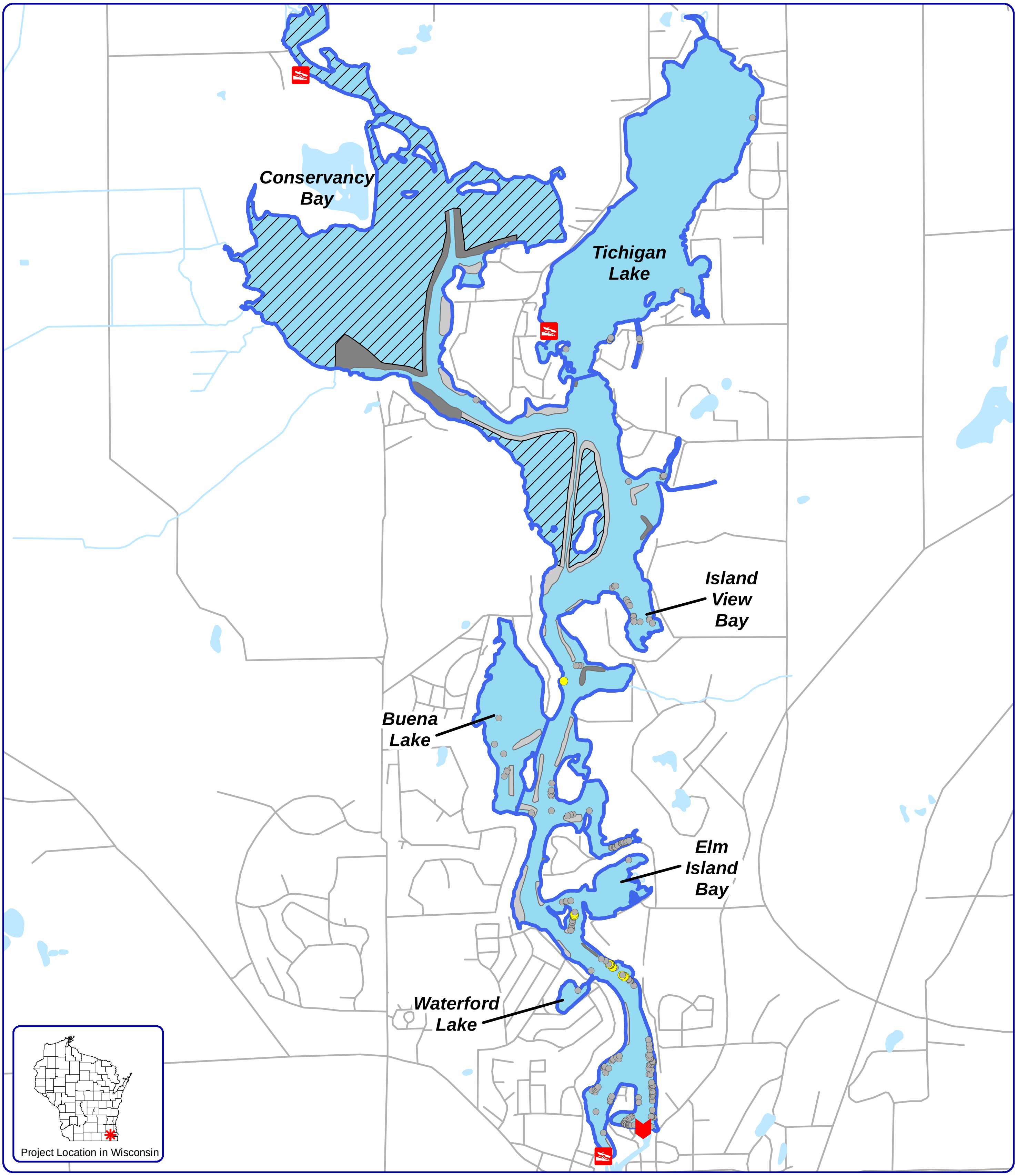
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: January 15, 2019 AMS
Filename: Waterford_Comm_2018_South

Map 7
Waterford Waterway-South
Racine County, Wisconsin

Aquatic Plant Communities



2,500
Feet

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920.338.8860
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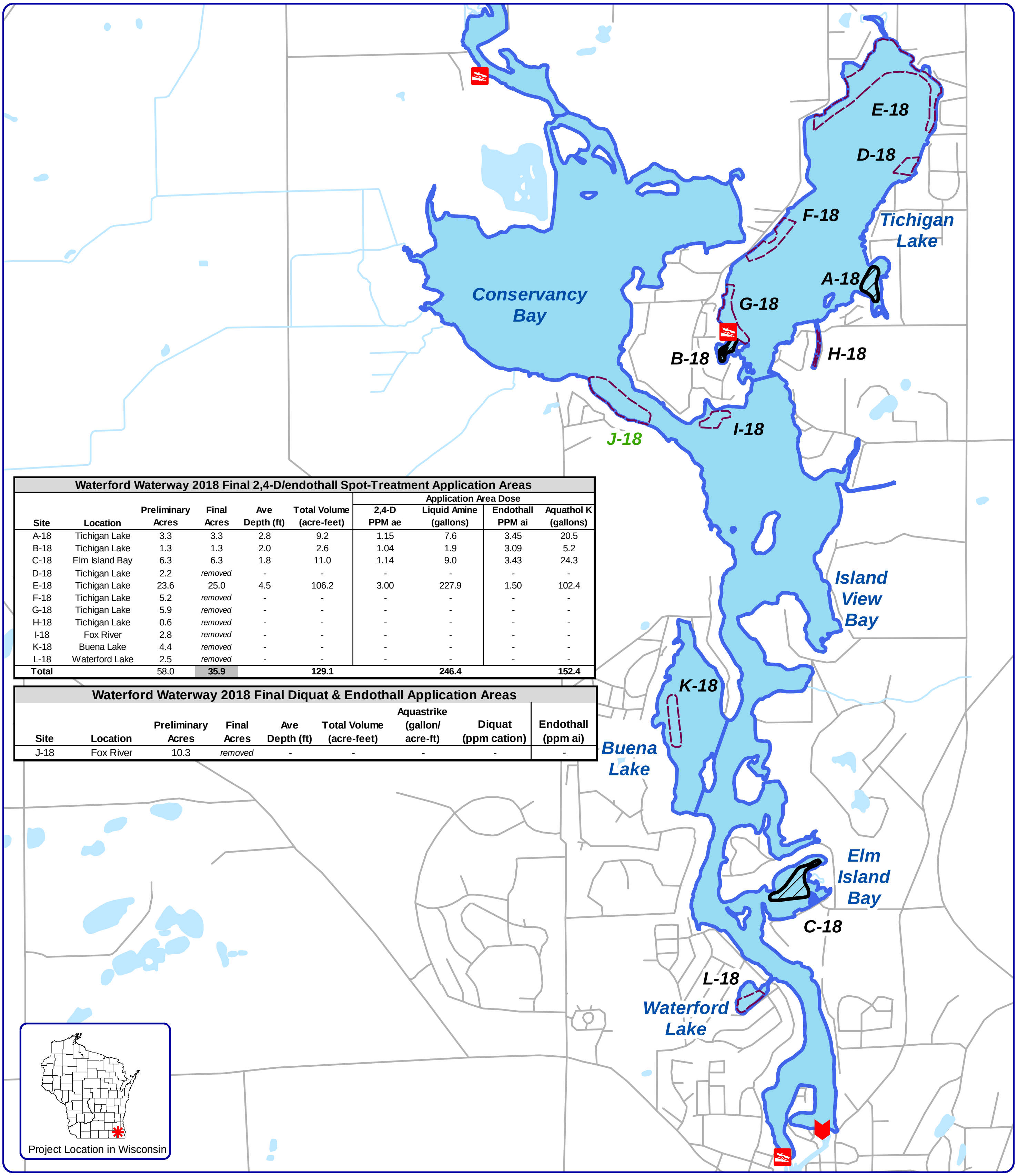
Sources:
Roads and Hyrdo: WDNR
Plant Survey: Onterra, 2018
Map Date: July 6, 2018 JLW
Filename:
Waterford_CLP_June18.mxd

Legend

- Highly Scattered *(49.7 acres)*
- Scattered *(33.3 acres)*
- Dominant *(none)*
- Highly Dominant *(none)*
- Surface Matting *(none)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Unable to survey, non-navigable
- Public Access
- Waterford Dam

Map 8
Waterford Waterway
Racine County, Wisconsin
June 2018
CLP Survey Results



Waterford Waterway 2018 Final 2,4-D/endothall Spot-Treatment Application Areas									
						Application Area Dose			
Site	Location	Preliminary Acres	Final Acres	Ave Depth (ft)	Total Volume (acre-feet)	2,4-D PPM ae	Liquid Amine (gallons)	Endothall PPM ai	Aquathol K (gallons)
A-18	Tichigan Lake	3.3	3.3	2.8	9.2	1.15	7.6	3.45	20.5
B-18	Tichigan Lake	1.3	1.3	2.0	2.6	1.04	1.9	3.09	5.2
C-18	Elm Island Bay	6.3	6.3	1.8	11.0	1.14	9.0	3.43	24.3
D-18	Tichigan Lake	2.2	*removed*	-	-	-	-	-	-
E-18	Tichigan Lake	23.6	25.0	4.5	106.2	3.00	227.9	1.50	102.4
F-18	Tichigan Lake	5.2	*removed*	-	-	-	-	-	-
G-18	Tichigan Lake	5.9	*removed*	-	-	-	-	-	-
H-18	Tichigan Lake	0.6	*removed*	-	-	-	-	-	-
I-18	Fox River	2.8	*removed*	-	-	-	-	-	-
K-18	Buena Lake	4.4	*removed*	-	-	-	-	-	-
L-18	Waterford Lake	2.5	*removed*	-	-	-	-	-	-
Total		58.0	**35.9**		**129.1**		**246.4**		**152.4**

Waterford Waterway 2018 Final Diquat & Endothall Application Areas								
Site	Location	Preliminary Acres	Final Acres	Ave Depth (ft)	Total Volume (acre-feet)	Aquastrike (gallon/ acre-ft)	Diquat (ppm cation)	Endothall (ppm ai)
J-18	Fox River	10.3	*removed*	-	-	-	-	-

N W E S

2,500

Feet

Legend

2018 Proposed Herbicide Application Areas

2018 Final Herbicide Application Areas

Public Access

Waterford Dam

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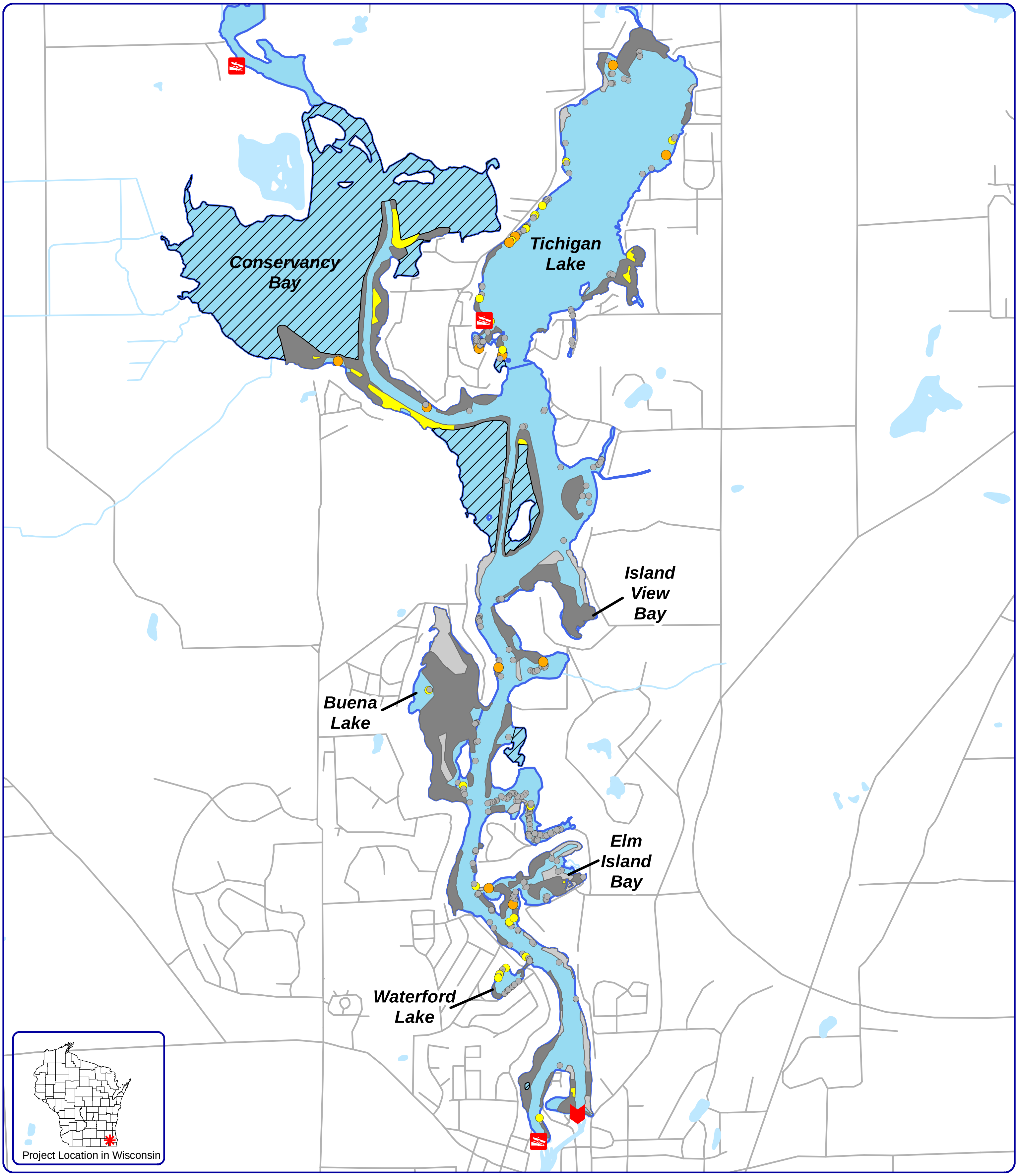
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hyrdo: WDNR
Plant Survey: Onterra, 2017
Map Date: May 14, 2018 - TWH
Filename: Waterford_EWMSpotTreat_T2018_Perm1.mxd

Map 9
Waterford Waterway
Racine County, Wisconsin

2018 Final AIS Treatment Strategy



N
W E
S

2,500
Feet

Onterra LLC
Lake Management Planning
815 Prosper Rd
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920.338.8860
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Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2018
Map Date: December 10, 2018 JMB/HAL
Filename: *Waterford_EWMPB_Oct18.mxd*

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(none)*
- Surface Matting *(none)*
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Non-navigable; unable to survey
- Public Access
- Waterford Dam

Map 10
Waterford Waterway
Racine County, Wisconsin

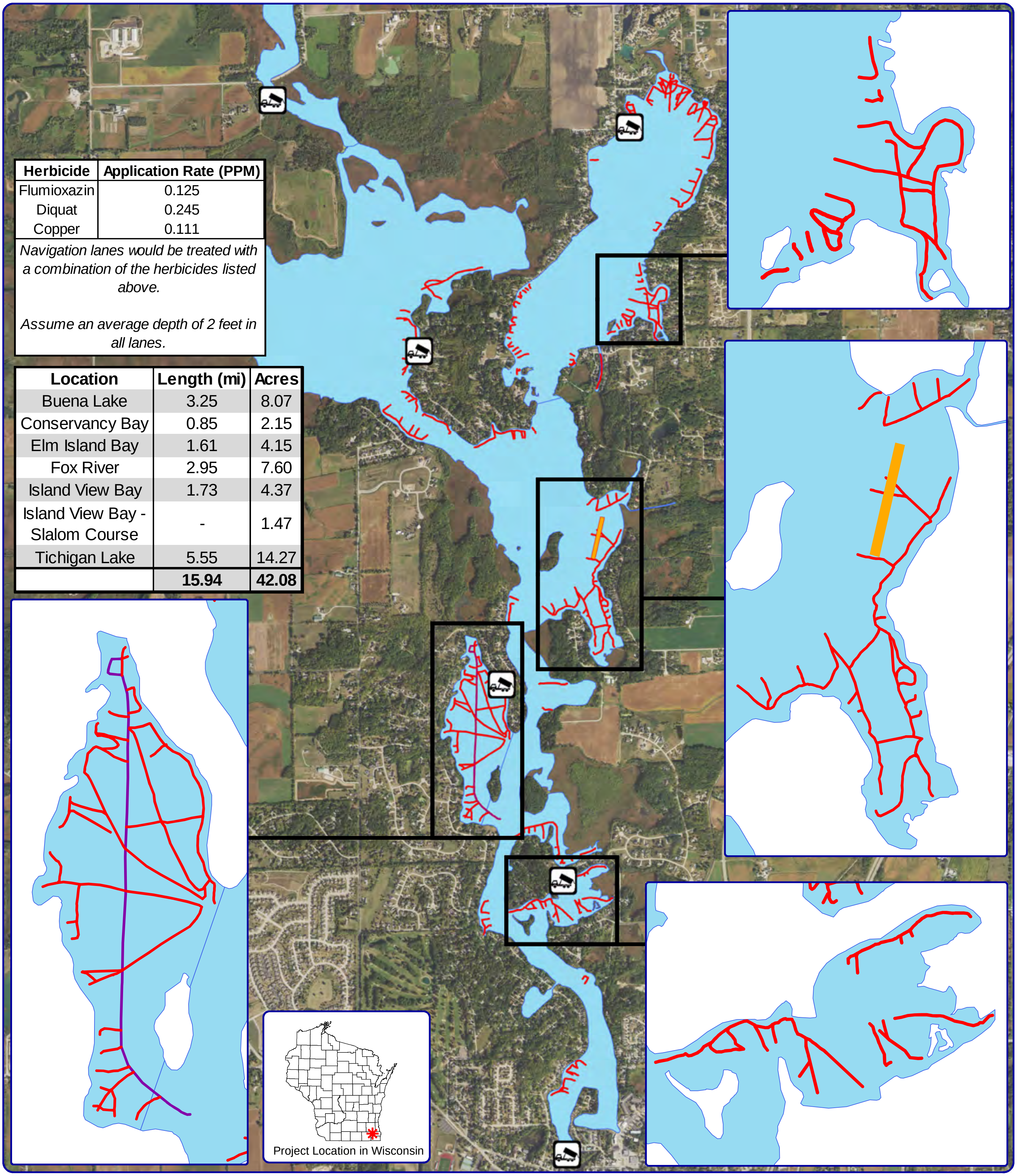
October 2018
EWM Survey Results

Herbicide	Application Rate (PPM)
Flumioxazin	0.125
Diquat	0.245
Copper	0.111

Navigation lanes would be treated with a combination of the herbicides listed above.

Assume an average depth of 2 feet in all lanes.

Location	Length (mi)	Acres
Buena Lake	3.25	8.07
Conservancy Bay	0.85	2.15
Elm Island Bay	1.61	4.15
Fox River	2.95	7.60
Island View Bay	1.73	4.37
Island View Bay - Slalom Course	-	1.47
Tichigan Lake	5.55	14.27
	15.94	**42.08**



Legend

Potential Navigation Lanes

- 20' Lane
- 50' Lane
- Slalom Course (850' x 75')
- Harvester offloading site
- Public Access
- Waterford Dam

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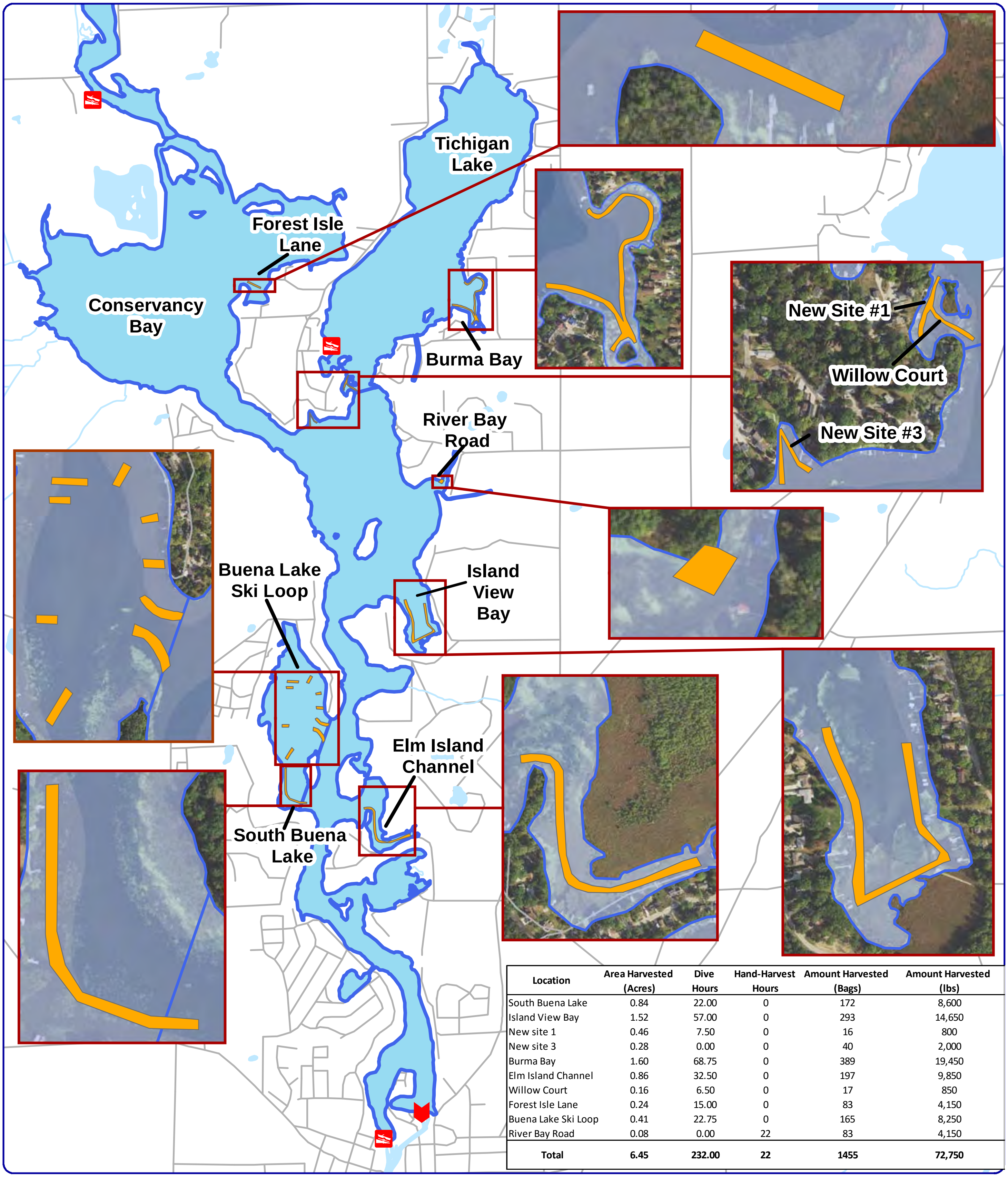
Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR, digitized by Onterra
Map Date: April 2, 2019
Filename: *WaterfordWaterway_Potential_Herbicide_Lanes*

Map 11

Waterford Waterway

Racine County, Wisconsin

Potential Navigation Lanes



Location	Area Harvested (Acres)	Dive Hours	Hand-Harvest Hours	Amount Harvested (Bags)	Amount Harvested (lbs)
South Buena Lake	0.84	22.00	0	172	8,600
Island View Bay	1.52	57.00	0	293	14,650
New site 1	0.46	7.50	0	16	800
New site 3	0.28	0.00	0	40	2,000
Burma Bay	1.60	68.75	0	389	19,450
Elm Island Channel	0.86	32.50	0	197	9,850
Willow Court	0.16	6.50	0	17	850
Forest Isle Lane	0.24	15.00	0	83	4,150
Buena Lake Ski Loop	0.41	22.75	0	165	8,250
River Bay Road	0.08	0.00	22	83	4,150
Total	**6.45**	**232.00**	**22**	**1455**	**72,750**

N
W E
S
2,600
Feet

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920.338.8860
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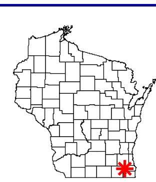
Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR, digitized by Onterra
DASH Locations: Eco Waterway Services, LLC
Map Date: March 5, 2019 AMS
Filename: *Waterford_DASH_2018.mxd*



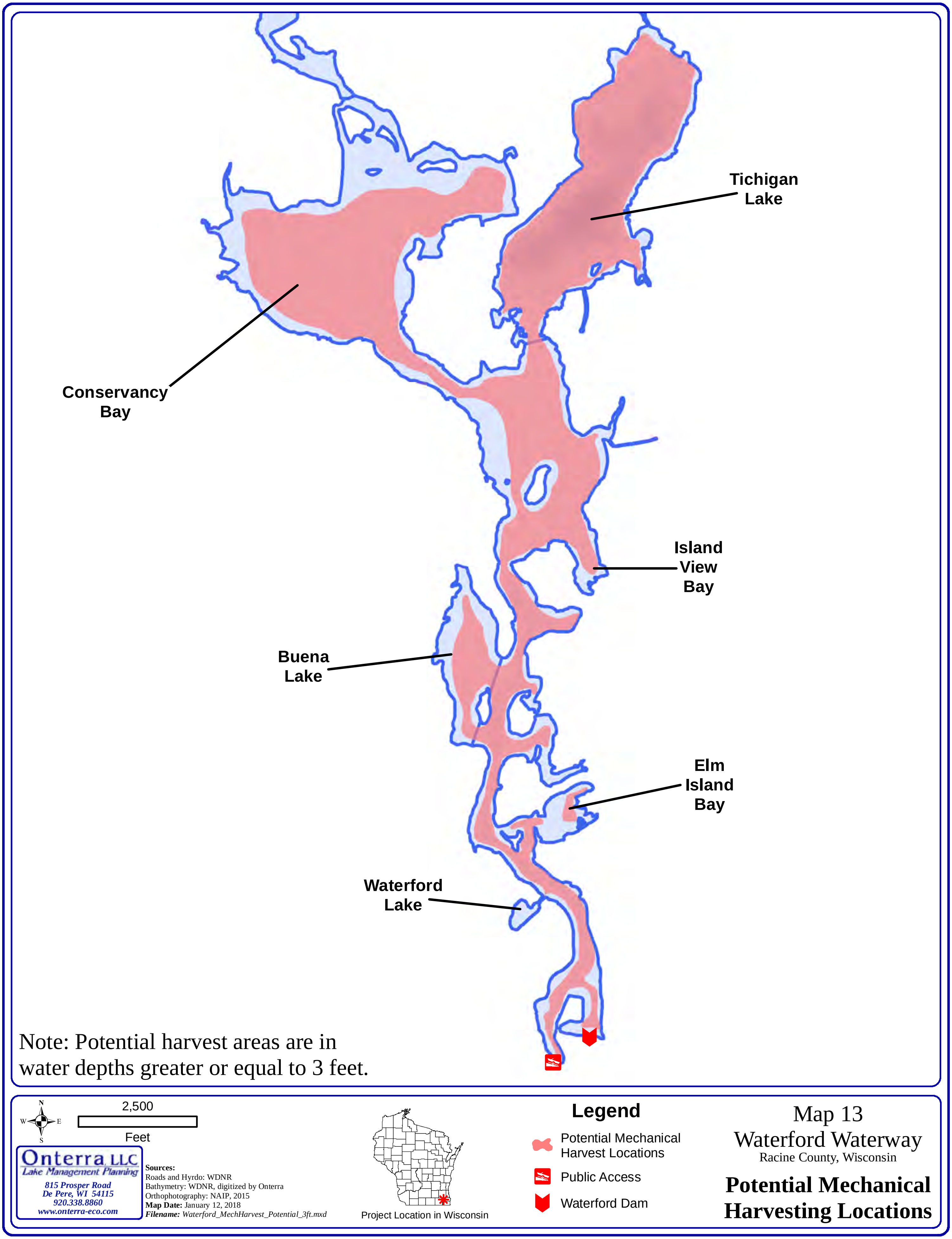
Project Location in Wisconsin

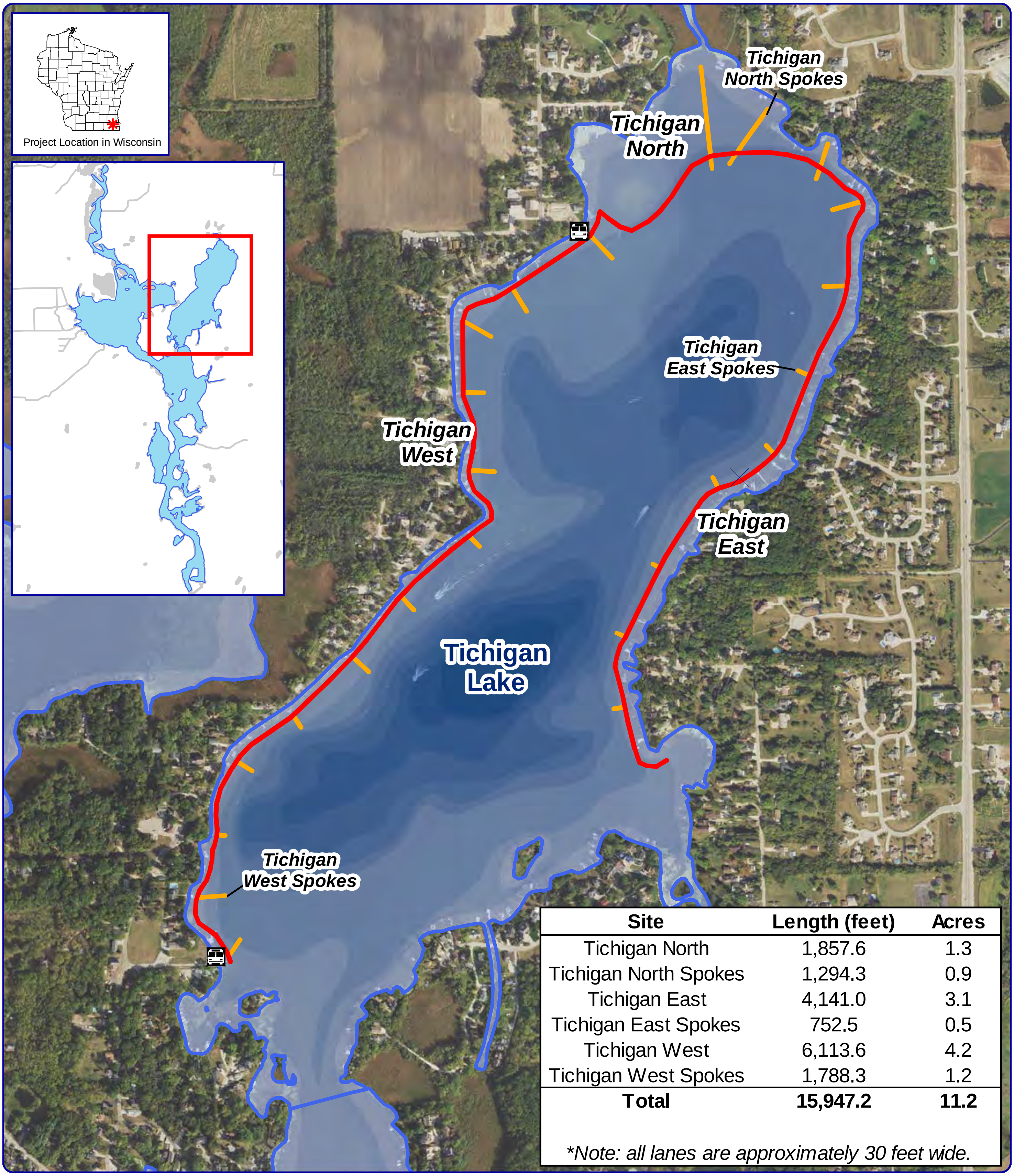
Legend

- 2018 DASH Locations
- Public Access
- Waterford Dam

Map 12
Waterford Waterway
Racine County, Wisconsin

2018 DASH Locations


Tichigan Lake
Conservancy Bay
Island View Bay
Buena Lake
Elm Island Bay
Waterford Lake
Note: Potential harvest areas are in water depths greater or equal to 3 feet.
N
W
E
S
2,500
Feet
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotography: NAIP, 2015
Map Date: January 12, 2018
Filename: Waterford_MechHarvest_Potential_3ft.mxd
Project Location in Wisconsin
Legend
Potential Mechanical Harvest Locations
Public Access
Waterford Dam
Map 13
Waterford Waterway
Racine County, Wisconsin
Potential Mechanical Harvesting Locations



Site	Length (feet)	Acres
Tichigan North	1,857.6	1.3
Tichigan North Spokes	1,294.3	0.9
Tichigan East	4,141.0	3.1
Tichigan East Spokes	752.5	0.5
Tichigan West	6,113.6	4.2
Tichigan West Spokes	1,788.3	1.2
Total	**15,947.2**	**11.2**

**Note: all lanes are approximately 30 feet wide.*

N E S W

750

Feet

Legend

Mechanical Harvest Lanes (30 ft)

Mechanical Harvest Spokes (30 ft)

Mechanical Harvester Offload Sites

Waterford Dam

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De Pere, WI 54115
920.338.8860
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Sources:
Roads and Hyrdo: WDNR
Bathymetry: WDNR, digitized by Onterra
Orthophotograph: NAIP, 2017
Map Date: September 13, 2019 TWH
Filename:
Waterford_MechHarvest_Update.mxd

Map 14
Tichigan Lake
Waterford Waterway
Racine County, Wisconsin
Mechanical Harvest Lanes