Deer Lake

Lincoln County, Wisconsin

Comprehensive Management Plan

December 2013

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Acknowledgements

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

Deer Lake Planning Committee

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Steve Laack
Pam Mack
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Cindy Schlachtenhaufen
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1.0 INTRODUCTION

Deer Lake, Lincoln County, is a 152-acre spring lake with a maximum depth of about 53 feet (Map 1). This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Deer Lake contains 36 native plant species, of which variable pondweed is the most common plant. Eurasian water milfoil, an exotic plant species, was discovered in Deer Lake during the 2008 aquatic plant surveys.

Field Survey Notes

Primarily sandy substrate, with some steeply sloped areas. Eurasian water milfoil discovered near outlet (2008) during summer survey. Water levels fluctuated greatly during field visits, varying between several feet below OHWM and several feet above OHWM.

Photograph 1.0-1 Deer Lake, Lincoln County

Lake at a Glance – Deer Lake

Morphology	
Acreage	152
Maximum Depth (ft)	53 (*at normal water level conditions*)
Mean Depth (ft)	24
Shoreline Complexity	3.5
Vegetation	
Curly-leaf Survey Date	July 2008
Comprehensive Survey Date	July 2008
Number of Native Species	21 + 16 incidentals = 37
Threatened/Special Concern Species	1 – Vasey's pondweed
Exotic Plant Species	1 – Eurasian water milfoil
Simpson's Diversity	0.92
Average Conservatism	7.4
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.5
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	1:1

Prior to 2008, no non-native plants had been documented in Deer Lake. However, given the lake's direct connection to the Rice Reservoir which is known to harbor populations of Eurasian water milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*), the Deer Lake District (DLD) wants to adopt a proactive strategy to protect and enhance the environmental integrity of their lake.

The DLD is interested in creating a lake management plan for two primary reasons: first, they would like to expand and enhance their program to prevent the introduction of aquatic invasive species (AIS), and second, they understand the value in gaining a better understanding of lake ecology and the overall condition of their lake. In the end, the information obtained would help guide future DLD plans and programs. Additionally, the district knows that the Wisconsin Department of Natural Resources (WDNR) can respond more quickly and accurately to address a new invasive species establishment if the lake has a management plan in place.

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 in chronological order. Materials used during the planning process can be found in Appendix A.

Kick-off Meeting

On June 7, 2008, a project kick-off meeting was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by the Deer Lake District board members. The attendees observed a presentation given by Tim Hoyman and Eddie Heath, aquatic ecologists with Onterra. Their presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Stakeholder Survey

During late 2008/early 2009, the Deer Lake Planning Committee worked with Onterra staff to produce a stakeholder survey that would be distributed to all lake property owners and district members. This survey was reviewed and approved by a WDNR sociologist prior to distribution. During March 2009, a six-page, 23-question survey was mailed to 63 riparian property owners in the Deer Lake watershed. 73 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Deer 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.

Planning Committee Meeting I

On April 15, 2010, Tim Hoyman of Onterra met with several members of the Deer Lake Planning Committee for nearly 3 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including, Eurasian water milfoil survey results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, including the presence of Eurasian water milfoil, low water levels, and issues concerning the intermittent stream channel between Deer and Bridge Lakes.

Deer Lake Channel Discussion Meeting

On February 23, 2010, Tim Hoyman met with Deer Lake District President Phi Schlachtenhaufen as well as representatives from the Wisconsin Valley Improvement Corporation (WVIC) and the Wisconsin Department of Natural Resources (WDNR) regarding water levels in Deer Lake and the erosion of the Deer Lake channel. At the conclusion of this meeting, all parties agreed to work together to address the Deer Lake resident's concerns in an appropriate manner. More discussion regarding this issue and the February 23 meeting can be found in Section 3.5 Deer Lake Outlet Channel.

Management Plan Review and Adoption Process

In April 2010, a draft of the Results & Discussion portions of this report (Sections 3.1, 3.2, 3.3 & 3.4) was provided to the Planning Committee for review. Based upon comments received, an additional section (3.5) was drafted to convey information regarding the Deer Lake outlet channel. This section and a draft of the Conclusions section and Implementation Plan was created and provided to the Planning Committee for review in August 2011. The Planning Committee provided several revisions to the draft report, which was subsequently updated and then sent to the WDNR for review in February of 2012. Following approval of the management plan by the WDNR, the Deer Lake District will vote on the Deer Lake Management Plan at an annual meeting to officially adopt the plan and management goals.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Deer Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Deer Lake's water quality analysis:

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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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 process 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 below:

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.

*Lack of summer months temperature/dissolved oxygen profiles and hypolimnetic phosphorus data prevents these analyses from being performed. The explanation provided under this heading is strictly for the information of the reader.

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 its watershed and the composition of the watershed's land cover. For this reason, the water quality of Deer 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 all of the 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), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

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

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

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

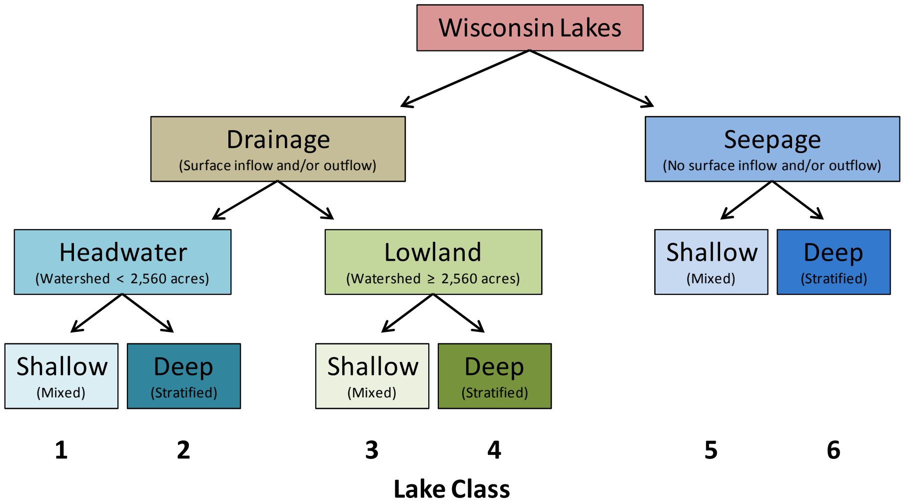

Figure 3.1-1. Wisconsin Lake Classifications. Deer Lake is classified as a deep (stratified), headwater drainage lake (Class 2). Adapted from WDNR PUB-SS-1044 2008.

Lathrop and Lillie 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 (Figure 3.1-2). **Ecoregions** are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Deer Lake is within the Northern Lakes and Forests ecoregion.

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act. It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. One of the assessment methods utilized is Carlson's Trophic State Index (TSI). They divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and their experience.

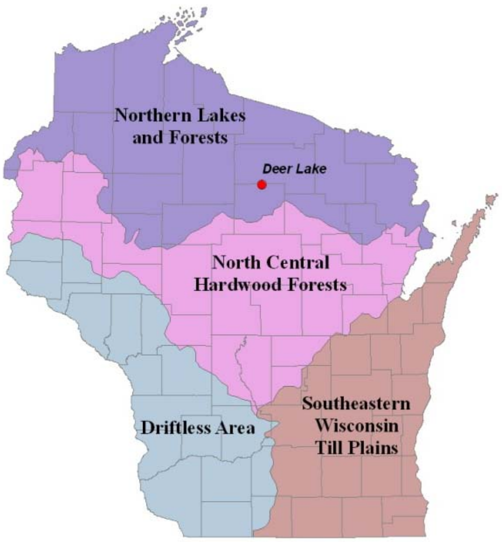

Figure 3.1-2. Location of Deer Lake within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Deer Lake is displayed in Figures 3.1-3 - 3.1-10. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Deer Lake Water Quality Analysis

Deer Lake Long-term Trends

Water quality data has been collected from Deer Lake on a more or less consistent basis since 2000. The largest gap during this timeframe extended from 2002 – 2007. While these data are not sufficient for long-term trend analysis, it does lead to an understanding of the lake's water quality condition over the past decade.

Figure 3.1-3 contains total phosphorus data collected at Deer Lake. With the exception of the data from 2001, the values are consistently good to excellent. Regarding the 2001 data, the high growing season values for total phosphorus and chlorophyll-*a* (Figure 3.1-4) are the result of elevated readings collected on May 1 of that year. Both of these results, 48 µg/l for total phosphorus and 13 µg/l for chlorophyll-*a*, are the highest concentrations within the historic dataset and may have been caused by high runoff amounts associated with an unusual amount of precipitation that preceded the sampling date.

The Secchi disk clarity data (Figure 3.1-5) follows much the same basic pattern as the phosphorus and chlorophyll-*a* results. This is expected because, as described above, the three parameters are very much related. Within the historic clarity dataset, there are two values collected during July 1979. Averaged, these two values produce a clarity value of 15.5 feet, which is obviously better than any other value in Figure 3.1-5. However, it must be stated that having two values collected within weeks of each other is not necessarily representative of the entire summer or growing season. Further, without data from the two decades between 1979 and 1999, we cannot determine if water clarity has truly gotten worse on Deer Lake, as the chart indicates, or if the values varied wildly with no pattern at all.

Overall, the three parameters discussed here have stayed within the excellent and good range and have been much better than values normally found within similar deep, headwater drainage lakes and those of the Northern Lakes and Forests Ecoregion.

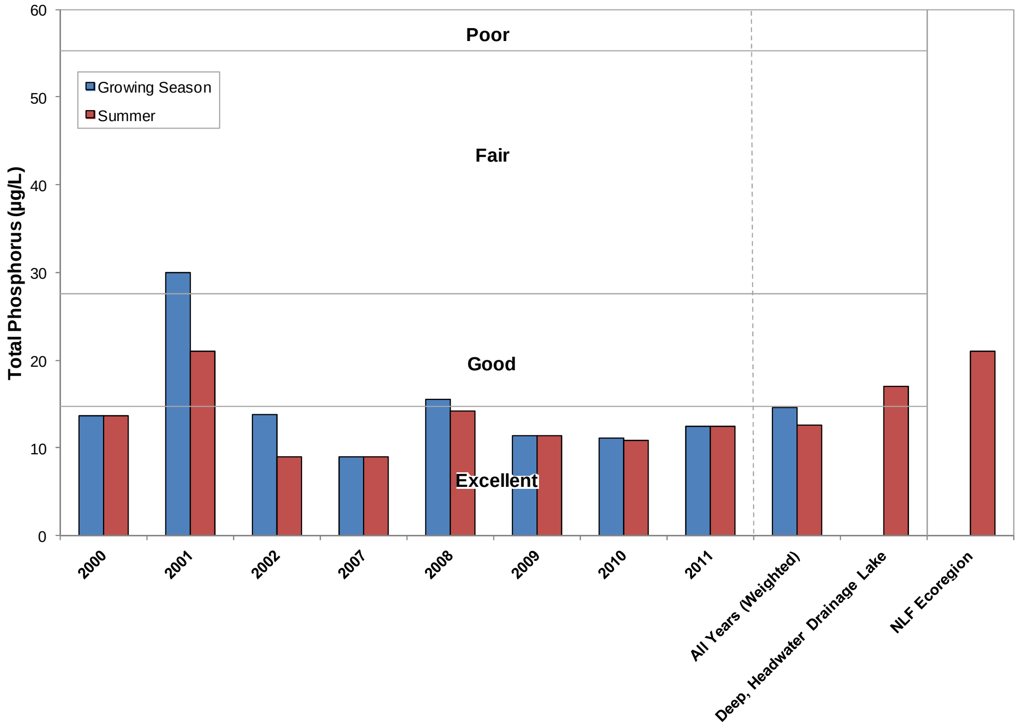

Figure 3.1-3. Deer Lake, state-wide class 2 lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

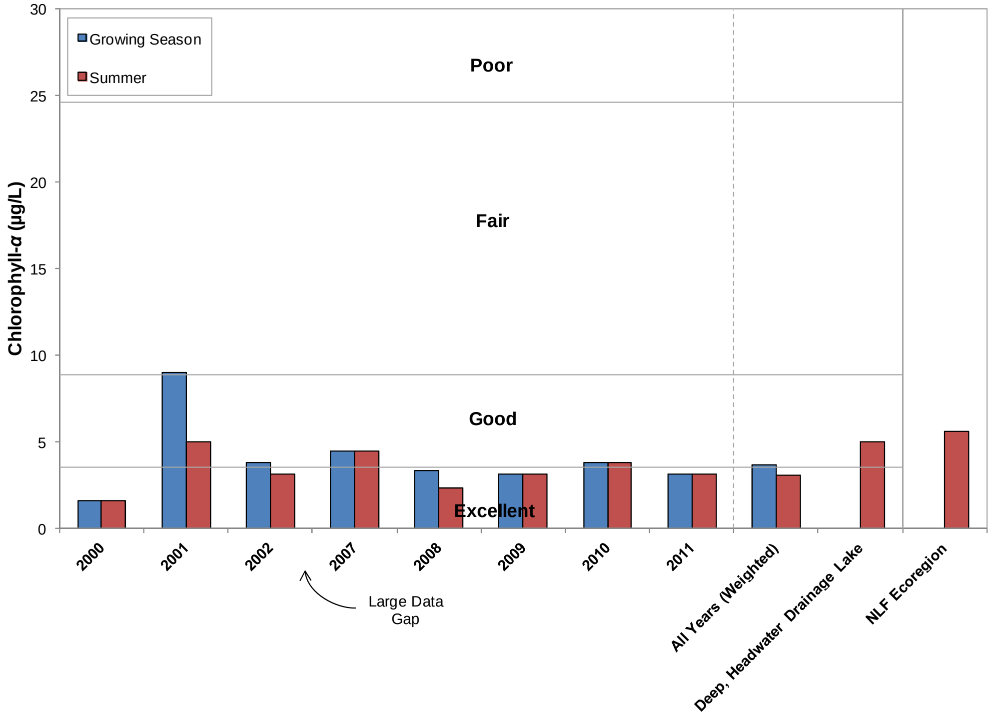

Figure 3.1-4. Deer Lake, state-wide class 2 lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

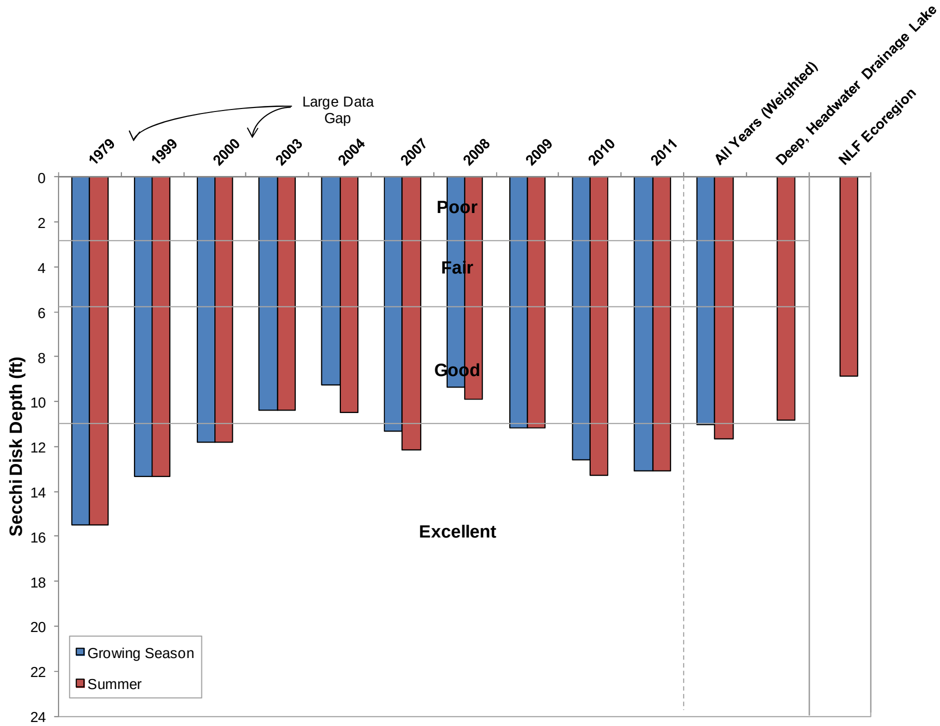

Figure 3.1-5. Deer Lake, state-wide class 2 lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Deer Lake

Using midsummer nitrogen and phosphorus concentrations from Deer Lake, a nitrogen:phosphorus ratio of 32:1 was calculated. This finding indicates that Deer Lake is highly phosphorus limited as are the vast majority of Wisconsin Lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Deer Lake Trophic State

Figure 3.1-6 contain the WTSI values for Deer Lake. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower to upper mesotrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* WTSI values, it can be concluded that Deer Lake is in an mid mesotrophic state – meaning that that lake is moderately productive.

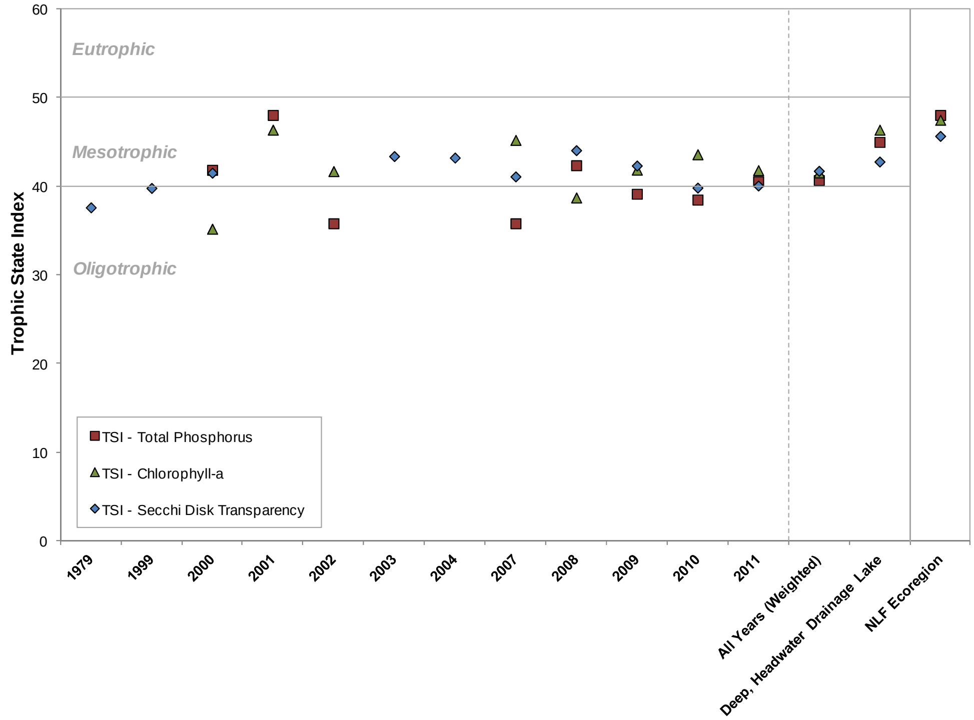

Figure 3.1-6. Deer Lake, state-wide class 2 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Deer Lake

Figure 3.1-7 contains dissolved oxygen and temperature profiles collected at Deer Lake during 2008. The profiles indicate that the Deer Lake stratifies during ice cover and summer months. For most of the summer, the entire water column of the lake holds high amounts of dissolved oxygen; however, during the August 19,' 2008 collection, it was discovered that a small portion of the lake's volume below 24 feet in depth becomes anoxic. The anoxic conditions are brought about by the decomposition of plant and animal matter in the lake's sediment. As the decomposition progresses, the limited amount of oxygen that occurs within the lake's bottom layer is consumed. It should be noted that even with the anoxic hypolimnion, the vast majority of water volume in Deer Lake still holds sufficient levels of oxygen to support aquatic life, including fish; therefore, no concerns should be raised by the anoxic conditions described above.

Significance of Internal Nutrient Loading in Deer Lake

Internal nutrient loading is not believed to be significant in Deer Lake. This is supported by the fact that hypolimnetic phosphorus levels reached only 39 µg/l during summer stratification, which is well below the threshold of concern as discussed in the introduction to this section.

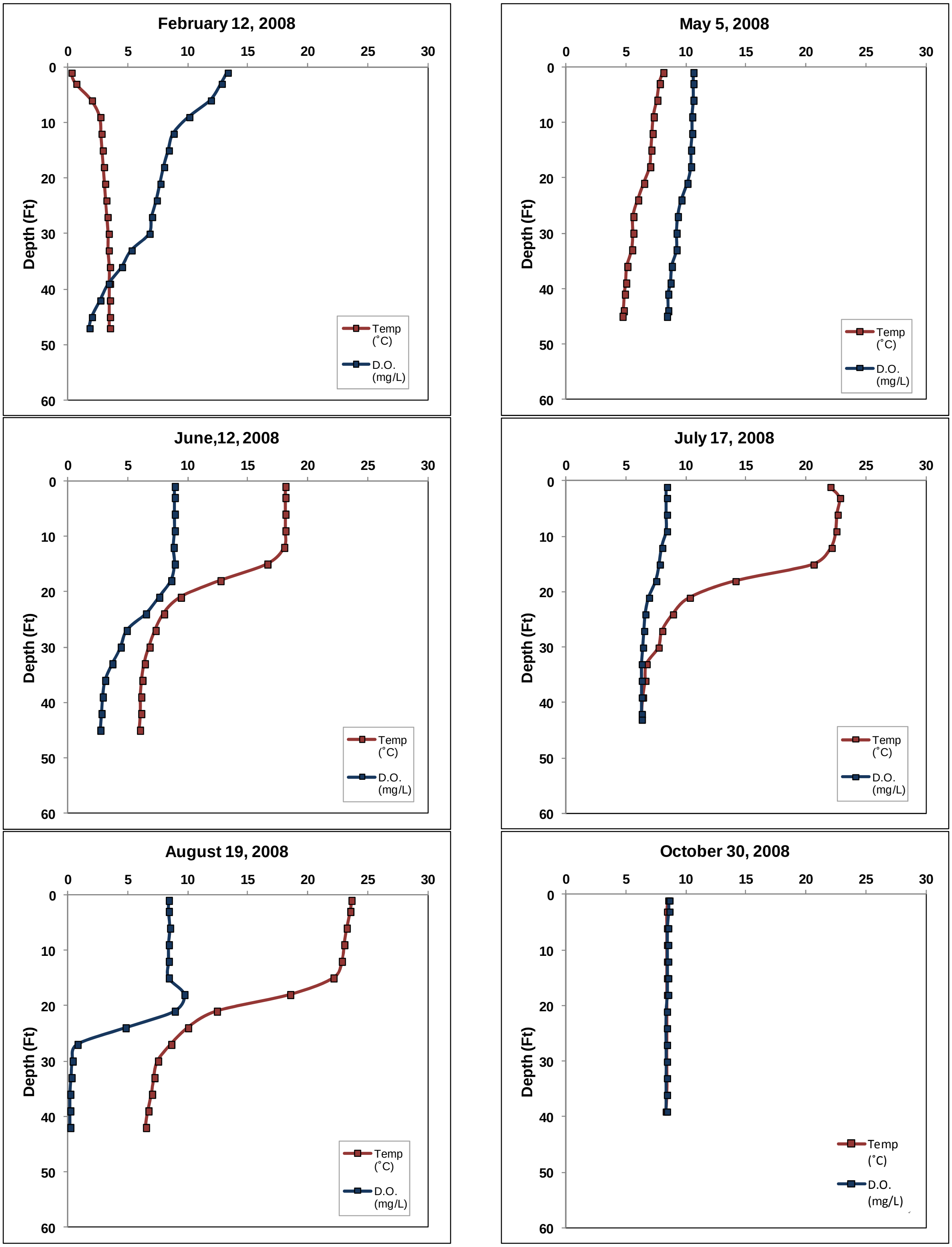

Figure 3.1-7. Deer Lake dissolved oxygen and temperature profiles.

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw et al. 2004). The pH of the water in Deer Lake was found to be slightly above neutral with a value of 7.5, 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^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Deer Lake was measured at 24.0 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

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 Deer Lake's pH of 7.5 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 Deer Lake was found to be 6.3 mg/L, falling well below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2008 and these samples were processed by the WDNR for larval zebra mussels. At that time, no zebra mussel veligers were observed.

3.2 Watershed Assessment

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

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

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

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

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

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

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

Deer Lake's 322 acre watershed consists of almost equal portions of the lake surface (152 acres or 47%) and forest (49% or 159 acres) while pasture / grass (3%) and wetlands (1%) round out the rest of the land cover within the watershed (Figure 3.2.1 and Map 2). The relatively small watershed is only slightly larger than the lake itself, which creates a 1:1 watershed to lake area ratio. As discussed above, in watersheds with a small ratio, the land uses within the watershed have great potential in regulating the water quality of the lake. Fortunately, almost half of the watershed is covered in forest, which exports minimal amounts of nutrients and sediment to the lake via surface runoff. Furthermore, almost the entire second half of the watershed is made up of the lake's surface. In fact, as discussed below, the lake surface is the primary nutrient source to Deer Lake.

WiLMS modeling utilizing the land cover types and acreages found in Figure 3.2-1 results in an estimated annual phosphorus load of 55 lbs for Deer Lake. This is a very small amount of phosphorus for a lake of this size and volume. This is the result of the large amount of forested land in the watershed, which prevents runoff by allowing water to permeate the soil more efficiently than other land cover types. . Interestingly, the largest contributor to the phosphorus load is the lake's surface (72% or 39.7 lbs), which collects phosphorus through atmospheric fallout. The remaining 28% of the phosphorus load is delivered by forests (24%) and pasture / grass (4%) while the small amount of wetlands in the watershed yield quantities below measurement by WiLMS to Deer Lake (Figure 3.2-2).

While the annual phosphorus load to Deer Lake is minimal for a lake of this size, the phosphorus accumulates within the lake due to its very low flushing rate. The system flushes less than 0.1% of its water in a year's time, which allows for a very high residence time of 15.5 years. Because of the high residence time, phosphorus is able to accumulate in the sediment of the lake.

However, the lake receives only a small amount of phosphorus on a yearly basis, and the lake is quite voluminous, so it is able to dilute any excess phosphorus with its volume.

With such a small watershed it is important that the most vulnerable area of the watershed, the immediate shoreland zone, be protected from disturbance. If shoreline vegetation is removed and impervious surfaces are increased through development the sediment and nutrient load to Deer Lake will increase dramatically. WiLMS was utilized to develop a scenario where 50% of the shoreline of Deer Lake was converted into medium density urban land cover. The model predicted that under these circumstances, the phosphorus load would increase by 24% (13 lbs) on an annual basis (Figure 3.3-3 and Appendix D). Though this increase is seemingly insignificant, remember that with the high water residence time, phosphorus remains in the lake and accumulates over time. The additional phosphorus will accelerate this accumulation. Thus, efforts must be concentrated to preserve natural shoreland vegetation as this will likely have the biggest impact in mitigation against possible runoff pollution while enhancing water quality and habitat protection.

Under normal flowage situations, Deer Lake flows into Bridge Lake through a stream outlet, which in turn flows into the rest of the Rice River Reservoir. Because of the flow regime and of Deer Lake's geographical situation, it may be classified as a spring lake. While some lakes have streams that carry water to them, spring lakes receive water only through groundwater inputs, surface runoff, and precipitation. With a watershed as small as Deer Lake's, surface runoff is likely a very small contributor and groundwater likely is the primary water source for the lake.

Drought conditions in northern Wisconsin have greatly reduced the amount of regional precipitation in the past 8 – 10 years. Without adequate precipitation, spring lakes will collect water only from the ground. The lake water level, also a reflection of the groundwater level, will slowly lower as precipitation fails to "recharge" depleted groundwater stocks. And as evaporation occurs, the water levels in the lake will continue to decrease. The outlet stream can eventually become intermittent, only carrying water in the "wet" months of the year. While these changing water levels may have negative recreational and short-term biological impacts, it is important to remember that lake water level fluctuations are part of a naturally occurring cycle and may actually benefit the lake ecosystem in the long-term by increasing the level of habitat diversity

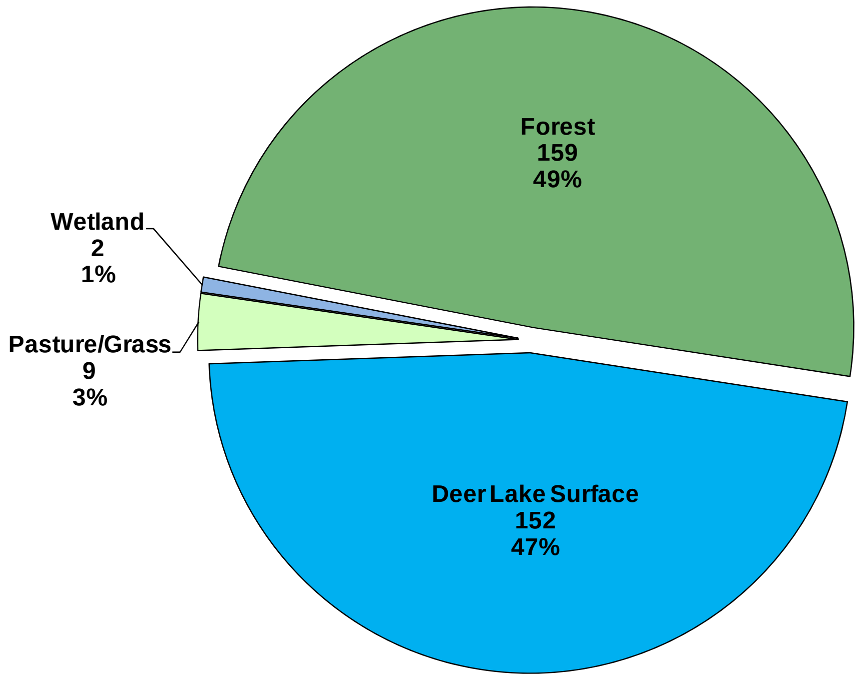

Figure 3.2-1. Deer Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

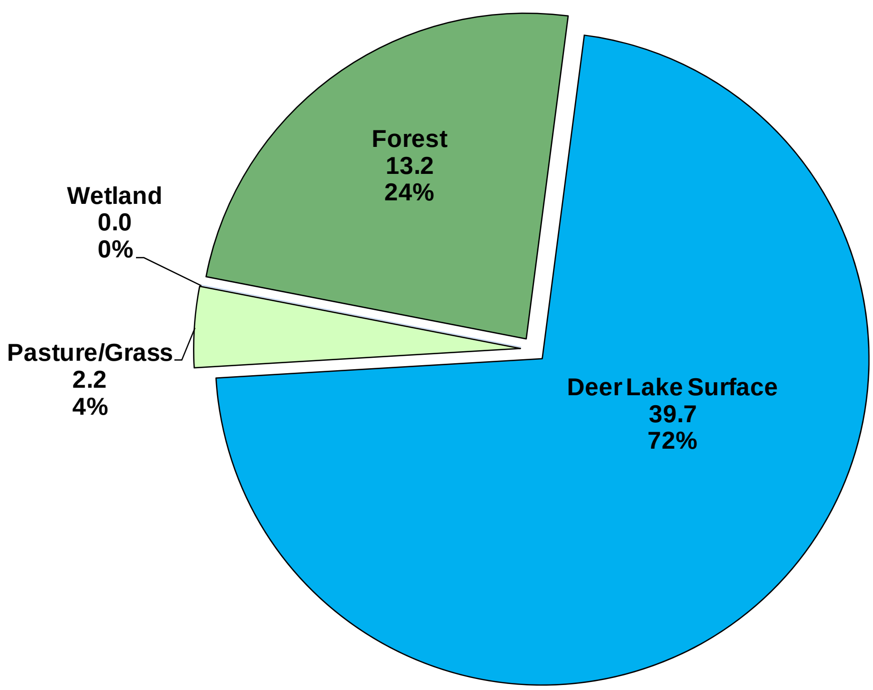

Figure 3.2-2. Deer Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

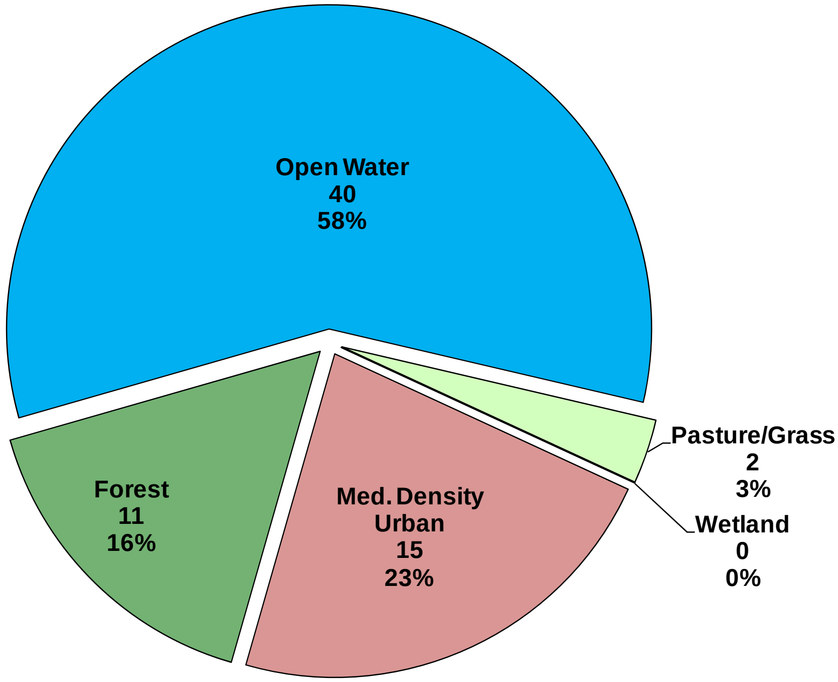

Figure 3.2-3. Potential Deer Lake watershed phosphorus loading in pounds under an alternative scenario. In this scenario, 50% of a 200 ft. shoreline buffer was developed to medium density urban land use. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 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

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

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

Permits

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

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

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 shoreline. 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 shoreline 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 depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:

- o An upland buffer zone measuring 35’ x 100’.
- o An aquatic zone with shallow-water and deep-water areas of 10’ x 100’ each.
- o Site is assumed to need little invasive species removal prior to restoration.
- o Site has a moderate slope.
- o Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
- o Plant spacing for the aquatic zone would be 3 feet.
- o Each site would need 100’ of biolog to protect the bank toe and each site would need 100’ of wavebreak and goose netting to protect aquatic plantings.
- o Each site would need 100’ of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
- o There is no hard-armor (rip-rap or seawall) that would need to be removed.
- o 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 shoreline erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • 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.

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 affects 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.

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 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. Some herbicides are applied at a high dose with the anticipation that the exposure time will be short. Granular herbicides are usually applied at a lower dose, but the release of the herbicide from the clay carrier is slower and increases the exposure time.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothall (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.

Triclopyr (Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a surfactant to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*). Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Imazapyr (Habitat®) Broad spectrum, system herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

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 waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*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 Deer 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 Deer Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. 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

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.

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 Deer 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. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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 Deer Lake will be compared to lakes in the same ecoregion and in the state.

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 plan 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 3.3-1). 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.

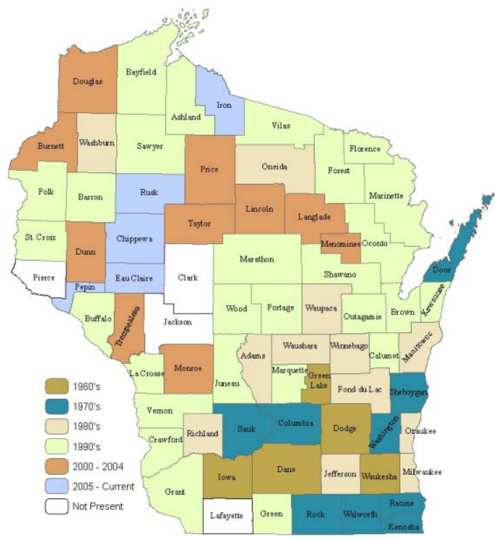

Figure 3.3-1. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

As mentioned above, numerous plant surveys were completed as a part of this project. On July 1, 2008, a survey was completed on Deer Lake that focused upon curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed. It is believed that this aquatic invasive species either does not occur in Deer Lake or exists at an undetectable level. It is important to note that curly-leaf pondweed is known to exist in Lake Nokomis and in Bridge Lake, which is intermittently connected to Deer Lake.

The point intercept survey was conducted on Deer Lake in July 2008 by Onterra. Additional surveys were completed by Onterra on Deer Lake to create the aquatic plant community maps (Map 3) during August 2008.

During the point-intercept and aquatic plant mapping surveys, 37 species of plants were located in Deer Lake (Table 3.3-1), only one of which is considered a non-native invasive species, Eurasian water milfoil. Twenty species were sampled during the point-intercept survey and are used in the FQI analysis below. Because of its importance, Eurasian water milfoil will be discussed in depth in a separate section. One species is listed by the WDNR's Natural Heritage Inventory Program as being species of 'Special Concern' in Wisconsin (Vasey's pondweed).

As stated within the Water Quality Section, Deer Lake is a relatively low nutrient lake with high water clarity values. Based on data collected as a part of the point-intercept vegetation survey, the vast majority (89%) of the littoral zone is comprised of sandy soils (Map 4). These habitats are often colonized by a collective group of rooted plants known as isoetids. The isoetids are small, slow-growing, inconspicuous plants usually found growing in sandy soils within the near-shore areas of a lake and greatly differ from the leafy plants most people have in their minds when it comes to aquatic plants (Boston and Adams 1987). Deer Lake contains numerous isoetid species including needle spikerush, the third most abundant plant within the lake (Figure 3.3-2). The most common species in the lake was variable pondweed. As its name suggests, variable pondweed exhibits variable growth, usually in relation to the depth of water in which it is found. Within Deer Lake, variable pondweed was found growing between 3 and 11 feet deep, with highest occurrences between 6 and 8 feet. This dominant pondweed provides valuable habitat for invertebrates and foraging opportunities for fish species.

Aside from the recently discovered Eurasian water milfoil, only one milfoil species (genus *Myriophyllum*), dwarf water milfoil, was located from Deer Lake. This isoetid species is morphologically much different from the other 6 milfoil species known to occur in Wisconsin waters. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and high water clarity. While these conditions occur in Deer Lake, this species does not. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the 'reddish' appearance of Eurasian water milfoil as the plant reacts to increased sun exposure, largely from lowering water levels. Since northern water milfoil is not known to exist in Deer Lake, any milfoil species observed, other than dwarf water milfoil, should be suspect of being Eurasian water milfoil.

Table 3.3-1. Aquatic plant species located on Deer Lake during July-August 2008 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	Onterra (2008)
Emergent	*Alisma trivale*	Northern water plantains	4	I
	Acorus calamus	Sweetflag	Exotic (Naturalized)	I
	Carex comosa	Bristly sedge	5	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Equisetum fluviatile	Water horsetail	7	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Typha latifolia	Broad-leaved cattail	1	I
FL	*Nuphar variegata*	Spatterdock	6	I
	Polygonum amphibium	Water smartweed	5	I
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	I
	Sparganium emersum	Short-stemmed bur-reed	8	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes lacustris	Lake quillwort	8	X
	Lobelia dortmanna	Water lobelia	10	X
	Megalodonta beckii	Water marigold	8	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic (Invasive)	I
	Myriophyllum tenellum	Dwarf water milfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Juncus pelocarpus	Brown-fruited rush	8	X

FL = Floating-leaf; FL/E = Floating-leaf & Emergent;S/E = Submergent & Emergent
X = Located on rake during point-intercept survey; I = Incidental species

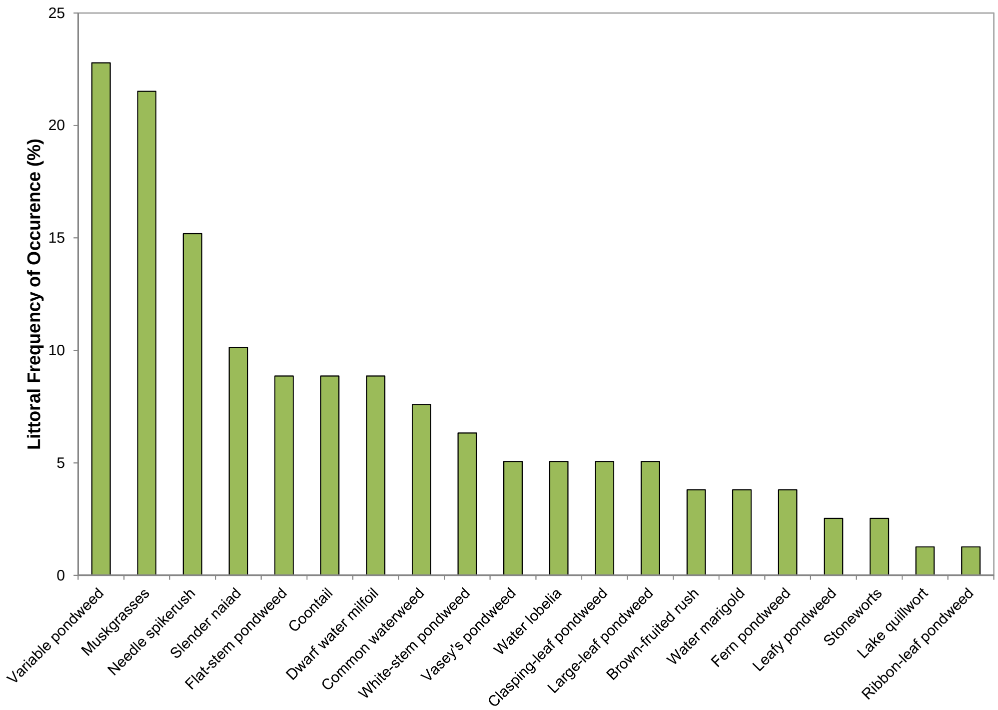

Figure 3.3-2 Deer Lake littoral aquatic plant frequency of occurrence. Created using data from 2008 surveys. Exotic species indicated with red.

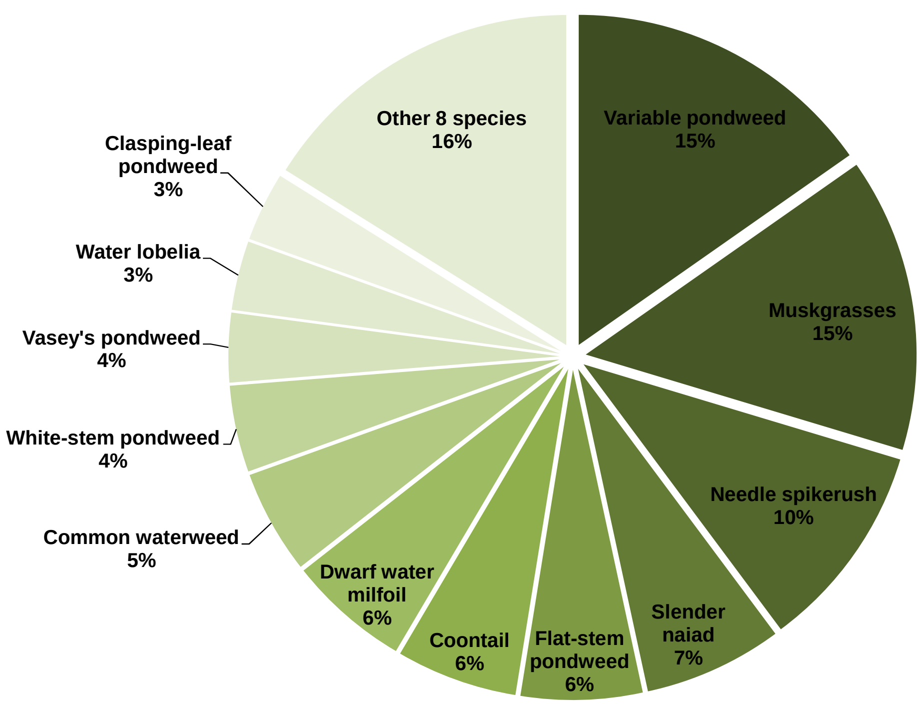

Figure 3.3-3 Deer Lake aquatic plant relative frequency of occurrence. Created using data from 2008 surveys. Exotic species indicated with red.

Data collected from the aquatic plant surveys indicate that the average conservatism values are higher than the state median and the Northern Lakes Ecoregion median. This shows that the aquatic plants within Deer Lake are more indicative of a pristine condition than those found in most lakes in the state and the ecoregion.

Traditional forms of disturbance that often affect lakes include human development of the lake's shoreline and motorboat traffic. A stakeholder survey sent to district members indicate that motor boats with a 25 horsepower or greater motor are the most prevalent watercraft on the lake, followed by three passive watercrafts (Appendix B, Question #8). Many studies have documented the adverse effects of motorboat traffic on aquatic plants (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997). In all of these studies, lower plant biomasses and/or declines and higher turbidity were associated with motorboat traffic. Eurasian water milfoil infestation can also be viewed as a disturbance and if this plant becomes established in Deer Lake, will likely cause a shift of the aquatic plant community, particularly in respect to those species with higher coefficients of conservatism (Table 3.3-1).

Combining the lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a high value of 34.8 (calculation shown below) which is well above the median values of the state and ecoregion (Figure 3.3-4).

FQI = Average Coefficient of Conservatism (7.8) * √ Number of Native Species (20)
FQI = 34.8

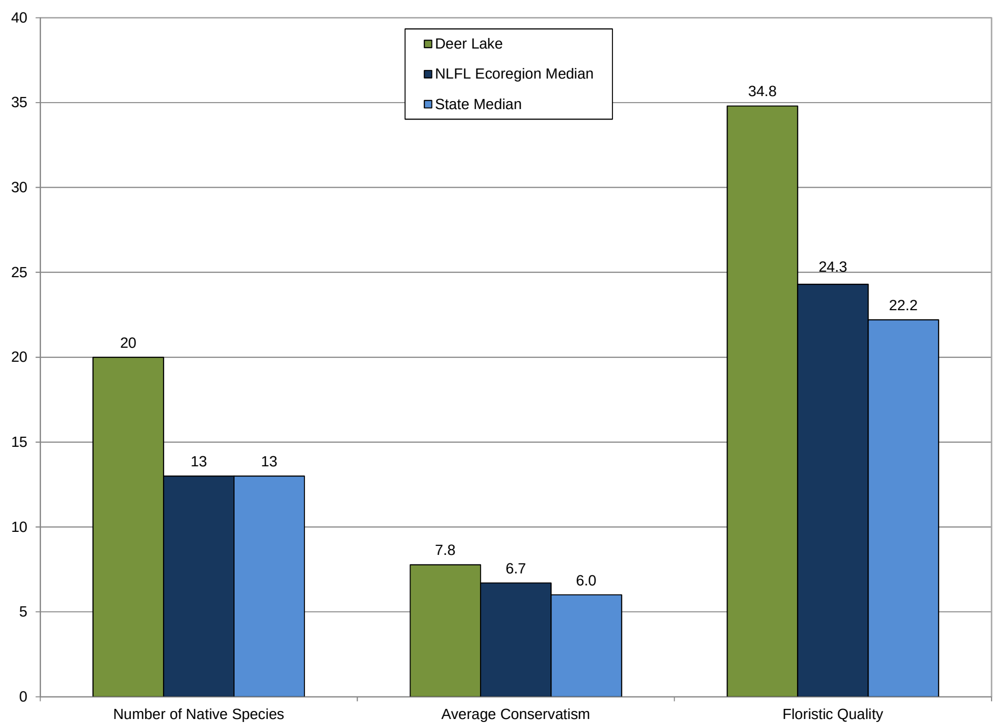

Figure 3.3-4. Deer Lake Floristic Quality Assessment. Created using data from 2008 surveys. Analysis following Nichols (1999).

The aquatic plant community in Deer Lake was found to be highly diverse, with a Simpson's diversity value of 0.92 (Figure 3.3-5). This value ranks above state and ecoregion upper quartiles. Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. 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.

The quality is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2008 community map indicates that approximately 14.6 acres (9%) of the 152-acre lake contains these types of plant communities (Table 3.3-2, Map 3). Fifteen floating-leaf and emergent species were located on Deer Lake, providing valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important since structural habitat of fallen trees and other forms of coarse-woody habitat are quite sparse along the shoreline of Deer Lake.

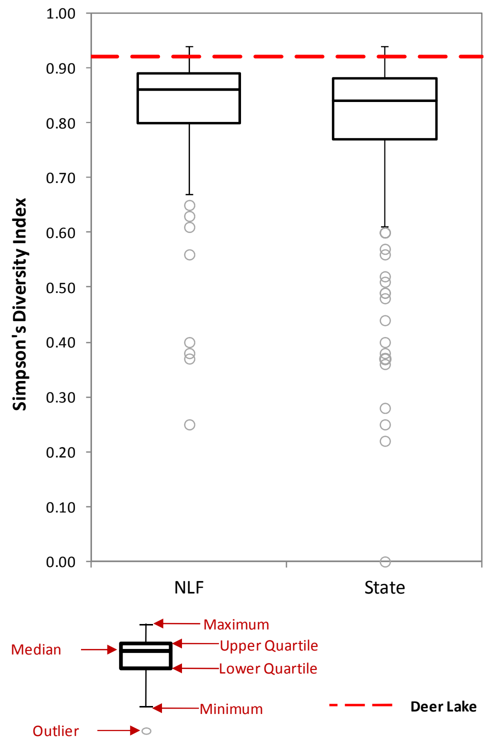

Figure 3.3-5. Deer Lake species diversity index. Created using data from 2008 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

The high incidence of emergent plant species on Deer Lake may be related to water level fluctuations that occur on the system. Perennial emergents respond well to falling water levels by increasing vigor of rhizomes and facilitating germination. Floating-leaf plant species usually do not respond as favorably to lowering water levels, especially if the large tubers of these species become exposed and susceptible to desiccation (drying out) or freezing.

Table 3.3-2. Deer Lake acres of plant community types. Communities mapped in a July 2008 survey.

Plant Community	Acres
Emergent	1.4
Mixed Floating-leaf and Emergent	13.2
Total	14.6

Continuing the analogy that the community map represents a 'snapshot' of the important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Deer 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 reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with developed shorelines.

Two non-native emergent species, purple loosestrife (*Lythrum salicaria)* and common reed (*Phragmites australis*) are known to occur along the shorelines of the connected waterbodies of the Rice Reservoir (Lake Nokomis and Bridge Lake). These plants have the ability to displace valuable emergent wetland species and reduce the habitat values of these communities.

Eurasian Water Milfoil

In early July 2008, Onterra ecologists located a small bed of Eurasian water milfoil near the Deer Lake outlet (Map 5) while completing a curly-leaf pondweed survey as a part of the management planning project. Approximately two weeks later, a single Eurasian water milfoil plant was located and removed in another part of the lake. The original treatment plan for the colony near the outlet included hand-removal by professionals and training of Deer Lake riparians to assist in the task and perform maintenance removals. However, upon further review of the area, it was decided that the large amounts of tall native vegetation would minimize visibility and make maneuvering difficult for divers.

The WDNR awarded the Deer Lake District an AIS Rapid Response Grant to aid in the costs associated with the new infestation. In 2008, about 0.25 acres were treated on September 16 with granular 2,4-D (Navigate) at 150 lbs/acre. After this treatment, Eurasian water milfoil was located within and around this area. An expanded treatment of approximately 0.7 acres was treated on July 25, 2009 using the same herbicide, but at a higher dose (200 lbs/acre).

Early in September 2009, Onterra ecologists and Phil Schlachtenhaufen, president of the Deer Lake District, visited the treatment area and did not locate any plants from the surface. However, some Eurasian water milfoil plants were observed around the lake. Later that month, Onterra ecologists mapped all Eurasian water milfoil occurrences and scuba dove those locations that were suitable for hand removal. Unfortunately, some areas contained too much Eurasian water milfoil and other native plants to successfully control the exotic using this technique.

An aggressive, 2.4-acre treatment targeting these areas was initiated in spring of 2010 (Map 5). By completing the treatments at this time of the year, the collateral damage to native dicots is limited as many of these species have not yet sprouted or are at extremely low biomass. It is also generally believed that greater control of Eurasian water milfoil is achieved at this time of year as it is in an active growth stage. In late summer of 2010, Onterra ecologists visited Deer Lake to examine the areas treated earlier that spring. To their dismay, they found very high water levels on the lake, making viewing of Eurasian water milfoil from the water's surface impossible.

In early spring of 2011, Onterra ecologists visited Deer Lake once again to examine the 2010 treatment areas for signs of Eurasian water milfoil growth. Only several scattered plants were observed in the lake. A late summer 2011 visit to the lake confirmed that Eurasian water milfoil presence had been knocked back considerably, with only several plants being located in the lake at this time (Map 6). This amount is not sufficient to warrant a 2012 herbicide treatment, which is in a sense good news. However, as discussed further in the Implementation Section, monitoring and some future control actions will be necessary to keep this invasive plant under control.

3.4 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. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2010 & GLIFWC 2010). Deer Lake is intermittently joined to a larger system of connected waterways called the Rice Reservoir which includes Bridge and Nokomis Lakes, as well as the Rice River Flowage. Available data is summarized for these connecting waterbodies as well.

Fishery

Based on data collected from the stakeholder survey (Appendix B), fishing was the second highest ranked important or enjoyable activity on Deer Lake (Question #9). Approximately 46% of these same respondents believed that the quality of fishing on the lake was fair, while the remaining 54% of respondents were split between responses of either “poor” and “excellent” (Question #7). Approximately 92% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Question #7).

Tables 3.4-1 and 3.4-2 show the popular game fish and non-game fish that are present in the system. In recent fish surveys, native cisco has been found in Deer Lake. According to WDNR fish biologist Dave Seibel this is the only Lincoln County lake that this species is present in, making it a unique aspect of the fishery. The species is especially sensitive to eutrophication, as it prefers deep, cold and well oxygenated waters (Becker 1983).

Table 3.4-1. Gamefish present in the Rice Reservoir 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 muskgrasses or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other inverts
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Bowfin	*Amia calva*	30	Late April - Early June	Vegetated areas from 2-5ft with soft rootlets, sand or gravel	Fish, crayfish, small rodents, snakes, frogs, turtles
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pikes, 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 (ter. and aq.)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1cm-1m deep	Crustaceans, insect larvae, and other inverts
Smallmouth Bass	*Micropterus dolomieu*	13	Mid May - June	Nests more common on North and West shorelines, over gravel	Small fish including other bass, crayfish, insects (aq. and ter)
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wave-washed 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 vegetation	Small fish, aquatic invertebrates

Table 3.4-2. Non-gamefish present in the Rice Reservoir.

Common Name	Scientific Name	Common Name	Scientific Name
Burbot	*Lota lota*	Shorthead Redhorse	*Moxostoma macrolepidotum*
Golden Shiner	*Notemigonus crysoleucas*	Silver Redhorse	*Moxostoma anisurum*
Logperch	*Percina caprodes*	White Sucker	*Catostomus commersoni*
Northern Hog Sucker	*Hypentelium nigricans*	Cisco*	*Coregonus artedii*

**Cisco found in Deer Lake only*

Management actions that have taken place and will likely continue on Deer Lake according to this plan include herbicide applications to control Eurasian water milfoil. In the future, these applications will occur in May when the water temperatures are below 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. Muskellunge is another species that may be impacted by early season treatments as water temperatures and spawning locations often overlap.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.4-1). Deer Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. GLIFWC and WDNR fisheries biologist believe that approximately 35% of a lake's walleye or muskellunge population can be removed annually without adversely affecting the ability of the population to maintain itself. This 35% exploitation rate is called the total allowable catch. The safe harvest level is set at approximately one third (33%) of the total allowable catch (GLIFWC 2010B). The six Wisconsin Chippewa Tribes declare a tribal quota based on a percent of the estimated safe harvest each year by March 15. The tribal declaration will influence the daily bag limits for hook-and-line anglers.

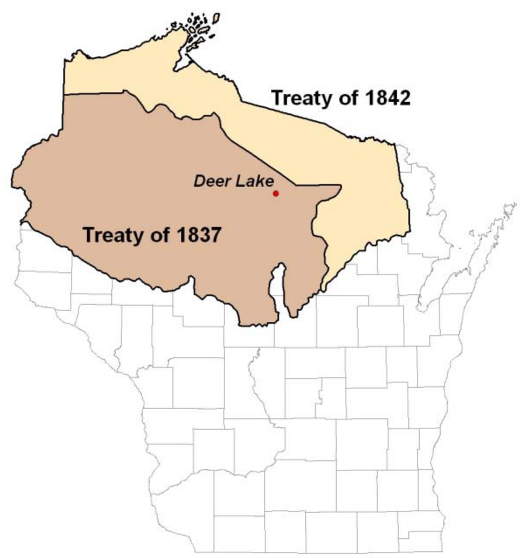

Figure 3.4-1. Location of Deer Lake within the Native American Ceded Territory (GLIFWC 2010A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2010B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly quota is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the quota is met or the season ends.

Although tribal spearers have declared a quota on Deer Lake in 2009 and also in years past, no harvest has been taken on either walleye or muskellunge. Walleye quotas are usually set at 53 to 56 fish while typically 2 or 3 muskellunge are declared for Deer Lake. Bridge Lake too has an annual tribal quota declared, but has not seen a harvest since spearing began. Harvest has occurred on the connecting Rice River Flowage, for walleye and occasionally for muskellunge, and a muskellunge spearing harvest does occur occasionally for Lake Nokomis as well. Open water spear harvest records for walleye in the Rice River Flowage are provided in Table 3.4-3 and Figure 3.4-2. One common misconception is that the spear harvest targets the large spawning females. Table 3.4-3 and Figure 3.4-2 clearly show that the opposite is true with only 8.6% of the total walleye harvest (401 of 4,655 fish) since 1998 comprising of female fish. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2007). This regulation limits the harvest of the larger, spawning female walleye.

Table 3.4-3. Spear harvest data of walleye for the Rice River Flowage (GLIFWC annual reports for the Rice River Flowage, Krueger 1998-2009).

Year	Tribal Quota	Tribal Harvest	% Quota	Mean Length (in)*	% Male	% Female	% Unknown
1998	781	781	100.0	13.7	87.6	6.5	5.9
1999	770	739	96.0	14.9	82.1	10.6	7.3
2000	785	773	98.5	15	89.3	5.6	5.1
2001	802	483	60.2	15.1	86.1	9.5	4.5
2002	731	721	98.6	15.3	86.3	8.4	5.4
2003	627	626	99.8	15.3	85.3	8.6	6.2
2004	806	771	95.7	14.6	88.3	6.8	4.9
2005	776	42	5.4	13.9	95.2	4.8	0.0
2006	779	746	95.8	14.9	83.5	11.5	5.0
2007	781	779	99.7	15.3	81.6	10.6	7.8
2008	776	734	94.6	15.1	80.1	16.1	3.8
2009	761	761	100.0	14.8	86.4	13.6	1.6

**Based on Measured Fish*

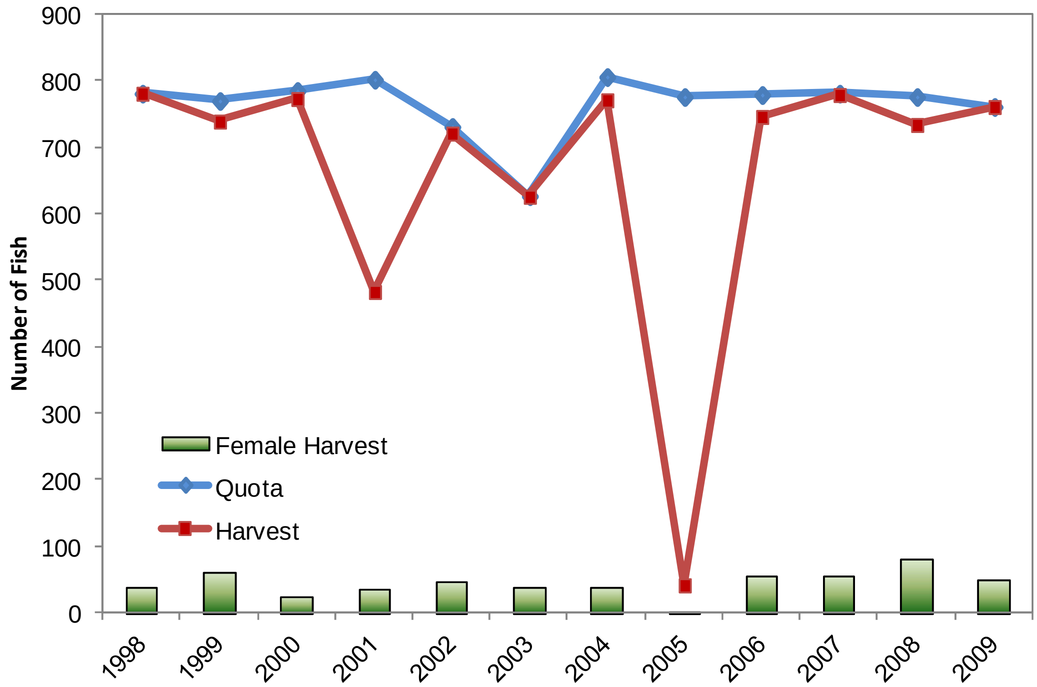

Figure 3.4-2. Walleye spear harvest data. Annual total walleye harvest and female walleye harvest are displayed since 1998 from GLIFWC annual reports for the Rice River Flowage (Krueger 1998-2009).

Table 3.4-4 displays the Native American open water muskellunge spear harvest since 1998. Muskellunge have not been taken harvested in Deer or Bridge Lake, however occasional spearing occurs in Lake Nokomis and the Rice River Flowage. In only seven of the past ten years has there been a harvest, with the highest harvest total being five fish in 1999.

Table 3.4-4. Spear harvest data of muskellunge for Lake Nokomis and the Rice River Flowage (GLIFWC annual reports for Lake Nokomis and the Rice River Flowage, Krueger 1998-2009).

Waterbody	Year	Tribal Quota	Tribal Harvest	% Quota	Mean Length (in)*
Lake Nokomis	1998	17	0	0.0	-
Lake Nokomis	1999	17	5	29.4	37
Lake Nokomis	2000	16	1	6.3	38.5
Lake Nokomis	2001	17	3	17.6	-
Lake Nokomis	2002	16	3	18.8	41.2
Lake Nokomis	2003	10	1	10.0	35
Lake Nokomis	2004	15	4	26.7	43
Lake Nokomis	2005	17	0	0.0	-
Lake Nokomis	2006	16	0	0.0	-
Lake Nokomis	2007	16	1	6.3	41.2
Lake Nokomis	2008	20	0	0	
Lake Nokomis	2009	20	5	25.0	40.9
Rice River Flowage	1998	9	1	11.1	38.2
Rice River Flowage	1999	9	1	11.1	34.6
Rice River Flowage	2000	8	0	0.0	-
Rice River Flowage	2001	8	0	0.0	-
Rice River Flowage	2002	8	0	0.0	-
Rice River Flowage	2003	4	0	0.0	-
Rice River Flowage	2004	8	0	0.0	-
Rice River Flowage	2005	9	0	0.0	-
Rice River Flowage	2006	9	0	0.0	-
Rice River Flowage	2007	9	0	0.0	-
Rice River Flowage	2008	11	0	0.0	-
Rice River Flowage	2009	11	0	0.0	-

**Based on Measured Fish*

Because Deer Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of muskellunge and walleye. Currently there are no special regulations for walleye in Deer Lake or the connecting waterbodies (Bridge Lake, Lake Nokomis, and Rice River Flowage). However, in these waterbodies a minimum length of 40” must be obtained in order to harvest muskellunge, which also has a bag limit of one per day.

Fish Stocking

In Deer Lake, walleye have been stocked periodically by the WDNR (Table 3.4-5) in an effort to influence their populations. Stocking has taken place for muskellunge in Lake Nokomis and the Rice River Flowage, but not in Deer Lake itself. Table 3.4-4 displays these stocking efforts for both species. In Deer Lake, walleye had been stocked to supplement natural reproduction. However through surveys performed in 2001 and 2006 it was determined that stocking was not improving walleye numbers, and the potential benefits were outweighed by the potential dangers of stocking fish (Dave Seibel, personal comm.). New challenges in fish stocking, particularly genetic concerns and the potential for introduction of invasive species, have surfaced which has resulted in managers reassessing stocking strategies. In the end, WDNR biologist Dave Seibel believes the Deer Lake fishery is strong, and naturally reproducing populations do not require the help of stocked fish at this time. The WDNR currently manages the lake for walleye, northern pike, muskellunge and panfish, all of which are supported through naturally reproduction.

Table 3.4-5. Fish stocking data available from the WDNR from 1982 to 2009 (WDNR 2010).

Waterbody	Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
Deer	1972	Walleye	Fingerling	5,000	5.00
Deer	1976	Walleye	Fingerling	30,000	2.00
Deer	1980	Walleye	Fingerling	4,666	5.00
Deer	1983	Walleye	Fingerling	7,600	3.00
Deer	1985	Walleye	Fingerling	7,600	3.00
Deer	1987	Walleye	Fingerling	21,000	4.00
Deer	1989	Walleye	Fingerling	15,200	2.50
Deer	1991	Walleye	Fry	7,640	2.00
Deer	1993	Walleye	Fingerling	7,696	2.00
Deer	1995	Walleye	Fingerling	7,605	2.30
Deer	1999	Walleye	Small Fingerling	15,200	1.40
Deer	2001	Walleye	Small Fingerling	15,200	1.70
Nokomis	1985	Muskellunge	Fingerling	2,500	10.00
Nokomis	1986	Muskellunge	Fingerling	3,000	11.67
Nokomis	1988	Muskellunge	Fingerling	2,503	10.00
Nokomis	1989	Muskellunge	Fingerling	1,300	11.00
Nokomis	1991	Muskellunge	Fingerling	1,330	11.00
Nokomis	1992	Muskellunge	Fingerling	3,800	10.48
Nokomis	1993	Muskellunge	Fingerling	3,800	12.00
Nokomis	1996	Muskellunge	Fingerling	3,196	11.60
Rice River Flowage	1991	Muskellunge	Fingerling	1,023	12
Rice River Flowage	1992	Muskellunge	Fingerling	1,100	10
Rice River Flowage	1993	Muskellunge	Fingerling	1,100	12
Rice River Flowage	1995	Muskellunge	Fry	100,000	0.4

Substrate

According to the point-intercept survey conducted by Onterra, 89% of the substrate sampled in the littoral zone on Deer Lake was sand, with 9% of the substrate classified as muck and only 2% being rocky (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. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so they do not get buried in sediment and suffocate. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

3.5 Deer Lake Outlet Channel

As described above, Deer Lake is a spring lake, which means that at times, the lake receives so much groundwater input that it actually looses water through an intermittent outlet. The outlet flows to Bridge Lake, which eventually flows into Lake Nokomis and over the Bradley Dam. The dam is owned and operated by WVIC. An operational license is granted by the Federal Energy Regulatory Commission to WVIC so it can store water in the Rice River Reservoir for subsequent release to maintain down river flows at constant rates for hydroelectric power generation. Deer Lake is unique in that often during spring runoff periods, when WVIC is filling the Rice River Reservoir, the water in Deer Lake's outlet reverses and water flows from Bridge Lake into Deer Lake. While this has increased Deer Lake's water levels in past years and has pleased Deer Lake riparians, it has had negative impacts on the channel itself.

Over the course of the past several years, a conspicuous sand delta has formed near the area where the outlet drains Deer Lake. Deltas are normally formed where rivers and streams enter larger bodies of water such as a lake. Flowing water has the capacity to carry a certain mass of sediment dependent upon its flow rate (velocity). As the flowing water enters the larger waterbody, the sediment drops out due to the decrease in velocity.

On September 21, 2009, Onterra staff visited Deer Lake to extract cores using a clear, plastic tube (Photographs 3.5-1 and 3.5-2). Cores were extracted from the delta formation discussed above and near a private boat landing on the southwest side of the lake. The delta core indicated that the natural organic-sand mixture present throughout the landing core was covered with approximately 13 inches of what appeared to be nearly pure sand. This indicates that the native sediments present near the lake's outlet have been covered with sand originating from the channel. Overall, this indicates that likely during WVIC filling operations when water flows from Bridge Lake to Deer Lake, the channel bottom is eroding, which of course means that the channel itself is getting deeper.

Photograph 3.5-1 (left) and 3.5-2 (right). Core samples drawn from Deer Lake sediment on September 21, 2009. Left photo was taken in delta formed on lake side of Deer Lake outlet on the north end of the lake and right photo taken near private landing on southwest side of lake. Left core indicates natural organic-sand mixture covered by sand eroding from outlet channel. Right core indicates natural organic-sand mixture throughout core.

Deer Lake is a natural spring lake that flows to the Rice River Reservoir. As described above, WVIC, stores water in the reservoir for future release. During normal spring refilling operations, Bridge Lake fills, overtops one of its inlets (Deer Lake outlet), and water is added to Deer Lake. It is unclear how much water is added to Deer Lake above and beyond its natural capacity as the Deer Lake channel outlet's maximum elevation at the time of the Bradley Dam's construction is not known. At that point in time, the elevation of the outlet channel set Deer Lake's maximum elevation (water level). Any water elevation added to Deer Lake's maximum water level, would essentially be the "property" of WVIC as its dam provided the additional volume to Deer Lake.

If the outlet channel elevation remained the same, then WVIC would only be able to withdraw water from Deer Lake equal to what it had added over the lake's natural volume. However, as described above, it is evident that the channel has eroded substantially over the course of the dam's life and as a result, WVIC is able to remove additional water volume from Deer Lake. In other words, WVIC has the ability to lower Deer Lake beyond its historical (natural) elevation.

Deer Lake stakeholders have voiced concern about water levels in the lake and attribute a part of that volume loss to the channel erosion (see stakeholder comments in returned surveys, Appendix B). To alleviate the water level issue brought on by the channel erosion, the Deer Lake District has strived to communicate its concerns to the WDNR and WVIC. On February 23, 2010, representatives from WVIC (Sam Morgan, Dave Coon, & Lon Hurder) and the WDNR (Keith Patrick) met with Phil Schlachtenhaufen, Deer Lake District Chair, and Tim Hoyman, an aquatic ecologist with Onterra, the district's lake management consultant. During the meeting, WVIC staff acknowledged that the channel is eroding and that they would support efforts to remediate the issue with the Deer Lake District. The WDNR staff member provided information regarding permitting needs, including the recommendation that a strong public participation effort should be part of the plan. WVIC also agreed that an appropriate channel elevation would be 1461 feet mean sea level.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Deer Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian water milfoil.
3) Develop a general understanding of changes that have occurred to Deer Lake's outlet channel leading to Bridge Lake and to create an initial plan to possibly remediate issues.
4) Collect sociological information from Deer Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

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

Overall, the studies that were completed on Deer Lake indicate that it is healthy in terms of its watershed and water quality. With the exception of the small colony of Eurasian water milfoil located in the lake, the aquatic plant community is also very healthy.

Deer Lake is a unique system in that it is truly a spring lake, but due to its geographical setting and connection with Bridge Lake through Deer's intermittent outlet, Deer frequently receives water from Bridge Lake, especially during the spring when WVIC is refilling the Rice River Reservoir. However, the majority of Deer's water arrives via groundwater, as evidenced by the lake's low watershed to lake area ratio of 1:1. Deer Lake's small watershed is comprised primarily of forested areas; therefore, any water that does enter the lake through surface flow contains minimal amounts of phosphorus. The healthy watershed, combined with the groundwater inputs, leads to great water quality in the lake itself.

Deer Lake's water quality compares well with other lakes in the area and, as expected, is better than most lakes in the state. Low in-lake phosphorus levels lead to low algal abundance and very good water clarity. Over 80% of stakeholders who responded to the survey ranked Deer Lake's current water quality as better than "Fair". This includes the 20% of respondents who believe the water quality is "Excellent". Unfortunately, insufficient historical data exists to dispute or support the fact that nearly 38% of respondents believe that water quality has degraded over time. Still, nearly half of the respondents believe that the water quality has remained the same. It should be noted that a reference timeframe is not provided within the stakeholder survey question dealing with changing water quality; therefore, it is possible that some of the respondents may be responding simply to the lower water levels Deer Lake has experienced in the past few years as opposed to actual degradation in the lake's water quality.

Deer Lake's quality plant community is evidenced by high species richness and diversity as well as by high average conservatism and floristic quality values. As mentioned above, Eurasian water milfoil was found to exist within Deer Lake; however, the occurrences are infrequent and control actions by the district are keeping the plant in check. Continued monitoring and occasional treatments will be necessary to control this exotic species in the coming years.

A great deal of concern was voiced during the public meetings associated with this project, as well as in the stakeholder survey, regarding the erosion of Deer Lake's outlet channel and the impacts the erosion has had on Deer Lake water levels. Evidence is presented in the Deer Lake Outlet Channel section above documenting the erosion. Further, WVIC has acknowledged the erosion and has stated that it will support the district in its actions to have the channel restored to higher elevation; albeit this support may not be financial. It appears as though the stage has been set for a restoration project on the outlet channel.

A general outline of the steps necessary to plan and implement the restoration of the channel is contained within the Implementation Plan below. It is beyond the scope of this project and the expertise of Onterra to expand beyond the outline. While it is true that the district is much further along in its quest to restore the channel than it has ever been, its members and other interested Deer Lake stakeholders must keep the following in mind:

1. The actual restoration of the channel to a historical elevation is the final step in a long sequence of steps that will likely take greater than 18 to 24 months to complete. There is a great deal of planning, design, and permitting work to be completed and that will require substantial time and effort.
2. Public participation will be an important part of the planning and permitting process. While the vast majority of Deer Lake riparian property owners would like to see the restoration occur, the district should expect that some members of the public will not want the restoration to occur because it will likely limit the days of the open water season of which boats can access Deer Lake from Bridge Lake.
3. The costs associated with planning, designing, and implementing may entirely or partially be borne by the district. It is likely that WDNR and other grants would be applicable to the planning and design aspects of the project, but the actual restoration may be outside the scope of many grants.
4. When the restoration occurs, not all water level issues will be alleviated on the lake. Deer Lake is a spring fed lake, during times of drought when ground water levels are down, Deer Lake's water levels will be low regardless of the channel elevation. During this project's studies (2009 & 2010), water levels were often well below the current channel elevation, so adding even 10 feet to the channel bottom would not have sustained raised the water levels in Deer Lake.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the DLD Planning Committee and ecologist/planners from Onterra. It represents the path the DLD will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Deer Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain Current Water Quality Conditions

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

Timeframe: Continuation of current effort.

Facilitator: Board of Directors

Description: Monitoring water quality is an import 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 developing. Volunteers from the DLD have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizen Lake Monitoring Program. Stability will be added to the program by selecting an individual from the DLD to coordinate the lake's volunteer efforts and to recruit additional volunteers to keep the program fresh. Additionally, trained volunteers will help assure that this important aspect of Deer Lake's management plan is implemented for years and decades to come.

Action Steps:

1. Board of Directors recruits volunteer coordinator from district.
2. Coordinator directs water quality monitoring program efforts and volunteers.
3. Volunteers collect data and coordinator/volunteers report results to WDNR and to association members during annual meeting.

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to Deer Lake.

Timeframe: Begin 2012

Facilitator: Deer Lake Planning Committee

Description: As the Watershed Section discusses, the Deer Lake watershed is in good condition; however, watershed inputs still need to be focused upon, especially in terms of the lakes's shoreland properties. These sources include faulty septic systems, shoreland areas that are maintained in an unnatural manner, and impervious surfaces. To reduce these impacts, the DLD will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include news letter articles and guest speakers at association meetings.

Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts. This effort, if it results in shoreland restorations, would not only reduce phosphorus inputs into Deer Lake, but would also increase the amount of quality habitat around the lake.

Action Steps:

1. Recruit facilitator.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Lincoln County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for association meetings.

Management Action: Complete Shoreland Condition Assessment as a part of next management plan update

Timeframe: Begin with next management plan

Facilitator: Deer Lake Planning Committee

Description: As discussed within this report, unnatural and developed shorelands can negatively impact the health of a lake, both by decreasing water quality conditions as well as removing valuable habitat for fish and other animal species that reside in and around the lake. Understanding the shoreland conditions around Deer Lake will serve as an educational tool for lake stakeholders as well as identify areas that would be suitable for restoration. Shoreland restorations would include both in-lake and shoreline habitat enhancements. In-lake enhancements would include the introduction of course woody habitat in the littoral zone, which is considered to be a valuable fisheries habitat component around the shorelines of Wisconsin lakes. Shoreline enhancements would include leaving 30-foot no-mow zones to act as a buffer between residences and the lake or by planting native herbaceous, shrub, and tree species as appropriate for Lincoln Couny in this sensitive area. Ecologically high-value areas delineated during the survey would also be selected for protection, possibly through conservation easements or land trusts (www.northwoodslandtrust.org).

Projects that include shoreline condition assessment and restoration activities will be better qualified to receive state funding in the future. These activities could be completed as an amendment to this management plan and would be appropriate for funding through the WDNR small-scale Lake Planning Grant program. Janet Brehm, Lincoln & Langlade Counties Shoreland Protection Specialist (715-539-1087) would be a valuable source for the Deer Lake District to contact regarding this matter. Her position includes assisting groups with shoreland enhancement project design and implementation as well as researching and initiating cost-sharing options.

Action Steps: See description above.

Management Goal 2: Control Eurasian Water Milfoil within Deer Lake

Management Action:

Timeframe: Begin 2012

Facilitator: Board of Directors

Description: As described in the Aquatic Plant section, Eurasian water milfoil was discovered by Onterra staff during July 2008. Since that time, two small herbicide treatments were completed and limited hand-removal has been conducted via rakes from the surface and scuba divers. Further, surveys have been completed during the springs and summers of 2009-2011 to monitor and map Eurasian water milfoil occurrences within Deer Lake. The control actions and monitoring were funded by two WDNR AIS Early Detection and Response Grants.

The latest survey completed by Onterra staff occurred on September 1, 2011 and located only a few occurrences of Eurasian water milfoil (Map 6). Based upon these results, no herbicide treatments were warranted for the spring of 2012 and possibly a few years into the future. However, monitoring and hand-removal efforts should continue on the lake to assure that Eurasian water milfoil does not get out of control. Trained volunteers are able to monitor light infestations of Eurasian water milfoil and hand-remove any findings. John Preuss, Lumberjack AIS Coordinator, is a knowledgeable and excellent resource for the training of interested volunteers.

Monitoring for AIS, especially Eurasian water milfoil, should take place two or more times at Deer Lake. If possible, findings should be documented with GPS coordinates for future reference. Further, those GPS coordinates should be documented within a log that contains a description of what was located at each GPS point collected. If the population remains light, as found in 2011, then hand-removal should be utilized for control. If dense populations are found, the district should contact professionals to assess the situation, map the Eurasian water milfoil, and provide guidance on control options. If applicable, a herbicide treatment should be scheduled to occur in the same manner as earlier treatments have occurred on Deer Lake.

Please note: At the levels that were detected during the writing of this management plan, it was felt that the group could handle the monitoring and the control on their own. If levels of EWM increase to the point where professional help is needed, or where large-scale herbicide treatments are required, the District would consider applying for an AIS Established Population Control grant. If this occurs, that project would be increased to include preventative measures such as CBCW educational topics and other pertinent components typically included within that type of project.

Action Steps:

1. Contact John Preuss (717.369.9886) to arrange for volunteer training session.
2. Trained volunteers then train additional volunteers to keep program fresh.
3. Complete surveys and hand-removal at least twice each growing season.
4. Report results of efforts to district at annual meetings.

Management Goal 3: Eliminate Low Water Levels within Deer Lake Brought on by Unnatural Occurrences.

Management Action: **Restore Deer Lake outlet channel to historical elevation.**
Timeframe: Begin 2011
Facilitator: Phil Schlachtenhaufen and Board of Directors
Description: The issues surrounding the erosion of the Deer Lake outlet channel are described in both the Deer Lake Outlet Channel section and within the Summary and Conclusions. The management action outlines the basic steps required to plan and design the restoration project. Actual design specifications would need to be created by a fluvial geomorphologist (stream restoration engineer). WDNR Lake Management Planning Grants and Lake Management Protection Grants (under the Diagnostic/Feasibility Study category) may be applicable to help fund this portion of the management plan.

Action Steps:

1. Obtain an elevation level of the outlet as it is today for future references.
2. Preliminary restoration design and cost estimate created by qualified professional.
   a. Preliminary design shared with WDNR and WVIC for comments and guidance.
   b. District uses estimate to determine if implementation of channel restoration is feasible.
3. Public information hearing facilitated by district.
   a. The purpose of this meeting is to inform the public of the district's intent to restore Deer Lake's outlet channel to a historical level to assist in maintaining natural water levels in Deer Lake.
   b. The meeting will include a presentation of the preliminary design and cost estimate and an accurate indication of how access between Deer Lake and Bridge Lake will be impacted by restoration. This portion of the presentation will include information available from WVIC that would use historical water levels to compare the number of days during each open-water season that would allow boat navigation in the channel before and after the restoration.
   c. This information hearing will be part of the WDNR (Chapter 30) permitting process; therefore, the district will contact WDNR regulatory staff to assure that the meeting will meet all requirements.
4. Complete Chapter 30 permitting process with WDNR.
5. Complete final restoration design and cost estimate.
   a. This may be required in order to begin the Chapter 30 permitting process.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Deer Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll a	●		●		●		●		●			
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●	●	●	●	●	●	●	●	●	●	●
Calcium	●											

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 5.

Watershed Analysis

The watershed analysis began with an accurate delineation of Deer Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the 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 Deer Lake during a July 2008 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 Deer 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 July 30, 2008. A point spacing of 53 meters was used resulting in approximately 218 points.

Community Mapping

During the species inventory work, the aquatic vegetation community types within Deer 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 Deer Lake District.

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