Waushara County Lakes Study

Lake Lucerne

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University of Wisconsin Stevens Point
PRIMARY AUTHORS

Aquatic Plants
Jen McNelly (UW-Stevens Point)

Sediment Core
Dr. Samantha Kaplan (UW-Stevens Point) and Paul Garrison (Wisconsin DNR)

Shoreland Assessments
Ed Hernandez and Waushara County Land Conservation Department Staff

Dan McFarlane (UW-Stevens Point)

Water Quality and Watersheds
Nancy Turyk, Paul McGinley, Danielle Rupp and Ryan Haney (UW-Stevens Point)

Ed Hernandez and Waushara County Land Conservation Department Staff

Contributions from UW-Stevens Point Students to Water Quality and Report Compilation:

Melis Arik, Nicki Feiten, Sarah Hull, Chase Kasmerchak, Matt Pamperin, Scott Pero, Megan Radske, Cory Stoughtenger, Hayley Templar, Garret Thiltgen, Anthony Recht

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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 Lake Lucerne between fall 2010 and fall 2012.

ABOUT LAKE LUCERNE

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 and east of Highway 73, with one public boat launch located on its western side. Lake Lucerne is a 42 acre seepage lake with groundwater and surface runoff contributing most of its water. The maximum depth in Lake Lucerne is 33 feet (Figure 1). Lake Lucerne has an estimated water residence time of 2.9 years. The residence time helps determine the potential effects of nutrients entering the lake and the length of time pollutants may stay in the lake. Its bottom sediments are mostly muck with some sand and rock.
FIGURE 1. LAKEBED CONTOUR MAP OF LAKE LUCERNE.
The water quality in Lake Lucerne 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 man-made 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 Lake Lucerne’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 Lake Lucerne is called a surface watershed. Groundwater also feeds Lake Lucerne; 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 ultimately 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.
LAKE LUCERNE SURFACE WATERSHED

The surface watershed for Lake Lucerne is approximately 380 acres (Figure 2). The dominant types of land use in the watershed are forests (55%) and developed lands (19%). The land closest to the lake often has the greatest impact on water quality and habitat; Lake Lucerne’s shoreland is surrounded primarily by forests and wetlands with some development, including Lake Lucerne Camp.

FIGURE 2. LAND USE IN THE LAKE LUCERNE SURFACE WATERSHED.
LAKE LUCERNE GROUNDWATER

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 Lake Lucerne 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 Lake Lucerne from the north.

FIGURE 3. GROUNDWATER FLOW DIRECTION NEAR LAKE LUCERNE.
WATER QUALITY

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 Lake Lucerne 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. Lake Lucerne 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 have higher concentrations of minerals such as calcium and magnesium, which are picked up by groundwater moving through soil and rock. These lakes are more vulnerable to contamination moving towards the lake in the groundwater. Examples for Lake Lucerne 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 dissolve into the groundwater (Wetzel, 2001). Minerals such as calcium and magnesium in the soil around Lake Lucerne dissolve, making the water hard. The average hardness for Lake Lucerne during the 2010-2012 sampling period was 140 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 141 mg/L; higher alkalinity in inland lakes can support higher species productivity. Hardness and alkalinity also play roles in the type of aquatic plants that are found in a lake (Shaw et al., 2000).

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

<table>
<thead>
<tr>
<th>Lake Lucerne</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 (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Value</td>
<td>141</td>
<td>25.6</td>
<td>17.6</td>
<td>140</td>
<td>7.6</td>
<td>1.77</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.
Lake Lucerne had low average chloride, potassium, and sodium concentrations over the monitoring period (Table 2). These concentrations are not harmful to aquatic organisms, but indicate that some pollutants are entering the lake. Chloride sources include animal waste, septic systems, fertilizer, and road-salting chemicals. Atrazine (DACT), an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the samples that were analyzed from Lake Lucerne.

**TABLE 2. LAKE LUCERNE AVERAGE WATER CHEMISTRY, 2010-2012.**

<table>
<thead>
<tr>
<th>Lake Lucerne</th>
<th>Average Value</th>
<th>Reference Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Potassium (mg/L)</strong></td>
<td>0.57</td>
<td>&lt;0.75</td>
</tr>
<tr>
<td><strong>Chloride (mg/L)</strong></td>
<td>2.4</td>
<td>&lt;3</td>
</tr>
<tr>
<td><strong>Sodium (mg/L)</strong></td>
<td>1.0</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 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 Lake Lucerne from top to bottom at the time of sample collection during the 2010-2012 study. Temperature data illustrate a typical temperature profile for Wisconsin lakes. The lake water mixes from top to bottom in Lake Lucerne during spring and fall overturn (Figure 5). As water warms in the summer, the water at the top of the lake is much warmer than the bottom water, creating layering or stratification. During this period, the water at the top of the water column does not mix with the bottom water. Vertical profiles for spring and fall turnover are very clear, showing thorough mixing in November 2010, then again in late November 2011 and in early May 2012. Thermal stratification is developed by June in Lake Lucerne, with similar profiles observed between the two years (2011-2012).

Dissolved oxygen concentrations frequently mirror temperature profiles. When Lake Lucerne is stratified, the oxygen in the bottom water cannot be replenished by the atmosphere or respiration of algae, so the consumption of oxygen by decomposers at the lake bottom reduces the dissolved oxygen concentrations to nearly zero. Some of the dissolved oxygen measurements collected during the 2011-2012 study were suspect and were removed from the set of data displayed in Figure 6.
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 Lake Lucerne, color was relatively low (Table 1), so the variability in transparency throughout the year is primarily due to fluctuating algae concentrations and re-suspended sediment following storms and/or heavy boating.

The water clarity measured in Lake Lucerne was considered good. For Lake Lucerne, the average water clarity was best during August and poorest during September (Figure 7). The measurements ranged from
depths of 7 feet to 24 feet over the two-year monitoring period. Historic water clarity data was not available for Lake Lucerne, so interpretation about changes over time could not be made.

FIGURE 7. AVERAGE MONTHLY WATER CLARITY DEPTHS IN LAKE LUCERNE, 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. Additional 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 forms of plant tissue, animal tissue, and sediment. The phosphorus continues to cycle within the lake for many years.

Total phosphorus concentrations in samples collected from Lake Lucerne ranged from a high of 22 ug/L in June 2012 to a low of 3 ug/L in August 2012 (Table 3). The summer median total phosphorus concentrations for Lake Lucerne were 15 ug/L and 12 ug/L in 2011 and 2012, respectively. This is below Wisconsin’s phosphorus standard of 20 ug/L for deep seepage lakes and is down from measurements taken in the early 1980s, which averaged 20 ug/L. The median concentration measured in 2011 is at the flag value of 15 ug/L proposed by the WDNR for deep seepage lakes.

Chlorophyll \( a \) is a measurement of algae in the water. Chlorophyll \( a \) concentrations in Lake Lucerne varied throughout the 2012 monitoring season, ranging from a high of 6.7 ug/L in September 2011 to a low of 0.5 ug/L in June 2011. These concentrations are considered low and are similar to concentrations in samples that were collected sporadically during the summers of 1981 and 1982.

In lake water, nitrogen can also be responsible for the growth of aquatic plants and some forms of algae. Nitrogen concentrations in samples collected from Lake Lucerne were similar to background concentrations that would be observed in a minimally impacted lake in Waushara County (Table 3).
Studies of phosphorus from the landscape can help to understand the phosphorus sources to Lake Lucerne. 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 the distance from the lake also affect the contributions to the lake from a parcel of land. Based on modeling results, agriculture and forests had the greatest percentages of phosphorus contributions from the watershed to Lake Lucerne (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).

![Phosphorus Loading (%) in the Lake Lucerne Surface Watershed](image)

**FIGURE 8. ESTIMATED PHOSPHORUS LOADS FROM LAND USES IN THE LAKE LUCERNE WATERSHED.**

<table>
<thead>
<tr>
<th>Lake Lucerne</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>0.04 0.04 0.04</td>
<td>0.73 0.73 0.73</td>
<td>0.95 0.95 0.95</td>
<td>13 13 13</td>
<td>18 18 18</td>
</tr>
<tr>
<td>Spring</td>
<td>0.10 0.40 0.70</td>
<td>0.51 0.57 0.62</td>
<td>0.74 1.22 1.69</td>
<td>4 5 5</td>
<td>10 16 21</td>
</tr>
<tr>
<td>Summer</td>
<td>0.08 0.08 0.08</td>
<td>0.53 0.53 0.53</td>
<td>0.96 0.96 0.96</td>
<td>13 13 13</td>
<td>13 13 13</td>
</tr>
<tr>
<td>Winter</td>
<td>0.08 0.08 0.08</td>
<td>0.53 0.53 0.53</td>
<td>0.96 0.96 0.96</td>
<td>13 13 13</td>
<td>13 13 13</td>
</tr>
</tbody>
</table>

**TABLE 3. SUMMARY OF SEASONAL NUTRIENT CONCENTRATIONS IN LAKE LUCERNE, 2010-2012.**
TABLE 4. MODELING DATA USED TO ESTIMATE PHOSPHORUS INPUTS FROM LAND USES IN THE LAKE LUCERNE WATERSHED (LOW AND MOST LIKELY COEFFICIENTS USED TO CALCULATE RANGE IN POUNDS).

<table>
<thead>
<tr>
<th>Lake Lucerne 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>42</td>
<td>11</td>
</tr>
<tr>
<td>Developed</td>
<td>0.04</td>
<td>63</td>
<td>17</td>
</tr>
<tr>
<td>Barren/Herbaceous/Wetland</td>
<td>0.09</td>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>187</td>
<td>49</td>
</tr>
<tr>
<td>Cultivated Agriculture</td>
<td>0.45</td>
<td>40</td>
<td>10</td>
</tr>
</tbody>
</table>

*Values are not exact due to rounding and conversion.
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 in Lake Lucerne, eighty-eight percent (95) of the 108 sampled sites had vegetative growth. Of the sampled sites within Lake Lucerne, the average depth was 14 feet and the maximum depth that had plant growth was 28 feet. Because Lake Lucerne is a deep lake, more than 50% of the assigned sample sites were located in water depths that were too deep for plants to grow.

Eleven species of aquatic plants were found in Lake Lucerne during the 2011 survey (Table 5). Figure 9 shows the number of species that were identified at each sampling site. The greatest plant diversity was found on the northern and southern sides of the lake in the shallows.

### TABLE 5. LIST OF AQUATIC PLANTS IDENTIFIED IN LAKE LUCERNE, 2011.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific 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>Schoenoplectus tabernaemontani</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>Nymphaea odorata</em></td>
<td>white water lily</td>
<td>6</td>
</tr>
<tr>
<td><strong>Submergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ceratophyllum demersum</em></td>
<td>coontail</td>
<td>3</td>
</tr>
<tr>
<td><em>Chara spp.</em></td>
<td>muskgrass</td>
<td>7</td>
</tr>
<tr>
<td><em>Najas flexilis</em></td>
<td>slender naiad</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton foliosus</em></td>
<td>leafy pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton friesii</em></td>
<td>Fries’ pondweed</td>
<td>8</td>
</tr>
<tr>
<td><em>Potamogeton illinoensis</em></td>
<td>Illinois pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Potamogeton natans</em></td>
<td>floating-leaf pondweed</td>
<td>5</td>
</tr>
<tr>
<td><em>Potamogeton zostermiformis</em></td>
<td>flat-stem pondweed</td>
<td>6</td>
</tr>
<tr>
<td><em>Vallisneria americana</em></td>
<td>wild celery</td>
<td>6</td>
</tr>
</tbody>
</table>
FIGURE 9. NUMBER OF AQUATIC PLANT SPECIES OBSERVED AT EACH SAMPLE SITE IN LAKE LUCERNE, 2011.
The dominant plant species in the survey was muskgrass (Chara spp.), followed by slender naiad (Najas flexilis) and Fries’ pondweed (Potamogeton friesii). 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, and this common aquatic plant species also provides habitat for fish. Fries’ pondweed is also an important food source for a variety of waterfowl, and this submersed plant species offers shade and cover for fish, and habitat for invertebrates.

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 Lake Lucerne ranged from 3 to 8 (Table 5).

The FQI for a lake is calculated using the C-values of the aquatic plants in the lake. In 2011, the FQI for Lake Lucerne was 19.0. The average FQI for all lakes in the Waushara County Lakes Study was 23.2. The simple shape, hard water, and depth of the lake are all factors related to the lower FQI. No species of special concern in Wisconsin were found in Lake Lucerne.

The Simpson Diversity Index (SDI) quantifies biotic diversity 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 biotic diversity. Lake Lucerne had an SDI value of 0.71. This represents below average biotic diversity when compared to all of the other lakes in the Waushara County Lakes Study.

Because Lake Lucerne had been identified by the Wisconsin Department of Natural Resources as having curly-leaf pondweed (CLP), a special survey was conducted for this potentially invasive non-native species in the summer of 2012. The life cycle of curly-leaf pondweed can impact a lake’s ecosystem. CLP grows under the ice during late winter/early spring and starts to die back in late June to early July. This die-back releases phosphorus into the water at a time when new plants and algae are beginning to grow. This phosphorus release may help fuel algae blooms and excessive plant growth. CLP was not found in Lake Lucerne during the 2012 survey, but the lake should continue to be monitored.

Although it was not present at sites visited during the 2011 survey, a survey conducted in 2013 by staff from Golden Sands RC&D revealed the presence of Eurasian watermilfoil (EWM) near the boat launch on Lake Lucerne. This population was comprised of individual plants (Golden Sands RC&D, Inc., 2013). EWM can 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 Lake Lucerne can be characterized as having below average diversity when compared to all of the other lakes in the Waushara County Lakes Study, with several species that are typically found in relatively undisturbed systems. The identification of CLP within the lake is cause for concern and the lake should be routinely monitored for CLP in early June.
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 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. 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 Lake Lucerne 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. The majority of Lake Lucerne’s shorelands are in good shape; only three short segments indicate challenges that should be addressed. There were no stretches of Lake Lucerne shoreland that 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://www.co.waushara.wi.us/shorelineviewer/.
FIGURE 10. OVERALL SHORELAND HEALTH AROUND LAKE LUCERNE, 2011.
CONCLUSIONS AND RECOMMENDATIONS

Lake Lucerne had very good water quality during the study. The watershed had a fair amount of forests (55%) and developed land (19%). When properly managed, forests help to provide good water to lakes both in terms of surface runoff and abundant groundwater with good water quality. The degree of impact that developed land has on lake water quality depends on how the land is managed. When vegetation is left intact, and fertilizer use and impervious surfaces are minimal, the developed land may have minimal negatives impact to a lake. In general, more disturbed landscapes result in greater negative impacts to the lake.

- Groundwater is the primary source of water to Lake Lucerne, with much of it originating in forested land that provides good quality groundwater.
- The hardness of the water in Lake Lucerne (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 more 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 Lake Lucerne from any future land use changes in the watershed will be minimized.
- Routine monitoring for water clarity, phosphorus, and chlorophyll \(a\) (a measure of algae) should be done to evaluate changes in water quality in Lake Lucerne 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 survey, the majority of Lake Lucerne’s shorelands are in good shape; only three short segments indicated challenges that should be addressed.

- Strategies should be developed to ensure that healthy shorelands remain intact and efforts should be made to improve stretches of shorelands that exhibited 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 always a 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 Lake Lucerne appeared to be quite healthy based on the 2011 survey; however, a survey conducted by staff at Golden Sands RC&D revealed the presence of some Eurasian watermilfoil (EWM) plants near the boat launch. During the 2011 aquatic plant survey, several high
quality aquatic plants were observed in Lake Lucerne. Two of the notable species include Fries’ pondweed (*Potamogeton friesii*) and softstem bulrush (*Schoenoplectus tabernaemontani*). Softstem bulrush is particularly beneficial in providing shelter for young fish and tadpoles.

- Minimizing disturbance to aquatic plants can greatly benefit Lake Lucerne. Aquatic plants help to reduce the amount of sediment that is stirred up during windy high boating periods. Resuspension of sediments can result in algal blooms and reduced fish spawning beds. Aquatic plants also act as baffles, helping to break up the energy of waves and reduce shoreland erosion. Healthy native aquatic plant beds also make it difficult for non-native, potentially invasive aquatic plant species to become established.

- A survey conducted in 2013 by staff from Golden Sands RC&D revealed the presence of Eurasian watermilfoil (EWM) near the boat launch on Lake Lucerne. This population was comprised of individual plants. EWM can grow in dense beds that can 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 produces 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.

- Efforts should be made to control or eliminate this early infestation of EWM. Using proper techniques to manually remove EWM plants is the best approach to controlling this early infestation. Anyone interested in helping with this effort should be trained in proper removal techniques so that EWM plants are not fragmented during the removal process.

- The presence of EWM in the lake is a clear indication that aquatic invasive species are able to make their way into Lake Lucerne. Lake residents and lake users should be made aware of boat and trailer hygiene techniques to prevent the introduction of new species. Lake Lucerne 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”.

**Overturn:** 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.”