Mount Morris Lake

Waushara County, Wisconsin

Comprehensive Management Plan

April 2013

Sponsored by:

Mount Morris Lake Management District

WDNR Grant Program

LPL-1362-10, LPL-1350-10, & LPL-1389-11

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Onterra, LLC
Lake Management Planning

Mount Morris Lake

Waushara County, Wisconsin

Comprehensive Management Plan

April 2013

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C. Water Quality Data
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1.0 INTRODUCTION

Mount Morris Lake, Waushara County, is a 163-acre drainage lake (WDNR definition) with a maximum depth of 40 feet. The lake contains five basins that are locally referred to as lakes – Alfson (Lake A), Russell (Lake B), Hannah (Lake C), Morris (Lake D) and Emerald Lake (Lake E). This mesotrophic-eutrophic system has a relatively large watershed when compared to the size of the lake. In 2010, Mount Morris Lake contained 34 native plant species, of which muskgrasses are the most common. Four exotic plant species are known to exist in Mount Morris Lake.

Field Survey Notes

Water stained with organic acids; much darker than in previous years. Water clarity greatly reduced. Likely due to higher than normal precipitation in 2010. Chara dominated plant community. Large snapping turtles observed on occasion.

Photograph 1.0-1 Mount Morris Lake, Waushara County

Lake at a Glance - Mount Morris Lake

Morphology	
Acreage	163 (WDNR Definition)
Maximum Depth (ft)	40
Mean Depth (ft)	12
Shoreline Complexity	10.8
Vegetation	
Curly-leaf Survey Dates	June 9, 2010
Comprehensive Survey Date	August 27 & September 2, 2010
Number of Native Species	34
Number of Threatened/Special Concern Species	0
Number Exotic Plant Species	4
Simpson's Diversity	0.84
Average Conservatism	5.5
Water Quality	
Trophic State	Mesotrophic-Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.1 – 8.4
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	48:1 (Lakes A,B,C,D); 6:1 (Lake E)

In 2004, the Mount Morris Lake Management District (MMLMD) received Wisconsin Department of Natural Resources (WDNR) Planning Grant funds to complete a comprehensive lake management planning project. The project included multiple components focusing on the lake's water quality, watershed, aquatic plant community, educational issues, and updating the district's mechanical harvesting plan. This plan was finalized in 2006.

At the time of the planning project's completion, the primary concern of the MMLMD was the impacts of the non-native, invasive species curly-leaf pondweed present in the lake. It is not known when curly-leaf pondweed first became established in Mount Morris Lake, but it likely started as small, isolated colony and was unintentionally spread to every basin in the lake largely through the district's harvesting activities.

In February 2006, the MMLMD successfully applied for an Aquatic Invasive Species (AIS) Established Infestation and Control Grant for a five-year project aimed at reducing the curly-leaf pondweed population within the lake. The project was outlined to include herbicide treatment and associated monitoring activities during the first four years, followed by a whole-lake assessment of the aquatic plant community during the final year. 2010 was the fifth and final year of that project.

Great strides in curly-leaf pondweed control were made over the course of this multi-year project. However, the occurrence of another non-native invasive species, Eurasian water milfoil, has become a pressing management issue. Herbicide treatments aimed at controlling this species took place in 2008 through 2012, and progress in reducing this plant is being made.

In 2010, the MMLMD successfully applied for another WDNR Lake Planning Grant, with the intent of completing a management planning project on Mount Morris Lake. The MMLMD wanted to complete this project for four main reasons: 1) to determine current extent of aquatic invasive plant species within the lake, 2) to formulate an ecologically sound program to reduce nuisance levels of native aquatic plants that meets stakeholder's interests, 3) to understand the Mount Morris Lake ecosystem more fully, and 4) to update their existing lake management plan so they are eligible to receive additional WDNR grant funds to address the aquatic invasive species and other goals of lake stakeholders.

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting

On March 5, 2011, a combination project kick-off meeting and AIS wrap-up meetings was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Mount Morris Lake Management District board members. The approximately 30 attendees observed a presentation given by Tim Hoyman an aquatic ecologist with Onterra. Dan Cibulka from Onterra was also in attendance. Mr. Hoyman's portion of the presentation dealing with the management planning project started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting

On April 13, 2012, Eddie Heath and Brenton Butterfield of Onterra met with five members of the Mount Morris Lake Planning Committee. In advance of this meeting, a draft copy of the Results & Discussion Sections (3.0) was provided to attendees. Mr. Ted Johnson, WDNR, was invited to participate in the meeting, but was unable to do so due to a scheduling conflict. The primary focus of this meeting was the delivery of the study results and conclusions to the committee and the development of concise management goals. All study components including curly-leaf pondweed and Eurasian water milfoil treatment results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. The most pressing concern expressed by this group was the spread of invasive species in the lake.

Project Wrap-up Meeting

Has not yet occurred.

Management Plan Review and Adoption Process

In May 2012, an official first draft of the Mount Morris Lake Management Plan was supplied to the WDNR and the MMLMD Planning Committee for review. Comments were provided to Onterra by the district over the course of the next month. Official notice of WDNR approval was received on February 18, 2013.

Stakeholder Survey

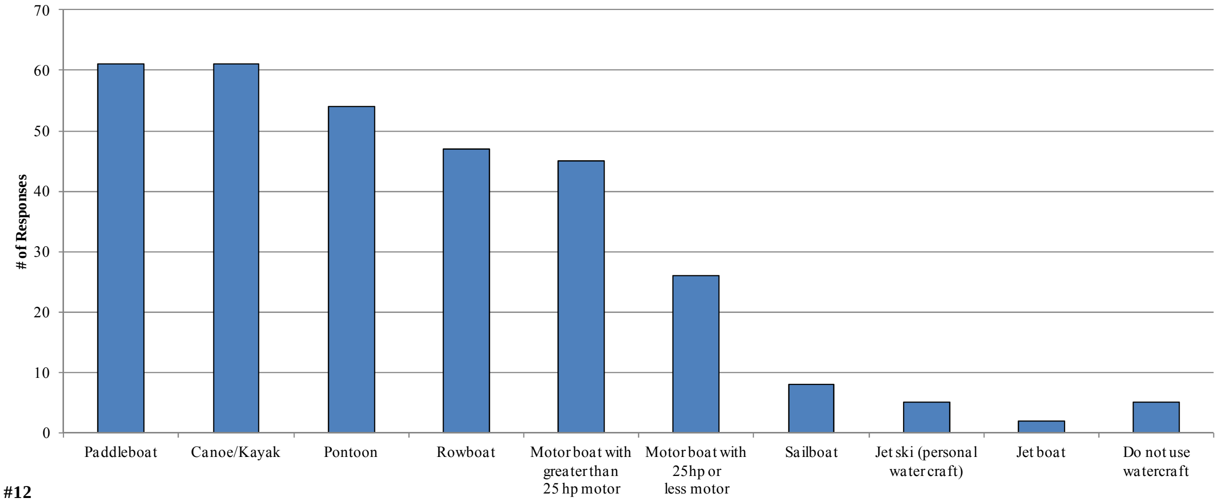
During October 2011, a seven-page, 29-question survey was mailed to the 185 riparian property owners in the Mount Morris Lake Management District. Sixty-three percent of the surveys were returned and those results were entered into a spreadsheet by members of the Mount Morris Lake Planning Committee. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Mount Morris Lake. The majority of stakeholders (39%) visit the lake on weekends throughout the year. About 30% of stakeholders own a seasonal (summer) residence on the lake, while about 27% live on the lake year-round. 62% of stakeholders have owned their property for over 15 years, and 40% 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. With respect to recreational watercraft use on the lake, paddleboats, canoe/kayaks and pontoon boats were the most popular options chosen on the survey (Question 12). On a relatively small lake such as Mount Morris, with numerous corridors and slow-no-wake zones, 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 13, several of the top recreational activities on the lake involve boat use. Boat traffic did not rank within the top five on a list of factors potentially impacting Mount Morris Lake in a negative manner (Question 19). Additionally, it ranked moderately on a list of stakeholder's top concerns regarding the lake (Question 20).

There were several reoccurring concerns noted by stakeholders throughout the stakeholder survey (see Question 19, 20 and survey comments – Appendix B). These concerns include aquatic invasive species, excessive aquatic plant growth, water quality degradation and silt/sediment accumulation. These topics are discussed more thoroughly within the Water Quality and Aquatic Plant Sections, as well as the Summary/Conclusions and Implementation Plan.

Question 12: What types of watercraft do you currently use on Mount Morris Lake?



#12

Question 11: Please rank up to three activities that are important reasons for owning your property on or near Mount Morris Lake.

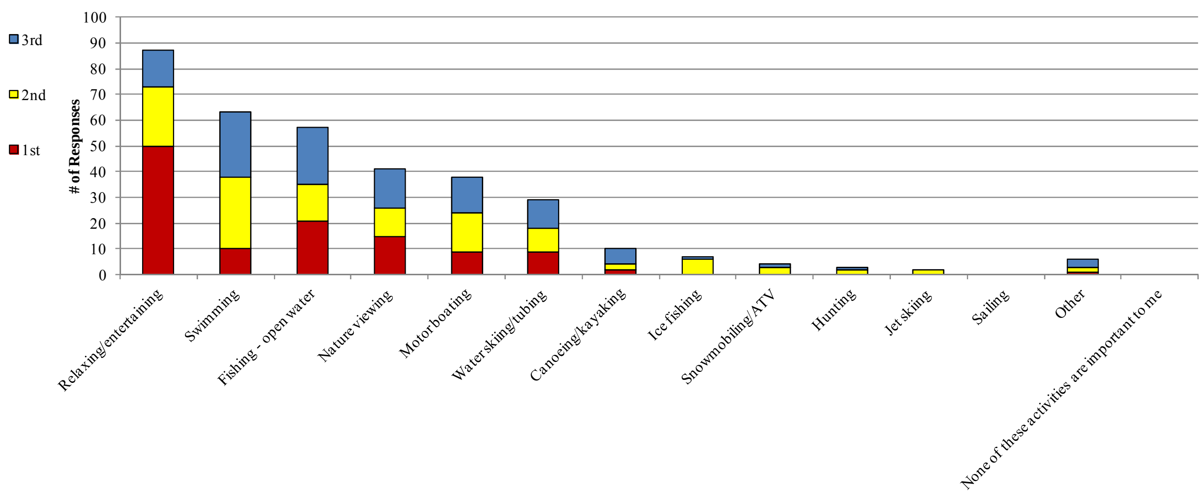


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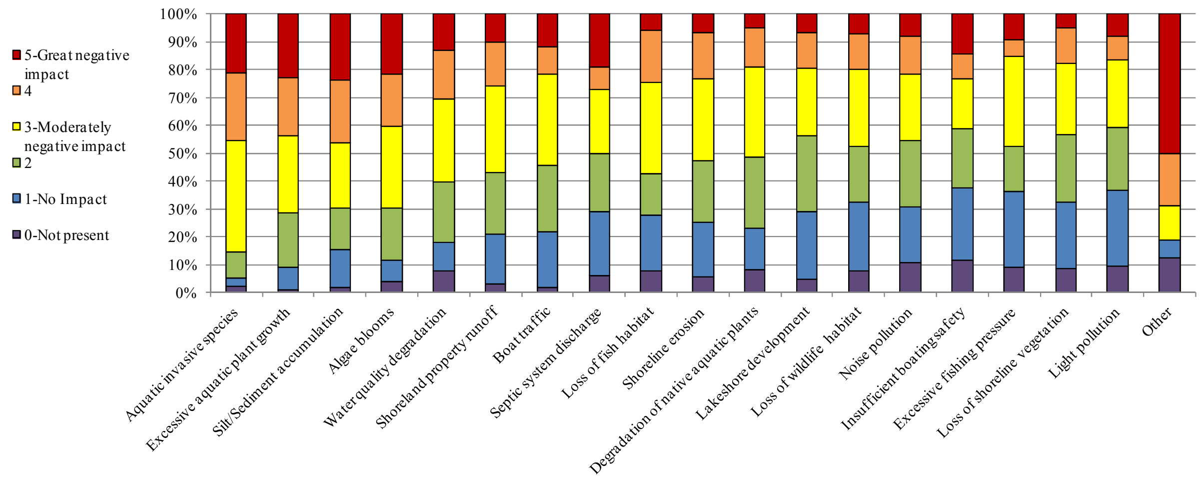
Figure 2.0-1. Select survey responses from the Mount Morris Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 19: To what level do you believe these factors may be negatively impacting Mount Morris Lake?



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Question 20: Please rank your top three concerns regarding Mount Morris Lake.

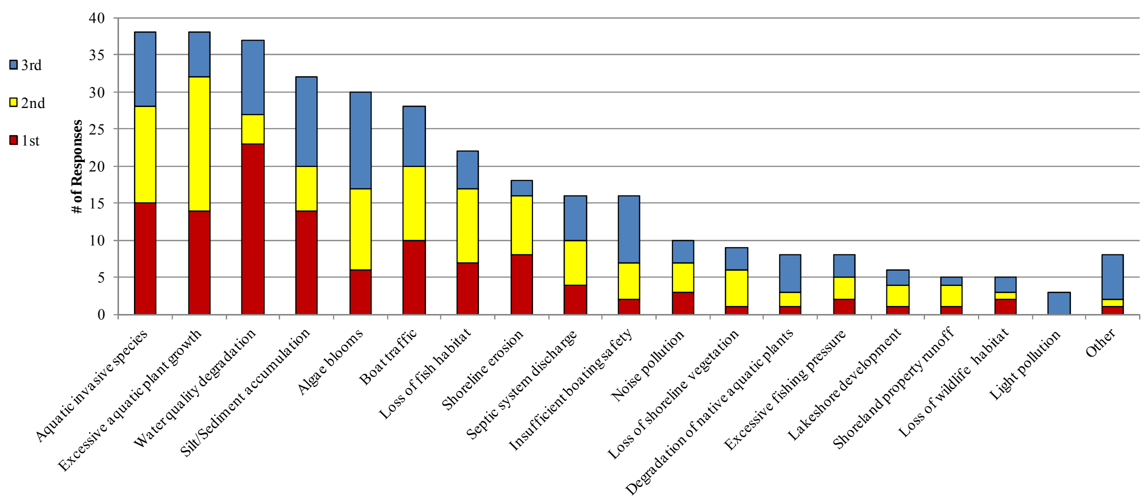

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Figure 2.0-2. Select survey responses from the Mount Morris Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 analysis 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 Mount Morris Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the central 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 used in the analysis of Mount Morris Lake's water quality:

> **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. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-*a*, and total phosphorus values.

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) 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 their watersheds and the composition of the watershed's land cover. For this reason, the water quality of Mount Morris Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: shallow (mixed) or deep (stratified). Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or the entire lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). An equation developed by Lathrop and Lillie (1980) that incorporates the maximum depth of the lake and the lake's surface area is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

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

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

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

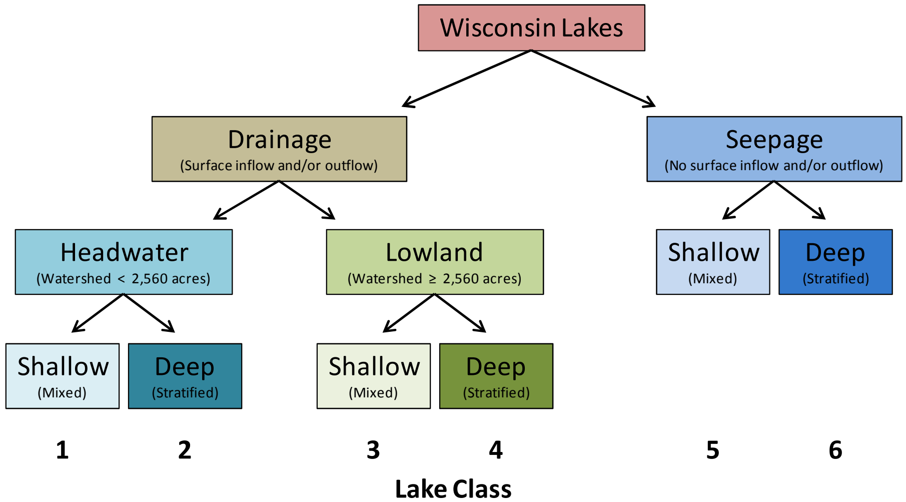


Figure 3.1-1. Wisconsin Lake Classifications. The four upstream-most basins of Mount Morris Lake are classified as deep (stratified), lowland drainage lakes (Class 4), while Emerald Lake is classified as a deep (stratified), seepage lake (Class 6). Adapted from WDNR PUB-SS-1044 2008.

The four upstream-most basins of Mount Morris Lake (A,B,C,D) are classified as deep (stratified), lowland drainage lakes. Although Lake E, or Emerald Lake has an outlet draining to Lake D, this outlet is man-made. Therefore, Lake E is classified as a deep (stratified) seepage Lake. The WDNR developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six 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. 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. Mount Morris Lake is within the North Central Hardwood Forests ecoregion (Figure 3.1-2).

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is another useful tool in helping lake stakeholders understand the health of their lake compared to others 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, they were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

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

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Mount Morris Lake are displayed in Figures 3.1-3 - 3.1-17. Please note that the data in these graphs represent concentrations taken only during the growing season (April-October) from all five basins in Mount Morris Lake. Since state and regional medians were calculated using summer (June, July, August) data, summer data for Mount Morris Lake has also been displayed. 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.

Mount Morris Lake Water Quality Analysis

Mount Morris Lake Long-term Trends

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

Perception of water quality often varies greatly from person to person. This variance is due to differences in the tolerance and past experiences of people. In short, the water quality of a given lake might be poor to one person, but rather good to another person who has spent considerable time on other lakes that have poor water clarity, algae problems, or other water quality issues. When asked how they would describe the current water quality of Mount Morris Lake, the majority of survey recipients responded positively, with 74% selecting good or excellent (Appendix B, Question #14). The majority of respondents (40%) also felt that the water quality in Mount Morris Lake has remained the same over the period of time they have visited the lake. However, while water quality degradation was not rated as one of the top factors negatively impacting Mount Morris Lake at present, respondents rated it as their primary concern regarding the lake (Appendix B, Question #19 and #20). Using the water quality data collected in 2010 along with available historic data, it is possible to not only assess the current status of Mount Morris Lake's water quality, but also determine if any long-term trends (positive or negative) are occurring.

As previously stated, there are three primary parameters that are analyzed when assessing the water quality of a lake – total phosphorus, chlorophyll-*a*, and Secchi disk clarity. These three parameters yield a great deal of information about the lake's water quality and are closely correlated with one another. As discussed earlier, phosphorus is the limiting nutrient in the majority of Wisconsin's lakes, and increases in this chemical often increases the growth and abundance of free-floating algae (measured by chlorophyll-*a*). The increase in free-floating algae decreases sunlight penetration into the water and lowers water clarity (measure by Secchi disk transparency). So, as phosphorus concentrations increase, algae (chlorophyll-*a*) increases, and water clarity (Secchi disk transparency) decreases. However, examining these data is not always this simple or straightforward as there are often other factors influencing the chemistry and clarity of a lake's water.

Lake A (Alfson Lake)

Total phosphorus and chlorophyll-*a* data for Lake A are only available from 2004 and 2010. Both the growing season and summer total phosphorus values were slightly lower in 2010 than in 2004, and the weighted average for these two years is similar to state-wide deep, lowland drainage lakes median and much lower than the median for lakes in the North Central Hardwood

Forests Ecoregion, falling in the *Good* category (Figure 3.1-3). Growing season chlorophyll-*a* levels were slightly higher in 2010 than in 2004, while summer values were lower in 2010 than in 2004. Overall, growing season chlorophyll-*a* levels fall within the *Good* category for state-wide deep, lowland drainage lakes, and summer levels fall within the *Excellent* category (Figure 3.1-4).

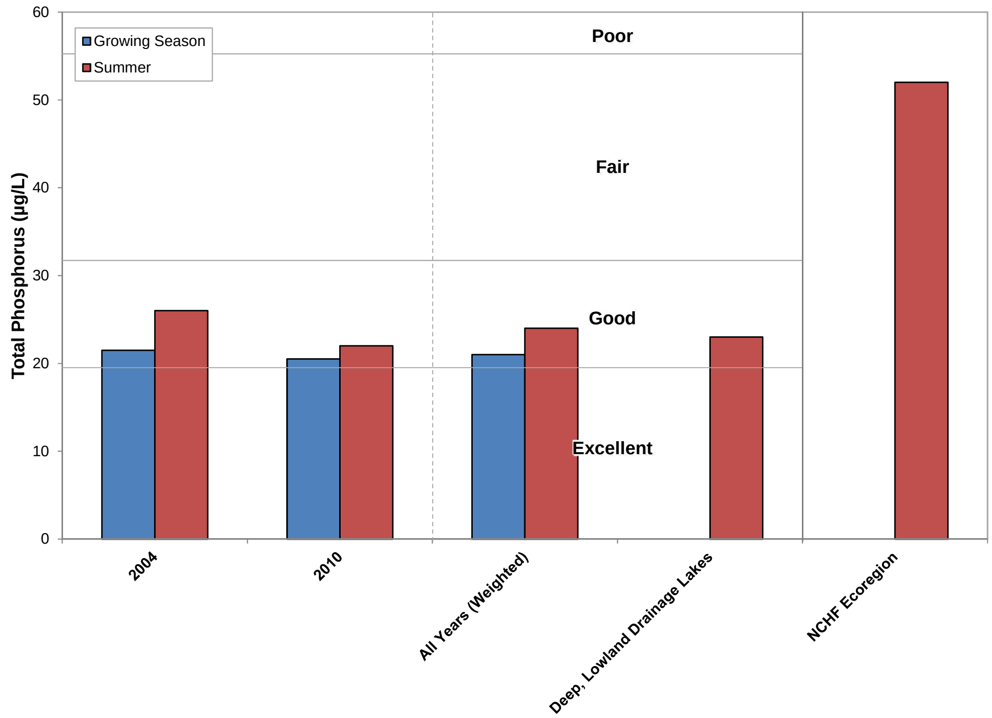


Figure 3.1-3. Mount Morris Lake A, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

While total phosphorus and chlorophyll-*a* data are limited for Lake A, substantial Secchi disk transparency data exists going back to 1986. Figure 3.1-5 indicates that, except for 2010, the water clarity in Lake A has remained relatively constant over the time period for which data are available. In 2010, water clarity values were the lowest on record and indicate that water clarity in 2010 declined by nearly six feet compared to previous years. This decline in water clarity can be attributed to unusually high amounts of precipitation in 2010 which increased surface runoff into Mount Morris Lake. Not only was snowfall in the winter of 2009/2010 higher, but precipitation data collected at the Waushara County Airport indicates that in May through September, 2010, rainfall totaled 24.5 inches compared to 11.2 inches over this same period in 2009. Often, high precipitation levels bring about higher nutrient levels reaching the lake. These higher nutrient loads then bring about higher algal abundance, increasing the turbidity in the lake, and lowering Secchi disk values. However, this is not strictly the case with Lake A in 2010.

As described above, declining water clarity is often correlated with increasing algae abundance; however, greatly elevated chlorophyll-*a* levels were not recorded in Lake A in 2010. After working on Mount Morris Lake for a number of years, Onterra ecologists noted that the water in 2010 was stained and much darker in color than in previous years. It is believed the decline in water clarity was caused by the increased precipitation flushing wetlands within Mount Morris Lake's watershed, delivering higher than normal amounts of organic acids to the lake, which stain the water a dark brown color. These naturally occurring acids are by-products of decomposing wetland plant material, and are not harmful to humans or aquatic life. This natural staining reduces light penetration into the water column, reducing visibility, and lowering water clarity.

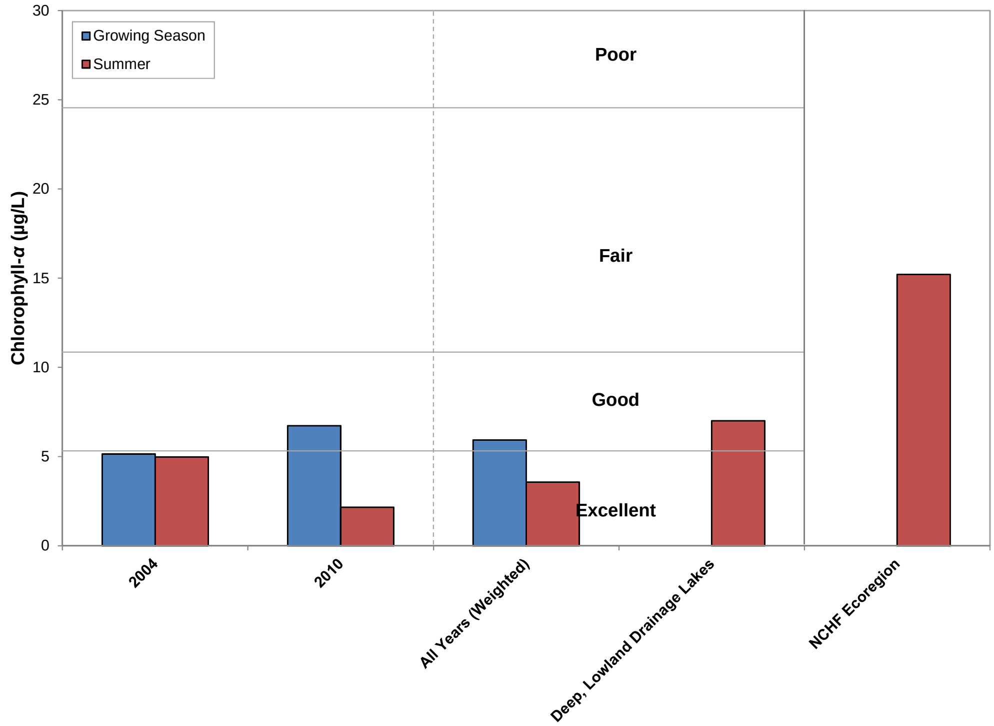


Figure 3.1-4. Mount Morris Lake A, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

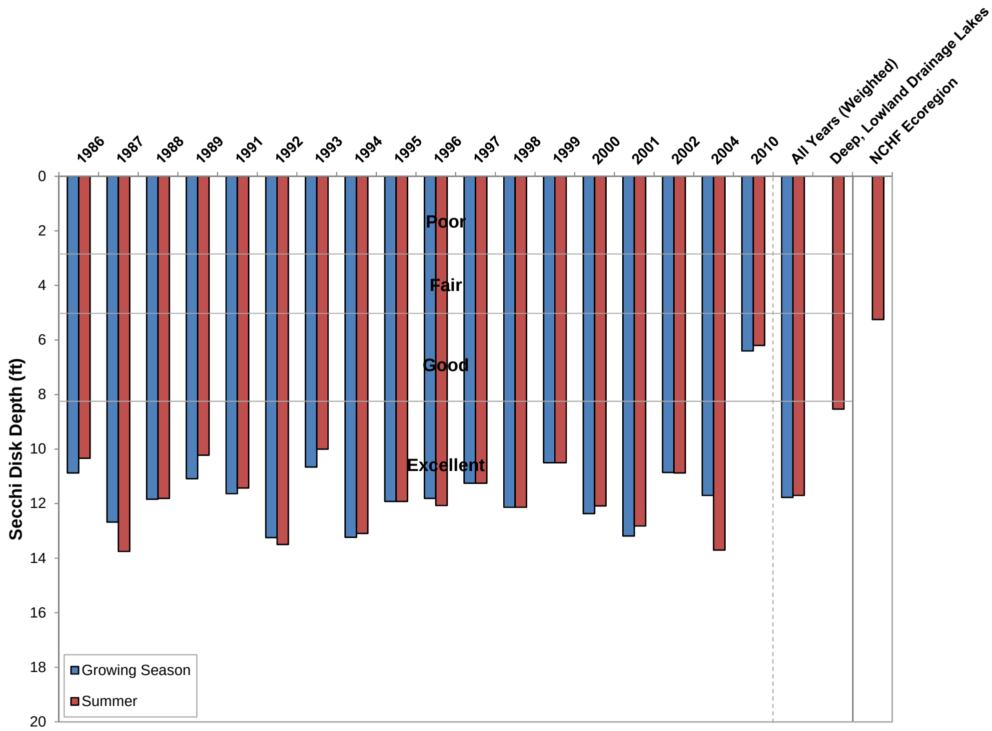


Figure 3.1-5. Mount Morris Lake A, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Lake B (Russell Lake)

Like Lake A, total phosphorus and chlorophyll-*a* data are only available from 2004 and 2010 for Lake B. However, unlike Lake A, total phosphorus values were slightly higher in 2010 than in 2004 (Figure 3.3-7). Chlorophyll-*a* followed this same pattern, with higher levels recorded in 2010 than in 2004 (Figure 3.3-8). Overall, phosphorus levels in Lake B straddle the *Excellent-Good* threshold for deep, lowland drainage lakes and fall well below the median for lakes within North Central Hardwood Forests Ecoregion.

In addition, high levels of phosphorus (> 200 µg/L) were recorded in the lower, cooler layer of water (hypolimnion) near the bottom in 2010, indicating internal phosphorus loading from bottom sediments may be a contributing factor; this will be discussed in more detail in the Internal Nutrient Loading Section.

Ample Secchi disk transparency data exists for Lake B, going back to 1986. Again, aside from 2010 and smaller inter-annual variations, water clarity has remained constant over this time period and no positive or negative trends are apparent. Like in Lake A, water clarity in 2010 was the lowest ever recorded, and is likely due to the high precipitation washing in large amounts of organic acid, which darken or stain the water. The higher levels of algae, as measured via chlorophyll-*a*, likely contributed to decreased water clarity in Lake B as well.

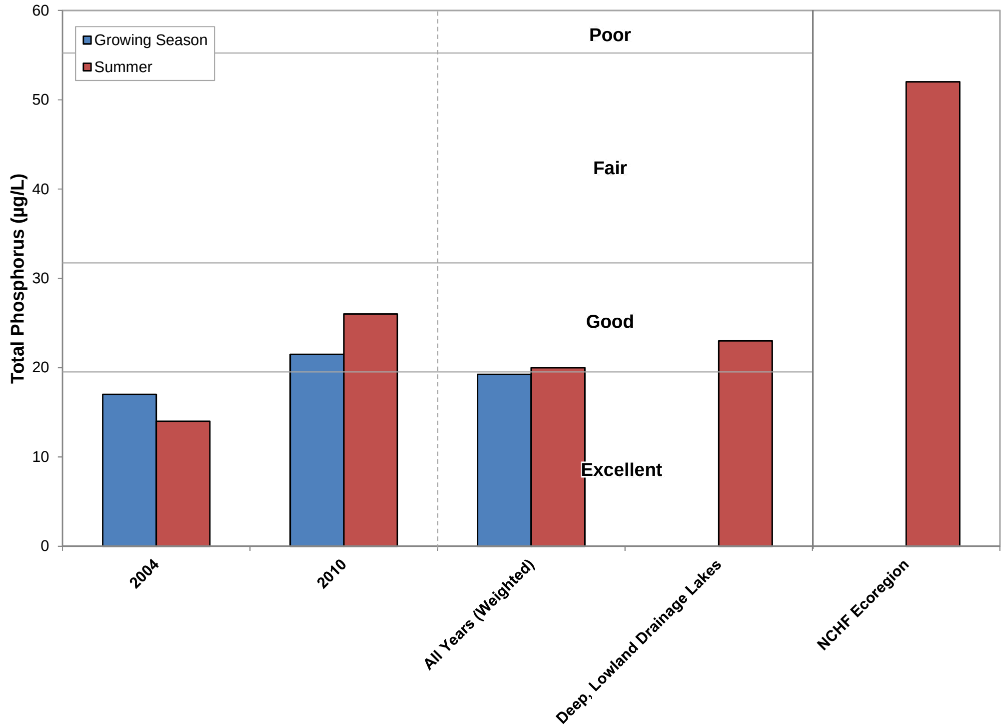


Figure 3.1-6. Mount Morris Lake B, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

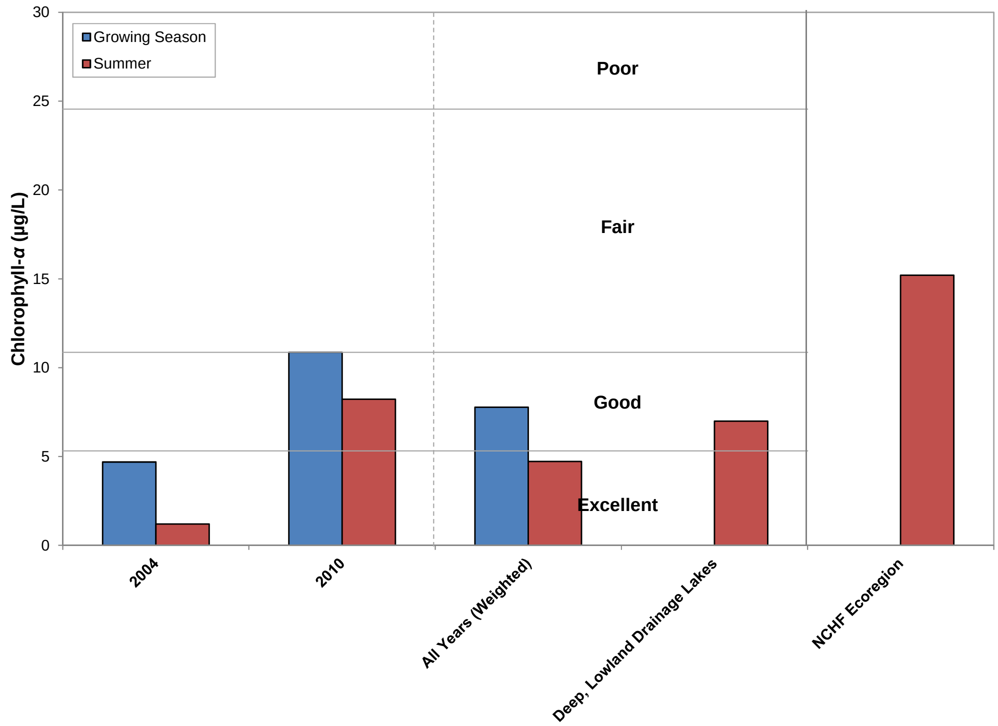


Figure 3.1-7. Mount Morris Lake B, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

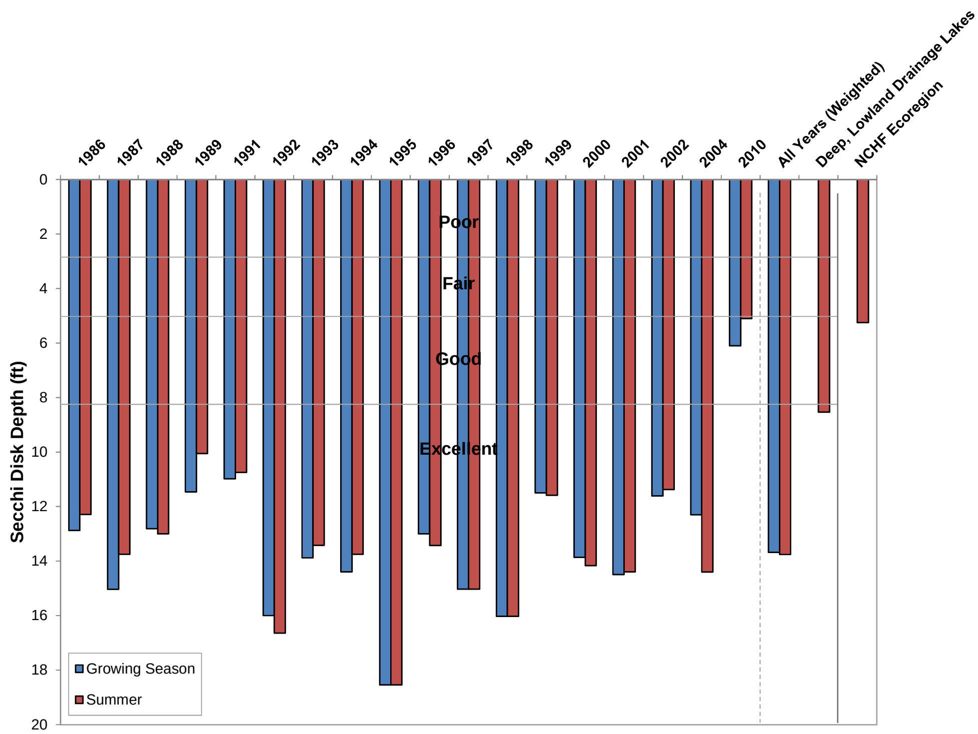


Figure 3.1-8. Mount Morris Lake B, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Lake C (Hannah Lake)

Consecutive total phosphorus data, except for 2005, are available for Lake C since 2004. As Figure 3.1-9 illustrates, 2010 total phosphorus values were similar to values observed in 2004 and 2008, while values in 2006, 2007, and 2009 were slightly lower. The weighted average for all years falls into the *Good* category for deep, lowland drainage lakes, and is far lower than the median for lakes in the North Central Hardwood Forests Ecoregion. Chlorophyll-*a* data are only available from 2004 and 2010, and levels recorded in 2010 were slightly higher than in 2004 (Figure 3.1-10). Overall, the weighted average chlorophyll-*a* falls into the *Good* category for the growing season and summer values fall in the *Excellent* category for deep, lowland drainage lakes.

Secchi disk transparency data are available from Lake C since 1986. Aside from 1993, 1999, and 2010, water clarity appears to have remained relatively constant in Lake C over this time period (Figure 3.3-11). Similar to other Mount Morris Lake basins already discussed, water clarity in 2010 was the lowest on record, and is likely due to the high amounts of organic acids in combination with increased algae abundance due to higher precipitation in 2010. Despite the low water clarity in 2010, the weighted average for all years falls within the *Excellent* category for deep, lowland drainage lakes and greatly exceeds the median value for other lakes in the North Central Hardwood Forests Ecoregion.

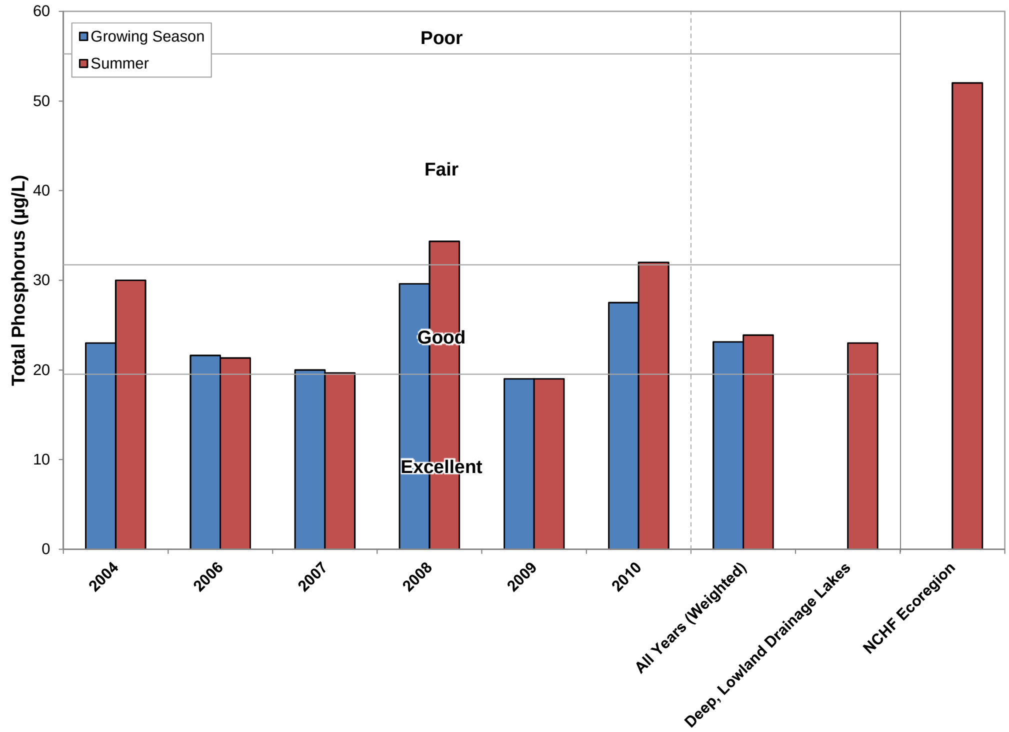


Figure 3.1-9. Mount Morris Lake C, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

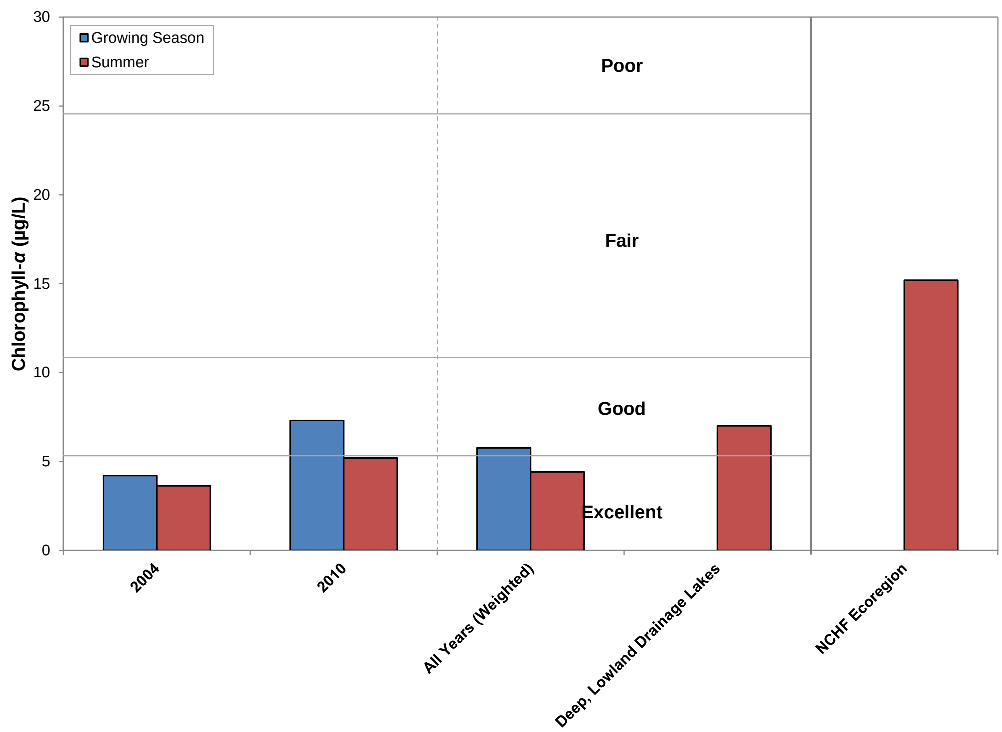


Figure 3.1-10. Mount Morris Lake C, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

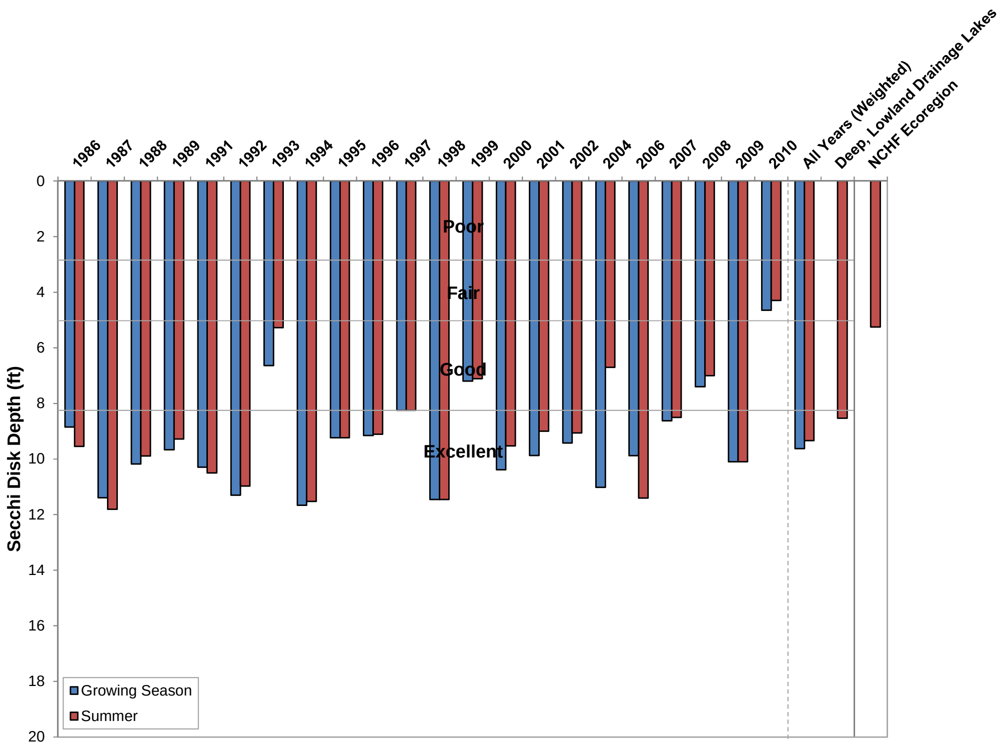


Figure 3.1-11. Mount Morris Lake C, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Lake D (Morris Lake)

Lake D is the primary basin for water quality sampling on Mount Morris Lake, and the location which has the most historic water quality data available. Historic total phosphorus data are available going back to 1988, and Figure 3.1-12 illustrates that higher phosphorus levels are recorded approximately every three to five years. Elevated levels of phosphorus were recorded in 1997, 2002, 2008, and 2010, and are likely a result of increased precipitation. High phosphorus values within the hypolimnion (>200 µg/L) were recorded in 2010, indicating that internal phosphorus loading from bottom sediments may also be occurring. Internal nutrient loading will be discussed in greater detail in the Internal Nutrient Loading Section. The weighted total phosphorus value for all years straddles the *Excellent-Good* threshold for deep, lowland drainage lakes and is well below the median value for other lakes within the North Central Hardwood Forests Ecoregion (Figure 3.1-12).

Chlorophyll-*a* data for Lake D are also available going back to 1988, though not for as many consecutive years as total phosphorus (Figure 3.1-13). Interestingly, when total phosphorus levels were high in 1997 and 2004, chlorophyll-*a* did not appear to increase as would be expected. However, chlorophyll-*a* levels in 2010 were the highest recorded, nearly twice as high as all the previous records and despite having similar total phosphorus values to what was recorded in 2004. It is possible that a portion of the total phosphorus recorded in 2004 was in a form that was not available for use by algae. For example, some of the phosphorus may have been bound to calcium carbonate (marl). The weighted average for all years straddles the

Excellent-Good threshold for deep, lowland drainage lakes and falls below the median for lakes in North Central Hardwood Forests Ecoregion (Figure 3.1-13).

Twenty-four years of Secchi disk transparency data going back to 1986 are available for Lake D (Figure 3.1-14). Except for 1993, 2008, and 2010, all of the Secchi disk data has fallen in the *Excellent* category. Like the three previous basins discussed, 2010 had the lowest water clarity measured during this period. As described previously, this is a result of the high amounts of organic acids present in 2010 which darkened the water, along with higher algae levels. Overall, Secchi disk clarity values for Lake D fall within the *Excellent* category for deep, lowland drainage lakes and greatly exceed the median value of other lakes in the North Central Hardwood Forests Ecoregion (Figure 3.1-14).

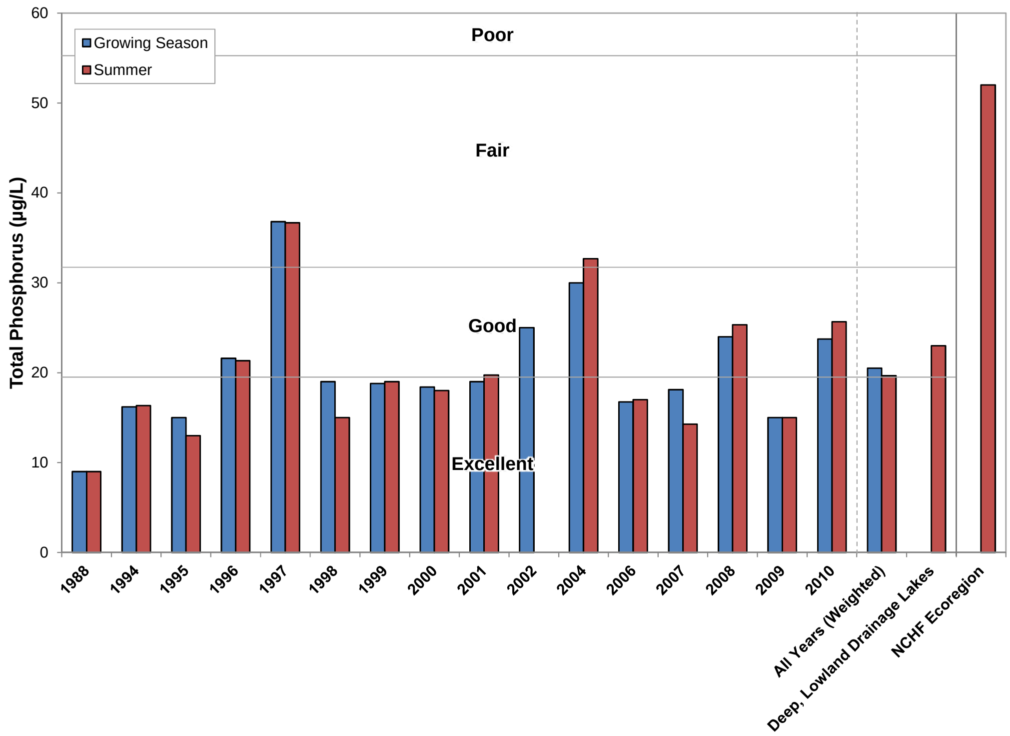


Figure 3.1-12. Mount Morris Lake D, state-wide class 4 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

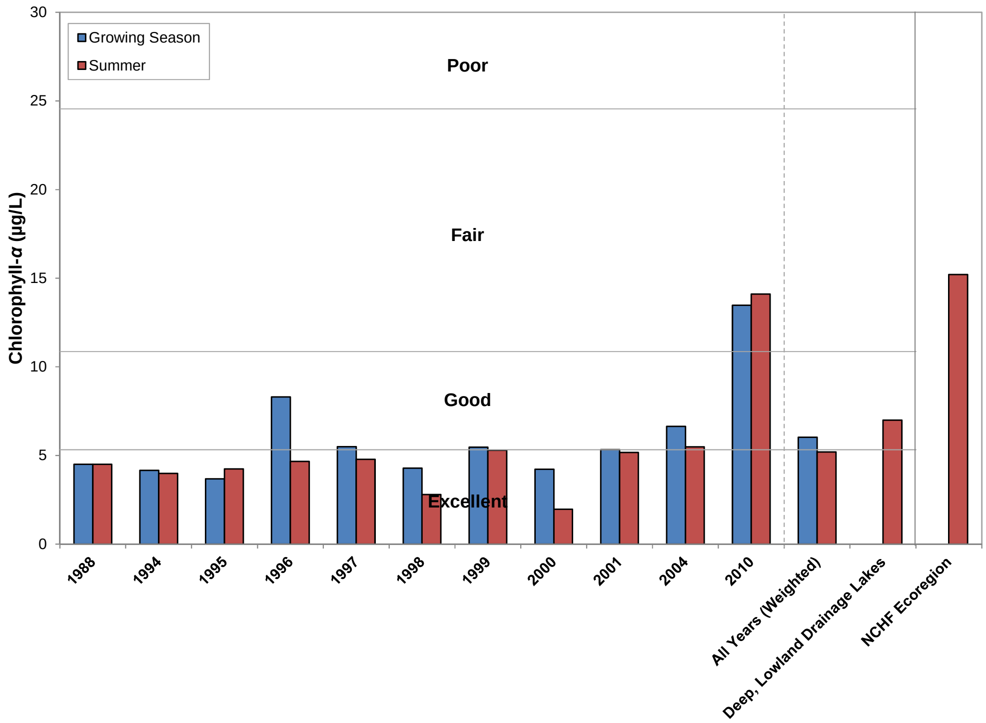


Figure 3.1-13. Mount Morris Lake D, state-wide class 4 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

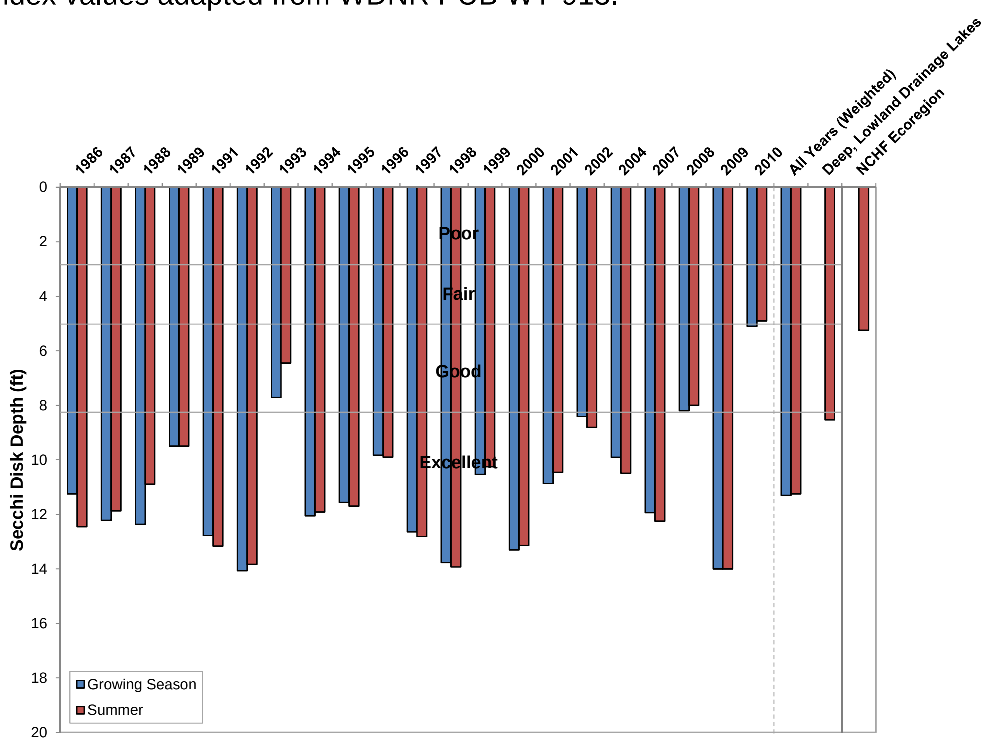


Figure 3.1-14. Mount Morris Lake D, state-wide class 4 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Lake E (Emerald Lake)

While Lakes A, B, C, and D, all flow consecutively into the next, these lakes do not flow into Lake E. Rather, Lake E is separate from the rest of these basins, has its own watershed, and flows into Lake D. Prior to the creation of a man-made channel connecting Lakes E and D, Lake E had no tributary inflow or outflow. For this reason, Lake E is classified differently from the other basins as a deep seepage lake, and has different index thresholds for water quality.

Total phosphorus and chlorophyll-*a* data for Lake E are only available from 2004 and 2010. Total phosphorus values in 2010 were approximately half of what was recorded in 2004, despite the high amount of precipitation in 2010. The weighted average for total phosphorus values fall within the *Good* category for deep seepage lakes, and are well below the median for lakes in the North Central Hardwood Forests Ecoregion (Figure 3.1-15). Like total phosphorus, chlorophyll-*a* values in 2010 were considerably lower than in 2004, and overall straddle the *Excellent-Good* threshold for deep, headwater drainage lakes (Figure 3.1-16).

Seventeen years of Secchi disk transparency data going back to 1986 are available for Lake E (Figure 3.1-17). These data indicate that for the most part, water clarity has remained relatively constant over this time period. And unlike the other four basins, the water clarity in Lake E in 2010 was not dramatically lower compared to previous years. As discussed previously, Lake E has a separate and much smaller drainage basin than the other four, and did not receive the large amount of organic acids and nutrients in 2010. The weighted average for all years of Secchi disk transparency data far exceed the *Excellent* threshold for deep seepage lakes, as well as the median for lakes in the North Central Hardwood Forests Ecoregion (Figure 3.1-17).

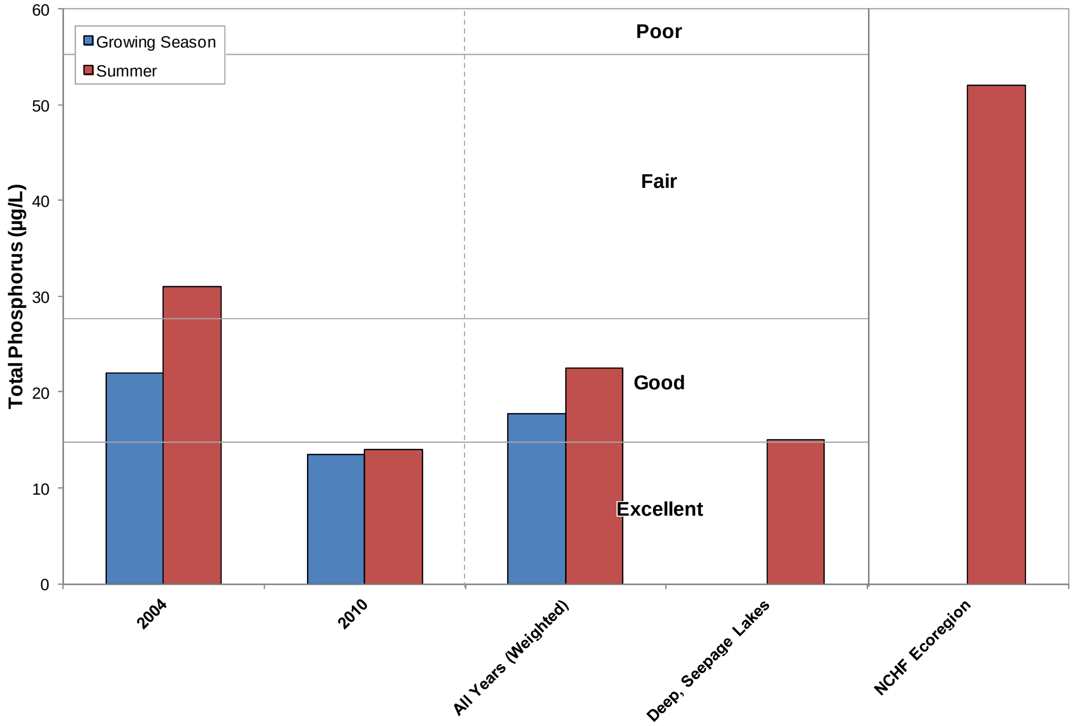


Figure 3.1-15. Mount Morris Lake E, state-wide class 3 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

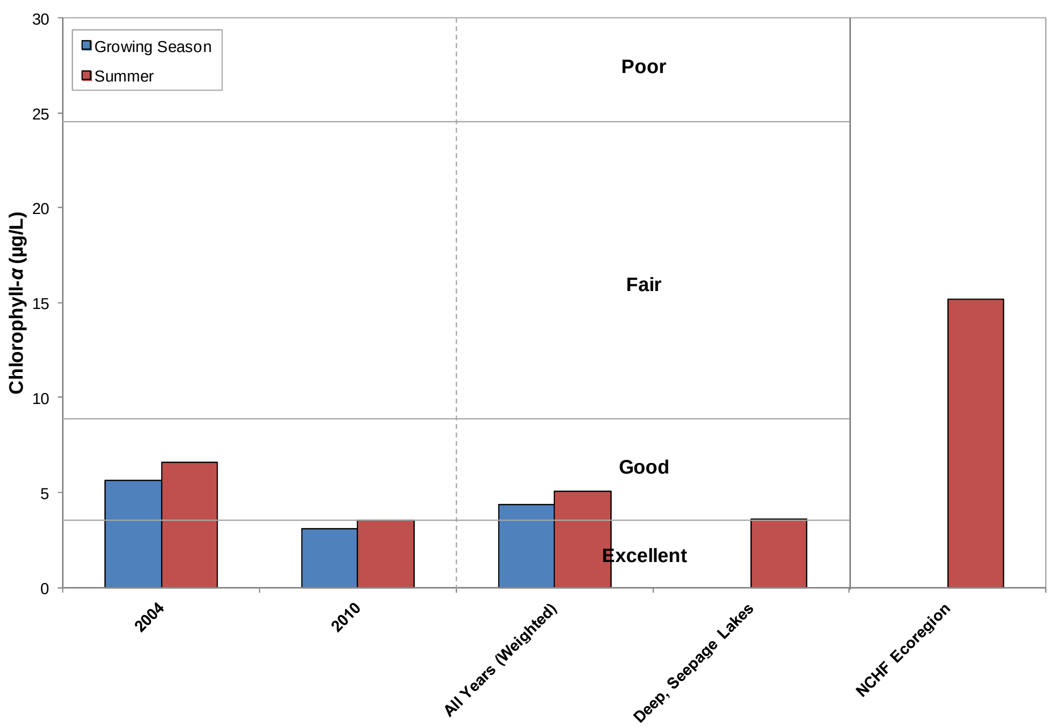


Figure 3.1-16. Mount Morris Lake E, state-wide class 3 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

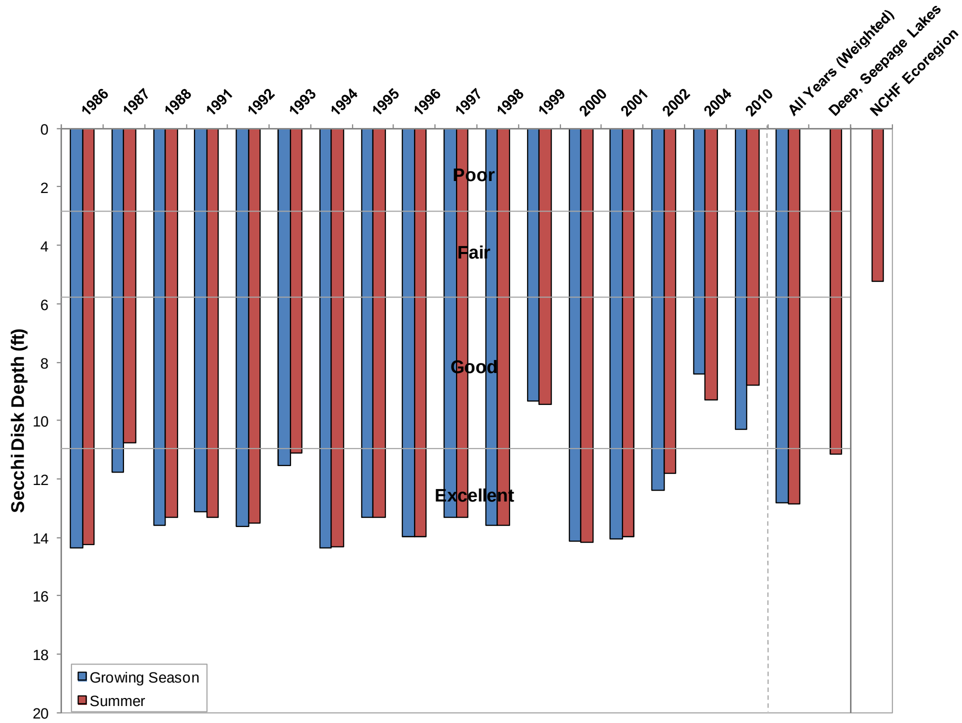


Figure 3.1-17. Mount Morris Lake E, state-wide class 3 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Internal Nutrient Loading

As discussed in the Water Quality Primer Section, internal nutrient loading is the recycling of nutrients, commonly phosphorus, from lake sediments. If a lake's nutrient-rich bottom sediments are exposed to anoxic (devoid of oxygen) conditions during stratification, the iron that normally holds the phosphorus in the sediments releases it into the hypolimnion (bottom water layer) of the lake. During turnover events, this nutrient-rich water is mixed into surface waters often spurring or maintaining algal blooms. Internal nutrient loading can be a significant source of phosphorus in lakes long after external sources have been minimized. In general, when hypolimnetic phosphorus values exceed 200 μg/L, it is possible internal nutrient loading may be impacting algal production and water clarity.

All five basins stratify during the summer and experience hypolimnetic anoxia. Growing season hypolimnetic phosphorus values ranged from 8.5 μg/L in Lake E to 374.8 μg/L in Lake D, and summer values ranged from 17.0 μg/L in Lake E to 413.3 μg/L in Lake D (Figure 3.1-18). Lakes A, C, and E did not have any hypolimnetic phosphorus values that exceeded 200 μg/L, indicating internal nutrient loading is likely not a significant source of phosphorus in these basins. In Lakes B and D, hypolimnetic values above 200 μg/L were recorded in 2010, and may indicate that a limited amount of internal nutrient loading occurs within these lakes. However, considering the size of Mount Morris Lake's watershed and the amount of phosphorus that enters this lake via surface runoff, the internal load would be considered negligible at this time.

The Osgood Index is a measure relating a lake's volume to its surface area and is used to determine whether a lake is dimictic or polymictic. Dimictic lakes completely mix or turnover two times per year, once in the spring and again in fall, while polymictic lakes have the potential to turn over multiple times per year depending on wind events. Osgood Index calculations for the five basins in Mount Morris Lake indicate that they are all dimictic, and likely remain stratified throughout the summer months. Even though these basins have the potential for internal nutrient loading from bottom sediments, the fact that they do not turnover during the growing season means that this phosphorus is not available to algae at that time. In addition, the data indicate that following spring and fall overturn periods, high phosphorus levels within surface waters do not carry through the summer or winter.

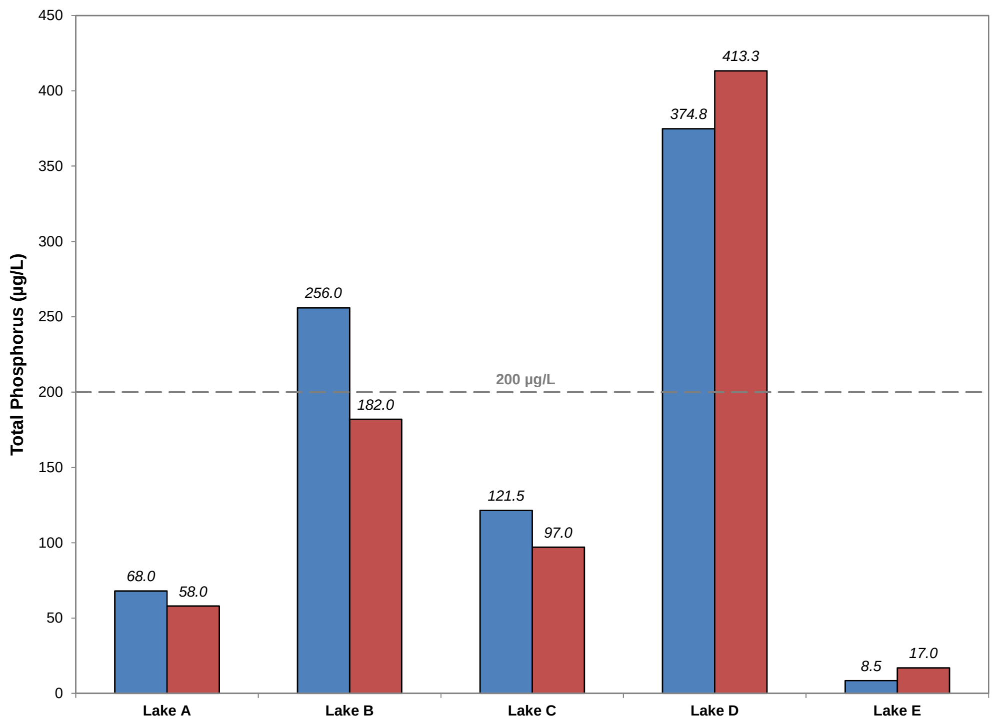


Figure 3.1-18. Mount Morris Lakes A,B,C,D, and E 2010 hypolimnetic phosphorus concentrations. Mean values calculated with summer month bottom sample data.

Limiting Plant Nutrient of Mount Morris Lake

Using midsummer nitrogen and phosphorus concentrations from Mount Morris Lake D, a nitrogen:phosphorus ratio of 42:1 was calculated. This was similar to the ratio calculated using midsummer data from 2004, with a ratio of 50:1. This finding indicates that Mount Morris Lake is indeed still phosphorus limited, as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant and algae growth within the lake.

Mount Morris Lake Trophic State

Figures 3.1-19 through 3.1-23 contain the Tropic State Index (TSI) (Carlson 1977) values for the five basins of Mount Morris Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from oligotrophic to eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters. While chlorophyll-*a* levels indicate that Mount Morris Lake is currently in a mesotrophic state, the lake supports a highly productive rooted aquatic plant community. For this reason, Mount Morris Lake can be classified as a mesotrophic-eutrophic system.

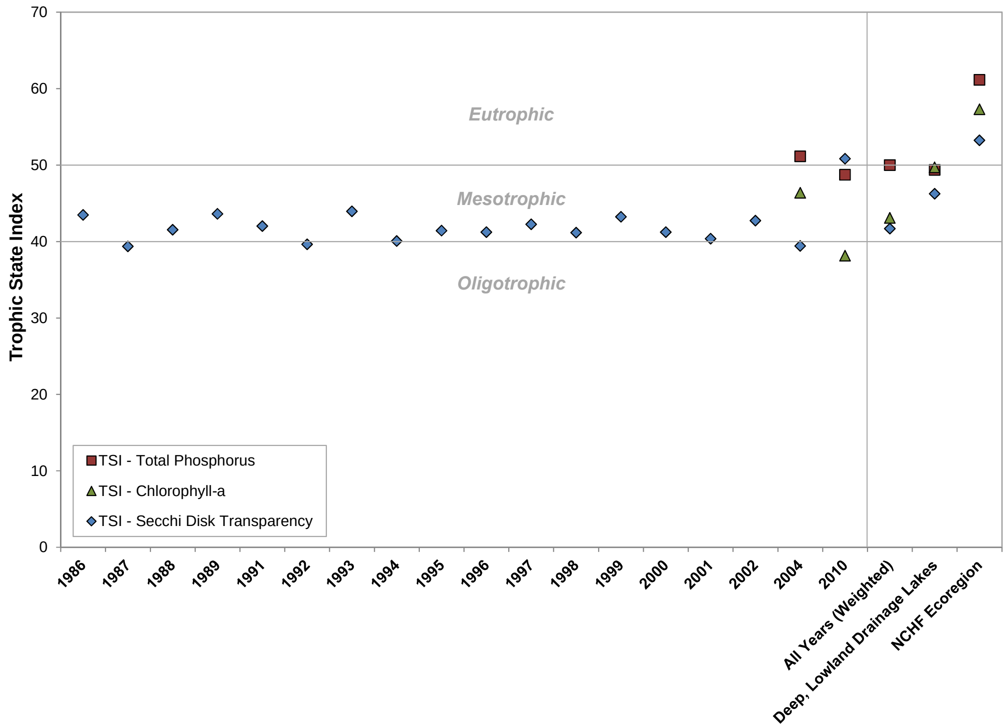


Figure 3.1-19. Mount Morris Lake A, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

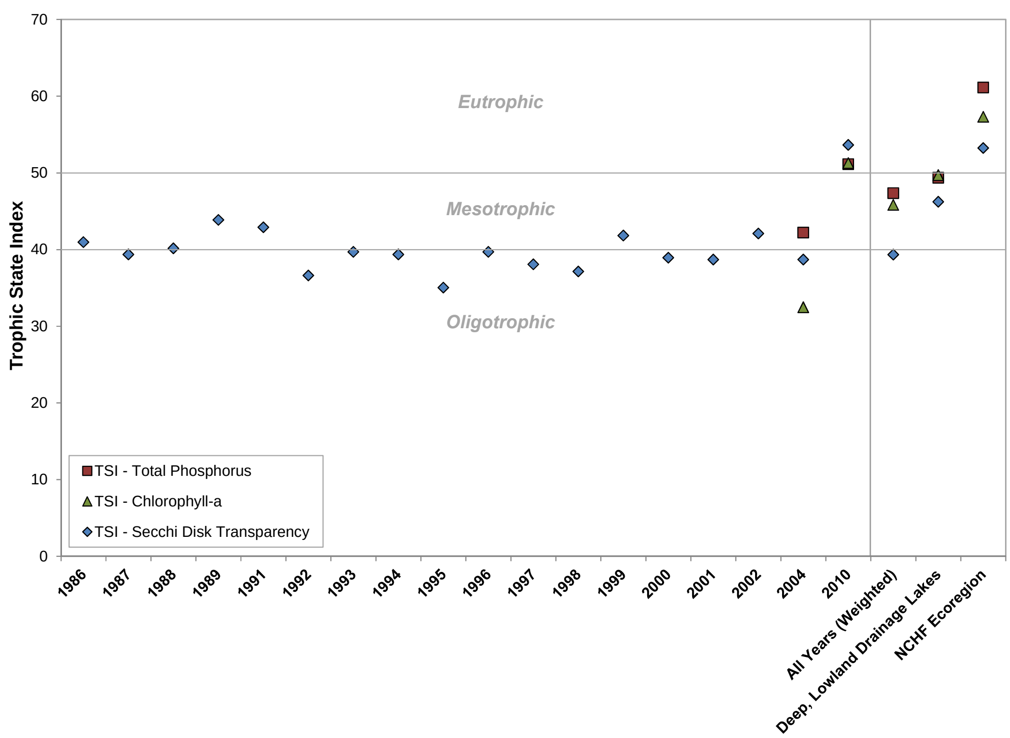


Figure 3.1-20. Mount Morris Lake B, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

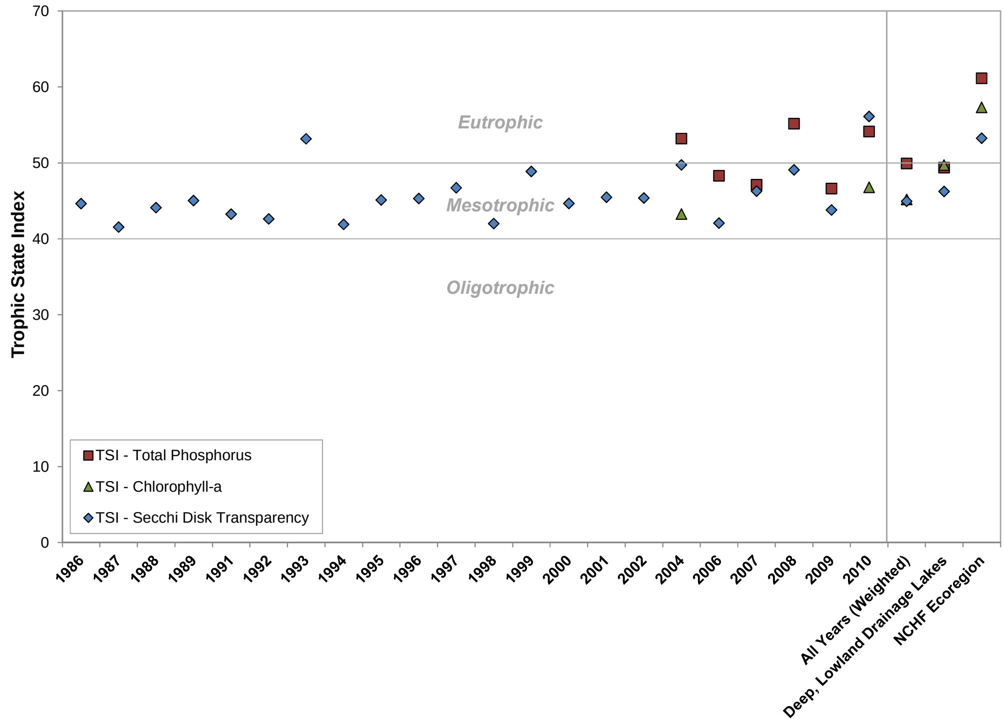


Figure 3.1-21. Mount Morris Lake C, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

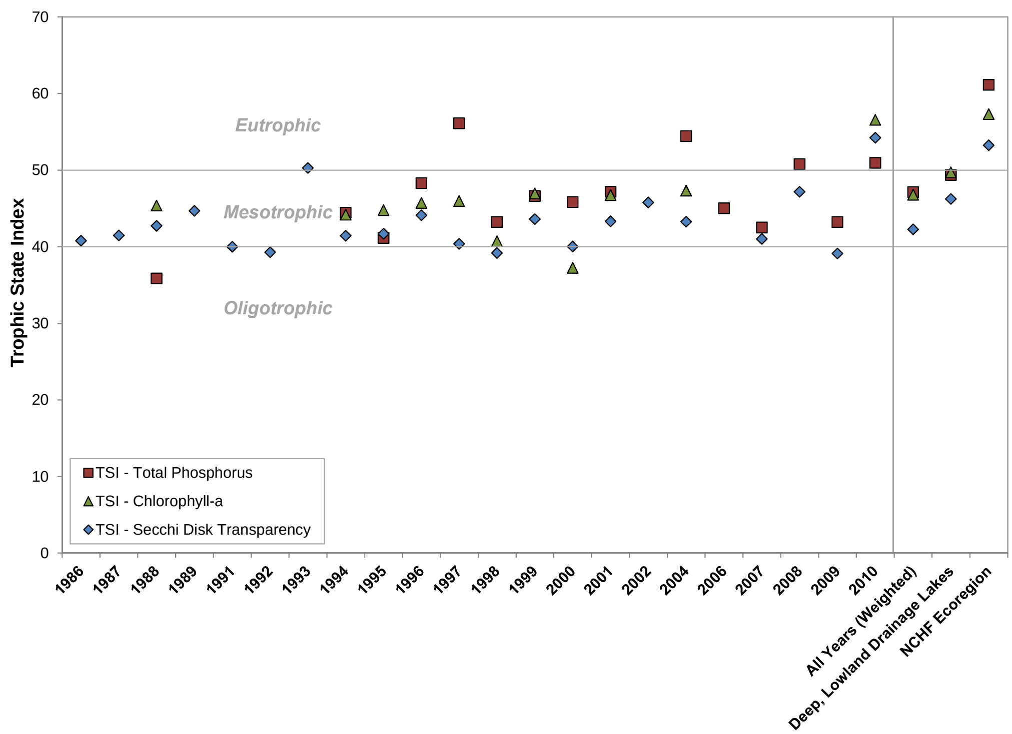


Figure 3.1-22. Mount Morris Lake D, state-wide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

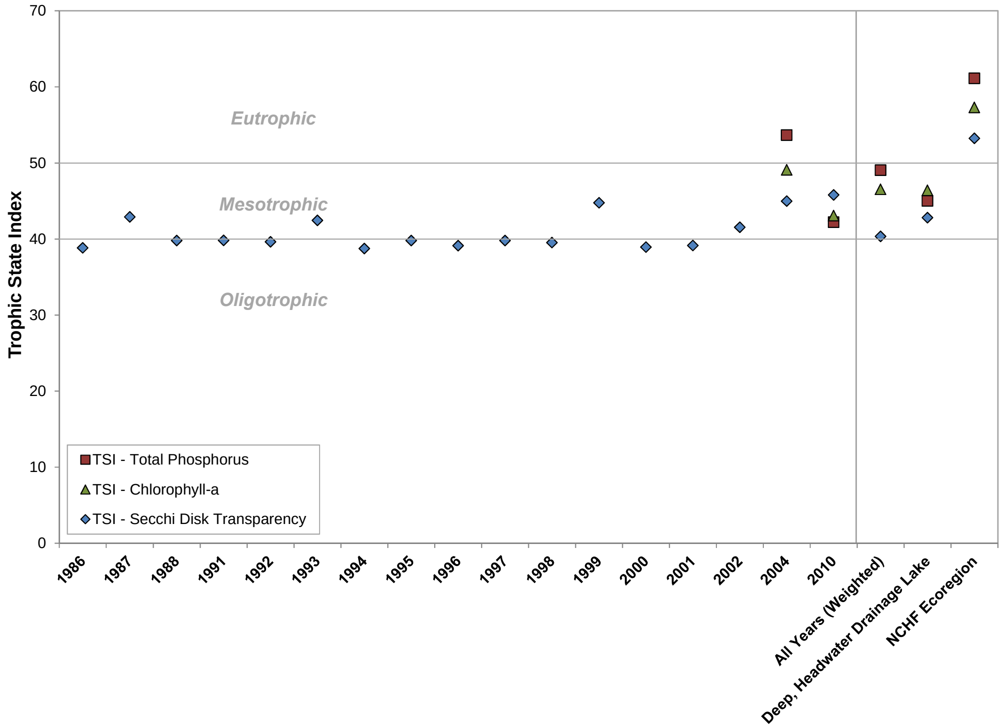


Figure 3.1-23. Mount Morris Lake E, state-wide class 3 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Mount Morris Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Mount Morris Lake by Onterra staff. Profiles depicting these data from Lake D are displayed in Figure 3.1-24. Profiles for Lakes A, B, C, and E can be found in Appendix C. Lake D remained stratified throughout the summer and maintained oxic conditions throughout most of the water column during winter.

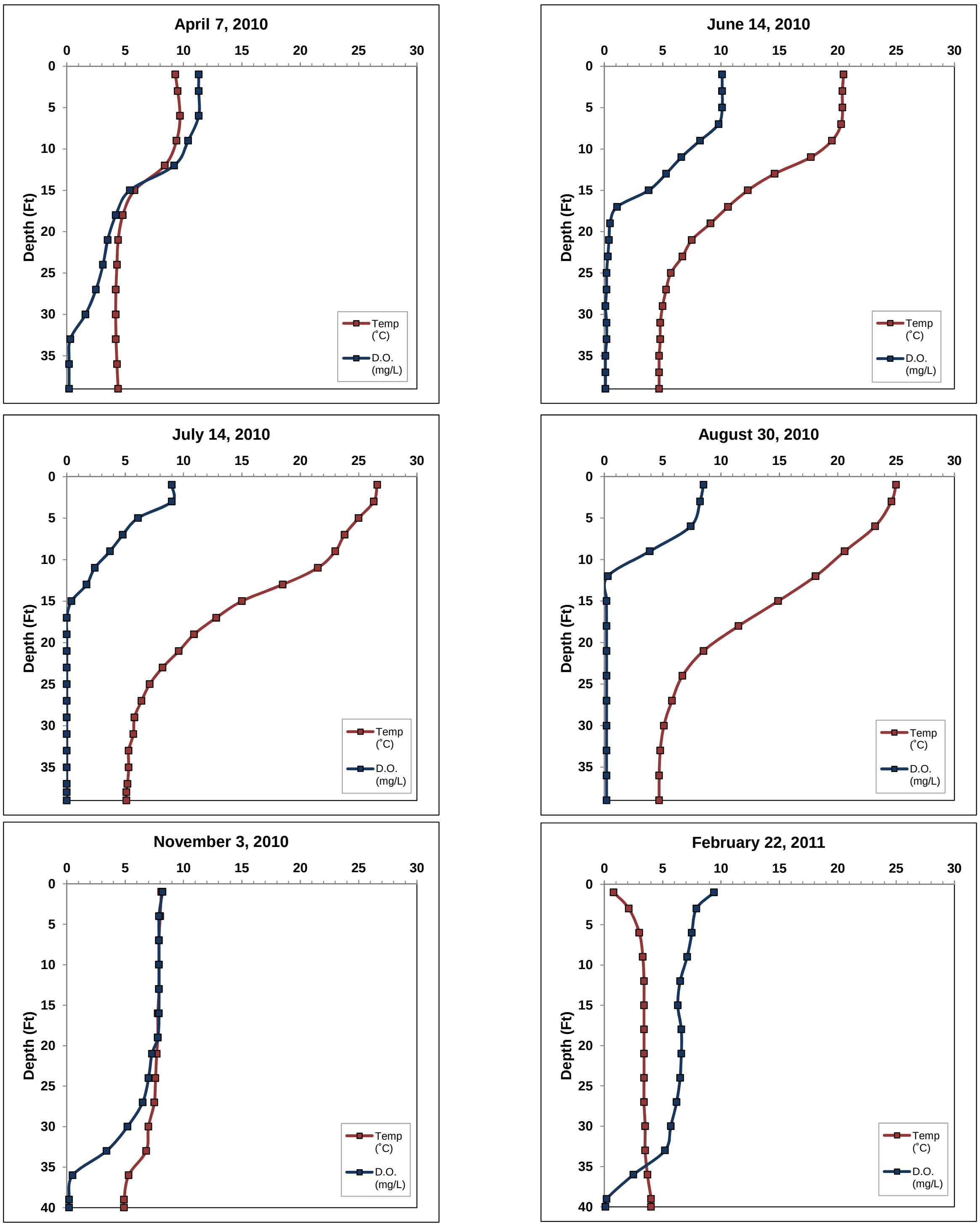


Figure 3.1-24. Mount Morris Lake D dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Mount Morris 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 Mount Morris Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, calcium, and total suspended solids. Table 3.1-1 displays the values of these parameters measured in Mount Morris Lake, while Table 3.1-2 displays the range of these parameter values from lakes sampled in Wisconsin by Lillie and Mason (1983). Please note that value ranges for total suspended solids, potassium, sodium, and atrazine were not developed.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in Mount Morris Lake was found to alkaline with surface values ranging from 8.0 to 8.4 (Table 3.1-1), and falls 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^{2-}), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering comes into contact with minerals such as calcite (limestone, $CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with little to no alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Mount Morris Lake ranged from 139.0 to 180.0 (mg/L as $CaCO_3$) (Table 3.1-1), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Mount Morris Lake's pH range falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Mount Morris Lake was found to be 41.8 mg/L, indicating a high susceptibility to zebra mussel establishment.

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, Mount Morris Lake is considered suitable for mussel establishment.

Plankton tows were completed by Onterra staff during the summer of 2010 and these samples were processed by the WDNR for larval zebra mussels. Their analysis did not find any larval zebra mussels. In addition, no adult zebra mussels were observed during pier removal in the fall of 2010 and 2011 on Lake C.

Total suspended solids (TSS) are a measure of inorganic and organic particles suspended in the water, and include everything from algae to clay particles. High TSS creates low water clarity, and prevents light from penetrating into the water to support aquatic plant growth. TSS was measured on Mount Morris Lake D during every water quality sampling event, and the data indicate that TSS is very low in Mount Morris Lake and even undetectable during some sampling events (Table 3.1-1).

In addition to the parameters discussed, turbidity, true color, magnesium, potassium, chloride, sodium, sulfate, and atrazine levels were collected in 2010 as part of a Waushara County-funded project. Turbidity, while influenced by TSS, is different in that it is a measure of the cloudiness of the water, or a measure of the water's capacity to scatter and absorb light. If turbidity is high, light passing through the water will be scattered in varying directions by suspended particles, and less will be able to pass into deeper water. If turbidity is low, water clarity will be higher as more light will be able to penetrate into the water uninhibited, and aquatic plants will be able to grow at deeper depths. Turbidity was measured in Mount Morris Lake in April and November of 2010, and was low with values of 2.9 and 1.4 NTU, respectively (Table 3.1-1).

A measure of water clarity once suspended material has been removed is called true color. True color measures the amount of light scattered and absorbed by organic materials dissolved within the water. Many lakes, such as Mount Morris Lake in 2010, have natural dissolved organic materials from decomposing plant material delivered from wetlands within the watershed. These compounds turn the water a tannish-brown and may decrease water clarity. In 2010, Mount Morris had true color values of 15 and 30 SU, which fall in the low category for Wisconsin Lakes (Lillie and Mason 1983).

The magnesium content of Mount Morris Lake in 2010 was also collected. This along with calcium concentration is used to calculate the hardness of the water. Concentrations of these minerals within a lake are correlated with the bedrock geology of the area (Lillie and Mason 1983). Magnesium levels for Mount Morris Lake exceed the median value for Wisconsin lakes (2 mg/L) with values of 21.1 and 23.9 mg/L. While these values are higher than median values, they are naturally occurring in Mount Morris Lake due to the geology of the lake's watershed.

Chloride, sodium, and potassium concentrations were also measured in 2010. These three elements exist at very low levels in natural environmental conditions, and elevated levels of either of these three may indicate possible pollution. Increasing levels of chloride and/or sodium may indicate contamination from road salts, plant fertilizers, or organic waste from septic systems or farm runoff. High levels of potassium are often also associated with plant fertilizers and organic waste materials entering the lake. All three of these parameters were low in Mount Morris Lake, and indicate there are likely no significant sources of road salts or organic waste entering the lake at this time (Table 3.1-1).

Sulfate is naturally occurring in Wisconsin lakes and is associated with mineral deposits within a lakes watershed (Lillie and Mason 1983). Elevated or increasing levels of sulfate over time may indicate atmospheric deposition from industry or the combustion of coal. Levels of sulfate measured in Mount Morris Lake were in the normal range for central Wisconsin (Table 3.1-1).

Levels of atrazine, an herbicide used to primarily kill weeds on farms, were sampled in July of 2010. This herbicide is classified as a possible cancer-causing agent, and has a drinking water standard of less than 3.0 parts per billion (ppb) (Wisconsin Department of Health 2000). Atrazine levels in Mount Morris Lake were below the detectable limit, and indicate that atrazine contamination is not an issue for the lake at this time.

Table 3.1-1. Additional water quality parameters collected from Mount Morris Lake D in 2010.

Parameter	04/08/10	06/14/10	07/14/10	08/30/10	11/03/10	02/22/11
pH	8.3	NA	8.4	8.2	8.0	NA
Total Alkalinity (mg/L as $CaCO_3$)	159.0	NA	139.0	NA	180.0	NA
Calcium (mg/L)	40.5	NA	NA	NA	43.0	NA
Magnesium* (mg/L)	21.1	NA	NA	NA	23.9	NA
True Color* (SU)	15.0	NA	NA	NA	30.0	NA
Total Suspended Solids (mg/L)	2.0	ND	3.0	ND	0.0	ND
Turbidity* (NTU)	2.9	NA	NA	NA	1.4	NA
Potassium* (mg/L)	0.9	NA	NA	NA	1.1	NA
Chloride* (mg/L)	3.2	NA	NA	NA	3.8	3.6
Sodium* (mg/L)	2.1	NA	NA	NA	2.3	NA
Sulfate* (mg/L)	12.9	NA	NA	NA	14.0	NA
Atrazine* (ppb)	NA	NA	<0.1	NA	NA	NA

*ND = None Detected; NA = Not Available; *Collected for Waushara County*
Note: Parameter results represent samples collected near the surface

Table 3.1-2. Range of values for select water quality parameters in Wisconsin lakes. Created using data from Lillie and Mason (1983).

Parameter	No. Lakes Sampled	Mean	Standard Deviation	Minimum	Maximum	Median
pH	660	7.15	0.85	4.3	9.6	7.2
Total Alkalinity (mg/L as $CaCO_3$)	660	52	59	1	290	30
Calcium (mg/L)	604	12	13	1	71	8
Magnesium (mg/L)	604	8	11	1	49	2
True Color (SU)	560	39	40	1	320	25
Turbidity (NTU)	645	3.1	4.6	0.5	72	2.1
Chloride (mg/L)	606	4	7	1	57	2

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 or water quality. 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. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

The watershed assessment was completed for Mount Morris Lakes A, B, C, and D, using water quality data from Lake D, the downstream-most basin. Lake E flows into the downstream portion of Lake D (below the water quality sampling site), and does not impact on Lake D's water quality. For this reason, and the fact it has its own watershed separate from the other basins, an assessment for Lake E was completed separately.

Mount Morris Lake Watershed (Lakes A,B,C,D)

Mount Morris Lake's watershed is significantly larger than the lake itself, yielding a watershed to lake area ratio of 48:1. The lake's flushing rate was calculated to be 0.3 times per year, indicating the water within Mount Morris Lake has a residence time of approximately 110 days. The drainage basin for Mount Morris Lake covers approximately 5,826 acres, which is slightly different from the 2006 report as Lake E's watershed is no longer included (Map 2). Figure 3.2-1 illustrates that forests cover the majority (26%) of Mount Morris Lake's watershed, followed by Norwegian Lake's watershed (25%), wetlands (16%), and row crop agriculture (15%). The remaining land cover is comprised of pasture/grasslands, rural residential areas, Porters Lake's watershed, and Mount Morris Lake's surface (Figure 3.1-1).

Phosphorus load modeling using standard export coefficients contained in WiLMS resulted in an total annual load of approximately 1,248 lbs, approximately 150 lbs more than what was estimated in 2004 (Figure 3.1-2). The increase in estimated phosphorus delivery is likely due to the increase in row crop agriculture, which increased from 10% of the land cover in 2004 to 15% in 2010 (Figure 3.1-1). The phosphorus load estimated in 2010 was used in other models to estimate in-lake phosphorus levels, including growing season, annual, and spring turnover means. To check the alignment of the model, estimates were compared to weighted means created from all available historic total phosphorus data collected in Lake D. Like in 2004, the model in-lake growing season values were much higher (57µg/L) than those actually measured (20.5 µg/L) within the lake, indicating that the annual phosphorus load of 1,249 lbs is unrealistically high.

As was discussed in the 2006 Mount Morris Lake Management Plan (Onterra 2006), the vast majority of croplands within the Mount Morris Lake watershed are likely using *high residue management* techniques. High residue management is a system which leaves at least 30% of the ground covered with crop residue after crops are planted, which can reduce soil loss by up to 60%. Additionally, most of the row crop areas are surrounded by forested areas, grasslands, or wetlands (Map 2). The tributaries that these lands drain to, which eventually make their way to Mount Morris Lake, are surrounded by floodplain wetlands. All of these factors reduce the actual amount of phosphorus loaded to the lake through filtering and soil percolation. These factors are not anticipated within the WiLMS and as a result, the modeling indicates higher load than actually occurs.

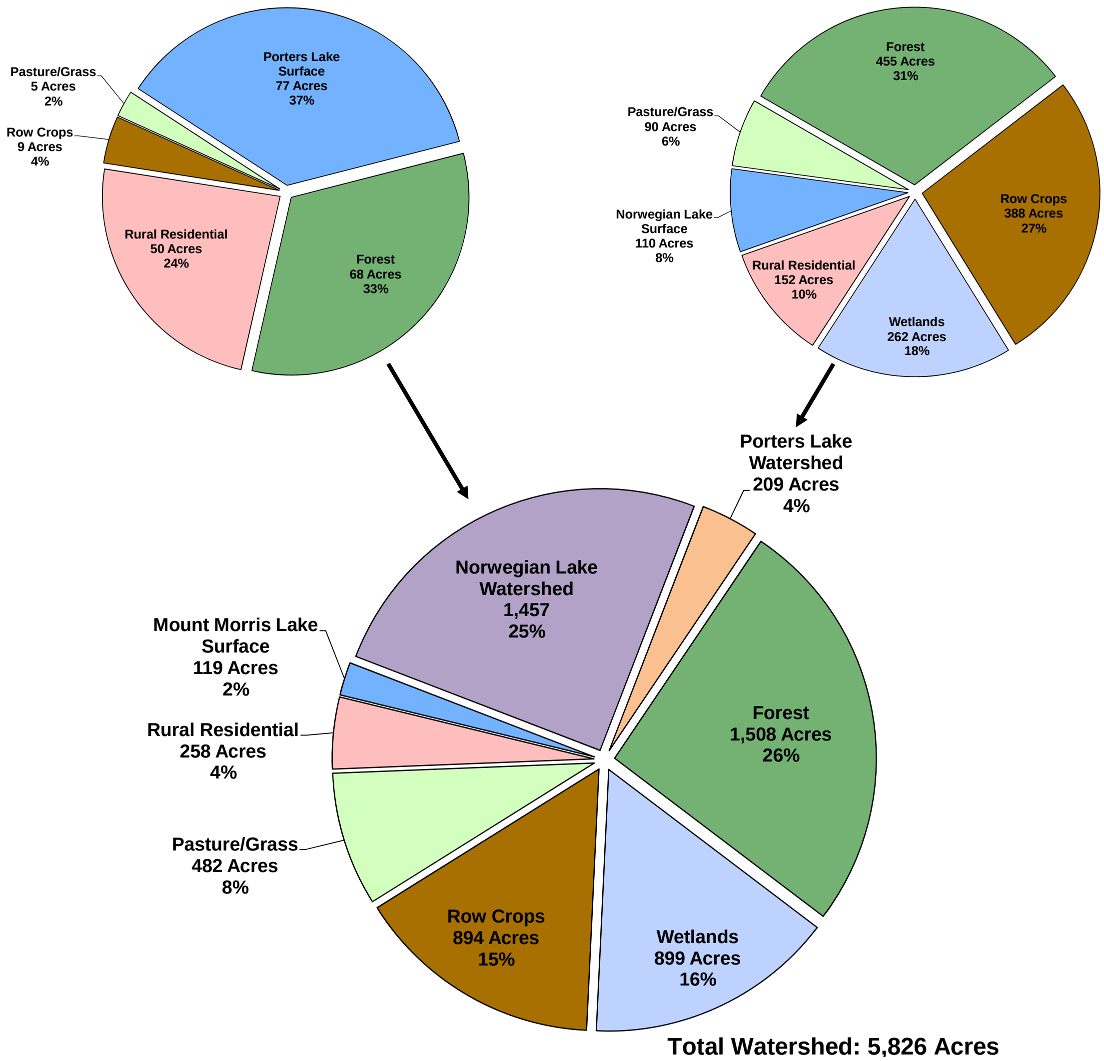


Figure 3.2-1. Mount Morris Lake watershed land cover types in acres. Based upon National Land Cover Database for the Conterminous United States (NLCD) (Fry et. al 2011). Modified by Onterra 2010.

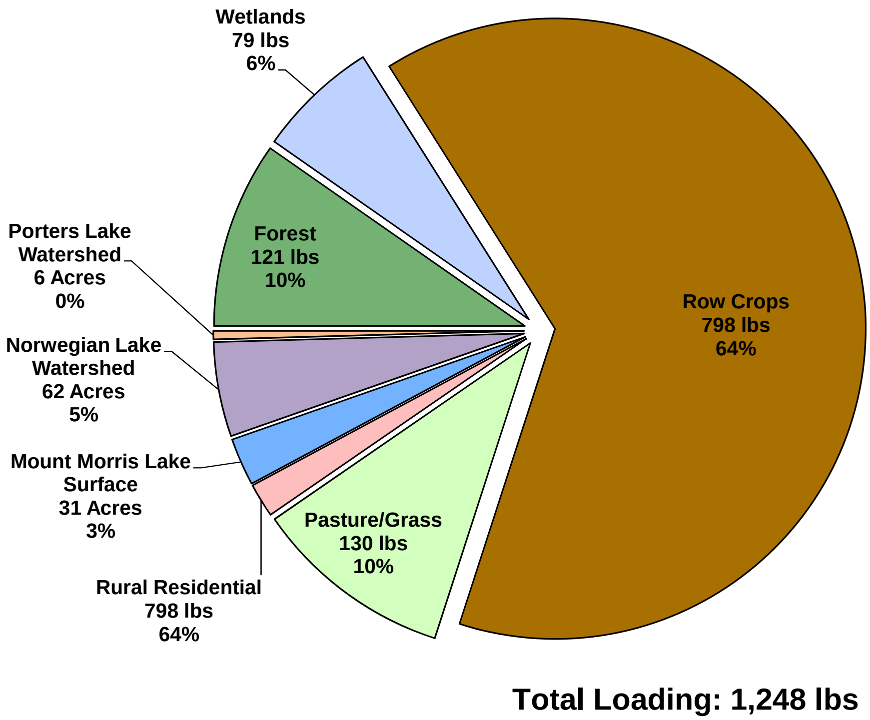


Figure 3.2-2. Mount Morris Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

The majority (54%) of Mount Morris Lake's watershed is presently comprised of forests and wetlands. While row crops comprise 22% of Mount Morris Lake's watershed, conservation efforts have mitigated nutrient-rich runoff from entering Mount Morris Lake. While some areas exist within the immediate shoreline areas of Mount Morris Lake (discussed in *Shoreline Assessment*) that could qualify as candidates for restoration, the restoration of these areas, while beneficial, would likely not have a noticeable impact on improving the water quality of the lake. However, restoration of these areas would improve wildlife habitat, most notable fish habitat, which have been shown to decline in abundance when associated with developed shorelines (Radomski and Goeman 2001). Restoration of these areas would also enhance the aesthetic beauty of the lake. As will be discussed in the next section, the MMLMD has been the number one lake in Waushara County in terms of shoreline restoration projects.

Lake E

As mentioned previously, Lake E's watershed is separate from the other four basins, and comprises an area of approximately 83 acres (Map 2). Lake E has a relatively small watershed to lake area ratio of 6:1, and a water residence time of approximately 1.6 years. The land cover types within the watersheds of lakes with small watershed to lake area ratios have a greater influence on the water quality of the lake. Figure 3.2-3 indicates that rural residential areas comprise the majority (52%) of Lake E's watershed, while forests, Lake E's surface, and pasture/grasslands comprise the remaining 22%, 14%, and 12%, respectively.

WiLMS modeling estimates that a total of 11 lbs of phosphorus are loaded to Lake E on an annual basis (Figure 3.2-4). Four pounds (40%) can be attributed to rural residential areas, 2 lbs

(20%) from forested areas, 2 lbs (20%) from atmospheric deposition directly onto the lake's surface, and 2 lbs (20%) from pasture/grasslands.

To check the alignment of the model, in-lake growing season total phosphorus estimates were compared to weighted means created from all available historic total phosphorus data collected in Lake E. The model in-lake growing season values were higher (26 µg/L) than those actually measured (17.8 µg/L) within the lake, indicating that the annual phosphorus load of 11 lbs is an overestimate. Many of the areas around Lake E classified as rural residential contain wooded lots which likely minimizing nutrient runoff. A substantial portion of the pasture/grassland area is surrounded by forest, which likely slows runoff and increases percolation into the soil.

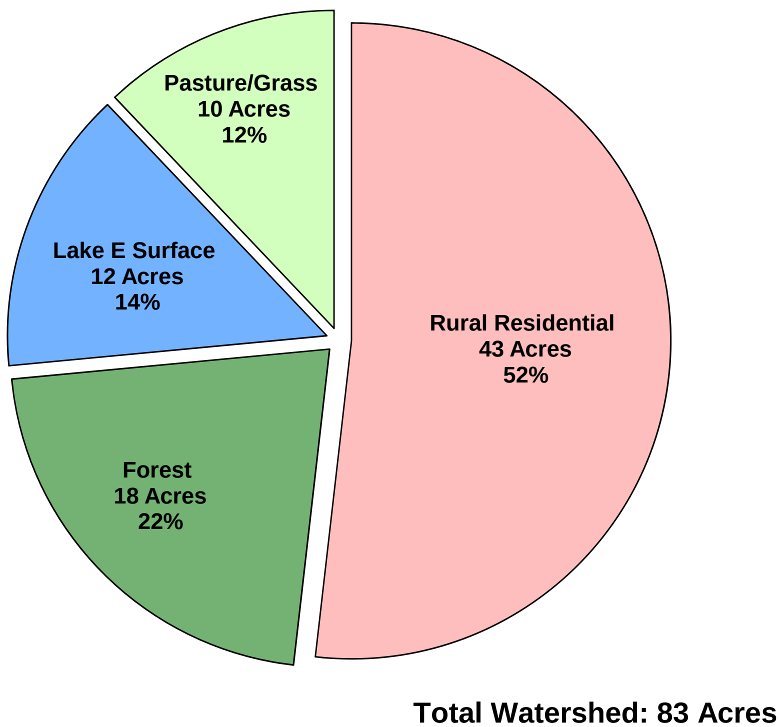


Figure 3.2-3. Lake E watershed land cover types in acres. Based upon National Land Cover Database for the Conterminous United States (NLCD) (Fry et. al 2011). Modified by Onterra 2010.

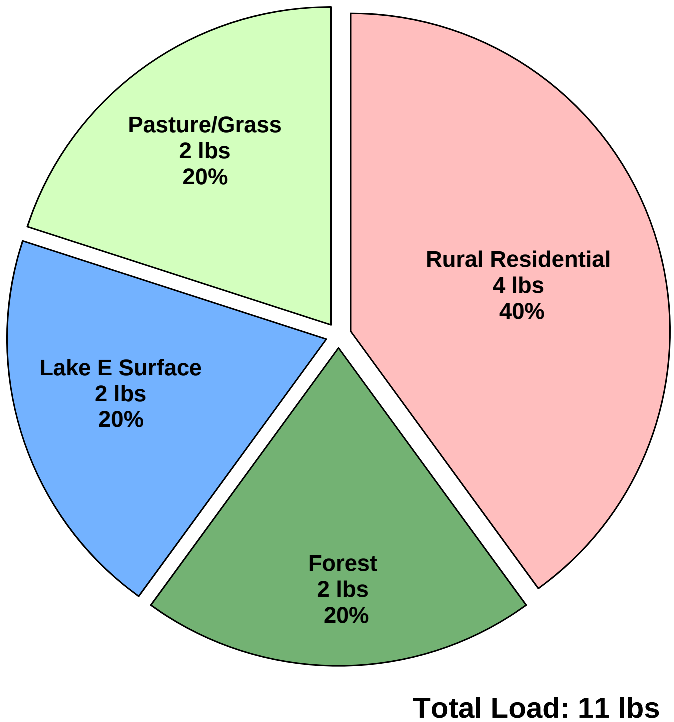


Figure 3.2-4. Lake E watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Shoreland Condition Assessment

The Importance of a Lake's Shoreland Zone

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

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 masonary, 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 more strict 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 of their own. County ordinances may be more restrictive than NR 115, but not less so. These policy regulations require each county to amend ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows (Note: counties must adopt these standards by February 2014, counties may not have these standards in place at this time):

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. 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. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: New language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods, dependent on the county.
- Contact the county's regulations/zoning department for all minimum requirements.

Wisconsin Act 31

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

Shoreland Research

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

A separate USGS study was conducted on the Lauderdale Lakes in southern Wisconsin, looking at nutrient runoff from different types of developed shorelands – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites (Garn 2002). One of the important findings stemming from this study was that the amount of dissolved phosphorus coming off 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.

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 debris 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 in many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

With development of a lake's shoreland zone, much of the coarse woody debris 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).

Native Species Enhancement

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

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

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

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do nott allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

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

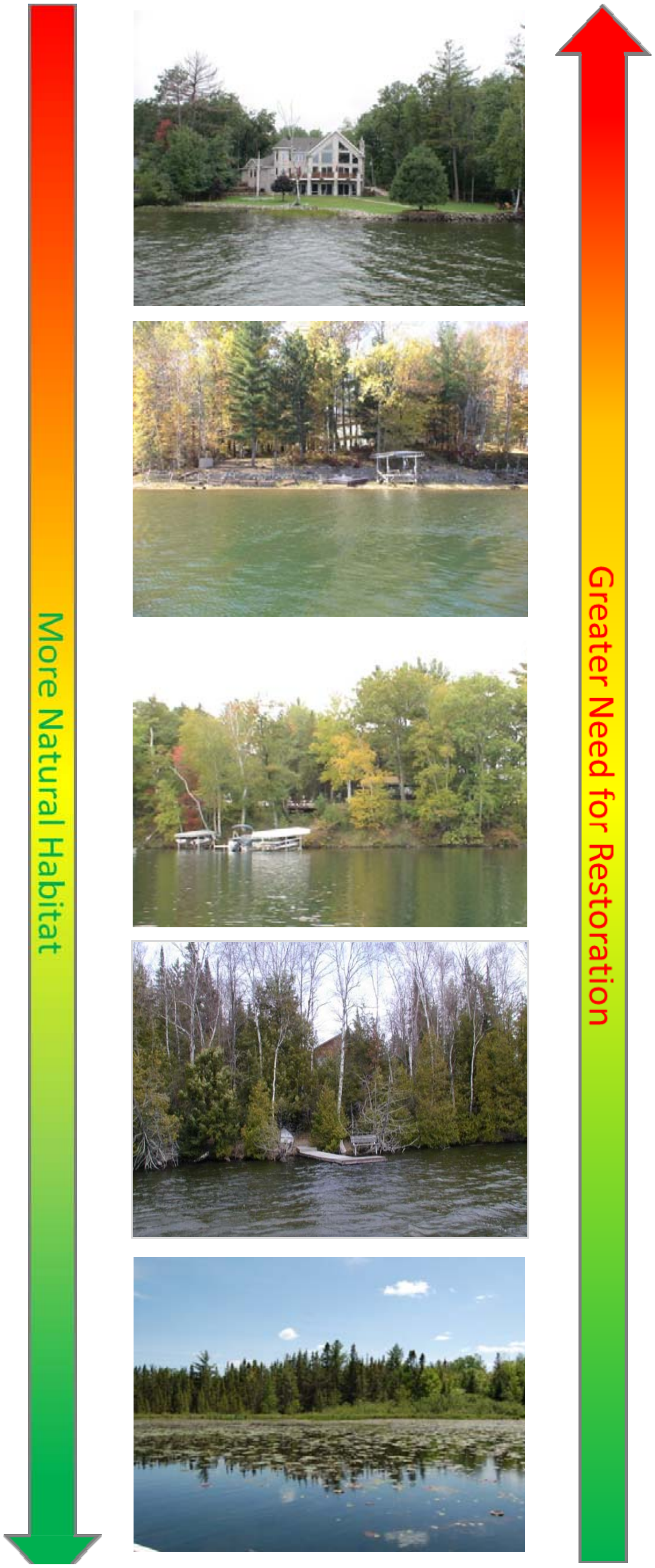
- In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owner's should contact the county's regulations/zoning department for all minimum requirements.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

Mount Morris Lake Shoreland Zone Condition

Shoreland Development

A lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelines are more stressful on a lake ecosystem, while definite benefits occur from shorelines that are left in their natural state. Figure 3.3-1 displays a diagram of shoreline categories, from *Urbanized*, meaning the shoreland zone is completely disturbed by human influence, to *Natural/undeveloped*, meaning the shoreline 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. Shoreline assessment category descriptions.

On Mount Morris Lake, the development stage of the entire shoreline was surveyed during the fall of 2010, using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

Mount Morris Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.1 miles of *Natural/undeveloped* and *Developed-Natural* shoreline 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, 2.9 miles of *Urbanized* and *Developed–Unnatural* shoreline were observed. If restoration of the Mount Morris Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. While it is always more beneficial to shift the condition of privately owned shoreland towards *Developed-Natural*, and individual property owners should be encouraged to enhance the ecological and buffering capacity of *Developed-Semi Natural* shorelines, it is typically more appropriate to direct district-wide restoration initiatives towards *Urbanized* and *Developed-Unnatural* shorelines. Map 3 displays the location of these shoreline lengths around the entire lake.

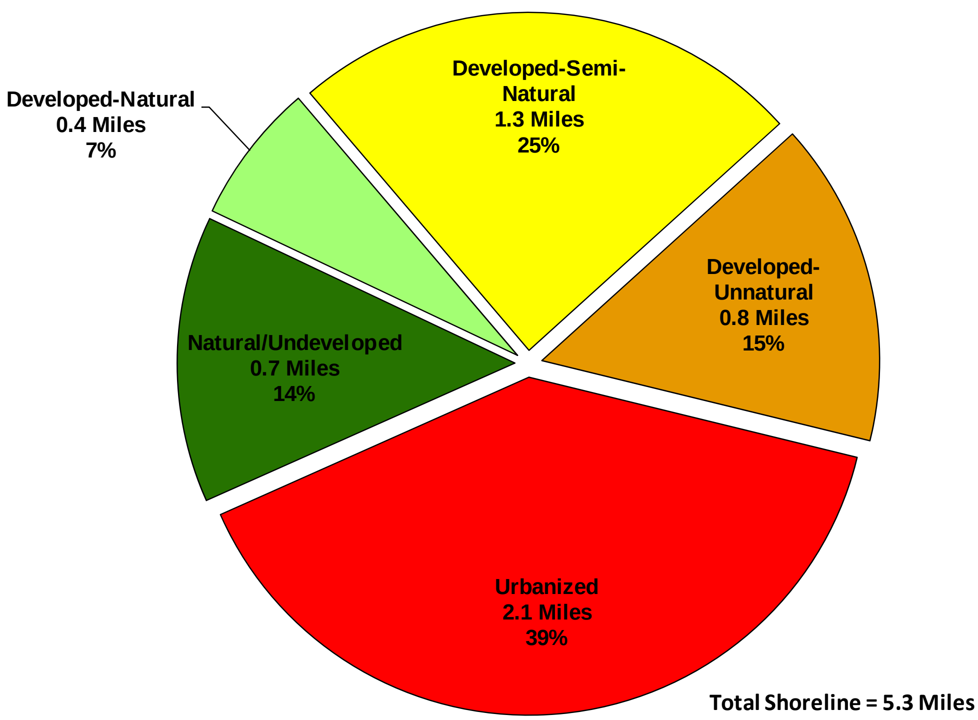


Figure 3.3-2. Mount Morris Lake shoreland categories and total lengths. Based upon a fall 2010 survey. Locations of these categorized shorelands can be found on Map 3.

In 2009, the MMLMD completed an $8,600 shoreline restoration demonstration project on the upstream face of the dam in 2009 using a Waushara County cost-share grant. By May 2010, individual property owners around Mount Morris Lake have restored shoreline areas totaling over half an acre and placed the lake at number one in the county for shoreline restoration.

These restoration projects cost approximately $80,000, with 70% being covered by a Waushara County grant. In addition, more shoreline restoration occurred around the lake in 2011.

During the planning meeting, committee members indicated that many MMLMD members have issues with large numbers of Canadian geese congregating on their property, and that an individual from the United States Fish and Wildlife Service was initiating control strategies (e.g. oiling eggs) to attempt to control geese population on the lake. While this control strategy would have to be implemented every year, a more-permanent solution is to plant and restore tall native vegetation along the lake shoreline. These taller plants block the geese's view and restrict their access, deterring them from coming ashore. Shorelines with short-cut vegetation to the water's edge are prime areas for geese to forage as their views for predators are unimpeded and access is easy.

3.4 Aquatic Plants

Introduction

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

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal

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

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

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

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

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • 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.

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

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

Water Level Drawdown

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

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

Advantages	***Disadvantages***
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian water-milfoil 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 (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

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

Costs

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

Advantages	***Disadvantages***
• Immediate results. • 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.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

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 does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

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.

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

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

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

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

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

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

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

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

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

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Advantages	*Disadvantages*
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments.	• Fast-acting herbicides may cause fishkills 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 herbicides are nonselective. • Most herbicides have a combination of use restrictions that must be followed after their application. • Many herbicides are slow-acting and may require multiple treatments throughout the growing season. • Overuse may lead to plant resistance to herbicides

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. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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

Cost

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

Advantages	*Disadvantages*
• Milfoil weevils occur naturally in Wisconsin. • 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 water-milfoil density.

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

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

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the comprehensive point-intercept surveys conducted in 2011 on Mount Morris Lake, plant samples were collected from plots laid out on a grid that covered the entire system (Map 1). Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage.

Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Mount Morris Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Water Quality section, Figure 3.1-2) and in the state.

Box Plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreline. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreline complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreline complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Mount Morris Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

> **Ecoregions** are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

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

Community Mapping

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

Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

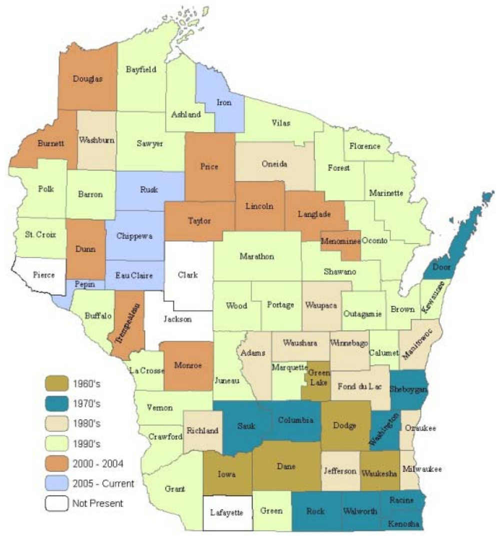


Figure 3.4-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

Littoral Zone is the area of a lake where sunlight is able to penetrate down to the sediment and support aquatic plant growth.

As mentioned earlier, numerous aquatic plant surveys were completed as part of this project. The first of these surveys focused upon the non-native plant curly-leaf pondweed. It is not known when curly-leaf pondweed first became established in Mount Morris Lake, but great strides in controlling this invasive plant have been made over the course of a five-year control project initiated in 2006. On June 9, 2010, a meander-based survey of Mount Morris Lake's *littoral zone* was conducted with the intent of locating curly-leaf pondweed. Because of its importance, the curly-leaf pondweed in Mount Morris Lake will be discussed in greater detail in the Non-native Aquatic Plant Section.

The comprehensive aquatic plant point-intercept and aquatic plant community mapping surveys were conducted on Mount Morris Lake on August 27 and September 2, 2010, by Onterra. During these surveys, 38 species of aquatic plants were located (Table 3.4-1), four of which are considered to be non-native, invasive species: curly-leaf pondweed, Eurasian water milfoil, purple loosestrife, and pale-yellow iris. Additionally, DNA analysis revealed that some suspect milfoil located in Lake C during a 2011 post-treatment survey is a hybrid between Eurasian water milfoil and the native northern water milfoil. These non-native plants will be discussed in detail in the Non-native Plants Section.

Table 3.4-1 compares the aquatic plant species located during the 2010 and 2004 surveys, and shows that some species located in 2004 were not located in 2010 and vice versa. However, the majority of the species located in 2004 were located in 2010. During the 2010 aquatic plant surveys, aquatic plants were found growing to a maximum depth of 19 feet. Sediment data gathered during the point-intercept survey indicates that the majority (61%) of Mount Morris Lake's substrate is comprised of fine organic sediment (muck), while the remaining is comprised of sand and a small amount of rock (Figure 3.4-2). Map 4 displays the spatial distribution of sediment types within Mount Morris Lake.

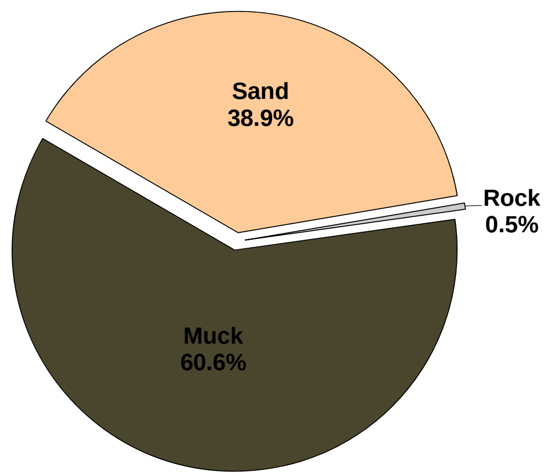


Figure 3.4-2. Mount Morris Lake proportion of substrate types within littoral areas. Created using data from 2010 aquatic plant point-intercept survey.

In 2010, approximately 87% of the point-intercept sampling locations that fell within the littoral zone contained aquatic vegetation. As Map 5 illustrates, the majority of Lakes A, C, and E are vegetated, while Lakes B and D have vegetation around the shallower near-shore areas. The combination of high water clarity and nutrient-rich sediments provides excellent conditions for supporting a lush aquatic plant community.

Table 3.4-1. Aquatic plant species located in Mount Morris Lake during July 2010 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	Mt. Morris 2004	Mt. Morris 2010
Emergent	*Bolboschoenus fluviatilis*	River bulrush	5		I
	Calla palustris	Water arum	9	I	I
	Carex comosa	Bristly sedge	5	X	I
	Carex stricta	Tussock Sedge	7	I	
	Eleocharis erythropoda	Bald spike-rush	3		X
	Eleocharis palustris	Creeping spikerush	6	X	
	Iris versicolor	Northern blue flag	5	I	
	Iris virginica	Southern blue flag	5		I
	Juncus effusus	Soft rush	4		I
	Lythrum salicaria	Purple loosestrife	Exotic	I	I
	Phalaris arundinacea	Reed canary grass	Exotic	I	I
	Pontederia cordata	Pickerelw eed	9	I	I
	Sagittaria latifolia	Common arrow head	3	I	I
	Schoenoplectus acutus	Hardstem bulrush	5	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Typha spp.	Cattail spp.	1	X	I
FL	*Nuphar variegata*	Spatterdock	6	X	X
	Nymphaea odorata	White w ater lily	6	X	X
FF	*Lemna minor*	Lesser duckw eed	5	X	
	Lemna trisulca	Forked duckw eed	6	X	X
	Lemna turionifera	Turion duckw eed	2		X
	Spirodela polyrhiza	Greater duckw eed	5	X	X
FL/E	*Sparganium eurycarpum*	Common bur-reed	5		I
Submergent	*Callitriche palustris*	Common w ater starw ort	8	I	
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common w aterw eed	3	X	X
	Heteranthera dubia	Water stargrass	6		X
	Myriophyllum sibiricum	Northern w ater milfoil	7	X	X
	*Myriophyllum sibiricum X M. spicatum**	Northern X Eurasian w ater milfoil	Exotic		I
	Myriophyllum spicatum	Eurasian w ater milfoil	Exotic	I	X
	Myriophyllum verticillatum	Whorled w ater milfoil	8		X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stonew orts	7		X
	Potamogeton crispus	Curly-leaf pondw eed	Exotic	X	X
	Potamogeton illinoensis	Illinois pondw eed	6	X	X
	Potamogeton natans	Floating-leaf pondw eed	5	X	
	Potamogeton praelongus	White-stem pondw eed	8	X	X
	Potamogeton richardsonii	Clasping-leaf pondw eed	5	X	X
	Potamogeton zosteriformis	Flat-stem pondw eed	6	X	
	Ranunculus aquatilis	White w ater-crow foot	8	X	
	Stuckenia pectinata	Sago pondw eed	3	X	X
	Utricularia vulgaris	Common bladderw ort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
	Zannichellia palustris	Horned pondw eed	7		I
S/E	*Sagittaria cuneata*	Arum-leaved arrow head	7		I

FL = Floating-leaf; FF = Free-floating; FL/E = Floating-leaf and Emergent; S/E = Submergent and Emergent

*X = Located on the rake during point-intercept survey; I = Incidental species; * Located during 2011 survey*

Members of the muskgrasses were the most frequently encountered aquatic plants in Mount Morris Lake in 2010, with 63% of point-intercept locations within the littoral zone containing these plants (Figure 3.4-3). These macroalgae were also the most frequently encountered species in the 2004 survey. Several species of muskgrasses can be found in Wisconsin, though this study did not identify this group to the species level. As their name suggests, muskgrasses exude a strong skunk-like odor when brought out of the water. Often, large mats of these plants will break free from the bottom, float to the surface and wash ashore. They are common in calcareous waters like Mount Morris Lake and usually form large beds along the bottom where their fine branches provide excellent habitat for aquatic organisms.

Wild celery, also known as tape or eel grass, was the second-most common native species encountered during the 2010 point-intercept survey on Mount Morris Lake (Figure 3.4-3). Wild celery is relatively tolerant of low-light conditions and able to grow in deeper water. Its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruit, tubers, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife.

Spatterdock, a floating leaf species, was the third-most frequently encountered aquatic plant in 2010 (Figure 3.4-3). This water lily has heart-shaped leaves and produces large, yellow flowers that protrude above the water's surface. Like other water lilies, spatterdock provides excellent structural habitat for fish and other wildlife, especially where course woody debris is scarce.

Coontail, arguable the most common aquatic plant species in Wisconsin, was the fourth-most frequently encountered species in Mount Morris Lake in 2010. This plant has bushy whorls of leaves than resemble a raccoon's tail. Lacking roots, this species obtains the majority of its nutrients directly from the water and can grow prolifically in nutrient-rich water, often attaining nuisance levels and forming dense mats at the surface. The dense foliage of coontail provides excellent habitat for aquatic invertebrates and fish, especially in deeper water where other native aquatic plants cannot grow as it can tolerate low-light conditions. However, this species can create conditions that can impact navigation and recreation on some lakes.

As mentioned earlier, most of the species located during the 2004 surveys were located again in 2010. However, the occurrences of three of the four most frequent aquatic plant species in 2004 where shown to have declined in 2010. In 2004, common waterweed, northern water milfoil, and flat-stem pondweed where the second, third, and fourth-most frequently encountered aquatic plant species, respectively. In 2010, the occurrences of common waterweed and northern water milfoil were found to be much lower, while flat-stem was not located at all in 2010 (Figure 3.4-3). While the survey methodology in 2004 was slightly different than the one completed in 2010, it is not believed that the decline in these species is due to differences in sampling methodologies. Mount Morris Lake has been chemically treating areas of curly-leaf pondweed and Eurasian water milfoil every spring on an annual basis since 2004. It is possible that these treatments have had some adverse impacts on the native aquatic plant community, as captured by the 2010 survey.

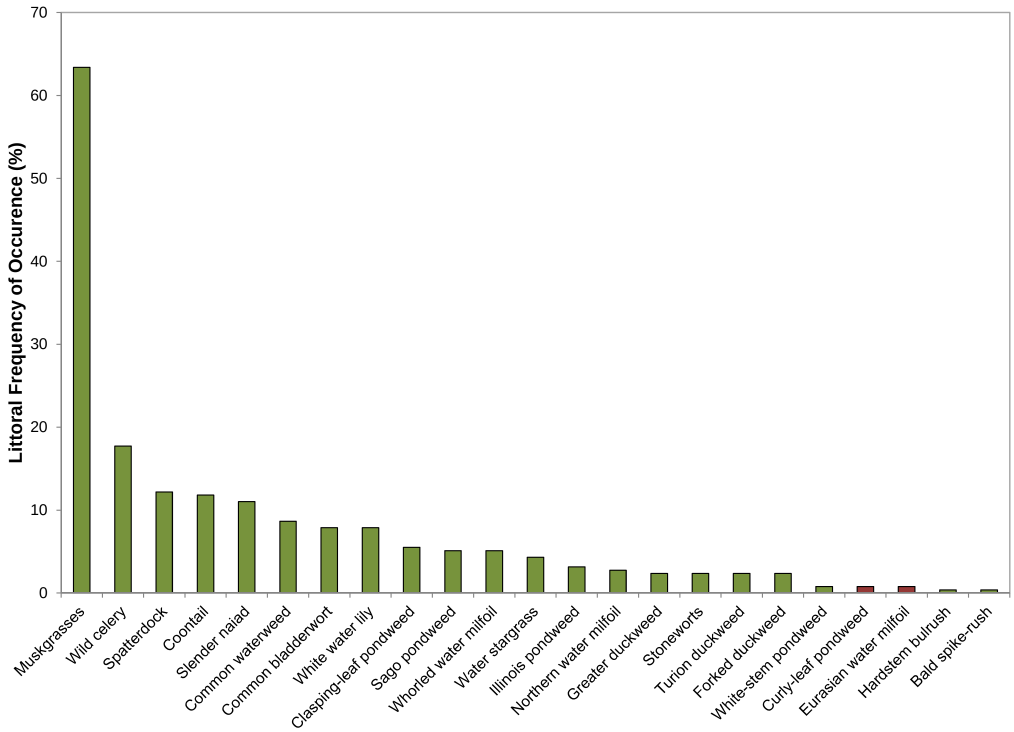


Figure 3.4-3. Mount Morris Lake aquatic plant littoral occurrence analysis. Created using data from 2010 aquatic plant point-intercept survey. Exotic species indicated with red.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 34 native aquatic plant species were located in Mount Morris Lake during the 2010 surveys, 21 were encountered on the rake during the point-intercept survey. These native species encountered on the rake and their conservatism values were used to calculate the FQI of Mount Morris Lake's aquatic plant community (equation shown below).

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

Figure 3.4-4 compares the FQI values calculated from the 2004 and 2010 aquatic plant surveys to the North Central Hardwood Forests (NCHF) Ecoregion and Wisconsin state medians. The native species richness for Mount Morris Lake in 2004 (23) was slightly higher than the species richness in 2010 (21). However, the species richness for both years falls above the medians for both the region and the state. Although two fewer species were encountered on the rake in 2010, the average conservatism was slightly higher in 2010 than in 2004 (Figure 3.4-4). The conservatism value in 2010 was similar to the median value for lakes in the NCHW Ecoregion, while it fell below the median for lakes state-wide (Figure 3.4-4). Combining Mount Morris Lake's species richness and average conservatism yields a FQI of 25.1, which exceeds the median for both the NCHF Ecoregion and the state, and indicates the Mount Morris Lake's aquatic plant community is of higher quality than most lakes within the region and the state (Figure 3.4-4).

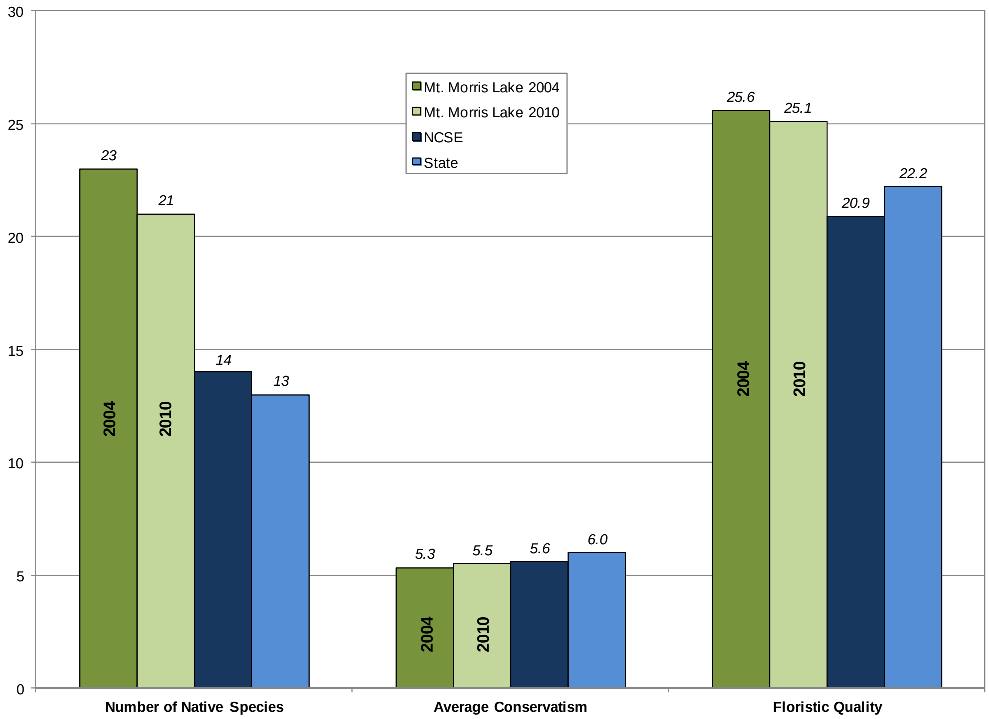


Figure 3.4-4 Mount Morris Lake Floristic Quality Assessment. Created using data from 2004 and 2010 aquatic plant point-intercept surveys. Analysis follows Nichols (1999).

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

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 Mount Morris Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 71 lakes within the NCHF Ecoregion (Figure 3.4-5). Using the data collected from the 2010 point-intercept survey, Mount Morris Lake's plant community was shown to have moderate species diversity with a Simpson's diversity value of 0.84. Mount Morris Lake's diversity value falls right on the median diversity value for lakes within the ecoregion and the state. This means that half of the lakes within the ecoregion and the state have higher species diversity then Mount Morris Lake, while the other half has lower species diversity.

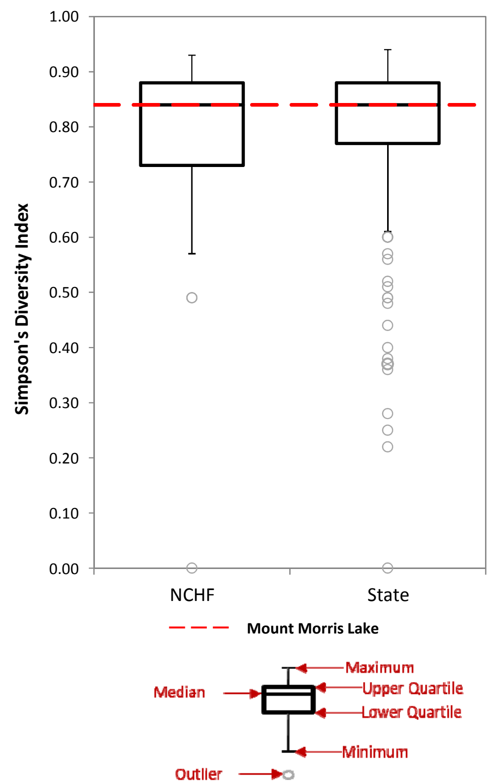


Figure 3.4-5. Mount Morris Lake species diversity index. Created using data from 2010 point-intercept surveys.

As explained previously 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 plant species 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 muskgrass was found at 63% of the sampling locations in Mount Morris Lake in 2010, its relative frequency of occurrence is 35%. Explained another way, if 100 plants were randomly sampled from Mount Morris Lake, 35 of them would be muskgrass. In calcareous systems like Mount Morris Lake, muskgrasses are often highly abundant.

Figure 3.4-6 displays the relative frequency of occurrence of aquatic plant species from the 2004 and 2010 point-intercept surveys and illustrates that the species within the aquatic plant community had a more even distribution in 2004 than in 2010. In 2004, muskgrasses, common waterweed, and northern water milfoil comprised 39% of the plant community, while muskgrasses alone comprised 35% of the plant community in 2010.

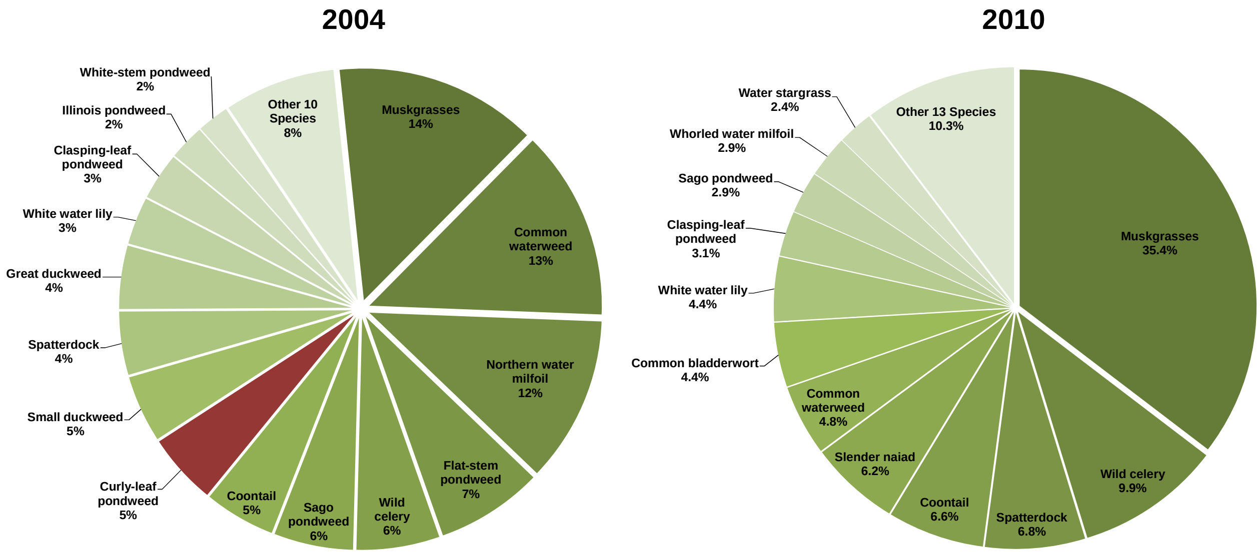


Figure 3.4-6. Mount Morris Lake aquatic plant relative occurrence analysis. Created using data from 2004 and 2010 aquatic plant point-intercept surveys. Exotic species indicated with red.

The 2010 community mapping surveys on Mount Morris Lake were the second surveys of this type to be conducted, the first being conducted by Onterra in 2004. The quality of Mount Morris Lake's aquatic plant community is also indicated by the high incidence of floating-leaf and emergent aquatic plant communities. Sixteen floating-leaf and emergent aquatic plant species were located in 2010 (Table 3.1-1). The 2010 community map indicates that approximately 23 acres of Mount Morris Lake contain these types of plant communities (Map 6).

Some floating-leaf and emergent plant communities were shown to have expanded since 2004, while others contracted. However, overall, the total acreage of these communities changed only slightly from 2004 to 2010 (Table 3.4-2). The extents of floating-leaf and emergent plant communities can be extremely dynamic, especially in systems with fluctuating water levels. While drastic reductions or expansions of these communities will be clear signs that changes within the Mount Morris ecosystem are occurring, accumulating this type once every 5 years can allow lake managers to detect finer levels of change.

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

Table 3.4-2. Mount Morris Lake acres of emergent and floating-leaf plant communities from the 2004 and 2010 community mapping surveys.

	Acres	
Plant Community	**2004**	**2010**
Floating-leaf	13.9	9.4
Emergent	0.0	0.3
Floating-leaf/Emergent	10.5	13.1
Total	**24.4**	**22.8**

Non-native Aquatic Plants in Mount Morris Lake

Curly-leaf pondweed and Eurasian water milfoil

In 2006, the Mount Morris Lake Management District (MMLMD) received Wisconsin Department of Natural Resources (WDNR) grant funds to complete a five year treatment and treatment monitoring program for curly-leaf pondweed. As the project progressed, Eurasian water milfoil control also became a management focus. Herbicide treatments from 2006 to 2010 were covered under the grant-funded project, while costs for the 2011 treatment were covered by the MMLMD.

As the biology of these two exotic AIS differs greatly, the strategies used to control their spread and density within Mount Morris Lake differed as well. Because curly-leaf pondweed, an annual plant, produces reproductive structures (turions) that may sprout years after the initial parent plant is gone, a strategy was devised that included treating similar acreage year after year. The goal for curly-leaf pondweed control was to reduce the plant's occurrence through the lake and as a result, minimize its spread during summer harvesting activities. In part, this would be achieved by reducing the turion (reproductive structure) base within the infected areas of the lake. To accomplish this, the same areas and roughly same acreage were treated annually for six years with a contact herbicide (endothall).

On the other hand, the perennial Eurasian water milfoil reproduces primarily through auto-fragmentation in which fragments of the plant disperse through the lake and colonize new areas. As a result, populations of Eurasian water milfoil are very difficult to control. When surveys in 2006 turned up only a small isolated location of this plant within Mount Morris Lake, it was decided that controlling and even possibly eradicating the plant was an achievable goal due to its limited presence. Unfortunately, this pioneer infestation spread into other areas of the lake, and by 2008 14.4 acres of the plant were being treated with a systemic herbicide (2,4-D).

Table 3.4-3 shows the treatment acreage in Mount Morris Lake from 2006 to 2011. Some of each year's curly-leaf pondweed and Eurasian water milfoil treatment areas overlapped, and as a result in 2008 several areas were treated both with endothall to target curly-leaf pondweed and 2,4-D to target Eurasian water milfoil. As explained in the 2009 annual report, it is believed that the use of this "cocktail" blend may have resulted in the removal of the above-ground biomass of Eurasian water milfoil plants by the contact herbicide, not allowing the foliar uptake of the systemic herbicide. The root crown of the Eurasian water milfoil plant would not be affected, allowing it to rebound later in the summer. It's not clear if current research confirms or rejects this hypothesis. In the years to follow (2009-2011) a different strategy was utilized involving a split treatment of 2,4-D to target Eurasian water milfoil, followed a few days later by an endothall treatment within curly-leaf pondweed treatment areas.

Table 3.4-3. CLP and EWM treatment acreage on Mount Morris Lake from 2006 to 2011.

	2006	2007	2008	2009	2010	2011
CLP	31.6	27.1	28.6	28.6	26.2	23.9
EWM	0.0	0.0	14.4	10.9	14.9	2.1

Over the course of the five-year grant-funded project from 2006 to 2010, curly-leaf pondweed occurrence has decreased substantially within the treatment areas (Figure 3.4-7). Decreases are observed each year except in 2009-2010, when curly-leaf pondweed occurrence increased from 4.2% to 13.6%. While this increase is statistically valid, it does not warrant concern as there are several variables that explain the increase in curly-leaf pondweed occurrence.

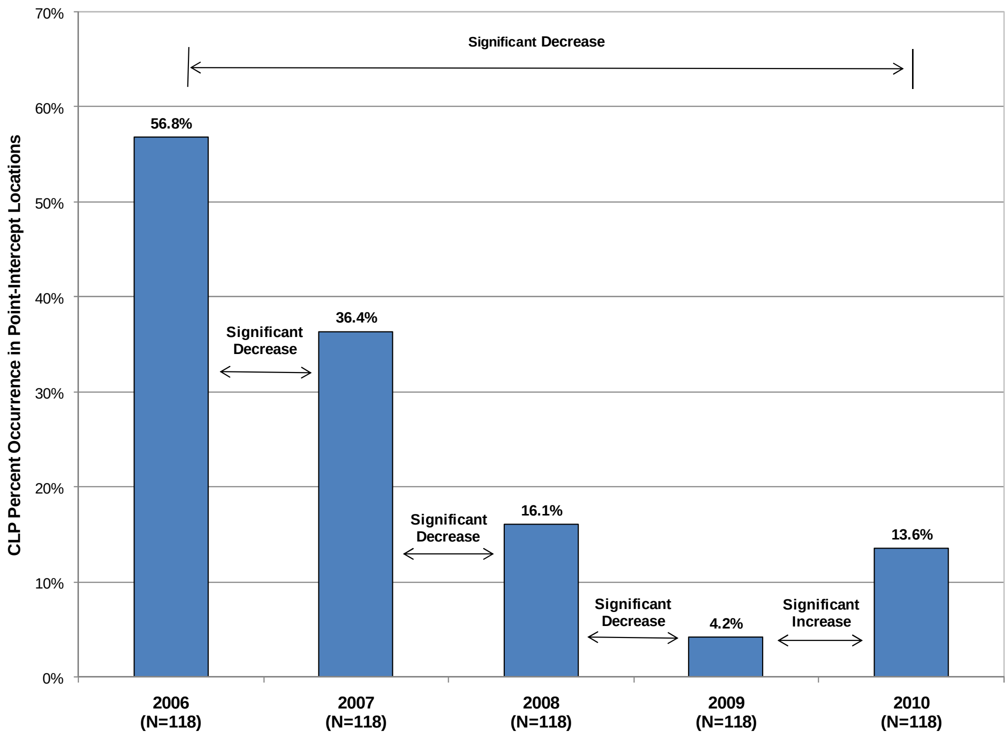


Figure 3.4-7. CLP percent occurrence from 2006-2010 pretreatment surveys on Mount Morris Lake. This data is based on the 59 point-intercept locations within CLP treatment areas.

In managing curly-leaf pondweed, the primary objective is to deplete the turion base that lies within the sediment. These turions may produce curly-leaf pondweed plants the year following their dispersal from the parent plant, or several years later. The increased presence of curly-leaf pondweed in 2010 likely indicates that environmental factors were favorable to sprout buried turions. While this means that more plants were sampled in this year, it also means that the turion base has depleted further. In the long run, this is beneficial in the MMLMD's attempt to control this exotic plant.

Each year, a rake-fullness rating of 1-3 was used to determine abundance of the curly-leaf pondweed at each point-intercept sampling location. Figure 3.4-9 displays the number of point-intercept locations exhibiting each of the rake-fullness ratings within Mount Morris Lake. These data show that along with the observed reduction in curly-leaf pondweed occurrence (Figure 3.4-8) in years 2006-2009, a reduction in curly-leaf pondweed density was also documented. During the 2006 pretreatment survey, almost half (44.8%) of the point-intercept locations that contained curly-leaf pondweed exhibited a rake-fullness rating greater than 1. In 2009, no sample locations contained rake-fullness rating greater than 1, indicating that along with documenting a decrease in curly-leaf pondweed occurrence, the density of curly-leaf pondweed has also been significantly reduced throughout the course of the project.

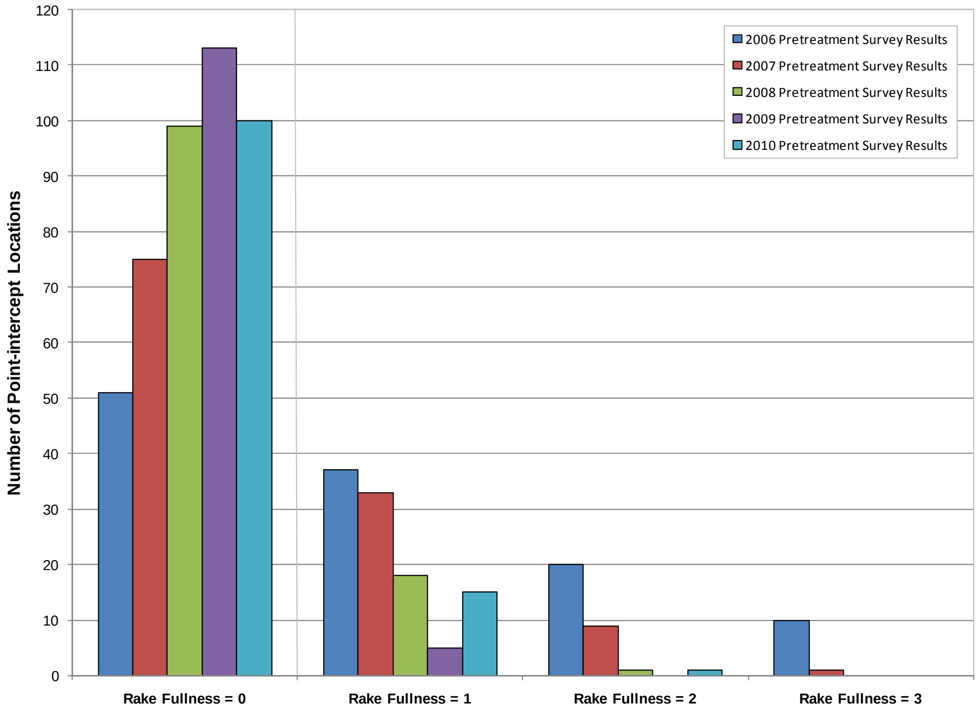


Figure 3.4-8. CLP rake-fullness distribution from 2006-2010 pretreatment surveys on Mount Morris Lake. This data is based on the 59 point-intercept locations within CLP treatment areas.

The length of time that a turion remains viable in the sediment is unknown, but it is thought to be about 5-7 years, perhaps longer if anoxic (void of oxygen) conditions exist. Bottom sediment disturbances such as carp or harvesting activities (both applicable to Mount Morris Lake) can expose buried turions where they are able to sprout. Table 3.4-4 shows a slight reduction in turion prevalence from 2006-2008 and a considerable reduction from 2008-2009. Turion data was not collected in 2010.

Table 3.4-4. Analysis of CLP turion data collected in 2006-2009 following each year's chemical treatment.

Year	Total	% Prevalence	Average	Range
2006	102	25.0	0.9	1-14
2007	135	23.2	1.2	1-23
2008	116	22.9	1.0	1-21
2009	66	16.9	0.6	1-18

This project is one of the first to attempt to quantify changes in the curly-leaf pondweed turion base over time. While the methodology devised has proven to be an accurate way to collect turions, some limitations have been discovered. Each year, two sample locations have contributed 39% (2006), 52% (2007), and 27% (2008) of the total turion counts. In 2009, one sample location accounted for 36% of all turions encountered. Please note that these sample locations were not the same between these years. Mount Morris 2006-2007 Annual Report suggests that 'hot spots' of turion accumulation occur, most likely due to subtle differences in bathymetry, substrate type, and submersed aquatic vegetation, and have the potential to significantly influence the data. The data collected in 2009 supports this hypothesis. Also, many areas of Mount Morris Lake are covered with a carpet of muskgrasses , which the Ponar dredge has difficulty 'cutting' through, possibly under-representing the amount of turions that exist within sample locations that contain this type of vegetation.

Eurasian water milfoil has emerged as a secondary aspect of the AIS Treatment Monitoring Project. In 2006, only several plants were known of, residing in the area of the public boat launch on Lake C. Hand removal efforts were deployed at this time, followed by monitoring of the lake for more occurrences. Eventually, herbicide treatments were required in 2008 to address expanding colonies in numerous areas in the lake. In Lake E, hand removal efforts in 2006 – 2008 appear to have been successful at removing Eurasian water milfoil from this part of the system as no occurrences were discovered in the east side of this lake. Only several plants were discovered in 2010 in the west bay of Lake E, and these were pulled during the 2010 post treatment survey by Onterra staff. Between 2009 and 2010, there were considerable strides made in controlling Eurasian water milfoil density within Lake A and Lake C.

While occasional Eurasian water milfoil plants still exist in Lake A, the amount observed during summer 2010 post treatment surveys does not warrant a treatment. The amount of treatable acreage decreased by 71% from 2009 to 2010 (14.9 acres to 4.3 acres, respectively). Compared to the previous Eurasian water milfoil herbicide treatments of over 10 acres, the treatment conducted in 2011 was the smallest one yet. Approximately 2.1 acres of scattered Eurasian water milfoil were treated within Lake C, and only 4.5 acres of Eurasian water milfoil treatment in Lake C were treated in 2012. An evaluation of the 2012 treatment and a Eurasian water milfoil peak-biomass survey will be conducted in late summer of 2012.

During the 2011 Eurasian water milfoil peak-biomass survey, milfoil plants displaying characteristics of both Eurasian water milfoil and the native northern water milfoil were located in Lake C. Samples of these plants were collected and sent to the Annis Water Resources Institute and Grand Valley State University in Michigan for DNA analysis. Their results indicate that this milfoil is indeed a hybrid between Eurasian and northern water milfoil. It is not known if the entire population of Eurasian water milfoil in Mount Morris Lake is comprised of hybrid individuals, or if this was a recent introduction or a result of a cross between the Eurasian and northern water milfoil already present. Emerging research is indicating that hybrid milfoil may be more resistant to herbicides.

The reduction of curly-leaf pondweed occurrence over the course of the project has been promising, as is the observed depletion of the turion base. However, since the start of the MMLMD curly-leaf pondweed control program, curly-leaf pondweed has not been allowed to grow to its full potential and be mapped when it is at its peak-biomass. For this reason, the

MMLMD has traditionally submitted a conditional treatment permit using the previous year's treatment areas to serve as a proposed treatment strategy for the following year. These areas would then be refined during the pretreatment survey if applicable.

The lack of knowing what the curly-leaf pondweed population of Mount Morris Lake is at its peak-biomass makes it difficult to understand the true effectiveness of the treatment program. However, the data that has been collected strongly indicate that incredible strides in curly-leaf pondweed management have occurred. At some point in the management of any AIS, the population of target species is reduced to a level that may not warrant further treatment. In order to fully understand this concept, the curly-leaf pondweed in Mount Morris Lake needs to be mapped at this peak-biomass in the absence of a curly-leaf pondweed treatment occurring during that year. No curly-leaf pondweed treatment occurred on Mount Morris Lake in 2012, and an assessment of the curly-leaf population within the lake was conducted in mid-May. With a better understanding of the current population a better strategy for control can be formulated.

On May 15, 2012, Onterra ecologists completed a lake-wide, meander-based survey to locate and map curly-leaf pondweed. With the early spring, curly-leaf pondweed was near its peak growth at this time. Map 9 displays the results of this survey, and indicates that curly-leaf pondweed is still widespread throughout much of Lakes A and C, and portions of Lakes B and D; only two single curly-leaf pondweed plants were located in Lake E. While curly-leaf pondweed is still prevalent within these areas, comparison with the curly-leaf population present in 2004 (Map 10) indicates that the density of these areas has decreased over this time period. Figure 3.4-9 illustrates that while curly-leaf pondweed colonial acreage has only decreased by 7.2 acres from 2004 to 2012, the density, most notably in the surface matting and highly dominant categories, has been reduced by nearly 12 acres.

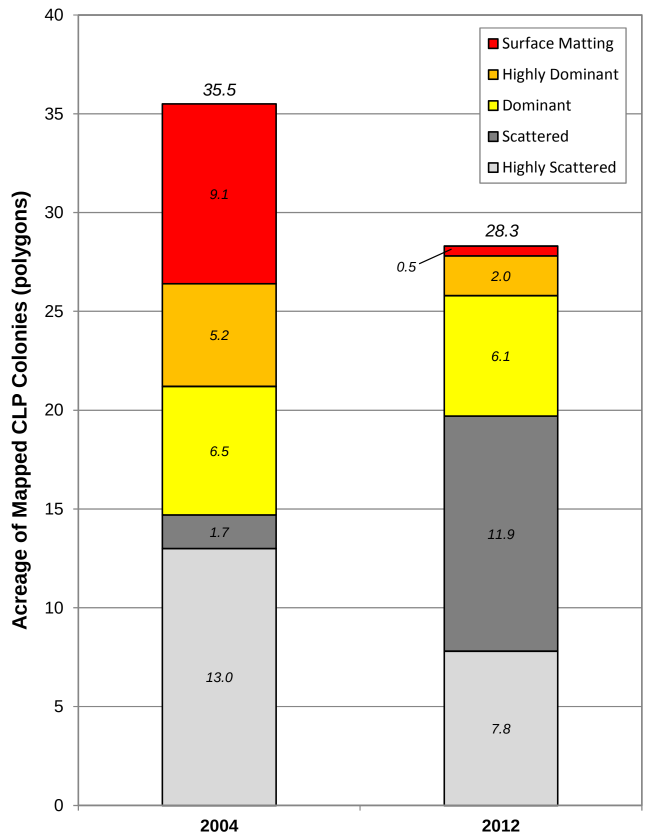


Figure 3.4-9. Acreage of mapped CLP colonies on Mount Morris Lake from 2004 and 2012.

While strides in curly-leaf pondweed control have been made over the course of this project, the amount of control observed did not meet expectations. The intent of these herbicide treatments is to cause curly-leaf pondweed mortality so the plants are unable to produce turions to maintain their population. Although the rates of the herbicides applied are intended to reach concentrations which cause mortality, current research being conducted by the United States Army Corps of Engineers (USACE) and the WDNR indicate that herbicides dissipate rather quickly from treatment sites and in some instances may not reach sufficient concentrations and exposure times to cause mortality, only injury. USACE research indicates that injured curly-leaf pondweed plants are still able to produce turions, and these stressed plants may produce even more turions in this condition.

After the herbicide is applied in Mount Morris Lake, it is not known if concentrations remain at levels high enough or long enough to cause mortality. If the treatments have been causing mortality, the curly-leaf pondweed present is a result of turions that were deposited prior to treatment in 2006. On the other hand, if the treatments have only been causing injury, density will likely be reduced but the plants may still be able to produce viable turions. For this reason, in conjunction with the USACE and WDNR, it is recommended that the 2013 curly-leaf pondweed treatment have herbicide concentration monitoring take place at various locations around the lake to determine the concentration of herbicide at various locations over time. With these data, it can be determined if the treatment strategy in terms of herbicide dosing needs to be modified.

Purple Loosestrife

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

Purple loosestrife populations were located on the shorelines of Lakes A, B, and D (Map 8). 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. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Mount Morris Lake.

Pale-yellow Iris

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was primarily observed flowering along the shorelines of Lake B, but plants were observed along the shorelines of Lakes A and D also (Map 8). At this time, the only means of controlling pale-yellow iris populations is continual hand removal and monitoring.

Mechanical Harvesting Program

In the 2006 lake management plan, Onterra and the MMLMD developed a mechanical harvesting plan to alleviate areas of nuisance aquatic plant growth. This plan maximizes the reduction of nuisance aquatic plant growth which impedes navigation, and at the same time minimizes the impact to important floating-leaf and emergent aquatic plant communities and the spread of curly-leaf pondweed and Eurasian water milfoil. After discussions with the MMLMD, this plan will continue unchanged. The approximate locations of theses harvesting areas are shown on Map 11. These areas total approximately 15.5 acres and as indicated, represent 30-

foot wide navigation lanes. These areas were created to allow lake users access to open water while avoiding important plant communities.

The same guidelines outlined in the 2006 plan will be used to realistically implement the harvesting plan on the lake:

- The proposed areas are essentially navigation lanes, so if navigation is unimpeded, then harvesting will not occur.
- If a harvesting area indicated on Map 11 is too deep, then the lane will be moved towards the shoreline as long as it does not impede on native plant communities.
- If a harvesting area is too shallow for the harvesting equipment to reach, then the lane will be removed to deeper water, but not so deep that navigation is no longer impeded and native communities are impacted.
- If a harvesting area indicated on Map 11 is found to contain dense stands of curly-leaf pondweed or Eurasian water milfoil, an alternate route will be chosen so these exotics are not spread via harvesting activities.
- Harvesting activities will begin May 1 and end by October 1 each year.

Sediment Accumulation

Sedimentation is a natural process that occurs on all lakes, but occurs much faster on impounded systems. Sedimentation rates can increase when near shore areas of the lake are in an unnatural state (manicured lawns and impervious surfaces). As discussed within the Shoreland Condition Section (3.3), 54% of Mount Morris Lake's shoreland was considered *Urbanized* or *Developed-Unnatural*.

During the project, MMLPRD stakeholders expressed concern over sediment build-up within certain parts of the lake (Appendix B, Question #19 & #20). Some sediment enters Mount Morris Lake from the watershed through the inlet streams. These sediments, mostly comprised of mineral particulates, fall out of the water column where stream velocity slows as it hits the open water of the lake. These mucky deltas can support a large amount of vegetation, which in turns dies and contributes greatly to the build-up of sediments in these areas. The decomposition of these plants contributes greatly to the organic sediments found within the lake. While a product of both external and internal sources, the sediment accumulation within these areas is likely caused by the buildup consists of dead plant matter that is accumulating on the lake bottom.

Along with accumulation of sediments due to decaying vegetation, accumulation of marl ($CaC0_3$ precipitate) likely also occurs on Mount Morris Lake. Concerns were also raised about sediment accumulation on each side of the constrictions between lake basins. As the fifth most highly ranked activity regarding the justification for owning property on the lake (Appendix B, Question #13), motor boat traffic can re-suspend fine particulate matter and contribute to sedimentation being transferred with wave action toward nearshore areas of the lake. Boating too fast within the channels can cause shoreline erosion which can be an additional source of sedimentation in these areas.

Options for slowing the buildup, or controlling it altogether are few and not without side effects. The options include 1) implementing best management practices within the watershed to reduce nutrient input, 2) removal of bottom sediments (dredging) and 3) compacting the bottom sediments to increase lake depth through water level drawdown. These three options are discussed further below.

As discussed within the Watershed Section (3.2), fewer nutrients enter into Mount Morris Lake than WiLMS Modeling predicted. Further, it is likely that best management practices in agriculture are likely already occurring within the Mount Morris Lake watershed. The focus of best management practices within the shoreland zone of the lake has been addressed by the district and should remain a priority.

The advantages of dredging are that there are few limitations as to how much depth is gained in the waterbody and the results are obtained very quickly. However, dredging is an incredibly expensive solution as it involves much time, heavy equipment, and transport/regulation of dredging spoils. For example, a typical cost to remove a cubic yard of sediment is roughly $14. To dredge one acre of bottom to be three feet deeper, the costs (at the estimate of $\$14/yd^3$) would be $67,760. The costs of removing three feet of sediment from five acres would be an estimated $338,800. Additionally, dredging exposes the lake bed to pioneering species, which includes aquatic invasive species such as Eurasian water milfoil and curly-leaf pondweed. In other words, exposing fresh lake bottom would give these aquatic invasive species an additional advantage within Mount Morris Lake. Because of the high costs of implementation and danger in exposing fresh sediment beds to aquatic invasive species, this option needs to be considered carefully before developing a management goal and associated management action utilizing this technique.

The third option for mitigating the build-up of organic sediments in Mount Morris Lake would be the compaction of these sediments through a drawdown of the lake. During a drawdown, the water level is reduced significantly in a waterbody. The sediments are exposed to the air and begin to dry. Additionally, the soil becomes oxygenated and microbial processes change the chemical composition of the sediment from organic material to its mineral components. If sediments are comprised of sand or marl, a drawdown will likely not lead to significant compaction and associated increase in water depth. With drawdowns, there is a loss of recreation during the time water levels are low and the potential for fish populations to be impacted. Additionally, overcoming the logistical and financial hurdles, as well as short-term economic loss can be challenging and frustrating.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Mount Morris Lake. The goal of this section is to provide an incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. fish stocking, angling regulations, etc.) that were brought forth by the MMLMD stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR (WDNR 2010).

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest pisciovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

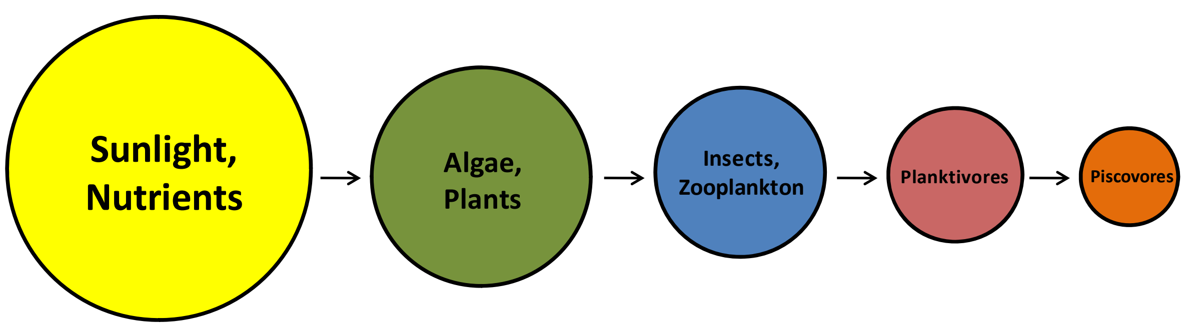


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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

Mount Morris Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the 3rd highest ranked important or enjoyable activity on Mount Morris Lake (Question #13). About 80% of survey respondents have fished the lake within the past three years (Question #9), and 83% of these respondents indicated the fishing to be "fair" or "good" (Question #10). While 43% of respondents believe the fishing has remained the same since they began fishing the lake, approximately 43% also believe that the fishing has gotten either much or somewhat worse (Question #11).

Table 3.5-1 shows the popular game fish that are present in the system. Management actions that have taken place and will likely continue on Mount Morris Lake according to this plan include herbicide applications to control Eurasian water milfoil and curly-leaf pondweed. These applications occur in late May / early June when the water temperatures are below 60 - 65°F. It is important to understand the effect the chemical has on the spawning environment which would be to remove the submergent plants that are actively growing at these low water temperatures.

Yellow perch is a species that could potentially be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species. A historic record indicates that longear sunfish, a species of special concern in Wisconsin, was once located in Mount Morris Lake. Conducting herbicide control activities after water temperatures reach 65°F may also have the ability to disrupt the spawning and nursery habitat of this fish species.

Table 3.5-1. Gamefish present in Mount Morris Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Brown Bullhead	*Ameiurus nebulosus*	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Common Carp	*Cyprinus carpio*	47	April - August	Shallow, weedy areas from 3 - 6 ft	Insect larvae, crustaceans, mollusks, some fish and fish eggs
Green Sunfish	*Lepomis cyanellus*	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Currently, there are no special fishing regulations on Mount Morris Lake besides those declared at the state level. Mount Morris Lake are in the southern region of the northern pike management zone, meaning that during the northern pike fishing season, 2 pike may be harvested daily with a minimum length of 26 inches. Largemouth bass may be harvested at a rate of 5 fish per day, and a minimum length limit of 14 inches was set on this gamefish.

Mount Morris Lake Fisheries Management

In 2009, WDNR biologists conducted sampling studies on Mount Morris Lake to assess the fish community and provide direction for management. This report is attached as Appendix F. Largemouth bass and northern pike were the two gamefish species sampled most in Mount Morris Lake. Bluegill were the most common panfish species found during these surveys. 42 walleye were sampled during the survey. Walleye do not reproduce naturally in Mount Morris Lake, and are only located here through private stocking. Table 3.5-2 highlights the 2009 survey data for several species of fish.

Table 3.5-2. 2009 WDNR fish survey summary data. Data summarized from Mount Morris Lake Fisheries Survey Summary Report – 2009 (WDNR; Appendix F)

Species	Population Estimate	Abundance	Size Structure	Growth and Condition
Bluegill	-	Slightly above average	Poor	Below average
Largemouth Bass	2,884 (18/acre)	Average	Good	Average
Northern Pike	761 (4.7/acre)	Above average	Poor	Below average
Walleye	42 (0.26/acre)	Low	Good	Above average

WDNR surveys over the past 60 years have noted heavy aquatic vegetation and small northern pike in Mount Morris Lake. In the 2009 summary report, fisheries biologist Dave Bartz notes that working to keep a healthy aquatic plant community and natural shoreline is vital to ensure the sustainability of this productive fishery. Additionally, the report mentions the consideration of modifying the size limit regulations on northern pike to address their small size structure and growth rate.

Mount Morris Lake Substrate Type

According to the point-intercept survey conducted by Onterra in 2010, 61% of the substrate sampled in the littoral zone of Mount Morris Lake was muck, with the remaining 39% being classified as sand (Map 4). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Some fish prefer to spawn over mucky areas. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result (Becker 1983). Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

4.0 SUMMARY AND CONCLUSIONS

The design of this comprehensive management planning project was intended to fulfill four objectives:

1) Collect baseline data to increase the general understanding of the Mount Morris Lake ecosystem.
2) Determine if recurring herbicide treatments to control aquatic invasive species are having an impact on the lake's native aquatic plant community.
3) Collect detailed information regarding the presence of curly-leaf pondweed and Eurasian water milfoil within the lake, and gain an understanding of the extent of purple loosestrife and pale-yellow iris along the lake's shoreline.
4) Collect sociological information from Mount Morris Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

These four objectives were fulfilled during the project, and have led to a better understanding of the Mount Morris Lake ecosystem, the people that care about the lake, and what needs to be completed to protect and enhance it into the future. As learned during the course of this project, while 15% of the lake's watershed is presently in agriculture, management practices aimed at reducing runoff from these areas appears to be highly successful as indicated by the excellent water quality in Mount Morris Lake. In addition, the majority of the land cover within the lake's watershed is comprised of intact forests and wetlands which filter runoff water before entering the lake, removing nutrients and sediment.

The water quality of Mount Morris Lake, in terms of total phosphorus and chlorophyll-*a* concentrations, is comparable to other lakes with similar characteristics in the state, but is better than the majority of the lakes within the North Central Hardwood Forests Ecoregion. On average, water clarity in Mount Morris Lake is much higher than similar lakes in the state as well as the central region. However, in 2010 Mount Morris Lake had the lowest water clarity values recorded since data collection began in the mid-1980s. While higher total phosphorus and chlorophyll-*a* concentrations were recorded in a couple basins in 2010, the decline in water clarity was believed to be primarily caused by higher amounts of dissolved organic acids. These dissolved organic acids which stain or give the water a tea-like color, originate from wetlands within the watershed. Higher-than-normal precipitation in 2010 likely flushed large amounts of these compounds into the lake.

Mount Morris Lake contains a species-rich aquatic plant community, with 34 native species located during the 2010 surveys. As highlighted in the Aquatic Plant Section, there are many different species from a variety of community types – submergent, emergent, and floating-leaf. The irregular shoreline of Mount Morris Lake, along with variations in slope and substrate types, contributes to the richness of the aquatic plant community by providing numerous habitat types for differing species to flourish. Comparisons of the 2010 aquatic plant surveys with those in 2004 reveal that abundances of some species changed markedly, while a few species found in 2004, like flat-stem pondweed, were not located in 2010. It is likely that recurring large-scale herbicide applications to control curly-leaf pondweed may have had adverse effects on some native aquatic plant species. However, standard analysis of the aquatic plant community in terms of average conservatism and floristic quality indicates that the overall quality of Mount Morris Lake's plant community has been maintained over this time period.

The management of the invasive species curly-leaf pondweed and Eurasian water milfoil has been very successful over the past seven years, with both populations being reduced in occurrence and density. However, while the curly-leaf pondweed survey in 2012 revealed that the densities of this plant of decreased over the course of this project, this plant is still widespread throughout much of the system. Control and monitoring of both of these species will need to continue into the future to reduce their populations and impacts to Mount Morris Lake's ecology.

At this time, the MMLMD does not have a sufficient volunteer base to initiate a Clean Boats Clean Waters watercraft inspection program. The intent of the boat inspections is to prevent additional invasives from entering the lake through its public access points, in addition to preventing exotics from Mount Morris Lake being transported to other waterbodies. Either through a limited volunteer effort or a coordinated paid effort, the MMLMD should strive to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread.

5.0 IMPLEMENTATION PLAN

During the planning meeting, the Mount Morris Lake Planning Committee discussed the results of the 2010 management plan study with ecologists/planners from Onterra and closely examined Mount Morris Lake as well as the people who live around it. The Planning Committee discussed the strengths and weaknesses of Mount Morris Lake and its stakeholders, as well as the opportunities and threats they face. These issues were discussed in terms of 1) feasibility of addressing the issue, and 2) level of the issue's importance. As a result of the discussion, the MMLMD was able to identify goals for protection and enhancing Mount Morris Lake, as well as communicating and education individuals who use the lake.

The implementation plan presented below represents the path the MMLMD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and achievable, as are the action steps required to reach these goals. The implementation plan is a living document that 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 lake's stakeholders.

Management Goal 1: Increase Mount Morris Lake Management District's Capacity of Communicate with Lake Stakeholders

Management Action: Support an Education Committee to promote safe boating, water quality, public safety, and quality of life on Mount Morris Lake.

Timeframe: Initiate summer 2012

Facilitator: Board of Directors to form Education Committee.

Description: Education represents an effective tool to address lake issues like water quality, invasive species, shoreline development, lawn fertilization, as well as other concerns such as community involvement, noise or light pollution, and boating safety (Map 12). An Education Committee will be created to promote lake preservation and enhancement through a variety of educational efforts.

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

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

Example Educational Topics

- Specific topics brought forth in other management actions
- Aquatic invasive species treatment and monitoring updates
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering (particularly on ice)
- Noise, air, and light pollution
- Shoreline restoration and protection
- Septic system maintenance
- Fishing regulations

Action Steps:

1. Recruit volunteers to form Education Committee.
2. Investigate if WDNR small-scale Lake Planning or AIS Education, Planning, and Prevention Grants would be appropriate to cover initial setup costs.
3. The MMLMD Board will identify a base level of annual financial support for educational activities to be undertaken by the Education Committee.

Management Goal 2: Maintain Current Water Quality Conditions

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

Timeframe: Continuation and expansion of current effort.

Facilitator: Planning Committee

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

The Citizens Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. While data has been collected through the advanced CLMN program in the past on Mount Morris Lake, there had been a lapse in the collection of this form of data. Starting in 2012, the MMLD plans to have a volunteer in place to continue this type of monitoring.

The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. Note: as a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

It is the responsibility of the Planning Committee to coordinate new volunteers as needed. When a change in the collection volunteer occurs, it will be the responsibility of the Planning Committee to contact Laura Herman (715.365.8998) or the appropriate WDNR/UW Extension staff to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Planning Committee recruits water quality sampling volunteer coordinator from district.
2. Coordinator directs water quality monitoring program efforts and volunteers.
3. Coordinator contacts Laura Herman (715.365.8998) to acquire necessary materials and training.
4. Volunteers collect data and coordinator/volunteers report results to WDNR and to association members during annual meeting.

Management Action: Investigate monitoring summer perchlorate levels in Mount Morris Lake in association with summer fireworks displays

Timeframe: Initiate summer 2013

Facilitator: Tim Dahlstrand

Description: The use of fireworks is a popular pastime, especially in relation to the Independence Day holiday tradition. Fireworks are often deployed over lakes, both for the increased field-of-view and for safety. During the Planning Committee Meeting, MMLMD members indicated that concerns had been raised about contamination of Mount Morris Lake from fireworks.

Used as a propellant in fireworks, perclorate is a chemical often focused upon to understand if fireworks displays are contaminating waterbodies. Perclorate levels have been shown so spike in some lakes following large municipally fireworks displays (Wilkin et al, 2007). However, dissipation of this chemical has also shown to be quite quickly.

Members of the MMLMD planning committee will investigate the monitoring of perclorate levels in Mount Morris Lake. Preliminary investigations suggest that it would likely be appropriate to test the top of the water column in all basins once in the spring (baseline), once during mid-July (firework season), and once during the fall (post).Although it is assumed that these levels will likely be extremely low or undetectable, it would provide some certainty regarding this issue.

Action Steps:

Please see description above.

Management Goal 3: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Mount Morris Lake

<u>Management Action:</u> Initiate/continue herbicide application strategy to control curly-leaf pondweed infestation on Mount Morris Lake.

Timeframe: Initiate 2012/2013

Facilitator: Planning Committee with professional help as needed

Description: As described in the Aquatic Plant Section, one of the most pressing threats to the health of Mount Morris Lake's aquatic plant community is curly-leaf pondweed. The 2012 curly-leaf pondweed peak-biomass map indicates that although efforts to control this invasive species in recent years have greatly reduced its density, this plant is still widespread throughout much of the lake (Map 9).

At this time, the most feasible method of control is herbicide applications – specifically, early spring treatments with endothall. The treatments would occur each year for the next 3-4 years when surface water temperatures are close to 50°F. The responsible use of this technique is supported by Mount Morris Lake stakeholders as indicated by approximately 64% if stakeholder survey respondents (excluding those that stated they need more information) indicating that they are at least moderately supportive of an herbicide control program (Appendix B, Question #23).

While curly-leaf pondweed density has been greatly reduced over the course of the five-year control project from 2006 to 2011, it is not known if the concentration/exposure time of endothall that has been applied is sufficient to cause mortality. If the concentration/exposure time has is sufficient to cause mortality, the curly-leaf pondweed present within the lake is a result dormant turions that were deposited prior to 2006. If herbicide concentration/exposure time has only caused injury, the population may be less dense but still producing viable turions on an annual basis and sustaining the population. For this reason, it is recommended that herbicide concentration monitoring take place during the 2013 curly-leaf pondweed treatment.

In conjunction with the WDNR and United States Army Corps of Engineers (USACE), herbicide concentration monitoring at multiple locations throughout the lake would take place to understand the concentration/exposure time of the herbicide at different time periods and locations following the treatment. This information would indicate whether or not the amount of herbicide applied is sufficient for causing curly-leaf pondweed mortality and if any adjustments in treatment strategy need to be made.

The objective of this management action is not to eradicate curly-leaf pondweed from Mount Morris Lake, as that would be impossible. The objective is to reduce curly-leaf pondweed to more manageable levels. In other words, the goal is to reduce the amount of curly-leaf pondweed in Mount Morris Lake to levels that may be suitable for smaller treatment areas to keep it under control.

Monitoring is a key aspect of any AIS control project, both to create the treatment areas and monitor the action's effectiveness. The monitoring would also facilitate the "tuning" or refinement of the control strategy as the control project progresses. It must be noted that this portion of the management plan (control plan) would be intended to span approximately 5 years before if would need to be updated to account for changes within the ecosystem. The ability to tune the control strategies is important because it allows for the best results to be achieved within the plan's lifespan. The series includes:

1. A lake-wide assessment of curly-leaf pondweed completed while the plant is at peak biomass (late Spring 2012-2017). Essentially, areas mapped during the 2012 peak biomass survey would be revisited to determine density levels and if colonial expansion has occurred.
2. Application during the August 1st, 2012 grant cycle for a WDNR Aquatic Invasive Species - Education, Prevention, and Control Grant.
3. Verification and refinement of early-season curly-leaf pondweed treatment areas in spring of 2013-2016.
4. Updated treatment areas submitted to the WDNR to serve as the final treatment permit, followed by completion of a curly-leaf pondweed herbicide treatment.
5. Areas surveyed (post-treatment survey) to determine treatment efficacy and strategy for the following year. The crux of this activity is included within Step 1.
6. Reports generated on treatment success level and following year's strategy.

In addition to refining each year's treatment areas, a quantitative sub-sampling of select proposed treatment areas would be completed during the spring survey. Monitoring would occur during early spring following a protocol currently being developed by the WDNR, and in general, would use guidance supplied in Aquatic Plant Management In Wisconsin (2007) and Pre and Post AIS Chemical Herbicide Treatment Monitoring (Draft) (April 2008). In general, control areas would be quantitatively monitored before and after treatments. At each point, we would complete one rake tow and if curly-leaf pondweed is located, estimate its abundance on the rake using a scale of 1-3. Depth and substrate would also be noted for each point. These data would then be used for comparisons with similar data collected after the treatment.

Quantitative sampling would be conducted the spring just previous to the treatment (pretreatment) and the spring following the treatment (post treatment). Because of the early senescence of this species, a post treatment survey a few weeks following the treatment would not differentiate if a reduction in occurrence can be attributed to the herbicide application or the natural die-off of this species.

Funds from the Wisconsin Department of Natural Resources Aquatic Invasive Grant Program have be awarded to partially fund this control program as well as the Eurasian water milfoil control program discussed in the subsequent management action. The approved project has a timeline of 2012-2017.

In the final year of the project, a series of comprehensive studies would be conducted on Mount Morris Lake, including a full-lake point-intercept survey. The results of these studies would be compared to studies conducted as a part of this management planning project.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2. Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3. Initiate control plan.
4. Revisit control plan in 5 years.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action: Initiate/continue herbicide application strategy to control Eurasian water milfoil infestation on Mount Morris Lake.

Timeframe: Initiate 2012/2013

Facilitator: Planning Committee with professional help as needed

Description: As described in the Aquatic Plant Section, the invasive Eurasian water milfoil has also been a target for control on Mount Morris Lake. Eurasian water milfoil treatment acreage has been reduced from 14.4 acres in 2008 to 4.5 in 2012 (Map 7). While the results of the 2012 treatment will not be assessed until late summer of 2012, it is likely that treatments to control this plant will need to occur into the future.

Like curly-leaf pondweed control, the most feasible method of control is herbicide applications – specifically, early spring treatments with 2,4-D. The treatments would occur each spring for the next 3-4 years when surface water temperatures are less than 65°F. The responsible use of this technique is supported by Mount Morris Lake stakeholders as indicated by approximately 64% of stakeholder survey respondents (excluding those that stated they need more information) indicating that they are at least moderately supportive of an herbicide control program (Appendix B, Question #23).

In 2011, some milfoil plants exhibiting morphological characteristics of both northern water milfoil and Eurasian water milfoil were sent to Grand Valley State University in Michigan for DNA analysis. Their results indicated that these specimens where in fact a hybrid between northern and Eurasian water milfoil. Recent studies are indicating that hybrid milfoil strains have a higher tolerance to herbicides and require a higher concentration/exposure time to cause mortality.

In conjunction with the WDNR and United States Army Corps of Engineers (USACE), herbicide concentration monitoring at multiple locations throughout the lake would take place to understand the concentration/exposure time of the herbicide at different time periods and locations following the treatment. This information would indicate whether or not the amount of herbicide applied is sufficient for causing curly-leaf pondweed mortality and if any adjustments in treatment strategy need to be made.

The objective of this management action is not to eradicate Eurasian water milfoil from Mount Morris Lake, as that would be impossible. The objective is to reduce Eurasian water milfoil to more manageable levels. In other words, the goal is to reduce the amount of Eurasian water milfoil in Mount Morris Lake to levels that may be suitable for smaller treatment areas to keep it under control. Similar to the curly-leaf pondweed control strategy outlined within the previous manage n action, a series of treatment monitoring activities would also take place in association with the Eurasian water milfoil treatments. This series of steps would only differ in the timing of the peak-biomass survey, as Eurasian water milfoil would be mapped towards the end of summer (not early summer) when this plant is at its peak growth stage.

Because the Eurasian water milfoil treatments on Mount Morris Lake in recent years have been relatively small (< 10 acres), quantitative monitoring using point-intercept methods is not feasible. However, qualitative monitoring in the form of density ratings and mapping will occur in late summer when these plants are at or near their peak growth.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2. Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3. Initiate control plan.
4. Revisit control plan in 3-4 years.
5. Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Goal 4: Maintain Navigation in Open Water and Near-shore Areas on Mount Morris Lake

Management Action: Use district-owned mechanical harvester to maintain reasonable navigation on Mount Morris Lake.

Timeframe: Ongoing

Facilitator: Mount Morris Lake Management District Board of Directors

Description: The purpose of the harvesting is to allow navigability in certain areas of the lake that contain dense, nuisance levels of native aquatic plants. Map 11 shows the mechanical harvesting plan that was developed in conjunction with Onterra ecologists, WDNR staff, and district members. The harvesting areas total approximately 15.5 acres and as indicated, represent 30-foot wide navigation lanes. These areas were created to allow lake users to access open water areas while avoiding important aquatic plant communities. Mechanical harvesting activities have the ability to spread aquatic invasive species throughout a lake. Harvesting activities will not occur if Eurasian water milfoil or curly-leaf pondweed is found within the harvest areas.

Action Steps:

1. District applies for a multiyear harvesting permit (3 year).
2. District harvests in areas shown on Map 11 while following the plan listed above and restrictions indicated on the WDNR permit.
3. Harvest summary report is provided to the WDNR annually after each harvesting season.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Mount Morris Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in each basin (A,B,C,D, and E) that would most accurately depict the conditions of the lake (Map 1). Samples were be collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B), and occur once in spring, fall, and winter and three times during summer in Lake D. Lakes A, B, C, and E were sampled once in the spring, summer, fall, and winter. Samples were kept cool and preserved with acid following normal protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured are displayed in Table 1.

Table 6.0-1. Water quality sampling parameters and timing.

	Spring		June		July		August		Fall		Winter	
Parameter	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**
Dissolved Phosphorus	●	●			●	●			●		●	●
Total Phosphorus	■	■	●	●	■	■	●	●	■	■	■	■
Total Kjeldahl Nitrogen	●	●			●	●			●		●	●
Nitrate-Nitrite Nitrogen	●	●			●	●			●		●	●
Ammonia Nitrogen	●	●			●	●			●		●	●
Laboratory Conductivity	●	●			●	●			●			
Laboratory pH	●	●			●	●			●			
Total Alkalinity	●	●			●	●			●			
Chloride*	●								●		●	
Chlorophyll-*a*	■		●		■		●		■			
True Color*	●								●			
Sulfate*	●								●			
Total Suspended Solids	●	●	●	●	●	●	●	●	●	●	●	●
Turbidity*	●								●			
Calcium*	●								●			
Magnesium*	●								●			
Potassium*	●								●			
Sodium*	●								●			
Atrazine (DATC)*					●							

NOTE: ■ = Samples collected at all 5 Lakes. ● = Samples collected only at Lake D.

Watershed Analysis

The watershed analysis began with an accurate delineation of Mount Morris Lake's drainage area using USGS 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 Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Mount Morris Lake during a May 2012 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 Mount Morris Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in "Appendix D" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used to complete this study on August 2010. A point spacing of 38 meters was used resulting in approximately 359 points.

Community Mapping

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

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium. A set of samples was also provided to the Mount Morris Lake Management District.

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