Waushara County Lakes Study

Curtis Lake

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CURTIS 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 Curtis Lake between fall 2010 and fall 2012.

ABOUT CURTIS 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. Curtis Lake is located in the township of Deerfield, southwest of the city of Wautoma, south of Highway 21, with one public boat launch located on its eastern side. Curtis Lake is a 35 acre drainage lake fed by a small inlet on the northwest side of the lake, as well as by surface runoff, groundwater, and direct precipitation. The maximum depth in Curtis Lake is 45 feet; the lakebed has a gradual slope (Figure 1). Its bottom sediments are mostly muck.
Figure 1. Contour map of the Curtis Lake lakebed.
The water quality in Curtis 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 Curtis 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 Curtis Lake is called a surface watershed. Groundwater also feeds Curtis 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 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 Curtis Lake is approximately 804 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; Curtis Lake’s shoreland is surrounded by forests, wetlands, and development.
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 Curtis 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 Curtis Lake from the northwest.

**Figure 3. Groundwater flow direction near Curtis 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 Curtis 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. Curtis Lake is a drainage lake (Figure 4), receiving most of its water from a small inlet on the northwestern side of the lake and from groundwater. Surface runoff and direct precipitation also contribute water that later leaves the lake via the north branch of Wedde Creek. A drainage lake often receives and retains more sediment and nutrients than lakes that receive most of their water as groundwater. Additional nutrients and sediment can result in increased growth of aquatic plants.

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, some substances are filtered out, but other materials dissolve into the groundwater. Minerals such as calcium and magnesium in the soil around Curtis Lake are dissolved in the water (Shaw et al., 2000). The average hardness for Curtis Lake during the 2010-2012 sampling period was 157 mg/L, which is considered hard (Table 1). Hard water provides the calcium necessary for building bones and shells of 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 a role in the types of aquatic plants that are found in a lake (Wetzel, 2001).

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

**Figure 4. Cartoon showing inflow and outflow of water in a drainage lake.**

<table>
<thead>
<tr>
<th>Curtis 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 (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Value</td>
<td>141</td>
<td>28.8</td>
<td>14.5</td>
<td>157</td>
<td>37.9</td>
<td>2.1</td>
</tr>
</tbody>
</table>

**Table 1. Minerals and physical measurements in Curtis Lake, 2010-2012.**
Chloride concentrations, and to a lesser degree 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 sources of water contaminants.

Curtis Lake had moderate average chloride, potassium, and sodium concentrations over the monitoring period (Table 2), indicating that the water quality in Curtis Lake was influenced by activities in its watershed. These concentrations are not harmful to aquatic organisms. Sources of chloride and sodium can include animal waste, septic systems, fertilizer, and road-salting chemicals. Potassium sources include animal waste, septic systems, and/or potash fertilizer. Atrazine (DACT), an herbicide commonly used on corn, was below the detection limit (<0.01 ug/L) in the samples that were analyzed from Curtis Lake.

<table>
<thead>
<tr>
<th>Curtis Lake</th>
<th>Average Value</th>
<th>Reference Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Medium</td>
<td>High</td>
</tr>
<tr>
<td>Potassium (mg/L)</td>
<td>1.30</td>
<td>&lt;.75 0.75-1.5</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>4.0</td>
<td>&lt;3 3.0-10.0</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>2.0</td>
<td>&lt;2 2.0-4.0</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 cold water species of fish and other aquatic organisms.

Water temperature and dissolved oxygen were measured in Curtis Lake from top to bottom at the time of sample collection. Temperature data illustrated a typical late winter profile in February 2011 and 2012 with freezing temperatures near the surface and gradual warming with depth. During the fall, the water in the lake was mixed and temperatures were nearly uniform from surface to bottom. If spring mixing following ice off occurred, it was not captured. During summer months, the temperatures varied with depth; the warmer water was near the surface and cooler water was near the bottom (Figure 5).

During the study, dissolved oxygen in Curtis Lake was uniform from surface to bottom when the fall 2011 concentrations were measured (Figure 6). The dissolved oxygen in Curtis Lake was greater at the surface and declined with depth. Concentrations fell below 5 mg/L at depths of approximately 17 feet. Over winter (February 2011), dissolved oxygen concentrations also declined with depth and fell below 5 mg/L at depths near 10 feet.
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 Curtis Lake, color was relatively low (Table 1), indicating that the variability in water clarity throughout the year is primarily due to fluctuating algal concentrations and re-suspended sediment following storms and/or heavy boating activity.
The water clarity measured in Curtis Lake during the study was considered good. For Curtis Lake, water clarity ranged from 6 to 17.5 feet during the two-year monitoring period (Figure 7). When compared with historic data, the average water clarity measured during the study was slightly better in June and August, slightly poorer in May, September, and November, and the same in July. Water clarity in Curtis Lake is typically slightly poorer during the summer months with the shallowest Secchi depth recorded in late summer. Historic data utilized in this analysis was collected between 1992 and 1998.

**Figure 7. Water clarity in Curtis 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.

Over the two-year monitoring period, total phosphorus concentrations for Curtis Lake ranged from a high of 50 ug/L in May 2012 to a low of 11 ug/L in August 2012 (Table 3). The summer median total phosphorus for Curtis Lake was 19 ug/L and 14 ug/L in 2011 and 2012, respectively. This is below the proposed phosphorus standard of 30 ug/L for deep drainage lakes such as Curtis Lake. During the study, inorganic nitrogen concentrations were high enough in all seasons to enhance algal blooms throughout the summer (Shaw et al., 2000).

Chlorophyll $a$ is a measurement of algae in the water. Chlorophyll $a$ concentrations in Curtis Lake varied slightly throughout the monitoring season, ranging from a high of 6 ug/L in late May 2012 to a low of 0.5 ug/L in July 2012. The average over the monitoring period was 2.6 ug/L, which is considered low.
Estimates of phosphorus from the landscape can help to understand the phosphorus sources to Curtis 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. Agriculture had the greatest percentages of phosphorus contributions from the watershed to Curtis 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).

![Figure 8. Estimated phosphorus loads from land uses in the Curtis Lake watershed.](image-url)
Table 4. Modeling data used to estimate phosphorus inputs from land uses in the Curtis Lake watershed (low and most likely coefficients used to calculate range in pounds).

<table>
<thead>
<tr>
<th>Curtis 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>35</td>
<td>4</td>
</tr>
<tr>
<td>Developed</td>
<td>0.04</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>Barren/Herbaceous/Wetland</td>
<td>0.09</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>Forest</td>
<td>0.04</td>
<td>215</td>
<td>27</td>
</tr>
<tr>
<td>Cultivated Agriculture</td>
<td>0.45</td>
<td>452</td>
<td>56</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 of Curtis Lake, eighty percent (71 of 89) of the sampled sites had vegetative growth. Of the sampled sites within Curtis Lake, the average depth was 9 feet and the maximum depth was 22 feet. Seventeen species of aquatic plants were found in Curtis Lake, which was slightly below average compared with all of the other lakes in the Waushara County Lakes Study (Table 5). The greatest plant species diversity was found in the northwestern portion of the lake (Figure 9).

### Table 5. List of aquatic plants identified in the 2011 aquatic plant survey of Curtis 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>Sagittaria (spp.)</td>
<td>arrowhead</td>
<td>3</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>Nuphar variegata</td>
<td>spatterdock</td>
<td>6</td>
</tr>
<tr>
<td>Potamogeton natans</td>
<td>floating-leaf pondweed</td>
<td>5</td>
</tr>
<tr>
<td><strong>Submergent Species</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceratophyllum demersum</td>
<td>coontail</td>
<td>3</td>
</tr>
<tr>
<td>Chara spp.</td>
<td>muskgrass</td>
<td>7</td>
</tr>
<tr>
<td>Elodea canadensis</td>
<td>common waterweed</td>
<td>3</td>
</tr>
<tr>
<td>Lemna minor</td>
<td>small duckweed</td>
<td>4</td>
</tr>
<tr>
<td>Myriophyllum sibiricum</td>
<td>northern water-milfoil</td>
<td>6</td>
</tr>
<tr>
<td>Najas flexilis</td>
<td>slender naiad</td>
<td>6</td>
</tr>
<tr>
<td>Najas guadalupensis</td>
<td>southern naiad</td>
<td>8</td>
</tr>
<tr>
<td>Potamogeton foliosus</td>
<td>leafy pondweed</td>
<td>6</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>
<tr>
<td>Utricularia vulgaris</td>
<td>common bladderwort</td>
<td>7</td>
</tr>
<tr>
<td>Vallisneria americana</td>
<td>wild celery</td>
<td>6</td>
</tr>
</tbody>
</table>
Figure 9. Number of aquatic plant species observed at each sample site in Curtis Lake, 2011.
The dominant plant species in the survey was muskgrass (*Chara* spp.), followed by southern naiad (*Najas guadalupensis*) and coontail (*Ceratophyllum demersum*). Muskgrass is a favorite food source for a wide variety of waterfowl. Beds of muskgrass offer cover and food for fish, especially young trout, largemouth bass, and smallmouth bass. The stems, leaves, and seeds of southern naiad are important food sources for waterfowl and marsh birds, and this common aquatic species also provides habitat for fish. Coontail offers an important food source to a wide range of waterfowl species. A number of invertebrate and fish species use the bushy stems and stiff whorls of coontail leaves as habitat, especially in the winter when other aquatic plants have died back (Borman et al., 2001).

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 Curtis Lake ranged from 3 to 8, with an average C-value of 5.6 (Table 5). Southern naiad was the only aquatic plant species present that was considered high quality, with a C-value of 8. The FQI for Curtis Lake was 22.0. This is slightly below the average FQI for the lakes in the Waushara County Lakes Study. No species of special concern in Wisconsin were found in Curtis 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. Curtis Lake had an SDI value of 0.86. This represents above-average biodiversity when compared to the lakes in the Waushara County Lakes Study.

The absence of non-native aquatic plant species in Curtis Lake is a good indicator of overall aquatic health within the lake, and it demonstrates diligence by lake users in cleaning watercraft before entering the lake in order to prevent non-native species transfer. Overall, the aquatic plant community in Curtis Lake can be characterized as having an above-average diversity when compared to all of the lakes in the Waushara County Lakes Study and minimal signs of impact from development. The habitat, food source, and water quality benefits offered by the plant community within Curtis Lake should be focal points for 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. 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. Higher scores denote healthier shorelines with good land management practices. These are areas where protection and/or conservation should be targeted. On the other hand, lower scores signify ecologically unhealthy shorelines. These are areas where management and/or mitigation practices may be desirable for improving water quality.

The summary of scores for shorelands around Curtis 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. Long stretches of Curtis Lake’s shorelands are in good shape, but a few segments have challenges that should be addressed. There were no stretches of Curtis 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/.
**Waushara County**  
**Shoreline Assessment CURTIS LAKE**

**Figure 10. Overall shoreland health around Curtis Lake, 2011.**

Summary
Shorelines are color-coded to show their overall health based on natural and physical characteristics. For example, shorelines shown in red indicate locations where management or mitigation may be warranted. Blue shorelines mark healthy riparian areas with natural vegetation and few human influences.

Calculating Shoreline Scores
Scores are based on the presence/absence of:
- Natural vegetation
- Human influences (docks, boathouses, etc)
- Erosion
- Structures

Map created by Dan McFarlane  
Center for Land Use Education
CONCLUSIONS & RECOMMENDATIONS

Overall, water quality in Curtis Lake was good, but it did have moderate average chloride, potassium, and sodium concentrations over the monitoring period that indicated the water quality in Curtis Lake was influenced by activities in its watershed. The concentrations that were observed are not considered harmful to aquatic organisms. Sources of chloride and sodium can include animal waste, septic systems, fertilizer, and road-salting chemicals. Potassium sources include animal waste, septic systems, and/or potash fertilizer.

- Of the lakes in the Waushara County Lakes Study, Curtis Lake had some of the highest nitrate (NO$_2$+NO$_3$-N) concentrations. Sources of nitrate include fertilizers, septic systems, and animal waste. The nitrate is likely moving to the lake in groundwater.
  - Water users around and upgradient of Curtis Lake should have water from their private wells tested to determine if nitrate levels exceed the federal drinking water standard.
  - In a lake, nitrate can be readily used by plants, thereby increasing the growth of aquatic plants and some types of algae.
- Concentrations of total phosphorus and chlorophyll $a$ (a measure of algae) were low, resulting in good water clarity.
- The hard water in Curtis Lake provides the calcium necessary for building bones and shells of animals in the lake, and the higher alkalinity can support higher species productivity. Hardness and alkalinity also play roles in the types of aquatic plants that are found in the lake.
- Atrazine, an herbicide used on corn, was not present in the samples tested from Curtis Lake.
- Based on the dissolved oxygen measurements taken during the study, there was sufficient oxygen in the lake to support most aquatic organisms.
- Routine monitoring of water quality can help to track changes in Curtis Lake. A monitoring plan should be designed and implemented.

In general, each type of land use contributes different amounts of phosphorus, nitrogen, and pollutants 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 Curtis Lake will depend upon understanding the sources of nutrients to the lake and identifying those that are manageable. Agriculture had the greatest percentages of phosphorus contributions from the watershed to Curtis Lake.
- Over-application of chemicals and nutrients should be avoided. Landowners in the watershed should be made aware of their connection to Curtis Lake and should work to reduce their impacts through the implementation of water quality-based best management practices.
- Shoreland health is critical to a healthy lake’s ecosystem. Curtis Lake’s shoreland was assessed for the extent of vegetation and disturbances. Shoreland vegetation provides habitat for many aquatic and terrestrial animals including birds, frogs, turtles, and 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. Alone, each manmade feature may not pose a problem for a lake, but on developed lakes, the collective impact of manmade disturbances can be a problem for lake habitat and water quality.
Long stretches of Curtis Lake’s shorelands are in good shape, but a few segments have challenges that should be addressed. There were no stretches of Curtis 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, 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.

- The diversity of an aquatic plant community is defined by the type and number of species present throughout the lake. Seventeen species of aquatic plants were found in Curtis Lake, which was slightly below-average compared with other lakes in the Waushara County Lakes Study.
- Southern naiad was the only aquatic plant species present that was considered high quality, with a C-value of 8.
- Curtis Lake had above-average biodiversity (based on the number of species per site) when compared to other lakes in the Waushara County Lakes Study.
- The amount of disturbed lakebed from raking or pulling of plants should be minimized, since these open spaces provide opportunities for aquatic invasive plants to become established.
- Early detection of aquatic invasive species (AIS) can help to prevent the establishment of invasive species should they become introduced to the lake.
  - Boats and trailers that have visited other lakes can be a primary vector for the transport of aquatic invasive species (AIS). Trained volunteers can help to educate lake users at the boat launch about how they can prevent the spread of AIS.
  - Routine monitoring should be conducted to look for AIS by trained volunteers or paid professionals.
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.”