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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY AUTHORS</td>
<td>3</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>3</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>5</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>6</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>6</td>
</tr>
<tr>
<td>DEER LAKE STUDY RESULTS</td>
<td>7</td>
</tr>
<tr>
<td>WAUSHARA COUNTY LAKES STUDY BACKGROUND</td>
<td>7</td>
</tr>
<tr>
<td>ABOUT DEER LAKE</td>
<td>7</td>
</tr>
<tr>
<td>WHERE IS THE WATER COMING FROM? - WATERSHEDS AND LAND USE</td>
<td>8</td>
</tr>
<tr>
<td>DEER LAKE SURFACE WATERSHED</td>
<td>9</td>
</tr>
<tr>
<td>DEER LAKE GROUNDWATER WATERSHED</td>
<td>10</td>
</tr>
<tr>
<td>WATER QUALITY</td>
<td>11</td>
</tr>
<tr>
<td>AQUATIC PLANTS</td>
<td>17</td>
</tr>
<tr>
<td>SHORELANDS</td>
<td>21</td>
</tr>
<tr>
<td>CONCLUSIONS AND RECOMMENDATIONS</td>
<td>23</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>25</td>
</tr>
<tr>
<td>GLOSSARY OF TERMS</td>
<td>26</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

FIGURE 1. LAND USE IN THE DEER LAKE SURFACE WATERSHED ................................................................. 9
FIGURE 2. GROUNDWATER FLOW DIRECTION NEAR DEER LAKE ................................................................. 10
FIGURE 3. CARTOON SHOWING INFLOW AND OUTFLOW OF WATER IN A SEEPAGE LAKE. ................................................................. 11
FIGURE 4. TEMPERATURE PROFILES IN DEER LAKE, 2010-2012 ................................................................. 13
FIGURE 5. DISSOLVED OXYGEN PROFILES IN DEER LAKE, 2010-2012 ................................................................. 13
FIGURE 6. WATER CLARITY IN DEER LAKE, 2010-2012 AND HISTORIC ................................................................. 14
FIGURE 7. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE DEER LAKE WATERSHED ................................................................. 15
FIGURE 8. ABUNDANCE OF AQUATIC PLANTS AT EACH SAMPLING SITE IN DEER LAKE, JULY 2011 ................................................................. 17
FIGURE 9. NUMBER OF AQUATIC PLANT SPECIES OBSERVED AT EACH SAMPLE SITE IN DEER LAKE, JULY 2011 ................................................................. 19
FIGURE 10. OVERALL SHORELAND HEALTH AROUND DEER LAKE, JULY 2011 ................................................................. 22

LIST OF TABLES

TABLE 1. MINERALS AND PHYSICAL MEASUREMENTS IN DEER LAKE, 2010-2012 ................................................................. 11
TABLE 2. DEER LAKE AVERAGE WATER CHEMISTRY, 2010-2012 ................................................................. 12
TABLE 3. SEASONAL SUMMARY OF NUTRIENT CONCENTRATIONS IN DEER LAKE, 2010-2012 ................................................................. 15
TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES IN THE DEER LAKE WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO CALCULATE RANGE IN POUNDS) ................................................................. 16
TABLE 5. LIST OF AQUATIC PLANTS IDENTIFIED IN THE 2011 AQUATIC PLANT SURVEY OF DEER LAKE ................................................................. 18
TABLE 6. DISTURBANCES WITHIN 15 FEET OF SHORE AROUND DEER LAKE, 2011 ................................................................. 21
DEER LAKE STUDY RESULTS

WAUSHARA COUNTY LAKES STUDY BACKGROUND

Lakes and rivers contribute to the way of life in Waushara County. Local residents and visitors alike enjoy fishing, swimming, boating, wildlife viewing, and the peaceful nature of the lakes. Healthy lakes add value to our communities. They provide places to relax and recreate, and they can stimulate tourism. Like other infrastructure in our communities, lakes require attention and good management practices to remain healthy in our developing watersheds.

Thirty-three lakes in Waushara County were selected for this study. The study focused on learning about the lakes’ water quality, aquatic plant communities, shoreland habitats, watersheds and histories in order to help people make informed lake management decisions. This report summarizes data collected for Deer Lake between fall 2010 and fall 2012.

ABOUT DEER LAKE

To understand a lake and its potential for water quality, fish and wildlife, and recreational opportunities, we need to understand its physical characteristics and setting within the surrounding landscape. The lake is located in the township of Marion, southeast of the city of Wautoma, and south of Highway 21, with one public boat launch located on its northern side. Deer Lake is a 15-acre seepage lake with surface runoff and groundwater contributing most of its water. The maximum depth in Deer Lake is 14 feet; the lakebed has a gradual slope with most of the lake’s depth averaging 5 feet (WDNR). The residence time is estimated to be 2 months. The residence time helps determine the potential effects of contaminants entering the lake and plays a role in the duration that pollutants may stay in the lake. Its bottom sediments are predominantly muck, with a small area of sand along the southeastern perimeter of the lake.
The water quality in Deer Lake is a reflection of the land that drains to it. The water quality, the amount of algae, aquatic plants, the fishery and other animals in the lake are all affected by natural and manmade characteristics. Natural characteristics that affect a lake include the amount of land that drains to the lake, the hillyness of the landscape, types of soil, extent of wetlands, and the type of lake. Within the lake’s watershed, alterations to the landscape, the types of land use, and the land management practices are examples of how people may affect the lake.

It is important to understand where Deer Lake’s water originates in order to understand the lake’s health. During snowmelt or a rainstorm, water moves across the surface of the landscape (runoff) towards lower elevations such as lakes, streams, and wetlands. The land area that contributes runoff to Deer Lake is called a surface watershed. Groundwater also feeds Deer Lake; its land area may be slightly different than the surface watershed. The surface watershed is shown in Figure 1.

The capacity of the landscape to shed or hold water and contribute or filter particles determines the amount of erosion that may occur, the amount of groundwater feeding a lake, and ultimately, the lake’s water quality and quantity. Essentially, landscapes with a greater capacity to hold water during rain events and snowmelt help to slow the delivery of the water to the lake. Minimizing excess runoff is desirable because it allows more water to recharge the groundwater, which feeds the lake year-round - even during dry periods or when the lake is covered with ice.

Land use and land management practices within a lake’s watershed can affect both its water quantity and quality. While forests and grasslands allow a fair amount of precipitation to soak into the ground, resulting in more groundwater and better water quality, other types of land uses may result in increased runoff and less groundwater recharge, and may be sources of pollutants that can impact the lake and its inhabitants. Areas of land with exposed soil can produce soil erosion. Soil entering the lake can make the water cloudy and cover fish spawning beds. Soil also contains nutrients that increase the growth of algae and aquatic plants. Development on the land often results in changes to natural drainage patterns, alterations to vegetation on the landscape, and may be a source of pollutants. Impervious (hard) surfaces such as roads, rooftops, and compacted soil prevent rainfall from soaking into the ground, which may result in more runoff that carries pollutants to the lake. Wastewater, animal waste, and fertilizers used on lawns, gardens and crops can contribute nutrients that can enhance the growth of algae and aquatic plants in our lakes.

A variety of land management practices can be put in place to help reduce impacts to our lakes. Some practices are designed to reduce runoff. These include protecting/restoring wetlands, installing rain gardens, swales, rain barrels, and routing drainage from pavement and roofs away from the lake. Some practices are used to help reduce nutrients from moving across the landscape towards the lake. Examples include manure management practices, eliminating/reducing the use of fertilizers, increasing the distance between the lake and a septic drainfield, protecting/restoring native vegetation in the shoreland, and using erosion control practices. Waushara County staff and other professionals can work with landowners to determine which practices are best suited to a particular property.
The surface watershed for Deer Lake is approximately 1,159 acres (Figure 1). The dominant types of land use in the watershed are forest (49%), developed land (30%), and agriculture (13%). The land closest to the lake often has the greatest impact on water quality and habitat; Deer Lake’s shoreland is surrounded primarily by forests and wetlands.

**Figure 1. Land use in the Deer Lake surface watershed.**
The more the lake’s water interacts with groundwater, the more influence the geology has on the lake. The length of time water remains below ground affects the temperature and chemistry of the groundwater. Groundwater temperature is near constant year round; during the summer, groundwater feeding Deer Lake will help keep the lake water cooler.

Groundwater flows below ground from higher to lower elevations, discharging into wetlands, streams, and lakes. The groundwater feeding the lakes in Waushara County originates nearby. The black arrows in Figure 2 indicate the general direction of groundwater flow. Much of the groundwater enters Deer Lake from the northwest.

**Figure 2. Groundwater flow direction near Deer Lake.**
Lake water quality is a result of many factors including the underlying geology, the climate, and land management practices. Assessing lake water quality allows us to evaluate current lake health and changes from the past. We can then identify what is needed to achieve a more desirable state or preserve an existing state for aesthetics, recreation, wildlife and the fishery. During this study, water quality in Deer Lake was assessed by measuring different characteristics including temperature, dissolved oxygen, water clarity, water chemistry, and algae.

The source of a lake’s water supply is important in determining its water quality and choosing management practices to preserve or influence that quality. Deer Lake is classified as a seepage lake, or a lake that receives its water primarily through groundwater, and, to a lesser extent, direct runoff and precipitation (Figure 3). Seepage lakes have higher concentrations of minerals that are picked up by groundwater moving through soil and rock. The water in Deer Lake is considered hard, which allows it to be more productive, hosting a greater variety of fish and other aquatic biota than softer counterparts. Seepage lakes are generally more vulnerable to contamination moving towards the lake in the groundwater. Examples for Deer Lake may include septic systems, agriculture, and road salt.

The geologic composition that lies beneath a lake has the ability to influence the acidity, minerals, and other properties in a lake. As water soaks into the ground, some substances are filtered out, but some materials in the soil dissolve into the groundwater. Minerals such as calcium and magnesium in the soil around Deer Lake are dissolved in the water, making the water hard. The average hardness concentration for Deer Lake during the 2010-2012 sampling period was 120 mg/L (Table 1). Hard water provides calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 121 mg/L; higher alkalinity in inland lakes can support greater species productivity. Hardness and alkalinity also play roles in the type and abundance of aquatic plants that are found in a lake (Shaw et al., 2000; Wetzel, 2001).

**Figure 3. Cartoon showing inflow and outflow of water in a seepage lake.**

**Table 1. Minerals and physical measurements in Deer Lake, 2010-2012.**

<table>
<thead>
<tr>
<th>Deer Lake</th>
<th>Alkalinity (mg/L)</th>
<th>Calcium (mg/L)</th>
<th>Magnesium (mg/L)</th>
<th>Hardness (mg/L as CaCO₃)</th>
<th>Color (SU)</th>
<th>Turbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Value</td>
<td>121</td>
<td>25.0</td>
<td>15.3</td>
<td>120</td>
<td>19.5</td>
<td>2.45</td>
</tr>
</tbody>
</table>
Chloride concentrations, and to a lesser degree sodium and potassium concentrations, are commonly used as indicators of how a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates sources of water contaminants.

Water in Deer Lake had moderate average chloride concentrations and high average sodium concentrations over the monitoring period (Table 2). Although these concentrations are not harmful to aquatic organisms, they indicate that pollutants from land management activities are entering the lake. Chloride and sodium sources include animal waste, septic systems, fertilizer, and road-salting chemicals. Potassium concentrations were low and Atrazine, an herbicide commonly used on corn, was below the detection limit (<0.01 µg/L DACT) in the samples that were analyzed from Deer Lake.

<table>
<thead>
<tr>
<th>Deer Lake</th>
<th>Average Value</th>
<th>Reference Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Medium High</td>
<td>Low Medium High</td>
</tr>
<tr>
<td>Potassium (mg/L)</td>
<td>0.55</td>
<td>&lt;.75 0.75-1.5 &gt;1.5</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>7.2</td>
<td>&lt;3 3.0-10.0 &gt;10</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>4.3</td>
<td>&lt;2 2.0-4.0 &gt;4</td>
</tr>
</tbody>
</table>

Dissolved oxygen is an important measure in aquatic ecosystems because a majority of organisms in the water depend on oxygen to survive. Oxygen is dissolved into the water from contact with the air, which is increased by wind and wave action. Algae and aquatic plants also produce oxygen when sunlight enters the water, but the decomposition of dead plants and algae reduces oxygen in the lake. Some forms of iron and other metals carried by groundwater can also consume oxygen when the groundwater discharges to the lake.

In a lake, the water temperature changes throughout the year and may vary with depth. During winter and summer when lakes stratify (layer), the amount of dissolved oxygen is often lower towards the bottom of the lake. Dissolved oxygen concentrations below 5 mg/L can stress some species of cold water fish and over time can reduce the amount of available habitat for sensitive cold water species of fish and other aquatic organisms.

Water temperature and dissolved oxygen were measured in Deer Lake from top to bottom at the time of sample collection during the 2010-2012 study. During most of the year, temperatures in Deer Lake were fairly constant from top to bottom (Figure 4). For much of the year, dissolved oxygen profiles showed relatively constant concentrations throughout the upper six to eight feet of the water column (Figure 5). Concentrations of dissolved oxygen decreased below those depths. This is typical of many lakes in Wisconsin. Dissolved oxygen concentrations measured in Deer Lake on February 5, 2012 were low throughout much of the lake. Only the sample point at the lake’s surface had concentrations above 5 mg/L. This low oxygen limits the fish species that are able to survive in the lake. During years with a long period of ice and/or snow cover, fish kills are likely to occur without additional life support by aeration.
Water clarity is a measure of the depth that light can penetrate into the water. It is an aesthetic measure and is also related to the depth that rooted aquatic plants can grow. Water clarity is affected by water color, turbidity (suspended sediment), and algae, so it is normal for water clarity to change throughout the year and from year to year.

The water clarity measured in Deer Lake during the study was considered good. September had the clearest water on average and the poorest average water clarity occurred in November (Figure 6). Prior to the study, only one observation was reported; therefore, water quality trends cannot be evaluated. In Deer Lake...
Lake, color (staining) was relatively low (Table 1), indicating that the variability in water clarity throughout the year is primarily due to fluctuating concentrations of algae and re-suspended sediments following storms or strong winds.

![Deer Lake Secchi Depth](image)

**Figure 6. Water clarity in Deer Lake, 2010-2012 and historic.**

Chlorophyll *a* is a measurement of algae in the water. Chlorophyll *a* concentrations in Deer Lake varied only slightly throughout the monitoring period, ranging from a high of 1.7 µg/L to a low 0.9 µg/L. The average for the monitoring period was 1.7 µg/L, which is low.

Nutrients (phosphorus and nitrogen) are used by algae and aquatic plants for growth. Phosphorus is present naturally throughout the watershed in soil, plants, animals, and wetlands. Common sources from human activities include soil erosion, animal waste, fertilizers, and septic systems.

It is most common for phosphorus to move from the land to the water through surface runoff, but it can also travel to the lake with groundwater. Once in a lake, a portion of the phosphorus becomes part of the aquatic system in the forms of plant tissue, animal tissue, and sediment. Once in the lake, the phosphorus can continue to cycle within the lake for many years.

Total phosphorus concentrations for Deer Lake ranged from a high of 42 µg/L in November 2010 to a low of 15 µg/L in June 2011 (Table 3). Summer median total phosphorus concentrations were 22 µg/L and 18 µg/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus standard of 40 µg/L for shallow seepage lakes such as Deer Lake, but above the proposed flag value of 15 µg/L.
Table 3. Seasonal summary of nutrient concentrations in Deer Lake, 2010-2012.

<table>
<thead>
<tr>
<th>Deer Lake</th>
<th>Inorganic Nitrogen (mg/L)</th>
<th>Organic Nitrogen (mg/L)</th>
<th>Total Nitrogen (mg/L)</th>
<th>Soluble Reactive Phosphorus (µg/l)</th>
<th>Total Phosphorus (µg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min Avg Max</td>
<td>Min Avg Max</td>
<td>Min Avg Max</td>
<td>Min Avg Max</td>
<td>Min Avg Max</td>
</tr>
<tr>
<td>Fall</td>
<td>0.01 0.01 0.01</td>
<td>1.11 1.11 1.11</td>
<td>1.12 1.12 1.12</td>
<td>10 10 10</td>
<td>42 42 42</td>
</tr>
<tr>
<td>Spring</td>
<td>0.07 0.09 0.10</td>
<td>0.63 0.69 0.75</td>
<td>0.76 0.82 0.87</td>
<td>5 5 5</td>
<td>20 26 31</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td></td>
<td>0.72 0.72 0.72</td>
<td></td>
<td>11 20 32</td>
</tr>
<tr>
<td>Winter</td>
<td>0.02 0.02 0.02</td>
<td>0.89 0.89 0.89</td>
<td>1.03 1.03 1.03</td>
<td>3 3 3</td>
<td>23 23 23</td>
</tr>
</tbody>
</table>

Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Deer Lake. Land use in the surface watershed was evaluated and used to populate the Wisconsin Lakes Modeling Suite (WILMS) model. In general, each type of land use contributes different amounts of phosphorus in runoff and through groundwater. The types of land management practices that are used and their distances from the lake also affect the contributions to the lake from a parcel of land. Based on modeling results, agriculture and developed land had the greatest percentages of phosphorus contributions from the watershed to Deer Lake (Figure 7). The phosphorus contributions by land use category, called phosphorus export coefficients, are shown in Table 4. The phosphorus export coefficients have been obtained from studies throughout Wisconsin (Panuska and Lillie, 1995).

![Phosphorus Loading (% in Deer Lake Surface Watershed)](image_url)

**Figure 7. Estimated phosphorus loads from land uses in the Deer Lake watershed.**
Table 4. Modeling data used to estimate phosphorus inputs from land uses in the Deer Lake Watershed (low and most likely coefficients used to calculate range in pounds).

<table>
<thead>
<tr>
<th>Deer Lake Land Use</th>
<th>Phosphorus Export Coefficient (lbs/acre-yr)</th>
<th>Land Use Area Within the Watershed</th>
<th>Estimated Phosphorus Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Acres</td>
<td>Percent</td>
</tr>
<tr>
<td>Water</td>
<td>0.1</td>
<td>93</td>
<td>8</td>
</tr>
<tr>
<td>Developed</td>
<td>0.04</td>
<td>320</td>
<td>28</td>
</tr>
<tr>
<td>Barren/Herbaceous/Wetland</td>
<td>0.09</td>
<td>88</td>
<td>8</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>525</td>
<td>45</td>
</tr>
<tr>
<td>Cultivated Agriculture</td>
<td>0.45</td>
<td>133</td>
<td>12</td>
</tr>
</tbody>
</table>

*Values are not exact due to rounding and conversion.
AQUATIC PLANTS

Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, amphibians, as well as invertebrates and other aquatic animals. They improve water quality by releasing oxygen into the water and utilizing nutrients that would otherwise be used by algae. A healthy lake typically has a variety of aquatic plant species which creates diversity that makes the aquatic plant community more resilient and can help to prevent the establishment of non-native aquatic species.

During the 2011 aquatic plant survey of Deer Lake, ninety-six percent (64) of the 67 sampled sites had vegetative growth. Of the sampled sites within Deer Lake, the average depth was 8 feet and the maximum depth was 15.5 feet. The abundance of aquatic plants was estimated at each site based on the amount of plant material on the sampling rake. Aquatic plants were dense at many of the sites in the primary lobe of the lake (Figure 8).

Figure 8. Abundance of aquatic plants at each sampling site in Deer Lake, July 2011.
Thirteen species of aquatic plants were found in Deer Lake (Table 5). Figure 9 shows the number of species that were identified at each sampling site. The greatest plant species diversity was found in the northwestern and southeastern parts of the lake.

The dominant plant species in Deer Lake during the survey was southern naiad (*Najas guadalupensis*), followed by floating-leaf pondweed (*Potamogeton natans*) and muskgrass (*Chara* spp.). Southern naiad provides shelter and grazing sites for fish, and muskrats and waterfowl feed on the plant and on the numerous invertebrates that use it as habitat. The fruit of floating-leaf pondweed is a valuable food source for waterfowl, and the submersed plant offers shade and foraging opportunities for fish. Muskgrass is a favorite food source for a wide variety of waterfowl, and muskgrass beds offer cover and food for fish, especially young trout, largemouth bass, and smallmouth bass (Borman et al., 2001).

**Table 5. List of aquatic plants identified in the 2011 aquatic plant survey of Deer Lake.**

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Coefficient of Conservatism Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Shoenoplectus tabermaemontani</em></td>
<td>softstem bulrush</td>
<td>4</td>
</tr>
<tr>
<td><strong>Floating Leaf Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Brasenia schreberi</em></td>
<td>watershield</td>
<td>6</td>
</tr>
<tr>
<td><em>Nuphar variegata</em></td>
<td>spatterdock</td>
<td>6</td>
</tr>
<tr>
<td><em>Nymphaea odorata</em></td>
<td>white water lily</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton natans</em></td>
<td>floating-leaf pondweed</td>
<td>5</td>
</tr>
<tr>
<td><strong>Submergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chara</em> spp.</td>
<td>muskgrass</td>
<td>7</td>
</tr>
<tr>
<td><em>Najas guadalupensis</em></td>
<td>southern naiad</td>
<td>8</td>
</tr>
<tr>
<td><em>Potamogeton gramineus</em></td>
<td>variable pondweed</td>
<td>7</td>
</tr>
<tr>
<td><em>Potamogeton illinoensis</em></td>
<td>Illinois pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton praelongus</em></td>
<td>white-stem pondweed</td>
<td>8</td>
</tr>
<tr>
<td><em>Potamogeton pusillus</em></td>
<td>small pondweed</td>
<td>7</td>
</tr>
<tr>
<td><em>Utricularia gibba</em></td>
<td>creeping bladderwort</td>
<td>9</td>
</tr>
<tr>
<td><em>Utricularia vulgaris</em></td>
<td>common bladderwort</td>
<td>7</td>
</tr>
</tbody>
</table>
Figure 9. Number of aquatic plant species observed at each sample site in Deer Lake, July 2011.
The Floristic Quality Index (FQI) evaluates the closeness of a plant community to undisturbed conditions. Each plant is assigned a coefficient of conservatism (C-value) that reflects its sensitivity to disturbance. These numbers are used to calculate the FQI. C-values range from 0 to 10. The higher the number, the more intolerant the plant is of disturbance. A C-value of zero is assigned to non-native species. The C-values in Deer Lake ranged from 4 to 9, with an average C-value of 6.6 (Table 5). Species with C-values of eight or higher are highly desirable. The FQI for Deer Lake in 2011 was 23.9. The average FQI for all lakes in the Waushara County Lakes Study was 23.2. No listed species of special concern in Wisconsin were found in Deer Lake; however, species with C-values of eight or higher indicate good conditions exist in parts of Deer Lake.

The Simpson Diversity Index (SDI) quantifies biodiversity of the aquatic plant community based on a formula that uses the number of species surveyed and the number of individuals per site. The SDI uses a decimal scale from zero to one. Values closer to one represent higher amounts of biodiversity. Deer Lake had an SDI value of 0.85, which represents above average biodiversity when compared to all of the other lakes in the Waushara County Lakes Study.

According to the WDNR, Eurasian watermilfoil (EWM) was confirmed in Deer Lake in 2008. It was not identified at any sites in Deer Lake during the 2011 survey of aquatic plants; however, it was observed at several sites in the southeast part of the lake during a June 2013 survey conducted by staff from Golden Sands Resource Conservation & Development Council, Inc. EWM may grow in dense beds that could potentially damage boat motors, make areas less navigable, stunt or alter the fishery, create problems with dissolved oxygen, and affect activities like fishing and swimming. This plant can produce a viable seed; however, its primary mode of reproduction and spread is fragmentation. A one-inch fragment is enough to start a new plant, making EWM very successful at reproducing.

Overall, the aquatic plant community in Deer Lake can be characterized as having above average diversity when compared to all of the other lakes in the Waushara County Lakes Study and showing minimal signs of impact from development as indicated by the presence of numerous high quality (high C-value) aquatic plants. The habitat, food source, and water quality benefits offered by the plant community within Deer Lake should be the focal points of future lake management strategies.
SHORELANDS

Shoreland vegetation is critical to a healthy lake ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. It also helps to improve the quality of the runoff that is flowing across the landscape towards the lake. Healthy shoreland vegetation includes a mix of tall grasses/flowers, shrubs and trees which extend at least 35 feet landward from the water’s edge.

To better understand the health of the Waushara County lakes, shorelands were evaluated by professionals from the Center for Land Use Education and Waushara County as a part of the Waushara County Lakes Study. The survey inventoried the type and extent of shoreland vegetation. Areas with erosion, rip-rap, barren ground, sea walls, structures and docks were also inventoried.

A scoring system was developed for the collected data to provide a more holistic assessment. Healthy areas need strategies to keep them healthy, and areas with potential problem areas and where management and conservation may be warranted need different strategies for improvement. The scoring system is based on the presence/absence and abundance of shoreline features, as well as their proximity to the water’s edge. Values were tallied for each shoreline category and then summed to produce an overall score. Higher scores denote a healthier shoreline with good land management practices. These are areas where protection and/or conservation should be targeted. On the other hand, lower scores signify an ecologically unhealthy shoreline. These are areas where management and/or mitigation practices may be desirable for improving water quality.

The summary of scores for shorelands around Deer Lake is displayed in Figure 10. The shorelands were color-coded to show their overall health based on natural and physical characteristics. Blue shorelands identify healthy shorelands with sufficient vegetation and few disturbances. Red shorelands indicate locations where changes in management or mitigation may be warranted. Large stretches of Deer Lake’s shorelands were in good shape, but some portions had challenges that may still need to be addressed.

There were no stretches of Deer Lake shoreland ranked as poor. A summary of shoreland disturbances is displayed in Table 6. For a more complete understanding of the ranking, an interactive map showing results of the shoreland surveys can be found on Waushara County’s website at http://gis.co.waushara.wi.us/ShorelineViewer/.

Table 6. Disturbances within 15 feet of shore around Deer Lake, 2011.
Figure 10. Overall shoreland health around Deer Lake, July 2011.
CONCLUSIONS AND RECOMMENDATIONS

In general, Deer Lake had good water quality. The watershed had a fair amount of forests (49%) and developed land (30%). If properly managed, forests help to provide good water to lakes both in terms of surface runoff and abundant groundwater with good water quality. Much of the developed land was comprised of a golf course. Typical management practices at golf courses include heavy applications of nutrients (nitrogen and phosphorus) and pesticides/herbicides. Fortunately, newer, more sustainable management techniques are known and could be utilized at this facility.

- Groundwater is the primary source of water to Deer Lake, with much of it originating in forested land that provides good quality groundwater.
- The hardness of the water in Deer Lake (from calcium in groundwater) helps to reduce the availability of phosphorus for use by algae and aquatic plants. If increased development, agriculture, and/or other land uses occur in the watershed that lead to nutrient loading, it is possible for a lake to receive more phosphorus than the hardness can control. Once this threshold is exceeded, phosphorus may become available for algal blooms and increased growth of aquatic plants. Therefore, measures should be put in place that will ensure that impacts to Deer Lake from any future land use changes in the watershed will be minimized.
- Currently, the abundant aquatic plant growth helps tie up phosphorus during the summer, making it less available for use by algae.
- Dissolved oxygen concentrations can become problematic during the winter and may cause fish kills during some years. On February 5, 2011, the monitored concentrations were at stressful levels below the upper two feet of water. While Deer Lake can naturally support a fishery with species that tolerate low concentrations of dissolved oxygen, it is inadvisable to introduce fish that cannot tolerate low dissolved oxygen unless additional life support options such as aeration are in place.
- Routine monitoring for water clarity, phosphorus, and chlorophyll a (a measure of algae) should be done to evaluate changes in water quality in Deer Lake over time.
- The Waushara County Land Conservation Department and Natural Resources Conservation Service (NRCS) have professional staff available to assist landowners interested in learning how they can improve water quality through adjustments in land management practices.

Healthy shorelands provide better water quality and habitat that is critical for frogs, turtles, birds, and other small animals. Based on the 2011 shoreland inventory, much of the shoreland around Deer Lake was in good condition, providing good habitat and water quality to the lake and its inhabitants. A few stretches would benefit from efforts to restore them to healthier conditions. Sedimentation and excessive nutrient inputs accelerate algae and aquatic plant growth in the lake. Some erosion and sedimentation occur naturally in the watershed, but they may be increased by shoreline disturbance and application of fertilizer and other chemicals.

- Strategies should be developed to ensure that the healthy shorelands remain intact and efforts should be made to improve stretches of shorelands that have disturbance. Depending upon the source of disturbance, erosion should be controlled, vegetation should be restored, and/or excess runoff should be minimized.
- Dissemination of relevant information to property owners is the recommended first step towards maintaining healthy shorelands.
- The Waushara County Land Conservation Department has professional staff available to assist shoreland property owners interested in learning how they can improve water quality through changes in land management practices.
- Property owners interested in protecting undisturbed shoreland may wish to consider a conservation easement for some of their land. Conservation easements allow property owners to determine how their land will be managed and which parts of the property will be protected, typically resulting in lower taxes. Unless public funds are used for the purchase of the easement, there is no requirement to allow access to the public.

The aquatic plant community in Deer Lake appeared to be quite healthy and quite resilient. Several high quality species of aquatic plants were present in the lake, including southern naiad (*Najas guadalupensis*), white stem pondweed (*Potamogeton praelongus*), and creeping bladderwort (*Utricularia gibba*). Aquatic plants were abundant in parts of Deer Lake, which is to be expected with its shallow depth. Measures should be taken to reduce inputs of sediment and phosphorus from near shore and watershed land management activities in order to prevent additional aquatic plant or algal growth which could become problematic in this lake.

- Eurasian watermilfoil (EWM) was identified in Deer Lake in 2009. The 2013 aquatic plant survey suggested that Deer Lake now hosts a type of milfoil that is a hybridized form of the native northern milfoil and the non-native EWM. Chemical treatments are less effective with hybridized milfoil, so hand pulling (with divers, if necessary) is recommended to keep this plant in check in Deer Lake. The amount of disturbed lake bed from raking or pulling of plants should be minimized, since these open spaces are ideal for the establishment of aquatic invasive plants.
- The presence of EWM in the lake is a clear indication that aquatic invasive species are able to make their way into Deer Lake. Lake residents and lake users should be made aware of boat and trailer hygiene techniques to prevent the introduction of new species. Deer Lake has a relatively small population, so it may be beneficial to work on collaborative efforts with other organizations in the county to inform the public about the presence of aquatic invasive plants and proper hygiene techniques.
REFERENCES


GLOSSARY OF TERMS

Algae: One-celled (phytoplankton) or multicellular plants either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Atrazine: A commonly used herbicide. Transports to lakes and rivers by groundwater or runoff. Has been shown to have toxic effects on amphibians.

Blue-Green Algae: Algae that are often associated with problem blooms in lakes. Some produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can fix nitrogen (N2) from the air to provide their own nutrient.

Calcium (Ca++): The most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed. Reported as milligrams per liter (mg/l) as calcium carbonate (CaCO3), or milligrams per liter as calcium ion (Ca++).

Chloride (Cl-): The chloride ion (Cl-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water.

Chlorophyll a: Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae, and is therefore used as a common indicator of algae and water quality.

Clarity: See “Secchi disk.”

Color: Color affects light penetration and therefore the depth at which plants can grow. A yellow-brown natural color is associated with lakes or rivers receiving wetland drainage. Measured in color units that relate to a standard. The average color value for Wisconsin lakes is 39 units, with the color of state lakes ranging from zero to 320 units.

Concentration units: Express the amount of a chemical dissolved in water. The most common ways chemical data is expressed is in milligrams per liter (mg/l) and micrograms per liter (ug/l). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (ug/l) to milligrams per liter (mg/l), divide by 1000 (e.g. 30 ug/l = 0.03 mg/l). To convert milligrams per liter (mg/l) to micrograms per liter (ug/l), multiply by 1000 (e.g. 0.5 mg/l = 500 ug/l).

Cyanobacteria: See “Blue-Green Algae.”

Dissolved oxygen: The amount of oxygen dissolved or carried in the water. Essential for a healthy aquatic ecosystem in Wisconsin lakes.

Drainage basin: The total land area that drains runoff towards a lake.

Drainage lakes: Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems, but generally have shorter residence times than seepage lakes.

Emergent: A plant rooted in shallow water and having most of its vegetative growth above water.

Eutrophication: The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Groundwater drainage lake: Often referred to as a spring-fed lake, it has large amounts of groundwater as its source and a surface outlet. Areas of high groundwater inflow may be visible as springs or sand boils. Groundwater drainage lakes often have intermediate retention times with water quality dependent on groundwater quality.
**Hardness:** The quantity of multivalent cations (cations with more than one +), primarily calcium (Ca++) and magnesium (Mg++) in the water expressed as milligrams per liter of CaCO3. Amount of hardness relates to the presence of soluble minerals, especially limestone or dolomite, in the lake watershed.

**Intermittent:** Coming and going at intervals, not continuous.

**Macrophytes:** See “Rooted aquatic plants.”

**Marl:** White to gray accumulation on lake bottoms caused by precipitation of calcium carbonate (CaCO3) in hard water lakes. Marl may contain many snail and clam shells. While it gradually fills in lakes, marl also precipitates phosphorus, resulting in low algae populations and good water clarity. In the past, marl was recovered and used to lime agricultural fields.

**Mesotrophic:** A lake with an intermediate level of productivity. Commonly clear water lakes and ponds with beds of submerged aquatic plants and mediums levels of nutrients. See also “eutrophication”.

**Nitrate (NO3-):** An inorganic form of nitrogen important for plant growth. Nitrate often contaminates groundwater when water originates from manure, fertilized fields, lawns or septic systems. In drinking water, high levels (over 10 mg/L) are dangerous to infants and expectant mothers. A concentration of nitrate-nitrogen (NO3-N) plus ammonium-nitrogen (NH4-N) of 0.3 mg/L in spring will support summer algae blooms if enough phosphorus is present.

**Oligotrophic:** Lakes with low productivity, the result of low nutrients. Often these lakes have very clear waters with lots of oxygen and little vegetative growth. See also “eutrophication”.

**Overtur:** Fall cooling and spring warming of surface water increases density, and gradually makes lake temperatures and density uniform from top to bottom. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. Common in many lakes in Wisconsin.

**Phosphorus:** Key nutrient influencing plant growth in more than 80% of Wisconsin lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

**Rooted aquatic plants (macrophytes):** Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects and provide food for many aquatic and terrestrial animals. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

**Secchi disk:** An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration).

**Sedimentation:** Materials that are deposited after settling out of the water.

**Stratification:** The layering of water due to differences in density. As water warms during the summer, it remains near the surface while colder water remains near the bottom. Wind mixing determines the thickness of the warm surface water layer (epilimnion), which usually extends to a depth of about 20 feet. The narrow transition zone between the epilimnion and cold bottom water (hypolimnion) is called the metalimnion. Common in many deeper lakes in Wisconsin.

**Watershed:** See “Drainage basin.”