Waushara County Lakes Study
Little Hills Lake

Final Report

to Waushara County and
Wisconsin Department of Natural Resources

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LITTLE HILLS 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 Little Hills Lake between fall 2010 and fall 2012.

ABOUT LITTLE HILLS 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 Wautoma, east of Highway 73, and south of Highway 21, with one public boat launch located on its southeastern side. Little Hills Lake is a 79-acre seepage lake with surface runoff and groundwater contributing most of its water. The maximum depth in Little Hills Lake is 23 feet; the lakebed has a moderate slope (Figure 1). Its bottom sediments are mostly sand with some rock found along the southern and northern shores.
Figure 1. Contour map of the Little Hills Lake lakebed.
The water quality in Little Hills 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 hilliness 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 Little Hills 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 Little Hills Lake is called a surface watershed. Groundwater also feeds Little Hills Lake; its land area may be slightly different than the surface watershed. The surface watershed is shown in Figure 2.

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 Little Hills Lake is approximately 956 acres (Figure 2). The dominant types of land use in the watershed are agriculture (59%) and forests (28%). The land closest to the lake often has the greatest impact on water quality and habitat; Little Hills Lake’s shoreland is surrounded by development, forests, and wetlands.

**Figure 2. Land use in the Little Hills 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 Little Hills 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 3 indicate the general direction of groundwater flow. Much of the groundwater enters Little Hills Lake from the northwest.

![Figure 3. Groundwater flow direction near Little Hills Lake.](image-url)
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 Little Hills 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. Little Hills Lake is classified as a seepage lake. Seepage lakes receive water primarily through groundwater, and, to a lesser extent, direct runoff and precipitation (Figure 4). Seepage lakes generally have a longer retention time (length of time water remains in the lake), which affects contact time with nutrients that feed the growth of algae and aquatic plants. They are also more vulnerable to contamination moving towards the lake in the groundwater. Examples for Little Hills Lake may include septic systems, agriculture, and road salt.

The geologic composition that lies beneath a lake has the ability to influence the temperature, pH, minerals, and other properties in a lake. As groundwater moves through the soil, some substances are filtered out, but other materials in the soil dissolve into the groundwater (Shaw et al., 2000). Minerals such as calcium and magnesium around Little Hills Lake are dissolved in the water, making the water hard. The average hardness for Little Hills Lake during the 2010-2012 sampling period was 126 mg/L, which is considered hard (Table 1). Hard water provides the calcium necessary for building bones and shells for animals in the lake. The average alkalinity was 126 mg/L; higher alkalinity in inland lakes can support higher species productivity. Hardness and alkalinity also play a role in the type of aquatic plants that are found in a lake (Wetzel, 2001).

![Figure 4. Cartoon showing inflow and outflow of water in a seepage lake.](image)

<table>
<thead>
<tr>
<th>Little Hills 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>126</td>
<td>22.6</td>
<td>16.7</td>
<td>126</td>
<td>8.6</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Table 1. Minerals and physical measurements in Little Hills Lake, 2010-2012.
Chloride concentrations, and to lesser degrees sodium and potassium concentrations, are commonly used as indicators of how strongly a lake is being impacted by human activity. The presence of these compounds where they do not naturally occur indicates the movement of pollutants from the landscape to the lake.

Little Hills Lake had moderate average chloride and sodium concentrations over the monitoring period, indicating that human activities may be influencing the water quality in the lake (Table 2). These concentrations are not harmful to aquatic organisms, but indicate that pollutants are entering the lake. Chloride sources include animal waste, septic systems, fertilizer, and road-salting chemicals. Atrazine, an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L DACT) in the samples that were analyzed from Little Hills Lake.

**Table 2. Little Hills Lake average water chemistry, 2010-2012.**

<table>
<thead>
<tr>
<th>Little Hills Lake</th>
<th>Average Value</th>
<th>Reference Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Potassium (mg/L)</td>
<td>0.70</td>
<td>7.3</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>7.3</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>4.0</td>
<td>&lt;2</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 fish and over time can reduce the amount of available habitat for sensitive species of fish and other aquatic organisms.

Water temperature and dissolved oxygen were measured in Little Hills Lake from surface to bottom at the time of sample collection in 2010-2012. During most of the year, temperatures in Little Hills Lake were consistent from the lake surface to its bottom (Figure 5).

Typical of many lakes in Wisconsin, dissolved oxygen concentrations were mixed from surface to bottom during the spring and fall, with the exception of the October 2011 sample (Figure 6). Data from February 2011 shows a very typical late winter profile with concentrations higher near the surface and declining with depth to 2 mg/L near the bottom. The dissolved oxygen concentrations measured during the study did not reveal any cause for concern about fish kill in Little Hills Lake during the winter. Similar to winter, dissolved oxygen in Little Hills Lake was stratified during the summer months with the concentrations highest at the surface, and dropping down below 5 mg/L towards the bottom. The oxygen concentrations at the bottom of the lake reflect the consumption of oxygen during decomposition processes.
**Figure 5. Temperature profiles in Little Hills Lake, 2010-2012.**

**Figure 6. Dissolved oxygen profiles in Little Hills Lake, 2010-2012.**

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. In Little Hills Lake, color was relatively low (Table 1), indicating that the variability in water clarity throughout the year is primarily due to fluctuating algae concentrations and re-suspended sediment following storms and/or heavy boating activity.
The water clarity measured in Little Hills Lake was considered good; however, water clarity in Little Hills Lake is typically poorer during the summer months. The shallowest Secchi depth was recorded in late summer. For Little Hills Lake, water clarity ranged from 8 feet to 24 feet during the monitoring period (Figure 7). When compared to historic data, the average water clarity measured during the study was slightly better in June, September, and October, about the same in April, July, and August, and worse in May. Historic data used in this analysis ranged from 1995-2009.

![Little Hills Lake Secchi Depth](image)

**Figure 7. Water clarity in Little Hills Lake, 2010-2012 and historic.**

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 in groundwater. Once in a lake, a portion of the phosphorus becomes part of the aquatic system in the form of plant tissue, animal tissue, and sediment. The phosphorus continues to cycle within the lake for many years.

During the study, total phosphorus concentrations in Little Hills Lake ranged from a high of 31 ug/L in July 2011 to a low of 7 ug/L in February 2011 and June 2011 (Table 3). Summer median total phosphorus for Little Hills Lake was 12 ug/L and 14 ug/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus standard of 40 ug/L for shallow seepage lakes such as Little Hills Lake.

Chlorophyll \(a\) is a measurement of algae in the water. Chlorophyll \(a\) concentrations in Little Hills Lake varied slightly throughout the monitoring season, ranging from a high of 12 ug/L in July 2011 to a low of 0.5 ug/L in June 2012. The average for the monitoring period was 4.2 ug/L, which is considered low.
Estimates of phosphorus from the landscape can help in understanding the phosphorus sources to Little Hills 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. While agriculture and forests comprised the greatest areas of the watershed, modeling results indicated that agriculture and developed land had the greatest percentages of phosphorus contributions from the watershed to Little Hills Lake (Figure 8). 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).

### Table 3. Seasonal summary of nutrient concentrations in Little Hills Lake, 2010-2012.

<table>
<thead>
<tr>
<th>Little Hills Lake</th>
<th>Inorganic Nitrogen (mg/L)</th>
<th>Organic Nitrogen (mg/L)</th>
<th>Total Nitrogen (mg/L)</th>
<th>Soluble Reactive Phosphorus (ug/L)</th>
<th>Total Phosphorus (ug/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>0.66 0.66 0.66</td>
<td>0.68 0.68 0.68</td>
<td>4 4 4</td>
<td>22 22 22</td>
</tr>
<tr>
<td>Spring</td>
<td>0.05 0.07 0.09</td>
<td>0.51 0.60 0.68</td>
<td>0.61 0.77 0.92</td>
<td>2 3 4</td>
<td>11 16 22</td>
</tr>
<tr>
<td>Summer</td>
<td></td>
<td>0.57 0.57 0.57</td>
<td>0.74 0.74 0.74</td>
<td>1 1 1</td>
<td>7 7 7</td>
</tr>
<tr>
<td>Winter</td>
<td>0.06 0.06 0.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Table 4. Modeling data used to estimate phosphorus inputs from land uses in the Little Hills Lake watershed (low and most likely coefficients used to calculate range in pounds).

<table>
<thead>
<tr>
<th>Little Hills 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>78</td>
<td>8</td>
</tr>
<tr>
<td>Developed</td>
<td>0.13</td>
<td>215</td>
<td>23</td>
</tr>
<tr>
<td>Barren/Herbaceous/Wetland</td>
<td>0.09</td>
<td>81</td>
<td>8</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>454</td>
<td>48</td>
</tr>
<tr>
<td>Cultivated Agriculture</td>
<td>0.45</td>
<td>127</td>
<td>13</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, and 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 the diversity that makes the aquatic plant community more resilient and helps to prevent the establishment of non-native aquatic species.

During the 2011 aquatic plant survey of Little Hills Lake, fifty-one percent (86 of 169) sampled sites had vegetative growth. Of the sampled sites within Little Hills Lake, the average depth was 12 feet and the maximum depth that had plant growth was 27 feet. Nine species of aquatic plants were found in Little Hills Lake, which is low compared with other lakes in the Waushara County Lakes Study (Table 5). The greatest plant diversity was found in the southern bay and western shore of the lake (Figure 9).

The dominant plant species in the survey was muskgrass (Chara spp.), followed by slender naiad (Najas flexilis) and Illinois pondweed (Potamogeton illinoensis). Muskgrass is a favorite food source for a wide variety of waterfowl, and muskgrass beds offer cover and food to fish, especially young trout, largemouth bass, and smallmouth bass. The stems, leaves, and seeds of slender naiad provide food for waterfowl and marsh birds; this common aquatic plant species also provides habitat for fish. Illinois pondweed is also an important food source for a variety of waterfowl. This submersed plant species offers shade and cover for fish, and habitat for invertebrates (Borman et al., 2001).

Table 5. List of aquatic plant species identified in the aquatic plant survey of Little Hills Lake, 2011.

<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>Schoenoplectus acutus</td>
<td>hardstem bulrush</td>
<td>6</td>
</tr>
<tr>
<td><strong>Floating Leaf Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nymphaea odorata</td>
<td>white water lily</td>
<td>6</td>
</tr>
<tr>
<td>Polygonum amphibium</td>
<td>water smartweed</td>
<td>5</td>
</tr>
<tr>
<td><strong>Submergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chara spp.</td>
<td>muskgrass</td>
<td>7</td>
</tr>
<tr>
<td>Najas flexilis</td>
<td>slender naiad</td>
<td>6</td>
</tr>
<tr>
<td>Potamogeton gramineus</td>
<td>variable pondweed</td>
<td>7</td>
</tr>
<tr>
<td>Potamogeton illinoensis</td>
<td>Illinois pondweed</td>
<td>6</td>
</tr>
<tr>
<td>Potamogeton zosteriformis</td>
<td>flat-stem pondweed</td>
<td>6</td>
</tr>
<tr>
<td>Stuckenia pectinata</td>
<td>sago pondweed</td>
<td>3</td>
</tr>
</tbody>
</table>
Figure 9. Number of aquatic plant species observed at each sample site in Little Hills Lake, 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 Little Hills Lake ranged from 3 to 7, with an average C value of 5.8 (Table 5). The FQI for Little Hills Lake was 15.5. This is very low compared with other lakes in the Waushara County Lakes Study, suggesting that the native aquatic plants are experiencing a fair amount of disturbance. No species of special concern in Wisconsin were found in Little Hills Lake.

The Simpson Diversity Index (SDI) quantifies biodiversity 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. Little Hills Lake had an SDI value of 0.66. This represents below-average biodiversity when compared to other lakes in the Waushara County Lakes Study.

Although no aquatic invasive species (AIS) were found in Little Hills Lake during the 2011 survey, an AIS reconnaissance survey conducted in 2013 by Golden Sands Resource Conservation & Development Council, Inc. revealed the presence of hybrid water milfoil (HWM). HWM is a cross of native water milfoil and Eurasian water milfoil (EWM). HWM/EWM can create dense beds that can damage boat motors, make areas non-navigable, stunt or alter the fishery, create problems with dissolved oxygen in the winter, and limit activities such as 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 HWM/EWM very successful at reproducing.

Overall, the aquatic plant community in Little Hills Lake can be characterized as having below-average diversity when compared to other lakes in the Waushara County Lakes Study, with aquatic species that are common to central Wisconsin lakes. The habitat, food source, and water quality offered by the plant community within Little Hills Lake should be focal points of future lake management strategies.
SHORELANDS

Shoreland vegetation is critical to a healthy lake’s ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. Vegetation 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 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, seawalls, structures and docks were also inventoried.

A scoring system was developed for the collected data to provide a more holistic assessment. Areas that are healthy will need strategies to keep them healthy, and areas with potential problem areas and where management and conservation may be warranted may need a different set of 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. Larger 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 Little Hills 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 human disturbances. Red shorelands indicate locations where changes in management or mitigation may be warranted. Many stretches of Little Hills Lake’s shorelands are in good to moderately-good shape, but some portions have challenges that should be addressed. A few short segments of Little Hills Lake’s shoreland ranked as poor. 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/.
FIGURE 10. OVERALL SHORELAND HEALTH AROUND LITTLE HILLS LAKE, 2011.
CONCLUSIONS & RECOMMENDATIONS

Little Hills Lake had fair water quality with some measurements indicating good conditions and others indicating that land use practices in the watershed are influencing the water quality in Little Hills Lake. Although sources of phosphorus from agriculture and developed land are present in the Little Hills Lake watershed, hard water (from calcium in the groundwater) in Little Hills Lake has helped to minimize the effects of additional nutrients.

- Little Hills Lake had moderate average chloride and sodium concentrations, indicating that certain human activities may be influencing the water quality in the lake. These concentrations were not harmful to aquatic organisms, but indicated that pollutants were entering the lake. Chloride sources include animal waste, septic systems, fertilizer, and road-salting chemicals.
- Overall, the measures related to aquatic plant and algal production in Little Hills Lake were good. Concentrations of inorganic nitrogen (which moves to the lake in groundwater) were low, total phosphorus measurements were below concentrations of concern, and chlorophyll \( a \) concentrations (a measure of algae) were low. Water clarity was poorest in July and August. When compared to historic data (1995-2009), the average water clarity measured during the study was slightly better in June, September, and October, about the same in April, July, and August, and worse in May.
- Dissolved oxygen concentrations were sufficient to support a variety of fish species.
- Routine monitoring of water quality can help to track changes in Little Hills Lake. A robust long-term dataset already exists for Little Hills Lake and data collection should continue. If one does not already exist, a monitoring plan should be developed and implemented.

In general, each type of land use contributes different amounts of phosphorus and nitrogen in runoff and through groundwater. The types of land management practices that are used and their distances from the lake affect the contributions to the lake from a parcel of land.

- Identifying and taking steps to maintain or improve water quality in Little Hills Lake will depend upon understanding the sources of nutrients to the lake and identifying those that are manageable. While agriculture and forests comprised the greatest areas of the watershed, modeling results indicated that agriculture and developed land had the greatest percentages of phosphorus contributions from the watershed to Little Hills Lake.
- Over-application of chemicals and nutrients should be avoided. Landowners in the watershed should be made aware of their connection to Little Hills Lake and should work to reduce their impacts through the implementation of water quality-based best management practices.
- Shoreland vegetation is critical to a healthy lake’s ecosystem. It provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and many small and large mammals. Vegetation 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 extending at least 35 feet landward from the water’s edge.
  - Many stretches of Little Hills Lake’s shorelands are in good to moderately-good shape, but some portions have challenges that should be addressed. A few short segments of Little Hills Lake’s shoreland ranked as poor.
- 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 changes in land management practices.
Aquatic plants are the forested landscape within a lake. They provide food and habitat for a wide range of species including fish, waterfowl, turtles, and 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.

- Overall, the aquatic plant community in Little Hills Lake can be characterized as having below-average diversity when compared to other lakes in the Waushara County Lakes Study, with only native aquatic plant species that are tolerant to disturbance. The habitat, food source, and water quality offered by the plant community within Little Hills Lake should be focal points of future lake management strategies.

- In 2013, a survey of aquatic invasive species revealed the presence of hybrid water milfoil (HWM). HWM is a cross of native water milfoil and Eurasian water milfoil (EWM). Studies have indicated that HWM tends to be more difficult to control with chemical than EWM.
  - HWM/EWM can create dense beds that can damage boat motors, make areas non-navigable, stunt or alter the fishery, create problems with dissolved oxygen in the winter, and limit activities such as fishing and swimming.
  - HWM/EWM 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 HWM/EWM very successful at reproducing.

- The amount of disturbed lakebed from raking or pulling plants should be minimized, since these open spaces are “open real estate” for aquatic invasive plants to establish.

- The presence of CLP indicates that non-native aquatic plant species can make their way into Little Hills Lake. Boats and trailers that have visited other lakes can be a primary vector for the transport of aquatic invasive species (AIS). Programs are available to help volunteers learn to monitor for AIS and to educate lake users at the boat launch about how they can prevent the spread of AIS.
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.

**Macrophyte:** 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.”