PEPPERMILL LAKE
LAKE CLASSIFICATION REPORT

Submitted by Reesa Evans, CLM, Lake Specialist
Adams County Land & Water Conservation Department
P.O. Box 287, Friendship, WI 53934

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PEPPERMILL LAKE
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EXECUTIVE SUMMARY

Background Information about Peppermill Lake

Peppermill Lake is located in the Town of Jackson, Adams County, WI, in the south central part of Wisconsin. It is reached off of County G as it goes south. Peppermill Lake is a mesotrophic impoundment with good to very good water quality and very good water clarity. It has 65 surface acres, with a maximum depth of 14 feet and an average depth about 6 feet. Peppermill Lake is at the head of a stream subsystem that flows eventually into the Fox River and Lake Michigan. There is a public boat ramp on the northeast end of the lake owned by the Town of Jackson, as well as about 200 feet adjacent to the boat ramp that can be used by the public for fishing. The dam is owned and maintained by Adams County. The lake is the headwaters for Peppermill Creek, two miles of which was placed on the Wisconsin 303(d) impaired waterways list in 1998 due to sedimentation, degraded habitat and elevated temperatures. The Peppermill Lake District has developed a lake management plan that is reviewed annually.

The primary soil type in both the surface and ground watersheds is loamy sand. The second most common soil type in both watersheds is sand. There are also pockets of muck, sand loam, and silt loam, along with gravel pits and landfills.

Loamy sands tend to be well-drained, with water, air and nutrients moving through them at a rapid rate. Runoff, when it occurs, tends to be slow. Loamy sands have little water-holding capacity and low natural fertility, although they usually have more organic matter present than do sandy soils. Both wind and water erosion are potential hazards with loamy sands, as is drought. There are difficulties with waste disposal and vegetation establishment because of slope and seepage.

Land Use in Peppermill Lake Watersheds

Both the surface and ground watersheds for Peppermill Lake are fairly small. In the surface watershed, the main two land use types are Woodlands and Residential. Residential land use is most concentrated around the lake. The two largest land uses in the ground watershed are Woodlands and Non-Irrigated Agriculture.

Peppermill Lake has a total shoreline of 4.4 miles (23,232 feet). Much of the northwestern shore of the lake has been left unaltered and contains a wetland conservancy. The rest of the lakeshore is in residential use. Residential concentration tends to vary in density, depending on the lobe of the lake and shore direction. Small parts of the shore are steeply sloped, but much of it is only gently sloped. Most of Peppermill Lake's shoreline is vegetated.

A 2004 shore survey showed that much of the shore had an "adequate buffer. As "adequate buffer" is a native vegetation strip at least 35 feet landward from the shore. Still, some 24% had inadequate buffers. Most of the "inadequate" buffer areas were those with mowed lawns and insufficient native vegetation at the shoreline to cover 35 feet landward from the water line.

Adequate buffers on Peppermill Lake in some places could be easily installed on the inadequate areas by either letting the first 35 feet landward from the water just grow without mowing it, except for a path to the water, or by planting native seedlings sufficient to fill in the first 35 feet or using biologs to protect the shore that are vegetated. Where areas are deeply eroded, shaping, revegetating and protecting the shores will be necessary to prevent further erosion.

Water Testing Results

Between 2004 and 2006, Adams County Land & Water Conservation Department gathered water chemistry and other water quality information on Peppermill Lake. Overall, Peppermill Lake was determined to be a mesotrophic lake with good water quality and very good water clarity.

Measuring the phosphorus in a lake system provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. The 2004-2006 summer average phosphorus concentration in Peppermill Lake was 28.03 micrograms/liter. This average is under the 30 micrograms/liter level recommended to avoid nuisance algal blooms. This concentration suggests that Peppermill Lake is unlikely to have frequent nuisance algal blooms from excessive phosphorus.

Water clarity is a critical factor for plants. If plants don't get more than 2% of the surface illumination, they won't survive. Water clarity is measured with a Secchi disk. Average summer Secchi disk clarity in Peppermill Lake in 2004-2006 was 9.2 feet. This is very good water clarity.

Chlorophyll-a concentration provides a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth, as well as result in unpleasing odor and appearance. The 2004-200 growing season (June-September) average chlorophyll-a concentration in Peppermill Lake was 4.98 micrograms/liter, a low algal concentration for an impoundment.

Peppermill Lake surface water testing results showed "very hard" water (average 198.67 milligrams/liter CaCO3), considerably above the overall hardness average impoundments in Adams County of 166 milligrams/liter of Calcium Carbonate. Hard water lakes tend to produce more fish and aquatic plants than soft water lakes because they are often located in watersheds with soils that load phosphorus into the lake water.

A lake with a neutral or slightly alkaline pH like Peppermill Lake is a good lake for fish and plant survival. Natural rainfall in Wisconsin averages a pH of 5.6. This means that if the rain falls on a lake without sufficient alkalinity to buffer that acid water coming in by rainfall, the lake's fish cannot reproduce. That is not a problem at Peppermill Lake, since its surface water alkalinity averages 203.64 milliequivalents/liter. The pH levels from the bottom of the lake to the surface hovered between nearly 7 and 8, alkaline enough to buffer acid rain.

Most of the other water quality testing at Peppermill Lake showed no areas of concern. The average calcium level in Peppermill Lake's water during the testing period was 38.85 milligrams/liter. The average Magnesium level was 23.76 milligrams/liter. Both of these are low-level readings. Both sodium and potassium levels in Peppermill Lake are very low: the average sodium level was 1.91 milligrams/liter; the average potassium reading was 20.55 milligrams/liter.

To prevent the formation of hydrogen sulfate gas, levels of 10 milligrams/liter are best. A health advisory kicks in at 30 milligrams/liter. Sulfate levels in Peppermill Lake are 9.61 milligrams/liter, below the level for formation of hydrogen sulfate and below the health advisory level. Turbidity reflects water clarity. The term refers to suspended solids in the water column—solids that may include clay, silt, sand, plankton, waste, sewage and other pollutants. Very turbid waters may not only smell and mask bacteria & other pollutants, but also tend to be aesthetically displeasing, thus curtailing recreational uses of the water. Turbidity levels for Peppermill Lake were at low levels between 2004-2006.

The presence of a significant amount of chloride over a period of time may indicate that there are negative human impacts on the water quality present from septic system failure, the presence of fertilizer and/or waste, deposition of road-salt, and other nutrients. Chloride levels found in Peppermill Lake during the testing period averaged

2.4 milligrams/liter, below the natural level of 3 milligrams/liter for this region of Wisconsin.

Nitrogen levels can affect other aspects of water quality. The sum of water testing results for nitrate, nitrite and ammonium levels of over .3 milligrams/liter in the spring can be used to project the likelihood of an algal bloom in the summer (assuming sufficient phosphorus is also present). Peppermill Lake's combination spring levels from 2004 to 2006 average .22 milligrams/liter, below the .3 milligrams/liter predictive level for nitrogen-related algal blooms. The nitrogen level should be monitored because the growth level of Eurasian watermilfoil, the main invasive aquatic plant species in Peppermill Lake, has been correlated with fertilization of lake sediments by nitrogen-rich runoff.

Phosphorus

Like most lakes in Wisconsin, Peppermill Lake is a phosphorus-limited lake: of the pollutants that end up in the lake, the one that most affects the overall quality of the lake water is phosphorus. The amount of phosphorus especially affects the frequency and density of aquatic vegetation and the frequency and density of various kinds of algae, as well as water clarity and other water quality aspects.

The total phosphorus (TP) concentration in a lake is considered a good indicator of a lake's nutrient status, since the TP concentration tends to be more stable than other types of phosphorus concentration. For a man-made lake like Peppermill Lake, a total phosphorus concentration below 30 micrograms/liter tends to result in few nuisance algal blooms. Peppermill Lake's growing season (June-September) surface average total phosphorus level of 28.03 micrograms is slightly under that limit, suggesting that that phosphorus-related nuisance algal blooms should be infrequent.

Land use plays a major role in phosphorus loading. Currently, the most phosphorus loading is coming from agriculture in the surface watershed and from the ground watershed. Some phosphorus deposition cannot be controlled by humans. However, some phosphorus (and other nutrient) input can be decreased or increased by changes in human land use patterns. Practices such as shoreland buffer restoration along waterways; infiltrating stormwater runoff from roof tops, driveways and other impervious surfaces; using no phosphorus lawn fertilizers; and reducing phosphorus input to and properly managing septic systems will minimize phosphorus inputs into the lake. Such practices need to be implemented in all of the Peppermill Lake Watershed in order for a significant impact on phosphorus reduction to occur.

Reducing the amount of input from the surface and ground watersheds results in less nutrient loading into the lake itself. Under the modeling predictions, reducing phosphorus inputs from human-based activities even 10% would improve Peppermill Lake water quality by .7 to 8 micrograms. A 25% reduction would save 1.7 to 20 micrograms/liter, substantially under the 30 micrograms/liter recommended to avoid nuisance algal blooms. These predictions make it clear that reducing current phosphorus inputs to the lake are essential to improve, maintain and protect Peppermill Lake's health for future generations.

<u>Aquatic Plant Community</u>

In 2006, a qualitative aquatic plant survey was done on Peppermill Lake by staff from WDNR and Adams County Land & Water Conservation Department. A prior survey was conducted by UWSP students in 2001.

The aquatic plant community is characterized by very good species diversity for both the North Central Hardwood Forest Region and all Wisconsin lakes. The aquatic plant community in Peppermill Lake is in the category of those closer to disturbance and more tolerant of disturbance than the average lake in the North Central Hardwood Region and Wisconsin Lakes overall. Disturbances include invasions of exotic species, boat traffic, shoreline development, harvesting and past herbicide treatments.

100% of the sample sites were vegetated. Of the 36 species found in Peppermill Lake, 35 were native and 1 was an exotic invasives. In the native plant category, 15 were emergent, 2 were free-floating plants, 3 were floating-leaf rooted, and 15 were submergent types. One exotic invasive, *Myriophyllum spicatum* (Eurasian Watermilfoil) was also found. Filamentous algae were found at 48.15% of the sample sites. 36 species is more than double the 17 species found in 2001.

The highest total occurrence and total density of plant growth was recorded in the 0-1.5feet depth zone. Total plant occurrence and density declined with increasing depth. The greatest species richness (mean number of species per site) was also found in the 0-1.5 feet depth zone. *Chara* spp (muskgrass, a plant-like algae) was the most frequently-occurring aquatic species in 2006. It was also the densest aquatic species and the dominant aquatic species in Peppermill Lake.

The presence of a highly invasive, exotic species like Eurasian Watermilfoil could be a significant factor in the future. Currently, EWM remains at high density and frequency, despite several years of chemical treatment and some mechanical harvesting. Its tenacity and ability to spread to large areas fairly quickly make it an ongoing danger to the diversity, habitat value and equality of Peppermill Lake's aquatic plant community.

Critical Habitat Areas

Wisconsin Rule 107.05(3)(i)(I) defines a "critical habitat areas" as: "areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water. Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, critical habitat areas often can provide the peace, serenity and beauty that draw many people to lakes. Two areas on Peppermill Lake were determined by a team of lake professionals to be appropriate for critical habitat designation.

PE1 extends along approximately 7000 feet of the shoreline up to the ordinary high water mark, comprised of about 2/3 of the northern shore of the lake and the southwest shore of the lake. 12% of the shore is wooded; 61% has shrubs; 27% is native herbaceous cover. Shrub-carr is found along part of the shore. Large woody cover is common for habitat. With minimal human disturbance along this shoreline, the area has natural scenic beauty. Eight species of emergent aquatic plants were found in this area. Emergents provide important fish habitat and spawning areas, as well as food and cover for wildlife. Two species of free-floating plants and three species of floating-leaf rooted plants were also present. These provide cover for fish and invertebrates and are eaten by fish and waterfowl. Floating-leaf rooted vegetation also provides cover and dampens waves, protecting the shore. Filamentous algae were common in this area. Eleven species of submergent aquatics were found in PE1. The only exotic invasive plant found in this area was Eurasian Watermilfoil. Most of the aquatic vegetation in this area has multiple uses for fish and wildlife. Because this site provides all three structural types of vegetation, the community has a diversity of structure and species that supports even more diversity of fish and wildlife.

PE2 extends along approximately 800 feet of the shoreline along the middle south part of the lake. 35% of the shore is wooded; 10% is native herbaceous cover; the remaining shore is cultivated lawn and a little hard structure. Shallow marsh covers part of the shore. Large woody cover is common for habitat. No threatened or endangered species were found in this area. One exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil), was found in this area. Filamentous algae were present, especially near the shores. Only two types of emergents were found here. Two species of floating-leaf rooted plants were present. Two free-floating plants were also at this site. The remaining five aquatics in this area were submergents. A diverse submergent community can provide many benefits. All of these plants have multiple fish and wildlife uses.

Fish/Wildlife/Endangered Resources

WDNR fish stocking for Peppermill Lake occurred mainly in the 1990s and consisted of northern pike and largemouth bass. A fish inventory recorded in 1970 found that largemouth bass, bluegills, pumpkinseeds and white suckers were common, with northern pike and rock bass present. By 1999, bluegills were abundant, but had stunted growth. A threatened fish species, *Fundulus diaphanous* (red-banded killifish), was found in the lake in 1995.

A number of efforts to improve fish habitat have been made on Peppermill Lake over the years. These include the installation of pea gravel spawning beds, installation of fish cribs; installation of aerators; stocking largemouth bass, northern pike and yellow perch; feeding the fish; and aquatic plant control.

An updated fishery inventory was performed in October 2006 by the WDNR. That survey found that largemouth bass and bluegills were abundant; northern pike was common; and black crappie, pumpkinseed and yellow perch were present.

Endangered resources reported in the Peppermill Lake watersheds include *Anemone nemorosa* (Early Anemone) and *Plantanthera hookeri* (Hooker's orchid).

Conclusion

Peppermill Lake is currently an impoundment impacted substantially by significant disturbances and possible phosphorus loading from the lake bed. The Peppermill Lake District will need to monitor the lake for water quality, aquatic plant growth and invasive species, as well as regularly review and update its lake management plan in order to address the management issues in a logical, cohesive manner.

RECOMMENDATIONS

Lake Management Plan

The Peppermill Lake District will need to regularly review and update its lake management plan in order to address the management issues needed. The plan needs to always address the following: aquatic plant management; control/management of invasive species; wildlife and fishery management; watershed management; shoreland protection; critical habitat protection; water quality protection; inventory & management of the larger watershed.

The District has an active Lake Advisory Group that reviews the plan annually. It is recommended that this group be used to gather information for the district and report to the District Board.

Watershed Recommendations

Results of the modeling certainly suggest that input of nutrients, including phosphorus, are factors that need to be explored for Peppermill Lake.

Therefore, it is recommended that both the surface and ground watersheds be inventoried, documenting any of the following: runoff from any livestock operations that may be entering the surface water; soil erosion sites; agricultural producers not complying with nutrient management plans and/or irrigation water management plans. If such sites are documented, steps for dealing with these issues can be incorporated into the lake management plan as needed.

The Peppermill Lake District should consider approaching the WDNR or conservancy organizations to explore putting the northwest area of the lake into a permanent easement or non-development area to assure that those areas won't be changed in a way that would degrade water quality of the lake.

Shoreland Recommendations

All lake residents should practice best management on their lake properties, including keeping septic systems cleaned and in proper condition, eliminating the use of lawn fertilizers, cleaning up pet wastes and not composting near the water.

Aquatic Plant Management Recommendations

1) Increase the involvement of lake citizens in water quality monitoring and invasive species monitoring through the Citizen Volunteer Lake Monitoring Program. The Lake District should also have volunteers actively involved in the Clean Boats, Clean Waters program to assist in preventing the introduction of other invasives into the lake and assist in boater education.

(2) Although chemical treatments have long been used on Peppermill Lake, consideration should be given to reduce the chemical uses to shallow water and consider adding other methods to its aquatic plant management plan.

(a) This could include increases the amount of mechanical harvesting done, to use target harvesting in May and September in areas over 5 feet deep for Eurasian watermilfoil management. Mid-summer harvesting would focus on the other goals of the harvesting plan. The early-season cutting should be conducted when mifloil is almost to the surface and cut near the sediment level without disturbing the sediments. This harvesting will stress the milfoil and open up the top canopy to allow light penetration into the water for the native species. The late-season harvesting would be conducted in September when native plants are going dormant. This cutting would focus on cutting the milfoil before it autofragments in the fall. This autofragmentation is a strategy milfoil has evolved to increase its spread.

(b) Become involved in increasing the population of native weevils that were found there during a 2007 survey.

(c) Continued larger scale use of chemicals is contraindicated because it is believed that the decaying plant material adds to the internal loading in the lake, further increasing the amount of aquatic plant growth and filamentous algae presence.

(d) Harvesting removes the nutrients found in the plant tissue and filamentous algae mats. There is evidence that mechanical harvesting may already be reducing filamentous algae and nutrients. The 0-1.5ft depth zone has the highest density and occurrence of plant growth, but is not practical for mechanical harvesting. Since the density and occurrence of plant growth is nearly as high in the 1.5-5ft depth zone, hand harvesting the 3-5 ft depth zone would be effective for nutrient removal.

(e) Get plant tissue testing annually to determine how much phosphorus is being removed through the harvesting program. Keep track of amount of aquatic vegetation removed through harvesting.

(3)The Lake Management Plan should include the option of treating the east and west areas of the lake separately for aquatic plant management, particularly in regard to target harvesting and chemical spot treatment. Observation of the lake in the last three years suggests that Eurasian watermilfoil reaches appropriate treatment time considerably earlier at the shallower east end of the lake than it does at the deeper west end of the lake

(4) Since Peppermill Lake has denser aquatic plant growth than is optimum for a balance fishery (no more than 85% aquatic plant coverage), the District should continue harvesting plan to reduce cover and open areas for fish. Dense vegetation removal by hand in shallow water can be removed to a maximum 30 feet channel out of 100 feet of shoreline at each property.

(5) Natural shoreline restoration and erosion control in some areas are needed. Biological shoreline restoration is preferred. If trees fall due to continued erosion, large portions of the banks will fall with them. The areas where there is undisturbed vegetated shore should be maintained and left undisturbed for water quality & habitat protection.

(6) To protect water quality, a buffer area of native plants should be restored on those sites that now have traditional lawns mowed to the water's edge. This is especially important because more than ¼ of the shoreline is currently impacted by disturbed shores.

(7) Buffers already installed around the lake should be maintained in their current condition.

(8) Stormwater management on the impervious surfaces around the lake is essential to maintain the high quality of the lake water. For example, County G runs near one edge of the lake, resulting in runoff from the pavement into the lake.

(9) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50 feet to the shore.

(10) Septic systems around the lake should be regularly inspected and maintained properly. This can be handled through the county, through the town or through the lake district itself.

(11)The Peppermill Lake District should continue to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

(12) Peppermill Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs.

(13) Critical habitat areas were formally determined in 2006 and a report released in 2007. The lake management plan should include recommendations for preserving these areas in its update.

(14) The Peppermill Lake District should make sure that its lake management plan takes into account all inputs from both the surface and ground watersheds and addresses the concerns of this lake community.

(15) Cooperation with the Town of Jackson in keeping the boat ramp in safe condition should help reduce any negative impacts caused by the heavy use of this public area.

Critical Habitat Recommendations

(1) Maintain current habitat for fish and wildlife.
(2) Do not remove fallen trees along the shoreline.
(3) No alteration of littoral zone unless to improve spawning habitat.
(4) Seasonal protection of spawning habitat.
(5) Maintain snag/cavity trees for nesting.
(6) Install nest boxes.
(7) Maintain or increase wildlife corridor.
(8) Maintain no-wake lake designation.
(9) Allow no further development of PE1. If possible, gain a permanent conservation easement to prevent development from ever happening.
(10) Protect and, if possible, enhance emergent vegetation.
(11) Minimize aquatic plant and shore plant removal to maximum 30' wide viewing/access corridor or for navigational purposes only. Leave as much vegetation as possible to protect water quality and habitat.
(12) Use forestry best management practices.
(13) No use of lawn products.
(14) No bank grading or grading of adjacent land.
(15) No additional pier placement, boat landings, development or other shoreline disturbance in the shore area of the wetland corridor.
(16) No additional pier construction or other activity except by permit using a case-by-case evaluation and using light-penetrating materials.
(17) No installation of pea gravel or sand blankets.
(18) No bank restoration unless the erosion index scores moderate or high.

(19) If the erosion index does score moderate or high, bank restoration only using biologs or similar bioengineering, with no use of riprap or retaining walls.
(20) Placement of swimming rafts or other recreational floating devices only by permit.
(21) Maintain buffer of shoreline vegetation where present. Install buffer where there is currently cultivated lawn.
(22) Maintain aquatic vegetation in undisturbed condition for wildlife habitat, fish use and water quality protection.
(23) Maintain sign for exotic species alert at boat landing

LAKE CLASSIFICATION REPORT
FOR PEPPERMILL LAKE, ADAMS COUNTY

INTRODUCTION

In 2003, The Adams County Land & Water Conservation Department (Adams County LWCD) determined that a significant amount of natural resource data needed to be collected on the lakes with public access in order to provide it and the public with information necessary to manage the lakes in a manner that would preserve or improve water quality and keep it appropriate for public use. In some instances, there was significant historical data about a particular lake; in that instance, the study activities concentrated on combining and updating information. In other instances, there was no information on a lake, so study activities concentrating on gathering data about that lake. Further, it was discovered that information was scattered among various citizens, so often what information was actually available regarding a particular lake was unknown. To assist in updating some information and gathering baseline information, plus centralize the data collected, so the public may access it. The Adams County LWCD received a series of grants from the Wisconsin Department of Natural Resources (WDNR) from the Lake Classification Grant Program.

Objectives of the study were:

- collect physical data on the named lakes to assist in assessing the health of Adams County lake ecosystems and in classifying the water quality of the lakes.
- collect chemical and biological data on the named lakes to assist in assessing the health of Adams County lake ecosystems and in classifying the water quality of the lakes.
- develop a library of lake information that is centrally located and accessible to the public and to City, County, State and Federal agencies.
- make specific recommendations for actions and strategies for the protection, preservation and management of the lakes and their watersheds.
- create a baseline for future lake water quality monitoring.
- Provide technical information for the development of comprehensive lake management plans for each lake
- provide a basis for the water quality component of the Adams County Land and Water Resource Management Plan. Components of the plan will be incorporated into Adams County's "Smart Growth Plan".
- develop and implement educational programs and materials to inform and education lake area property owners and lake users in Adams County.

METHODS OF DATA COLLECTION

To collect the physical data, the following methods were used:

- delineation & mapping of ground & surface watersheds using topographic maps, ground truthing and computer modeling;
- identification of flow patterns for both the surface & ground watersheds using known flow maps and topographic maps;
- inventory & mapping of current land use with orthographic photos and collected county information;
- inventory & mapping of shoreline erosion and buffers using county parcel maps and visual observation;
- inventory & mapping for historical and cultural sites using information from the local historical society and the Wisconsin Historical Society;
- identification & mapping of critical habitat areas with WDNR and Adams County LWCD staff;
- identification & mapping of endangered or threatened natural resources (including natural communities, plant & animal species) using information from the Natural Heritage Inventory of Wisconsin;
- identification & mapping of wetland areas using WDNR and Natural Resource Conservation Service wetland maps;
- preparation of soil maps for each of the lake watersheds using soil survey data from the Natural Resource Conservation Service.

To collect water quality information, different methods were used:

- for three years, lakes were sampled during late winter, at spring and fall turnover, and several times during the summer for various parameters of water quality, including dissolved oxygen, relevant to fish survival and total phosphorus, related to aquatic plant and algae growth;
- random samples from wells in each lake watershed were taken in two years and tested for several factors;
- aquatic plant surveys were done on all 20 lakes and reports prepared, including identification of exotics, identifying existing aquatic plant community, evaluation of community measures, mapping of plant distribution, and recommendations;
- all lakes were evaluated for critical habitat areas, with reports and recommendations being made to the respective lakes and the WDNR;
- lake water quality modeling was done using data collected, as well as historical data where it was available.

WATER QUALITY COMPUTER MODELING

Wisconsin developed a computer modeling program called WiLMS (Wisconsin Lake Modeling Suite) to assist in determining the amount of phosphorus being loaded annually into a lake, as well as the probable source of that phosphorus. This suite has many models, including Lake Total Phosphorus Prediction, Lake Eutrophic Analysis Procedure, Expanded Trophic Response, Summary Trophic Response, Internal Load Estimator, Prediction & Uncertainty Analysis, and Water & Nutrient Outflow. The models that various types of data inputs: known water chemistry; surface area of lake; mean depth of lake; volume of lake; land use types & acreage. This information is then used in the various models to determine the hydrologic budget, estimated residence time, flushing rate, and other parameters.

Using the data collected over the course of the studies, various models were run under the WiLMS Suite. These water quality models are computer-based mathematical models that simulate lake water quality and watershed runoff conditions. They are meant to be a tool to assist in predicting changes in water quality when watershed management activities are simulated. For example, a model might estimate how much water quality improvement would occur if watershed sources of phosphorus inputs were reduced. However, it should be understood that these models predict only a relative response, not an exact response. Modeling results will be incorporated into topic discussions as appropriate.

DISSEMINATION OF PROJECT DELIVERABLES

The results of this study will be distributed various agencies, organizations and the public as previously described. Based on the classification information, the Adams County Land and Water Conservation Department will identify assistance requests and determine the appropriate future activities, based on the classification determinations. To provide the requested assistance, Adams County Land and Water Conservation Department will incorporate the lake management plans goals, priorities and action items into its Annual Plan of Operations. Goals, priorities and action items may include educational programs, formation of lake districts, further development of lake management plans and implementation of lake management plans.

ADAMS COUNTY INFORMATION

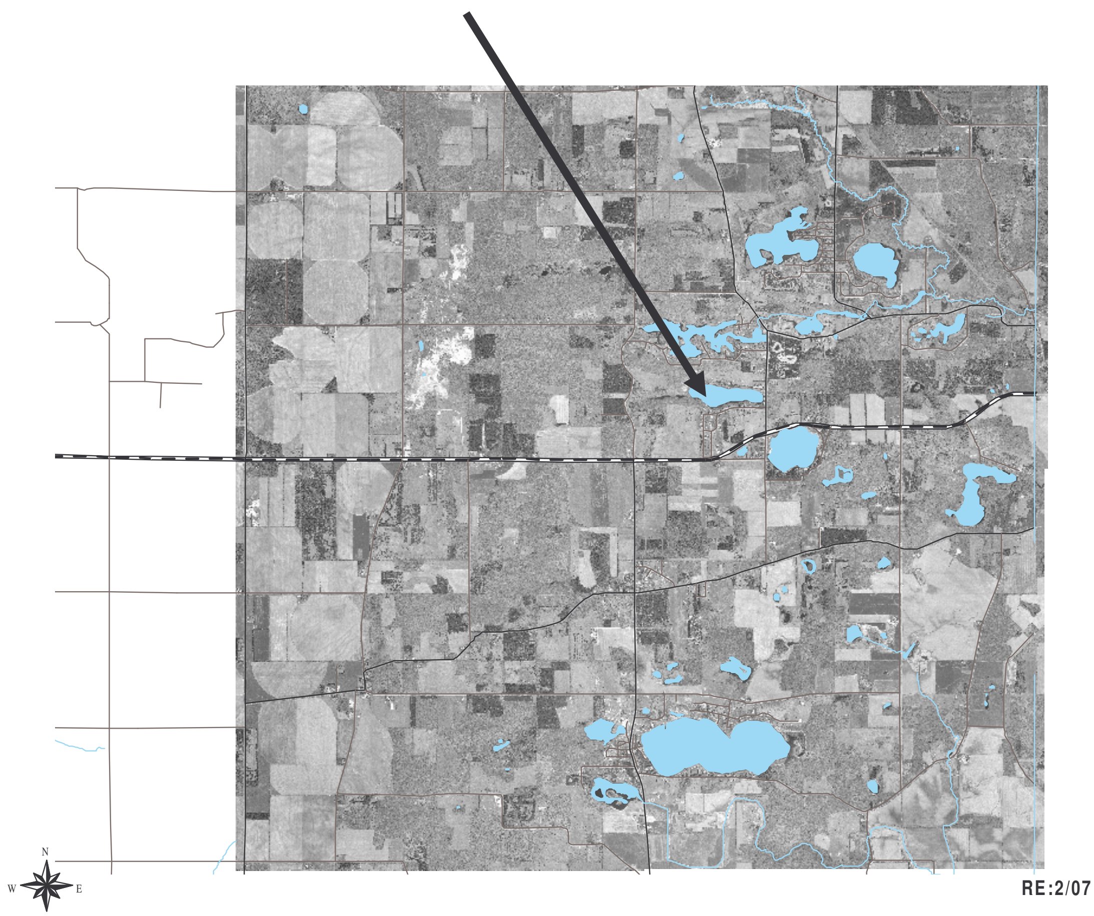
Adams County lies in south central Wisconsin, shaped roughly like the outline of Illinois. Adams County is a small rural county with a full-time population of about 20,000. Between 1980 and 2000, Adams County's population grew by more than 20%, with most of the population increase being located upon the lakes and streams. The population increase has resulted in a greater need for facilitation, technical assistance and education, including information on the lakes and streams.

Figure 1: Adams County Location in Wisconsin

PEPPERMILL LAKE BACKGROUND INFORMATION

Peppermill Lake is located in the Town of Jackson, Adams County, WI, in the south central part of Wisconsin. It is reached off of County G as it goes south. Peppermill Lake is a mesotrophic impoundment with good to very good water quality and very good water clarity. It has 65 surface acres, with a maximum depth of 14 feet and an average depth about 6 feet. Peppermill Lake is at the head of a stream subsystem that flows eventually into the Fox River and Lake Michigan. There is a public boat ramp on the northeast end of the lake owned by the Town of Jackson, as well as about 200 feet adjacent to the boat ramp that can be used by the public for fishing. The dam is owned and maintained by Adams County. The lake is the headwaters for Peppermill Creek, two miles of which was placed on the Wisconsin 303(d) impaired waterways list in 1998 due to sedimentation, degraded habitat and elevated temperatures. The Peppermill Lake District has developed a lake management plan that is reviewed annually.

Figure 2: Peppermill Lake location



The Central Sand Hills, which contain Peppermill Lake, are found on the eastern edge of what once was Glacial Lake Wisconsin. The area is characterized by a series of glacial moraines that were later partially covered by glacial outwash. The area is a mixture of farmland, woodlots, wetlands, small kettle lakes and cold water stream, all on sandy soils. The combination of glacial moraines and pitted outwash has resulted in extensive wetlands in the outwash areas and the headwaters of cold water streams that originate in glacial moraines. Lakes in these areas tend to be fairly clean, but the groundwater tends to be vulnerable to contamination. Terrain tends to be undulating or rolling

Bedrock and Historical Vegetation

Bedrock in this area is mostly sandstone, both weak and resistant, formed in the Cambrian Period of Geology (542 to 488 millions years ago). Bedrock tends to be between 50 and 100 feet of the land surface, which is covered by lake, organic, till and glacial meltwater deposition.

Historic upland vegetation was oak-forest, oak savanna and tallgrass prairie. Current vegetation is about one-third agricultural crops and a number of grasslands with open wetland, open water, shrubs, barren and more urbanized areas. Woodland types are oak-hickory, with smaller areas of white-red-jack pine, maple basswood, lowland hardwoods and spruce-fir.

Soils in the Peppermill Lake Watersheds

The primary soil type in both the surface and ground watersheds is loamy sand. The second most common soil type in both watersheds is sand. There are also pockets of muck, sand loam, and silt loam, along with gravel pits and landfills.

Loamy sands tend to be well-drained, with water, air and nutrients moving through them at a rapid rate. Runoff, when it occurs, tends to be slow. Loamy sands have little water-holding capacity and low natural fertility, although they usually have more organic matter present than do sandy soils. Both wind and water erosion are potential hazards with loamy sands, as is drought. There are difficulties with waste disposal and vegetation establishment because of slope and seepage.

Sandy soil tends to be excessively drained, no matter what the slope. Water, air and nutrients move through sandy soils at a rapid rate, so that little runoff occurs unless the soil becomes saturated. Although water erosion can be a problem, wind erosion may be more of a hazard with sandy soils, especially since these soils dry out so quickly. There are also draught hazards with sandy soils. Getting vegetation started in sandy soils is often difficult due to the low available water capacity, as well as low natural fertility and organic material. Onsite waste disposal in sandy soils is also a problem because of slope and seepage; mound systems are usually required.

The soil and soil slopes around lakes and streams are very important to water quality. They affect amount of infiltration of surface precipitation into the ground and the amount of contaminants that may reach the groundwater, as well as the amount of surface stormwater runoff. In addition, these two factors affect the amount and content of pollutants and particles (including soil) that may wash into a water body, affecting its water quality, its aquatic plant community and its fishery. Further, soil types and soil slopes help determine the appropriate private sewage system and other engineering practices for a particular site, since they affect absorption, filtration and infiltration of contamination from engineering practices.

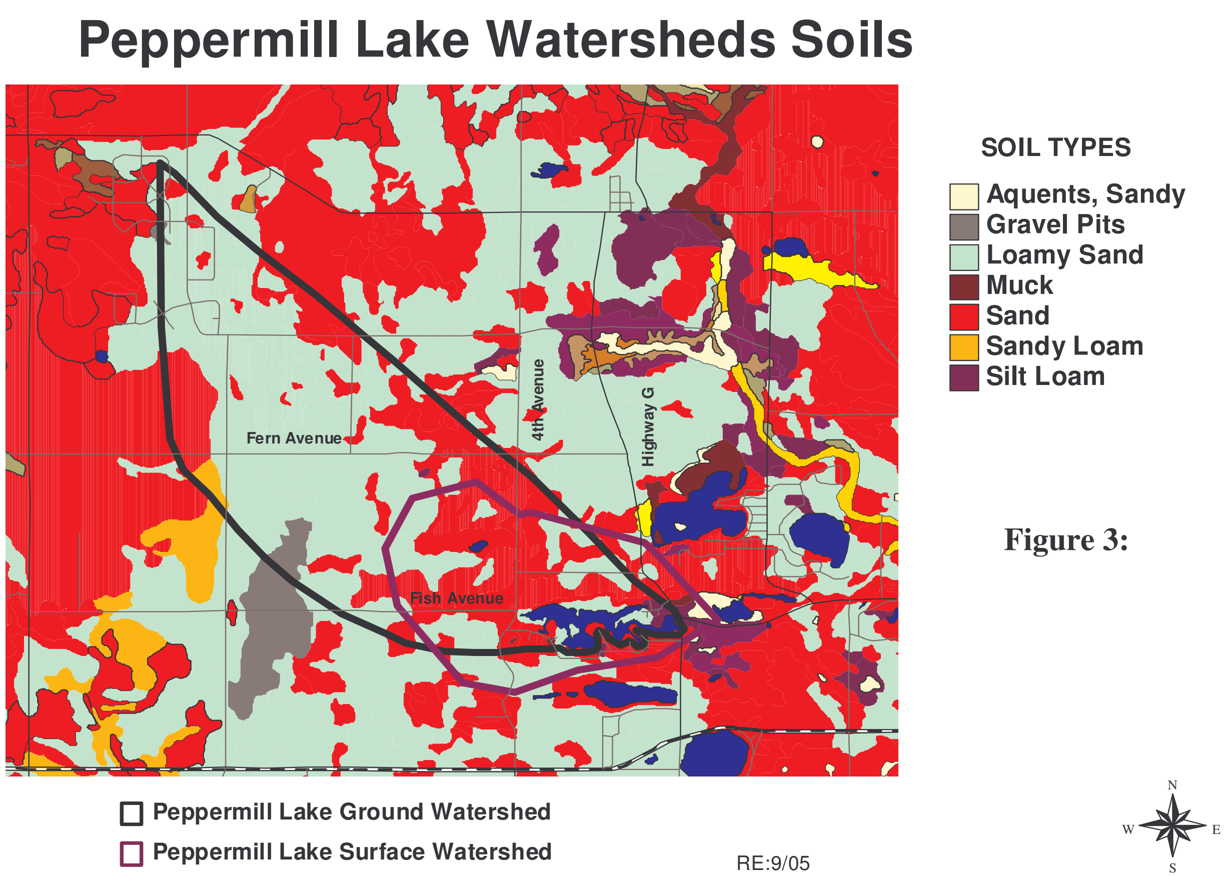


Figure 3:

PRIOR STUDIES OF PEPPERMILL LAKE AREA

A survey was sent out to Peppermill Lake property owners in 2001. It received a 74.12% return. 85.7% of those responding owned waterfront property on the lake, with 43% owning land at the east half of the lake and 57% owning land at the west half of the lake. The mean ownership length at that time was 11.6 years. Nearly 18% of the respondents were year-around residents. The top recreational uses of the lake were: fishing; boating; peace/solitude; wildlife observation; and scenic enjoyment.

Respondents were asked to rate the water and fishing quality of Peppermill Lake. Although 83.2% classified the lake's water as "good", "very good" or "excellent", 50.9% felt the water quality had declined since they started coming to the lake. The top two causes for water quality decline identified by the respondents were herbicide use and septics. Aquatic plant growth and algae/scum were identified as the major problems on the lake. 45.2% of the respondents felt the quality of fishing had declined, with the causes identified as septics and fertilizer use.

In 2002, a report was presented by the Environmental Task Force of University of Wisconsin-Stevens Point, written by N. Turyk and J. Stelzer, outlining the results of the study they had performed on Peppermill Lake in the early 2000s.

For their study, the lake was looked at in four lobes. Lobe #1 was the west lobe, with a maximum depth of 14 feet. Lobe #2 was the southwest lobe, with a maximum depth of 11.8 feet. #3 Lobe was north of the island on the east end of the lake, with a maximum depth of 8 feet. And the east end of the lake, identified as Lobe #4, had a maximum depth of 11.4 feet. The only areas that stratified in the summer were the deep holes in each lobe.

The report noted that 80 acres on the northwest side of the lake was zoned as a conservancy, with use restrictions, including a 1000 foot setback requirement for any buildings. At the far east end of the lake, by the public boat ramp, there is 250 feet of public fishing access off of Highway G.

As part of the study, piezometers were set around the lake shore to evaluate the flow of groundwater in and out of the lake. 56% of the piezometers showed groundwater inflow, suggesting that land use practices around those areas would more likely affect lake water quality than the areas where groundwater flowed out of the lake.

The lake surface water was tested for total phosphorus, Chlorophyll-a, water clarity, pH, alkalinity, hardness, chloride, sulfate, sodium and potassium. The average total phosphorus level was 22 micrograms/liter, with a range from 12 micrograms/liter to 54 micrograms/liter. The average growing season chlorophyll-a result was 2.98 micrograms/liter. Average water clarity depth, using a Secchi disk, was 10.99 feet.

Other water testing results showed the chloride was 0.8 milligrams/liter, sulfate was 10.3 milligrams/liter, sodium was 1.5 milligrams/liter and potassium was 0.6 milligrams/liter. The lake surface water was determined to be "very hard" (hardness of 181 milligrams/liter of calcium carbonate) and "very alkaline" (alkalinity of 181 milliequivalents/liter). Average pH was an alkaline 8.26.

This study also evaluated phosphorus loading sources, noting that the Peppermill Lake area had permeable soils with little surface runoff. This report estimated that 75% of the total phosphorus load in Peppermill Lake came from the groundwater and decaying plant matter within the lake.

Figure 4: Estimated Loading in 2001

	% Total	TP in lbs/acre/yr
Internal Loading	75%	169.52
External Loading		
agriculture	0.8%	1.78
atmosphere	3.1%	7.14
grass/pasture	4.3%	9.81
groundwater	6.7%	15.17
rural residential	1.3%	2.68
septics	4.7%	10.71
wetlands	0.5%	0.89
woodlands	3.6%	8.03
	100.0%	225.73

An aquatic plant survey was also performed as part of this study, using the transect method. Seventeen aquatic species were found. They included two emergent species, two free-floating species, two floating-leaf rooted species and eleven submergent species. The highest occurrence frequency, most dense and dominant species was the plant-like algae, *Chara* spp (muskgrass), seen as an indicator of good water clarity.

The report made a number of recommendations for management of the lake:

- A vegetative buffer should be maintained around the lake, with shoreline restoration occurring where it is needed.
- Phosphorus levels suggest internal loading by groundwater passing through sediments with decomposing plant materials is an important source of phosphorus to the lake. A nutrient budget should be developed to decrease the phosphorus loading.
- Continued water sampling, along with Secchi disk measurements and temperature/dissolved oxygen profiles should be collected routinely by lake residents. This information could be valuable in early detection of water quality problems and provide a better understanding of the variability in lake water quality due to year-to-year climatic variability.
- In most instances, shallow groundwater flows toward the lake. Though this water quality currently shows minimal impact from local land uses, septic influences might develop over time.
- 97% of the littoral zone was vegetated. This coverage by aquatic plants is higher than the ideal range for fish habitat (25%-85%).
- Peppermill Lake lacks diversity in the emergent aquatic plant community, which would provide additional valuable habitat for wildlife and fish. Emergent beds should be protected where they occur. Planting other emergent species in the shallow zone should be considered. Species to consider would be augmenting the bulrushes and adding burreeds, arrowheads, pickerelweed, water arum, native irises, sweet flag and sedges.
- An aquatic plant management plan should be developed for Peppermill Lake.
- Watershed-scale protection for Peppermill Lake should be incorporated into town and county land use plans. Considerations could include construction site erosion control, utilization of best management practices on agricultural land, septic system setbacks, maintenance and/or enhancement of shoreland buffers, reduction of mowed areas, and elimination or minimization of the use of lawn/garden chemicals.

CURRENT LAND USE

Both the surface and ground watersheds for Peppermill Lake are fairly small. In the surface watershed, the main two land use types are Woodlands and Residential. Residential land use is most concentrated around the lake. The two largest land uses in the ground watershed are Woodlands and Non-Irrigated Agriculture. (See Figures 5, 6a, 6b & 7).

Figure 5: Peppermill Lake Watersheds Land Use in Acres and Percent of Total

Peppermill Lake	Surface Acres	% Total	Ground Acres	% Total	Total Acres	% Total
Agriculture--Non Irrigated	97.51	9.31%	300.12	18.26%	397.63	14.77%
Agriculture--Irrigated	0	0.00%	214.39	13.04%	214.39	7.97%
Government	0	0.00%	45.2	2.75%	45.2	1.68%
Grassland/Pasture	0	0.00%	7.89	0.48%	7.89	0.29%
Residential	391.56	37.38%	233.21	14.19%	624.77	23.22%
Water	65.9	6.29%	0	0.00%	65.9	2.45%
Woodland	492.6	47.02%	842.77	51.28%	1335.37	49.62%
total	1047.57	100.00%	1643.58	100.00%	2691.15	100.00%

Studies have shown that land use around a lake has a great impact on the water quality of that lake, especially in the amount and content of surface runoff. (James, T., 1992, I-10; Kibler, D.F., ed. 1982. 271) For example, while natural woodland may (on the average) absorb 3.5” out of a 4” rainfall, leaving only .5” as runoff, a residential area with quarter-acre lots may absorb only 2.3” of the 4”, leaving 1.7” to run off the land into the lake—the same amount as may be expected to run off from a corn or soybean field. 1.7” of runoff translates into 46,200 gallons per acre ending up in the lake! Percentage of impervious surface, the soil type, vegetation present and slope of the site can all affect runoff volume. (Frankenberger, J, ID-230). The changes in the Peppermill Lake watersheds land uses are therefore likely to significantly increase the runoff in volume and content unless protection steps are taken.

Land Use--Peppermill Lake Surface Watershed

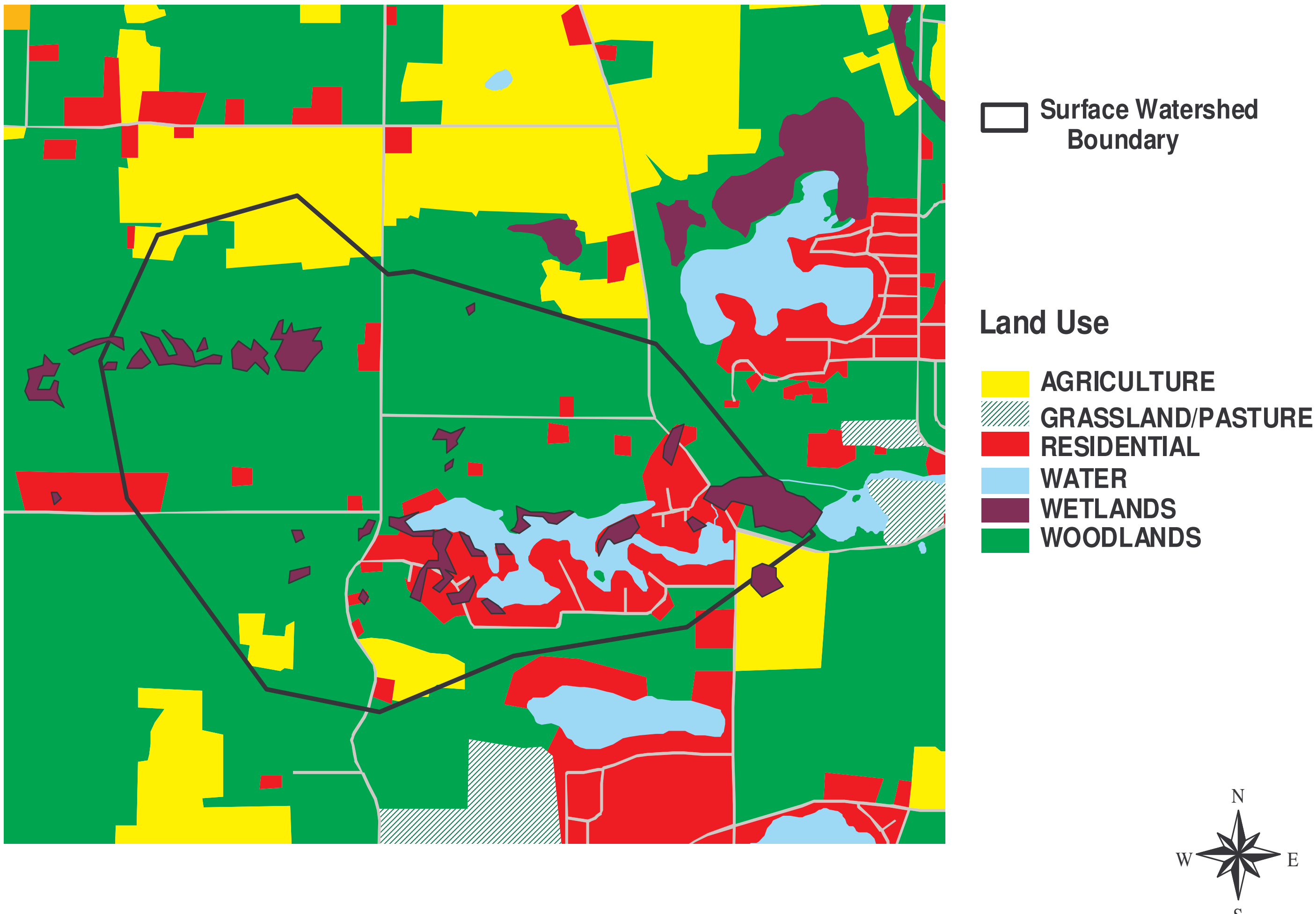


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Figure 6a: Land Use in Peppermill Lake Surface Watershed

Peppermill Lake--Ground Watershed Land Use

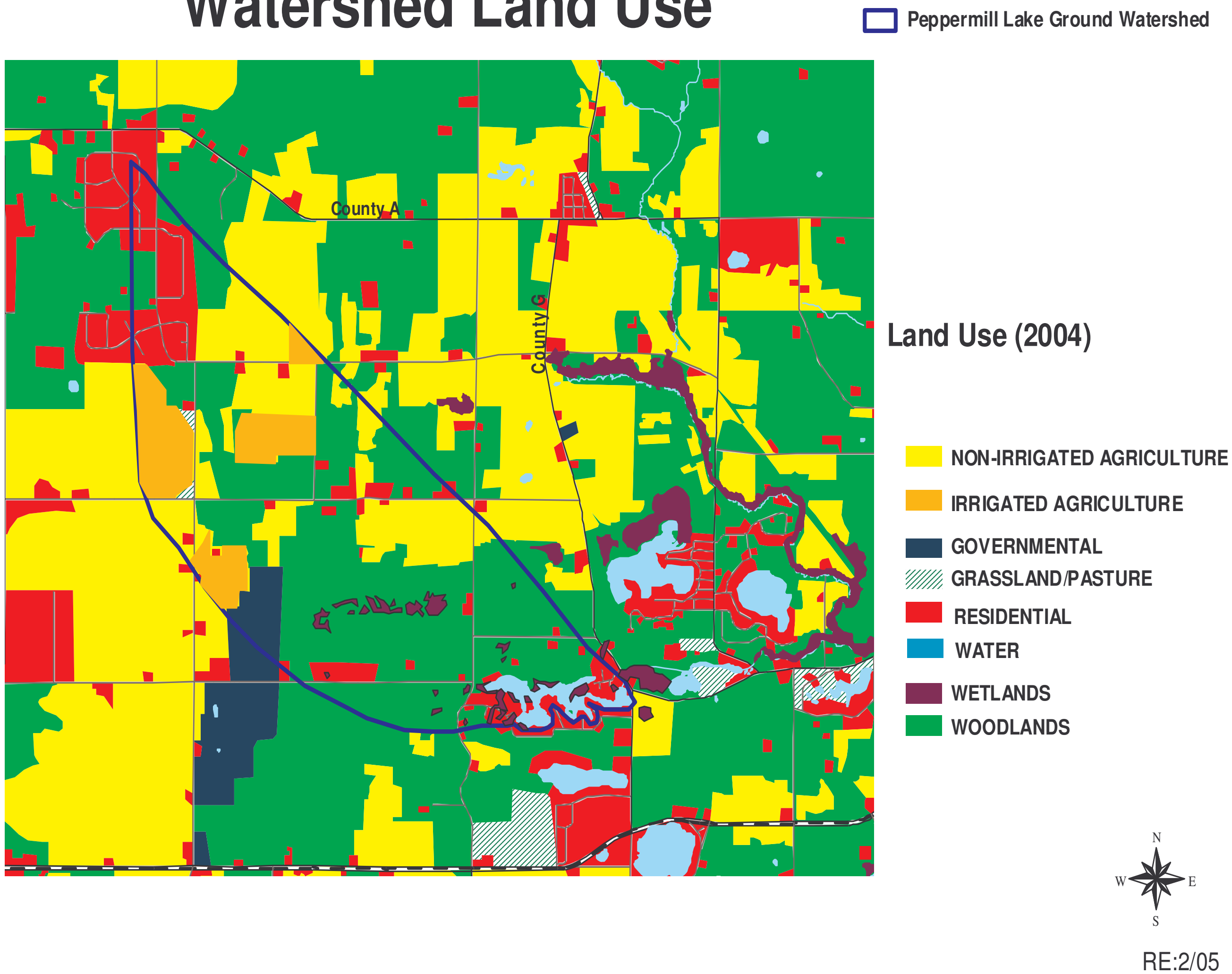
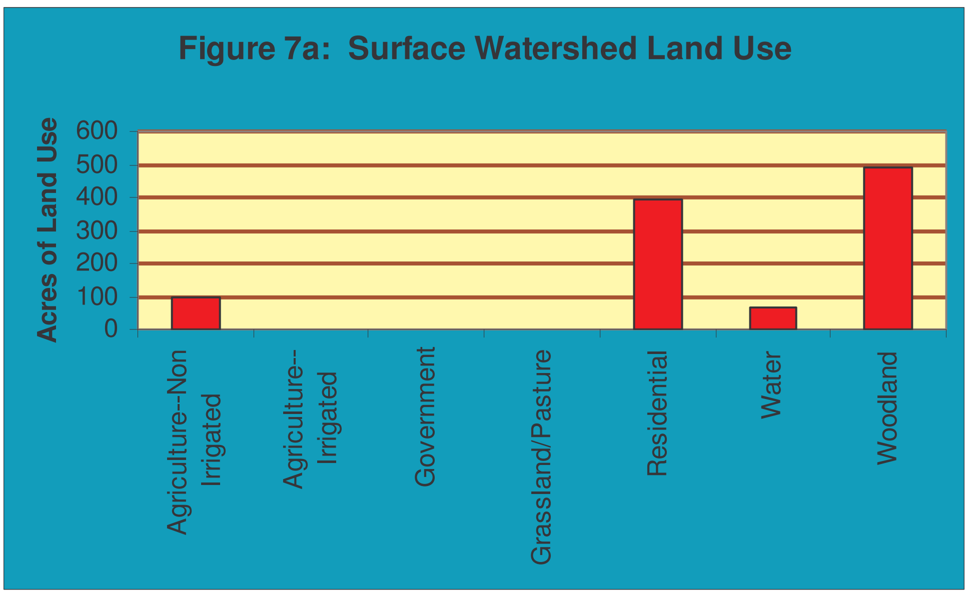
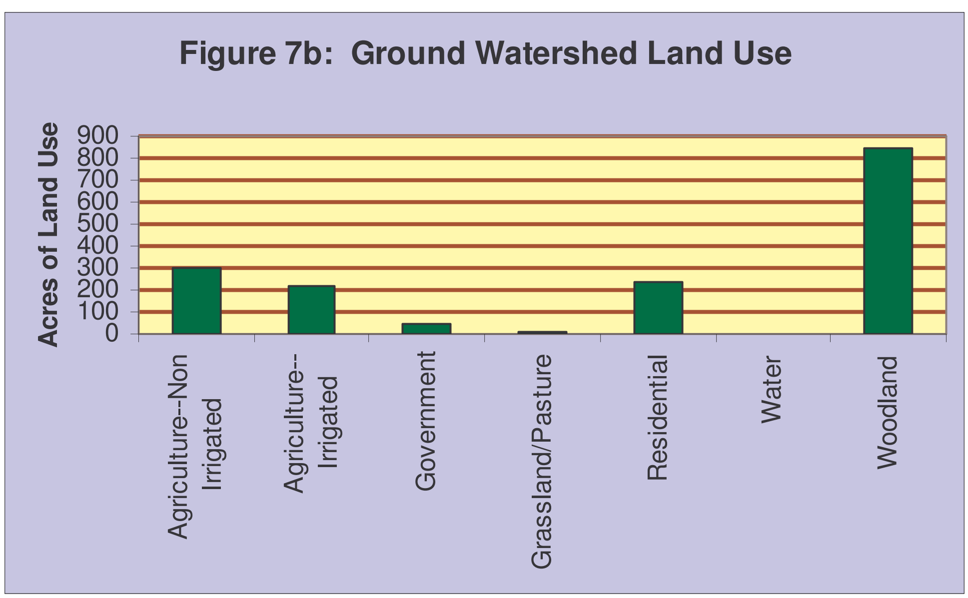


Figure 6b: Land use in Peppermill Lake Ground Watershed

When water runs over a surface, it picks up whatever loose pollutants—sediment, chemicals, metals, exhaust gas, etc—are present on that surface and takes those items with it into the lake. Increased development around a lake tends to increase the amount of pollutants being carried into the lake, thus negatively affecting water quality. Residential development areas with lots of one-quarter acre or less may deliver as much as 2.5 pounds of phosphorus per year to the lake for each acre of development.





There are two specific kinds of land use—wetlands and shorelands--that are so important to water quality that they will be separately discussed.

<u>WETLANDS</u>

A number of wetlands are located in the Peppermill Lake surface and ground watersheds, especially before the lake around the stream coming in (Figures 6a & 6b). In the past, wetlands were seen as "wasted land" that only encouraged disease-transmitting insects. Many wetlands were drained and filled in for cropping, pasturing, or even residential development. In the last few decades, however, the importance of wetlands has become evident, even as wetlands continue to decline in acreage.

Wetlands play an important role in maintaining water quality by trapping many pollutants in runoff and flood waters, thus often helping keep clean the water they connect to. They serve as buffers to catch and control what would otherwise be uncontrolled water and pollutants. Wetlands also play an essential role in the aquatic food chain (thus affecting fishery and water recreation), as well as serving as spaces for wildlife habitat, wildlife reproduction and nesting, and wildlife food.

The wetlands in the Peppermill Lake serve as filters and traps that help keep the lake as clean as it is. It is essential to preserve these wetlands for the health of Peppermill Lake.

Figure 8: Wetland at Shore of Peppermill Lake

SHORELANDS

Peppermill Lake has a total shoreline of 4.4 miles (23,232 feet). Much of the northwestern shore of the lake has been left unaltered and contains a wetland conservancy. The rest of the lakeshore is in residential use. Residential concentration tends to vary in density, depending on the lobe of the lake and shore direction. Small parts of the shore are steeply sloped, but much of it is only gently sloped. Most of Peppermill Lake's shoreline is vegetated.

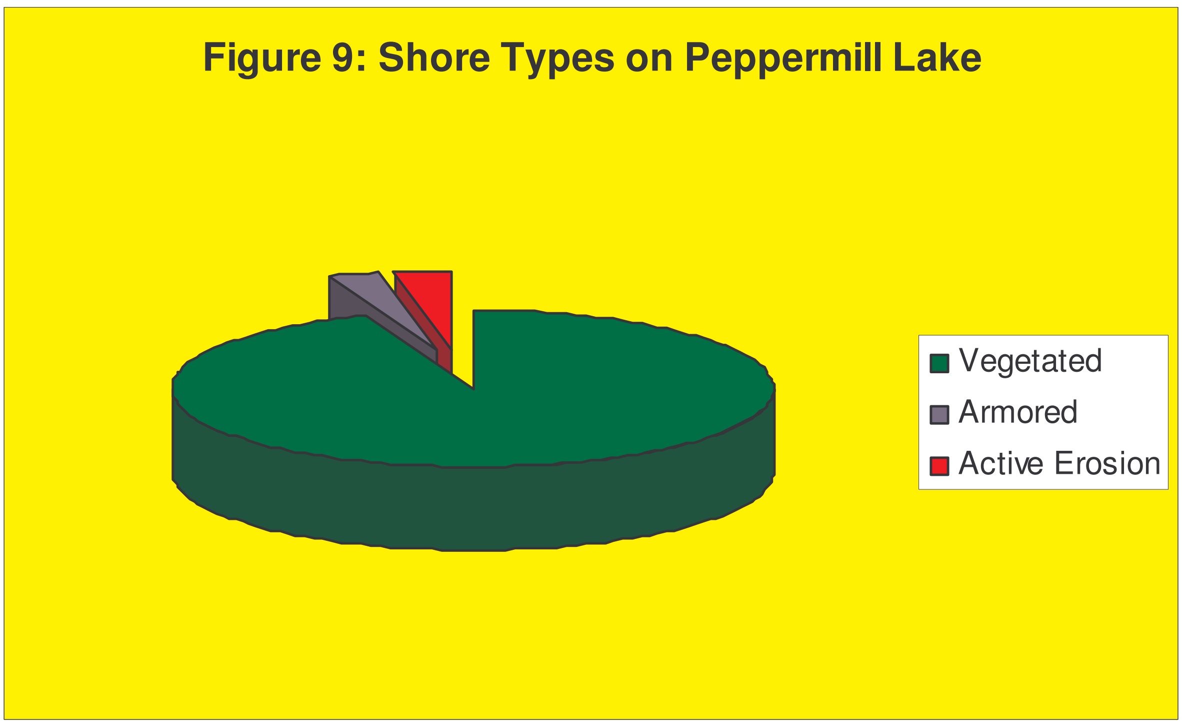
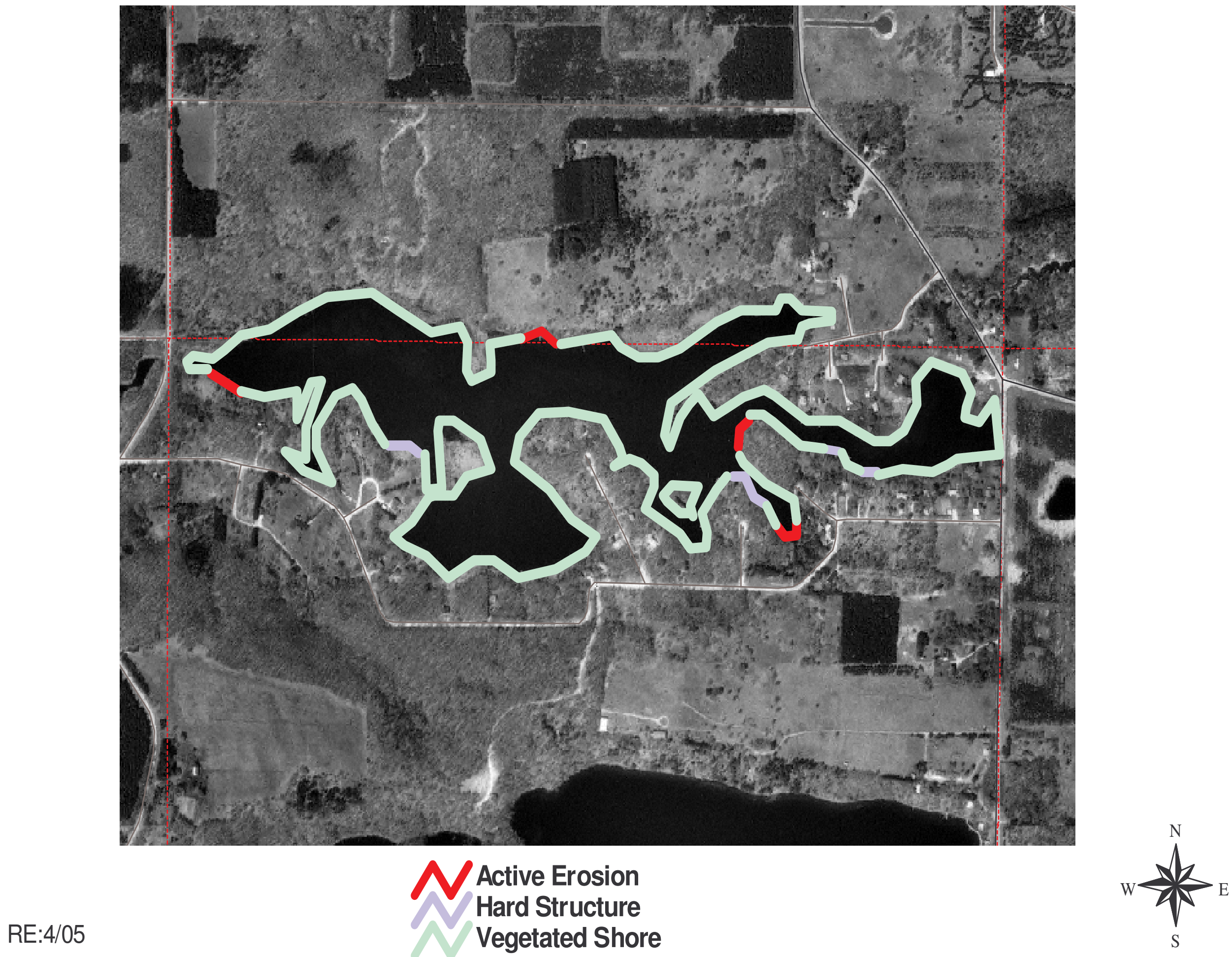
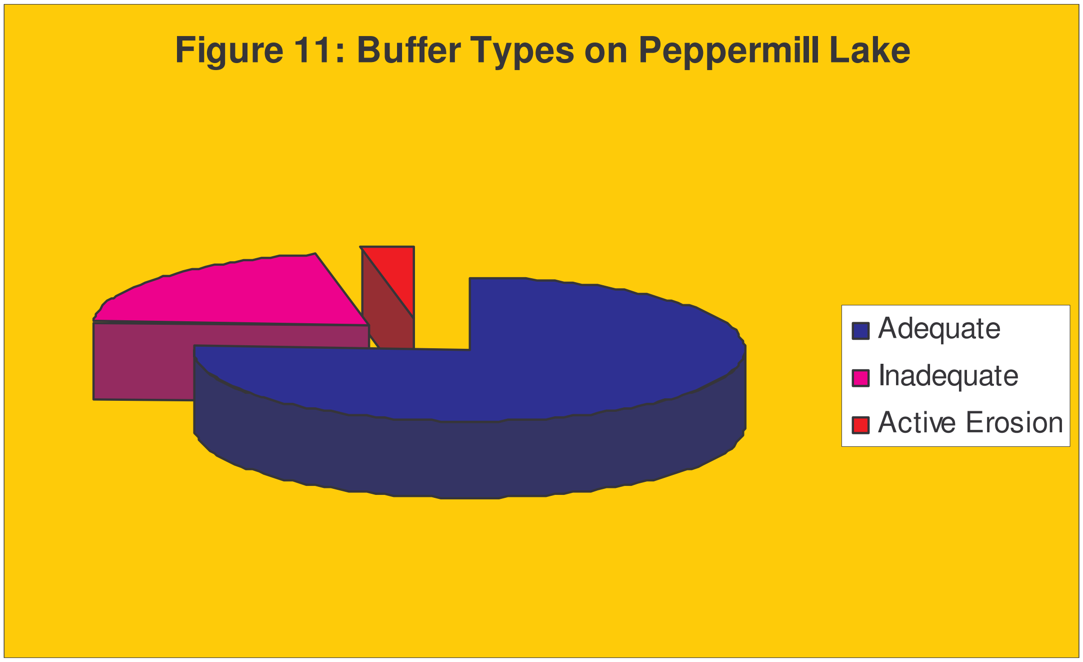


Figure 10: Shoreland Map of Peppermill Lake (2004)



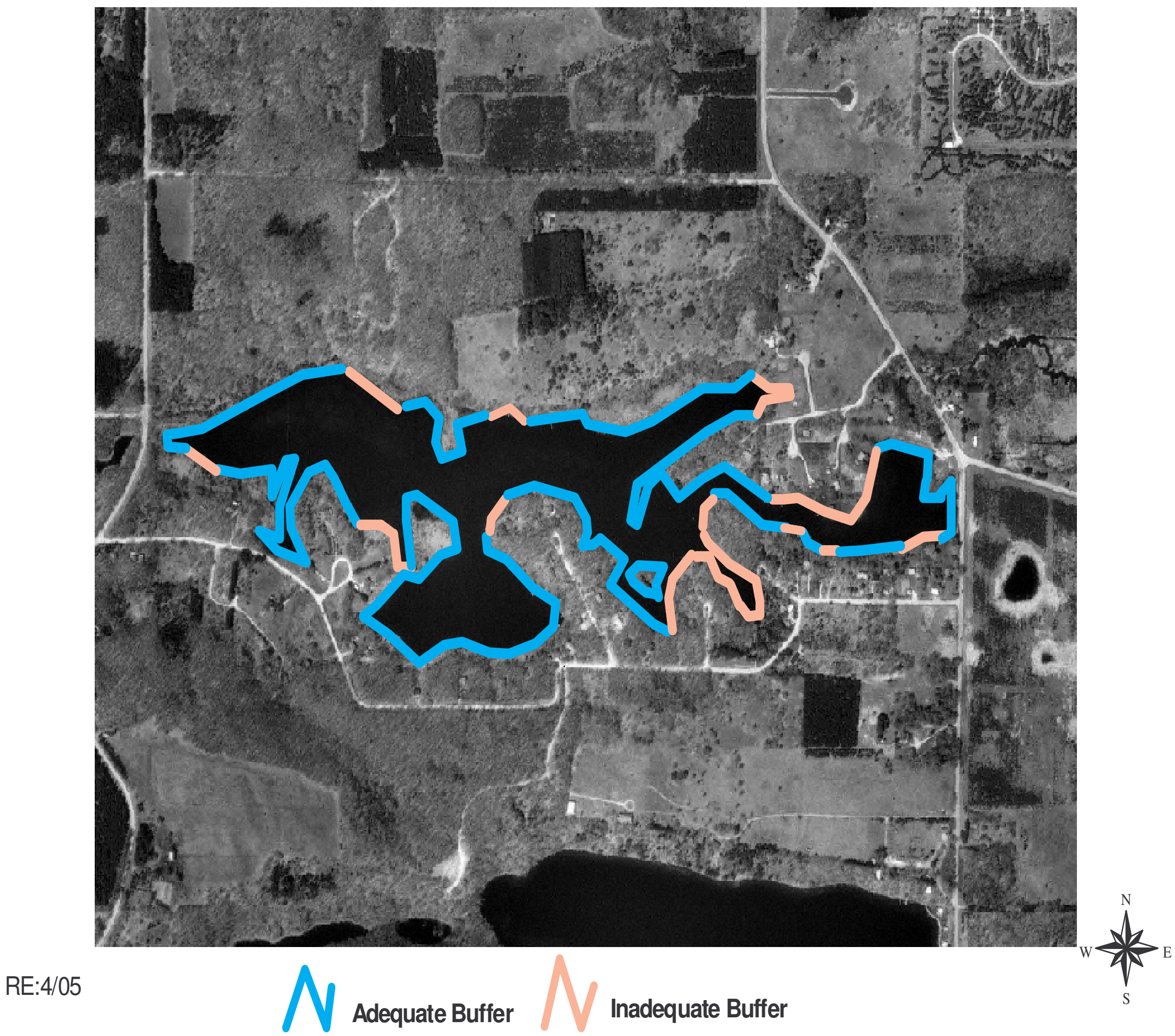
The Adams County Shoreline Ordinance defines 1000 feet landward from the ordinary high water mark as "shoreland". Under the ordinance, the first 35 feet landward from the water is a "buffer." Shoreland buffers are an important part of lake protection and restoration. These buffers are simply a wide border of native plants, grasses, shrubs and trees that filter and trap soil & similar sediments, fertilizer, grass clippings, stormwater runoff and other potential pollutants, keeping them out of the lake. A 1990 study of Wisconsin shorelines revealed that a buffer of native vegetation traps 5 to 18 times more volume of potential pollutants than does a developed, traditional lawn or hard-armored shore.

A 2004 shore survey showed that much of the shore had an “adequate buffer. As “adequate buffer” is a native vegetation strip at least 35 feet landward from the shore. Still, some 24% had inadequate buffers. Most of the “inadequate” buffer areas were those with mowed lawns and insufficient native vegetation at the shoreline to cover 35 feet landward from the water line.



Vegetated shoreland buffers help stabilize shoreline banks, thus reducing bank erosion. The plant roots give structure to the bank and also increase water infiltration and decrease runoff. A vegetated shore is especially important when shores are steep and soft, as are some of Peppermill Lake shores. Figure 12 maps the adequate and inadequate buffers on Peppermill Lake.

Figure 12: Peppermill Lake Buffer Map (2004)



Lakeside buffers also serve as important habitat. Lake edges usually contain aquatic and wetland plants, grading into drier groundcover, then shrubs and trees as one moves inland towards drier land. Buffers provide habitat for many species of water-dependent wildlife, including furbearers, reptiles, birds and insects. Many wildlife species, including birds, small mammals, fish & turtles breed, nest, forage and/or perch in shore buffer areas. Further, 80% of the endangered and threatened species listed spend part of their life in this near-lake buffer area. (Wagner et al, 2006)

When the natural shoreline is replaced by traditional mowed turf-grass lawns, rock, wooden walls or similar installments, bird and animal life, land-based insects, and aquatic insects that hatch or winter on natural shore are negatively impacted. For example, on many Adams County lakes, the non-native aquatic plant, Eurasian Watermilfoil has invaded. There is a weevil native to Wisconsin that weakens Eurasian Watermilfoil by burrowing into and developing within its stems, but that weevil depends on a native-plant shore to overwinter. If the shore is instead covered by rock, seawall or traditional lawn, these weevils will be unavailable for the lake to use as Eurasian Watermilfoil control.

The filtering process and bank stabilization that buffers provide help improve a lake's water quality, including water clarity. Studies in Minnesota, Maine and Michigan have shown that waterfront property value increases for every foot the water clarity of a lake increases. (Krysel et al, 2003).

Figure 13: Example of Inadequate Vegetative Buffer

Figure 14: Example of Adequate Buffer

Natural shoreland buffers serve important cultural functions. They enhance the lake's aesthetics. Studies have shown that aesthetics rank high as one of the reasons people visit or live on lakes. Shore buffers can provide visual & audio privacy screens for homeowners from other neighbors and/or lake users.

Adequate buffers on Peppermill Lake in some places could be easily installed on the inadequate areas by either letting the first 35 feet landward from the water just grow without mowing it, except for a path to the water, or by planting native seedlings sufficient to fill in the first 35 feet or using biologs to protect the shore that are vegetated. Where areas are deeply eroded, shaping, revegetating and protecting the shores will be necessary to prevent further erosion.

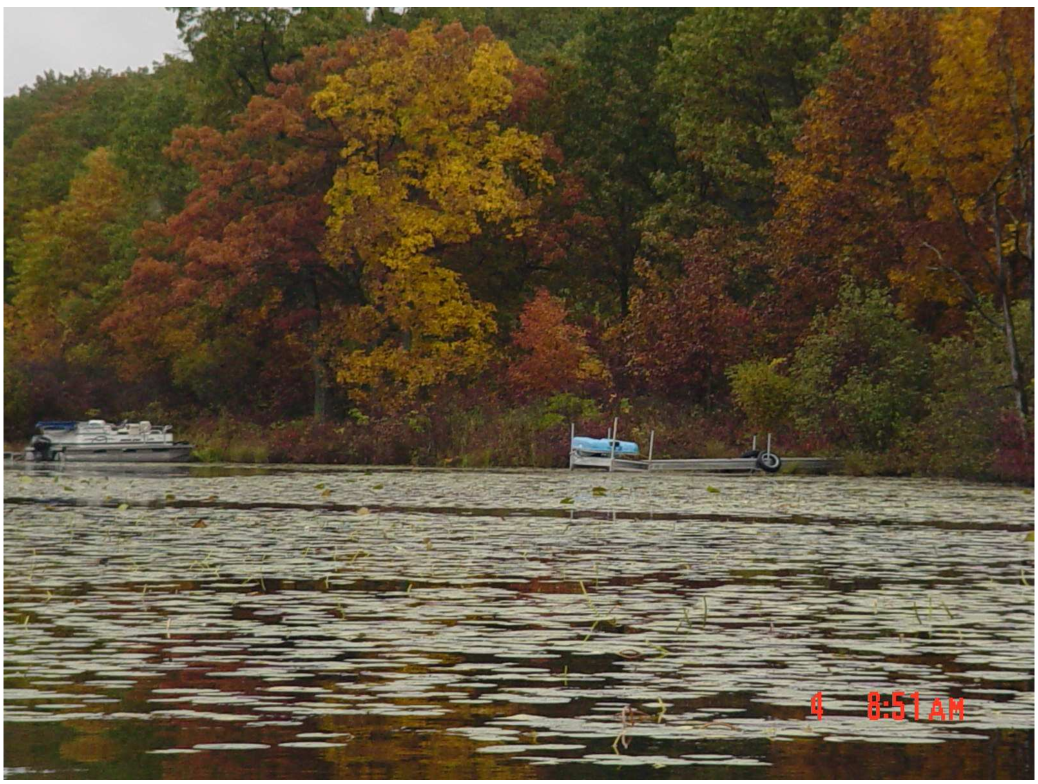


Figure 15: Vegetated Buffer on Peppermill Lake

WATER QUALITY

Between 2004 and 2006, Adams County Land & Water Conservation Department gathered water chemistry and other water quality information on Peppermill Lake. Part of the information was gained from periodic water sampling done by Adams County LWCD. Historic information about water testing on Peppermill Lake was also obtained from the WDNR in a series of tests in 1992 and 2000-2001, and from Self-Help Monitoring records from 1999-2007.

Phosphorus

Peppermill Lake is a phosphorus-limited lake: of the pollutants that end up in the lake, the one that most affects the overall quality of the lake water is phosphorus. The amount of phosphorus especially affects the frequency and density of aquatic vegetation and the frequency and density of various kinds of algae, as well as water clarity and other quality aspects. One pound of phosphorus can produce as much as 500 pounds of algae.

Phosphorus is not an element that occurs in high concentration naturally, so any lake that has significant phosphorus readings must have gotten that phosphorus from outside the lake or from internal loading. Some phosphorus is deposited onto the lake from atmospheric deposition, especially from soil or other particles in the air carrying phosphorus. A lake that includes a flooded wetland area may have a significant amount of phosphorus being released during the flushing of the wetland area. Phosphorus may accumulate in sediments from dying animals, dying aquatic plants and dying algae. If the bottom of the lake becomes anoxic (oxygen-depleted), chemical reactions may cause phosphorus to be released to the water column.

Although there are several forms of phosphorus in water, the total phosphorus (TP) concentration is considered a good indicator of a lake's nutrient status, since the TP concentration tends to be more stable than other types of phosphorus concentration. For an impoundment lake like Peppermill Lake, a total phosphorus concentration below 30 micrograms/liter tends to prevent nuisance algal blooms. Peppermill Lake's growing season (June-September) surface average total phosphorus level of 28.03 micrograms/liter is slightly under the level at which nuisance algal blooms can be expected. However, areas of Peppermill Lake do have nuisance-level algal blooms.

Since phosphorus is usually the limited factor, measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth.

The 2004-2006 summer average phosphorus concentration in Peppermill Lake places the lake in the “good” water quality section for impoundments, and in the “mesotrophic” level for phosphorus. The total epilimnetic phosphorus levels have been slowly creeping up in Peppermill Lake. In 1992, the earliest information available, eplimnetic total phosphorus was 16 micrograms/liter. By the summer of 2000, the eplimnetic total phosphorus averaged 17 micrograms/liter. It crept up to an average of 21.5 micrograms/liter in 2001. And in 2004-2006, it averaged 28.03 micrograms/liter. These levels suggest that nutrients are accumulating in the lake as time goes on.

However, the growing season total phosphorus levels have generally registered below the level recommended to avoid nuisance algal blooms. The eplimnetic total phosphorus levels since summer 1992 stayed below the state impoundment average of 65 micrograms/liter. Especially due to the increasing epilimnetic total phosphorus levels, phosphorus should continue to be monitored and steps should be taken to reduce the phosphorus levels in the lake.

Groundwater testing of various wells around Peppermill Lake was done by Adams County LWCD and included a test one year for total phosphorus levels in the groundwater coming into the lake. The average TP level in the wells tested an average of 28.2 micrograms/liter, very close to the lake surface water results.

Land use plays a major role in phosphorus loading. A key component of the computer models used is the phosphorus budget, that is, the estimated amount of phosphorus delivered to the lake from each land use type annually. The land uses that contribute the most phosphorus are non-irrigated agriculture and residences. Using the current land use data, as well as phosphorus readings from 2004 through 2006 water sampling, a phosphorus loading prediction model was run for Peppermill Lake. The current results are shown in Figure 16.

Figure 16: Current Phosphorus Loading by Land Use

MOST LIKELY CURRENT PHOSPHORUS LOADING		
Land Use	**% Loading**	**P in lbs/acre/yr**
Non-Irrigated Agriculture	15.4%	35.20
Residential	22.8%	50.60
Woodlands	9.7%	22.00
Ground Watershed	32.3%	332.20
Lake Surface	3.8%	8.80
Septics	16.0%	36.30
total in pounds/year	100.0%	485.10

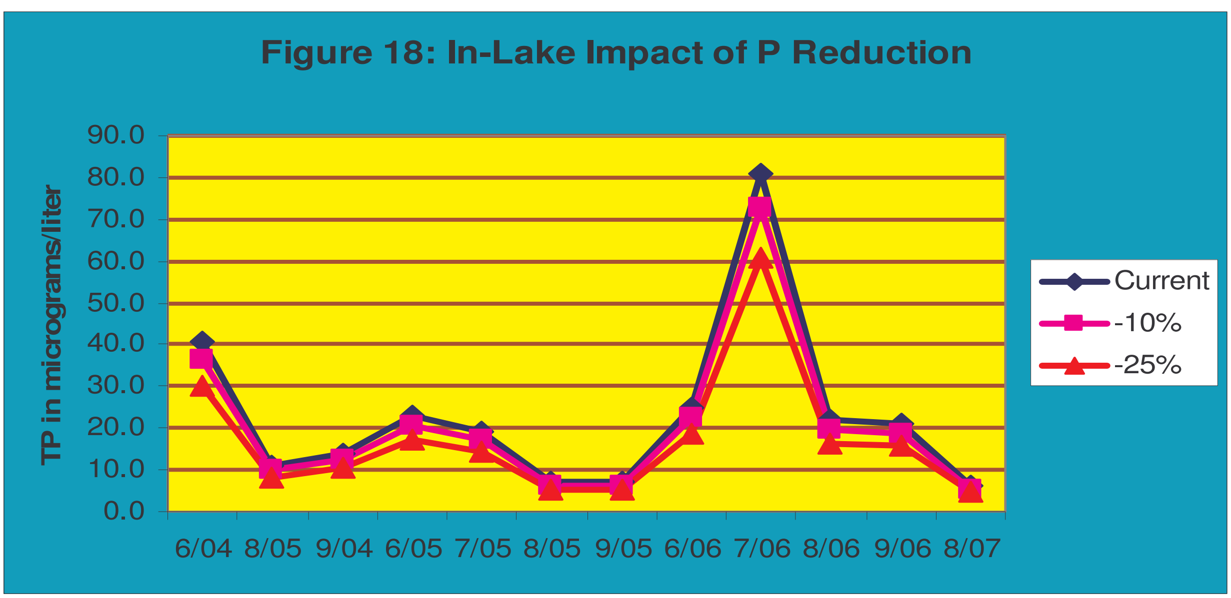
Currently, the most phosphorus loading is coming from agriculture in the surface watershed and from the ground watershed. Although phosphorus deposits such as that from flooded wetlands or from atmospheric deposition cannot be controlled by humans, phosphorus loads from human activities such as agriculture, residential development and septic systems can be partly controlled by changes in human land use patterns. Practices such as agricultural buffers, nutrient management, shoreland buffer restoration; infiltrating stormwater runoff from roof tops, driveways and other impervious surfaces; using no phosphorus lawn fertilizers; and reducing phosphorus input to and properly managing septic systems will minimize phosphorus inputs into the lake. Circumstances such as increased impervious surface, lawns mowed to water's edge, disturbance of shore areas, improperly-functioning septic systems and removal of native vegetation can greatly increase the volume and content of runoff—and thus increase the volume of phosphorus entering the lake. Many of these practices can also increase the concentration of phosphorus entering the lake, by runoff or other methods of entry.

The models were run using not only the current known phosphorus readings in the lake, but also representing decreases or increases of human-controlled phosphorus input by 10%, 25%, and 50%. Just a 10% reduction of the human-impacted phosphorus would reduce the overall load by 924.77 pounds/year. This figure may not seem like much---until you calculate that one pound of phosphorus can result in up to 500 pounds of algae. A 10% reduction in these three areas could result in up to 462,385 pounds less of algae per year!

Figure 17: Impact of Phosphorus Reduction

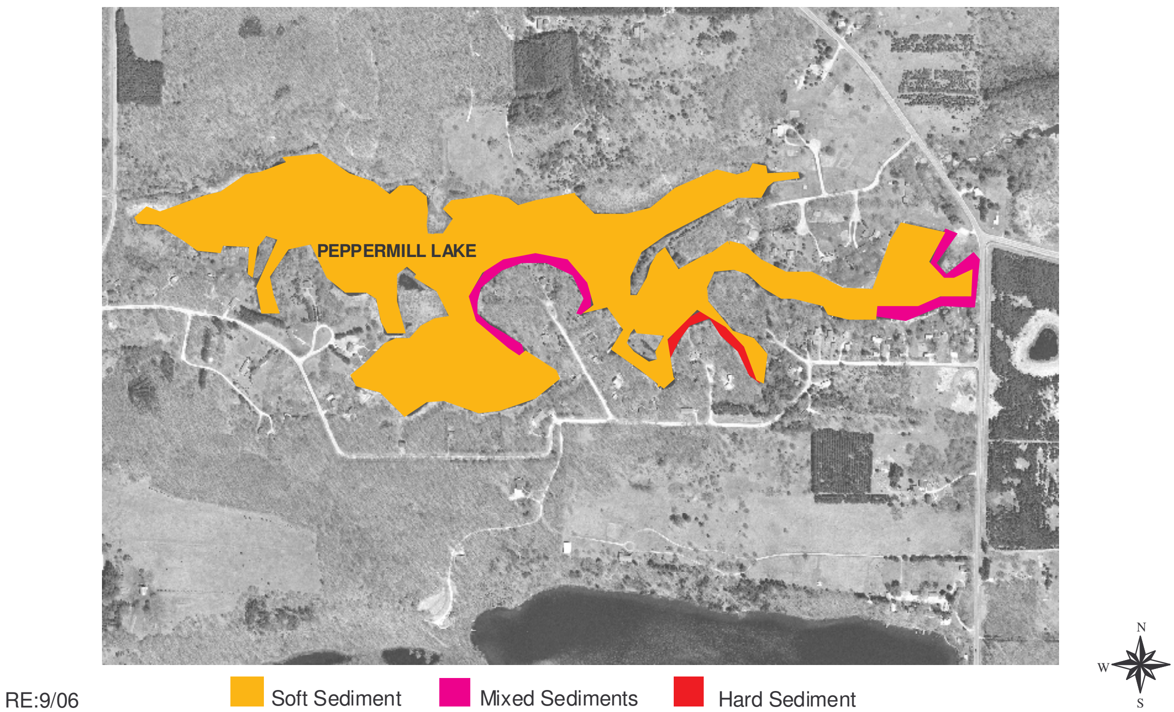
Land Use	P in lbs//yr	-10%	-25%	-50%
Non-Irrigated Agriculture	35.20	31.68	26.40	17.60
Residential	50.60	45.54	37.95	25.30
Woodlands	22.00	22.00	22.00	22.00
Ground Watershed	332.20	298.98	249.15	166.10
Lake Surface	8.80	8.80	8.80	8.80
Septics	36.30	32.67	27.23	18.15
total in pounds/year	485.10	439.67	371.53	257.95

Reducing the amount of input from the surface and ground watersheds results in less nutrient loading into the lake itself. Under the modeling predictions, reducing phosphorus inputs from human-based activities even 10% could improve Peppermill Lake water quality by up to 8 micrograms. A 25% reduction could save up to 20 micrograms/liter, substantially under the 30 micrograms/liter recommended to avoid nuisance algal blooms. These predictions make it clear that reducing current phosphorus inputs to the lake are essential to improve, maintain and protect Peppermill Lake's health for future generations.



In most lakes in Wisconsin, phosphorus concentration in the bottom sediments of the lake is considerably higher than the concentration in the water column itself. Bottom sediments can “bind up” phosphorus, making it unavailable for aquatic plants or algae to use. Some sediment types hold phosphorus at a higher rate than others.

Figure 19: Sediment Map of Peppermill Lake

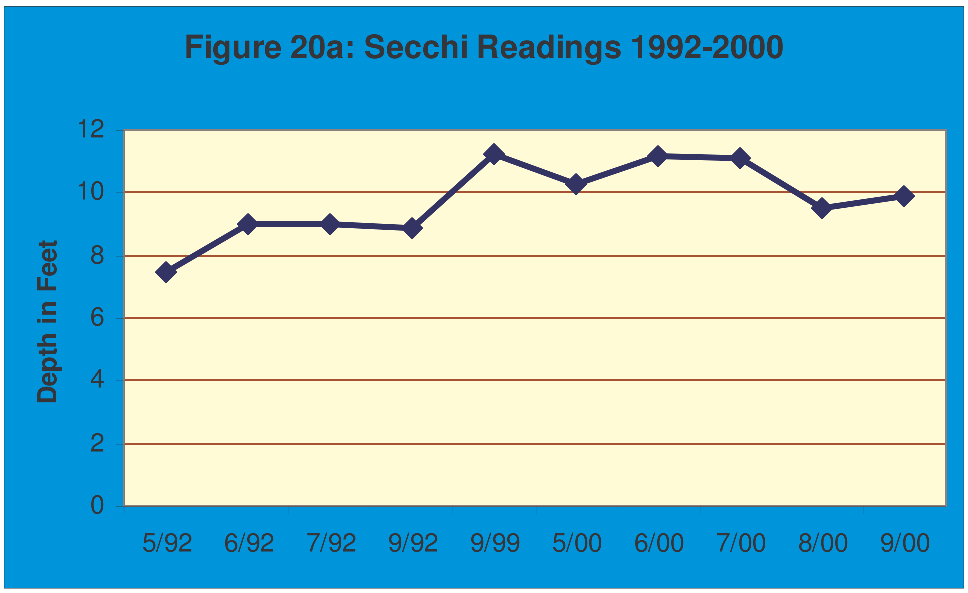


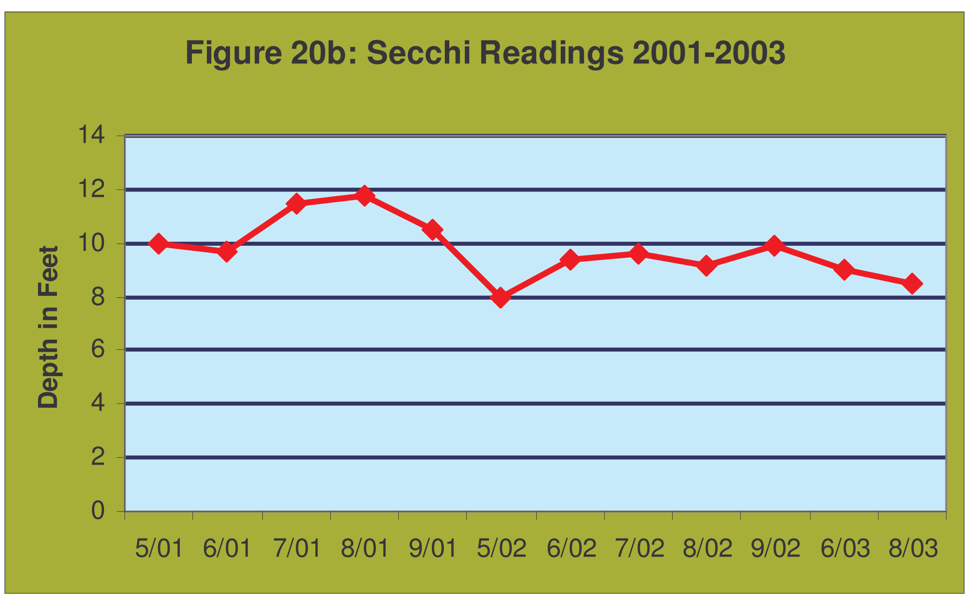
As the sediment map shows, most of the sediment in Peppermill Lake is soft, generally able to support significant aquatic plant growth. Several of the areas over 1.5 feet deep have marl as sediment. “Marl” is a calcium carbonate precipitate (solid) that forms in hard water lakes when both calcium and pH levels are high. Marl can be good for a lake because it has a high capacity to bind phosphorus, as well as other nutrients. Peppermill Lake may benefit from the marl removing phosphorus from water column, thus making it unavailable for algal and aquatic plant growth.

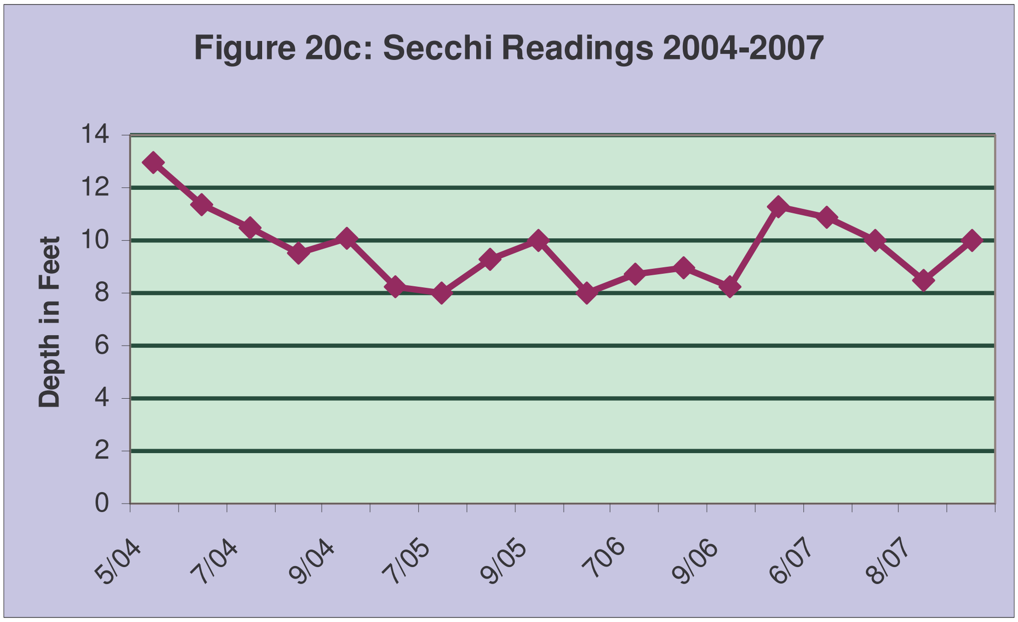
How much a marl sediment affects aquatic plant and algal growth will depend on where the marl sediment is located, i.e., if the aquatic plants are rooted in the marl, so that they can still draw phosphorus from it, the presence of marl may not reduce aquatic plant growth. Effect will also depend on how much phosphorus the marl has already absorbed. Most of the marl in Peppermill Lake is located in the west and southwest lobes. Considering that the 2006 Aquatic Plant Survey found 100% of Peppermill Lake's littoral zone vegetated, it is difficult to tell if the marl sediment in Peppermill Lake has been a limiting factor in aquatic plant growth—perhaps growth would be even denser if not for the effect of marl.

Water Clarity

Water clarity is a critical factor for plants. If plants don't get more than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. Average summer Secchi disk clarity in Peppermill Lake in 2004-2006 was 9.2 feet. This is very good water clarity.







Peppermill Lake has a considerable history of Secchi disk readings in a number of years. A look at the average Secchi depth for the growing season in each year since 1992 reveals fairly steady water clarity (see figure 21). The overall average depth for the years for which there are records is 9.73 feet.

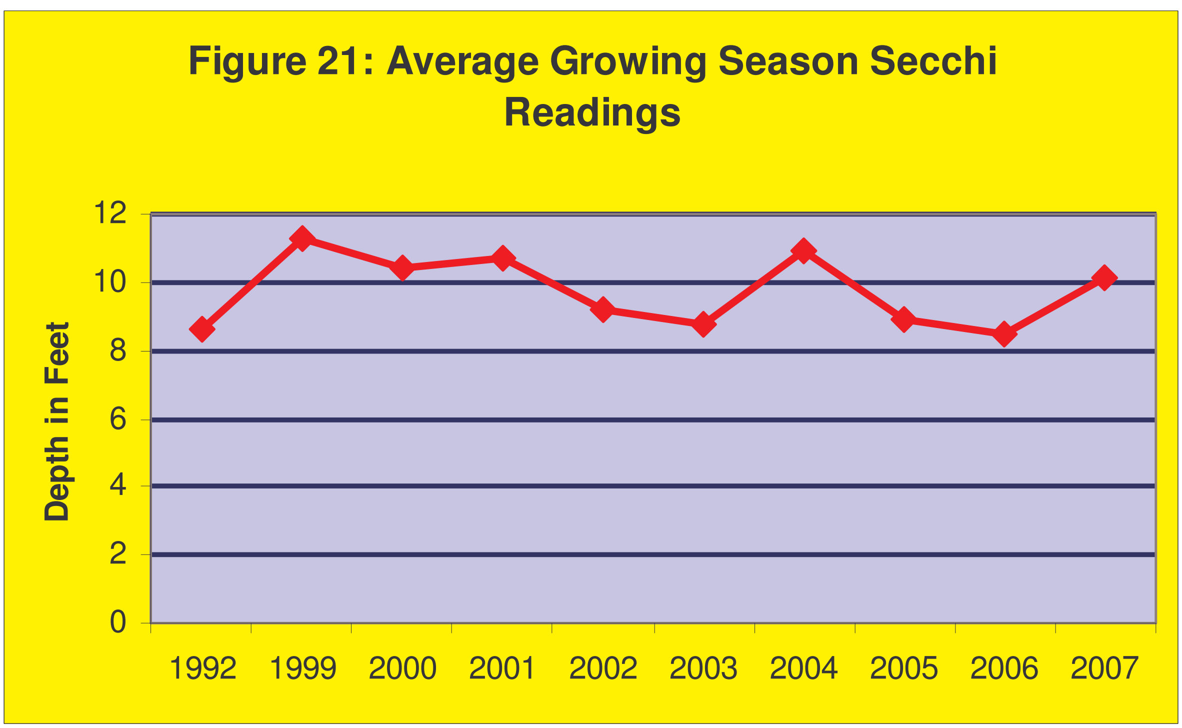


Figure 22: Photo of Testing Water Clarity with Secchi Disk

Chlorophyll a

Chlorophyll-a concentrations provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth, as well as result in unpleasing odor and appearance. Studies have shown that the amount of chlorophyll a in lake water depends greatly on the amount of algae present; therefore, chlorophyll-a levels are commonly used as a water quality indicator. The 2004-2006 growing season (June-September) average chlorophyll concentration in Peppermill Lake was 4.98 micrograms/liter. Such an algae concentration places Peppermill Lake at the "very good" level for chlorophyll a results.

Chlorophyll-a averages remained fairly low (under 5 micrograms/liter) until 2007, when summer figures were very elevated. These readings might have been a factor of the very hot summer of 2007, as plants slowed down photosynthesis due to the much hotter water and algal blooms were frequent.

Figure 23: Photo of a Lake in Algal Bloom

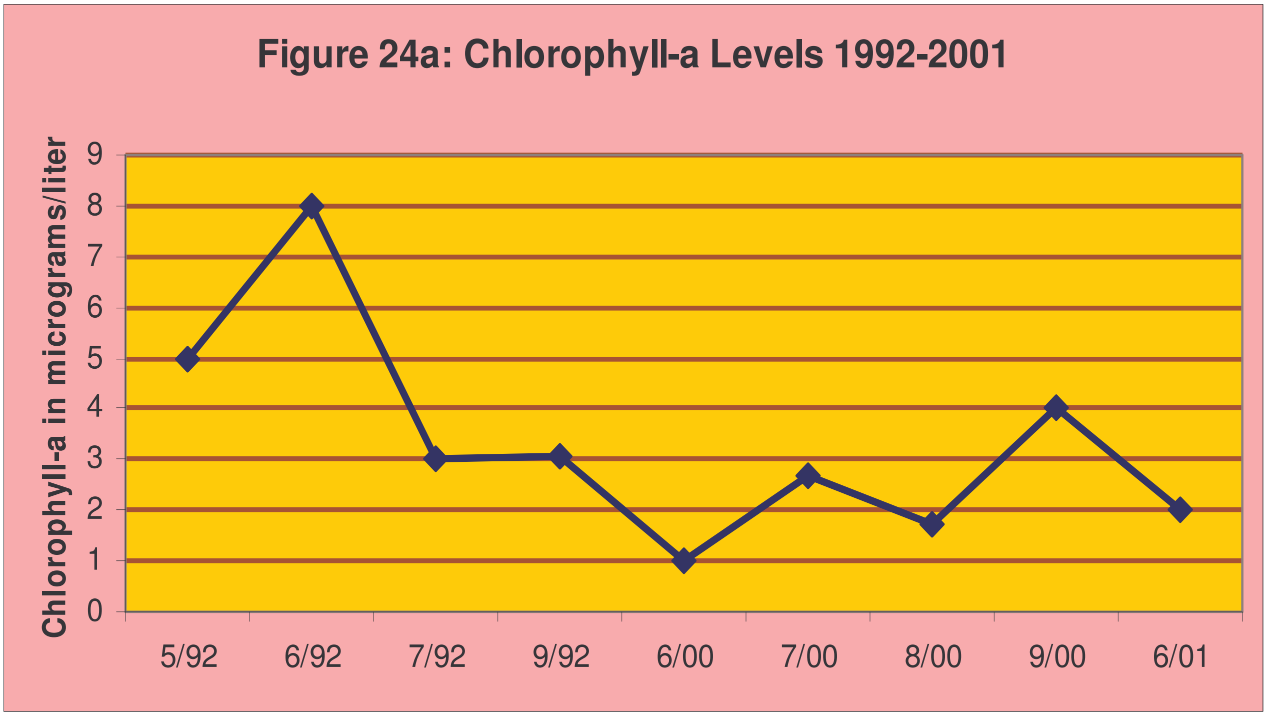


Figure 24a: Chlorophyll-a Levels 1992-2001
Chlorophyll-a in micrograms/liter
0
1
2
3
4
5
6
7
8
9
5/92
6/92
7/92
9/92
6/00
7/00
8/00
9/00
6/01

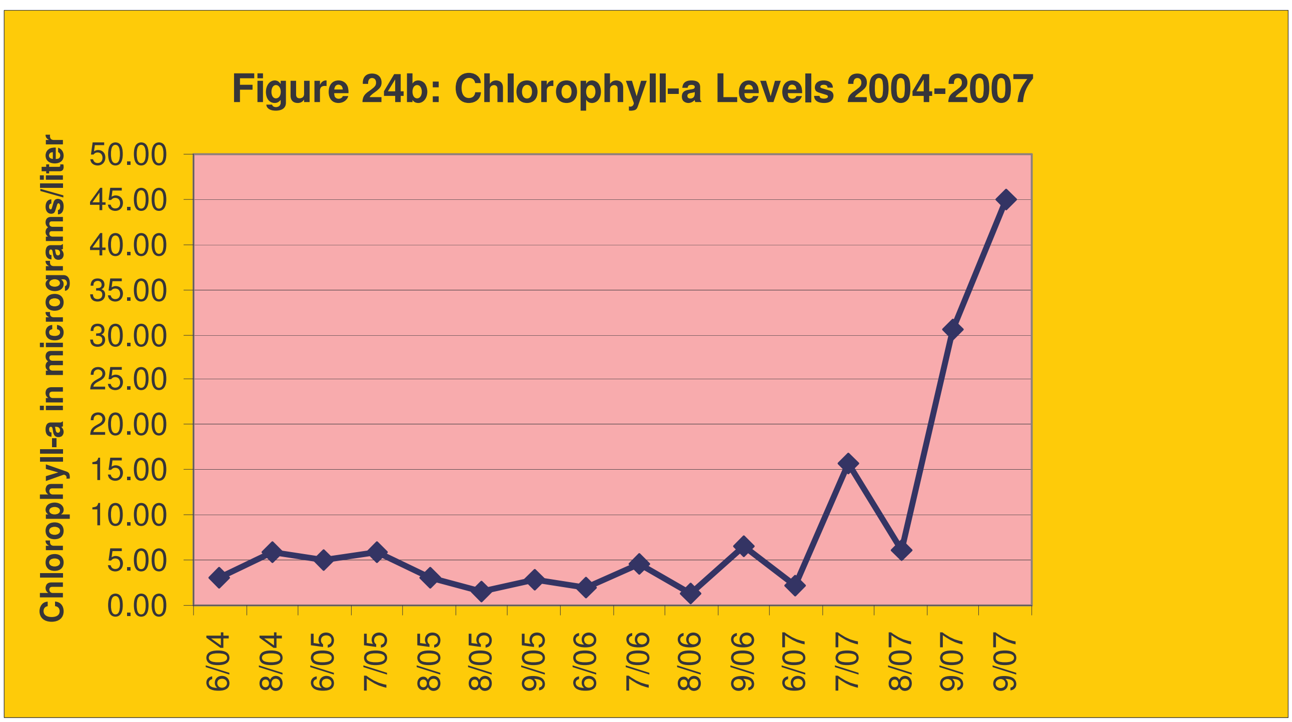


Figure 24b: Chlorophyll-a Levels 2004-2007
Chlorophyll-a in micrograms/liter
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
6/04
8/04
6/05
7/05
8/05
8/05
9/05
6/06
7/06
8/06
9/06
6/07
7/07
8/07
9/07
9/07

Dissolved Oxygen

Oxygen dissolved in the water is essential to all aerobic aquatic organisms. The oxygen in a lake comes from the atmosphere and from the process of photosynthesis. Aquatic plants and algae consume carbon dioxide and respirate oxygen back into the lake water. The distribution of oxygen within a lake is affected by many factors, including water circulation, water stratification, winds or storms, air temperature; water temperature, nutrient availability, and the density and location of algae and/or aquatic plants. Historically, Peppermill Lake had problems with low oxygen in the winter and at least four winterkills of fish. These problems eased after the installation of two aerators for winter use in 1992.

Oxygen consumption in the sediment and the water just above it (hypolimnion) is more sensitive that those in the two upper layers of water (metalimnion and epilimnion) because the bottom consumption is less likely to be balanced by the circulation and photosynthesis output available to the upper layers.

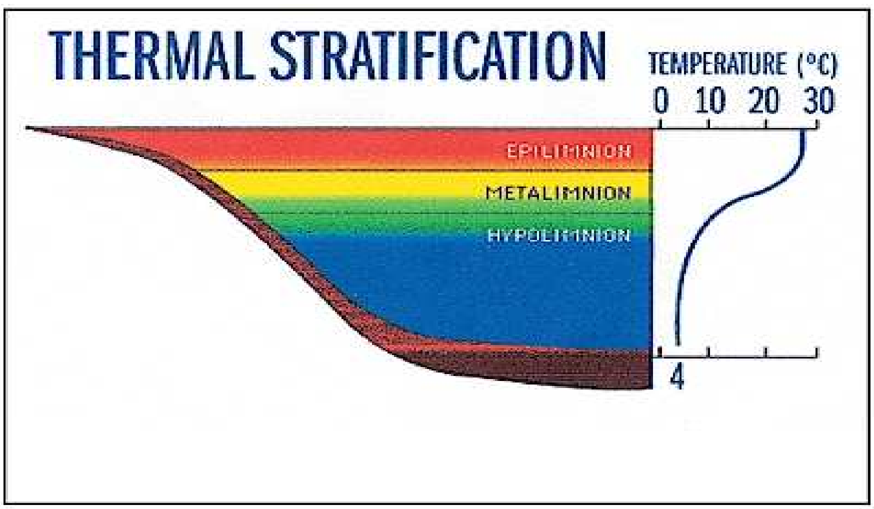


Figure 25: Stratification Layers found in Peppermill Deep Holes

Low oxygen during the summer in the bottom waters of a lake occurs naturally as oxygen in the bottom layer is consumed, but not replenished. It is common that as the summer progresses, the oxygen concentration of the bottom waters decreases. In Peppermill Lake, there were hypoxic periods in the lower feet during the summers of 2004 and 2005. By the end of summer 2004, oxygen concentration at 13 feet deep was only 3.3 milligrams/liter. In the summer of 2005, dissolved oxygen levels were 2.8 mg/l at 40 feet; in the summer of 2001, dissolved oxygen levels were down 1.75 milligrams/liter by July and still down in August at 2.9 milligrams/liter.again. This pattern was not present in 2006 when oxygen levels at all depths were over 5 mg/l (the minimum level for most fish survival).

The charts (Figures 26a, 26b, 26c & 26d) below show the annual variations in dissolved oxygen levels in milligrams/liter, depth in feet and months of the year for 2002-2003, 2004, 2005 and 2006.

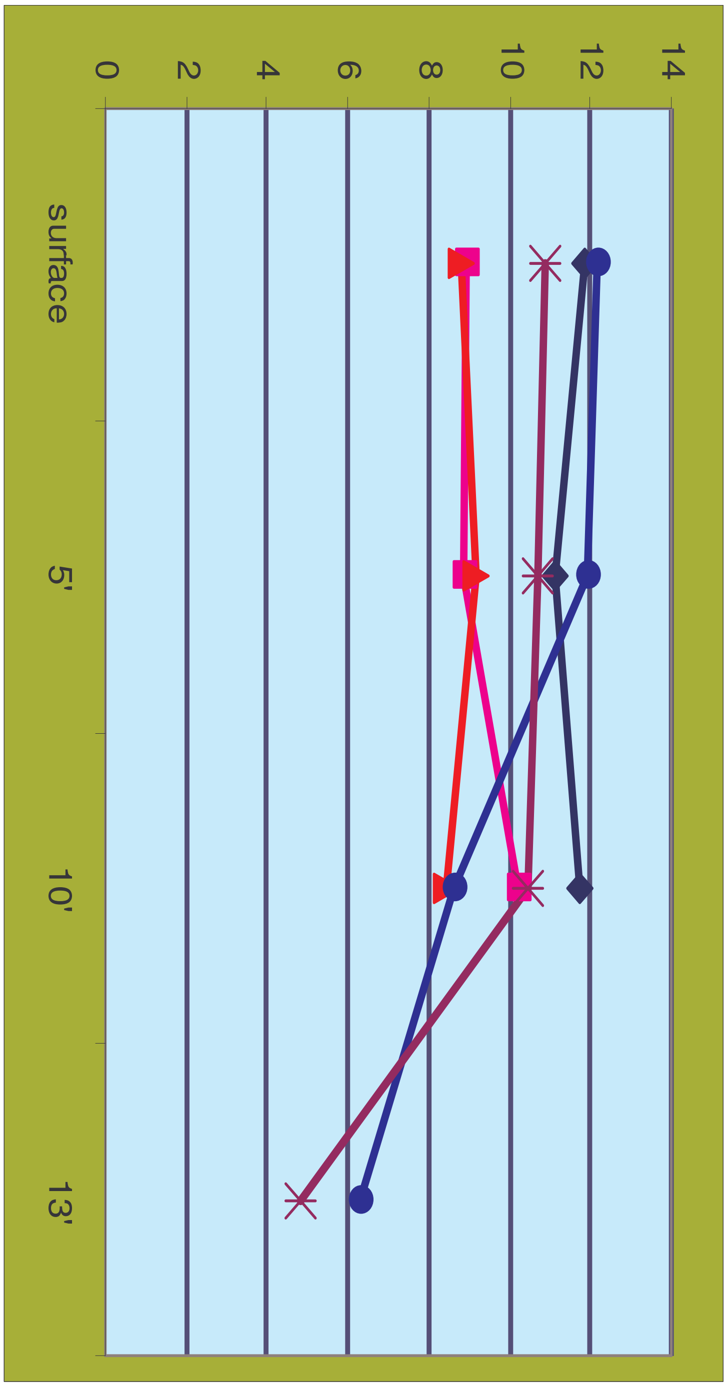
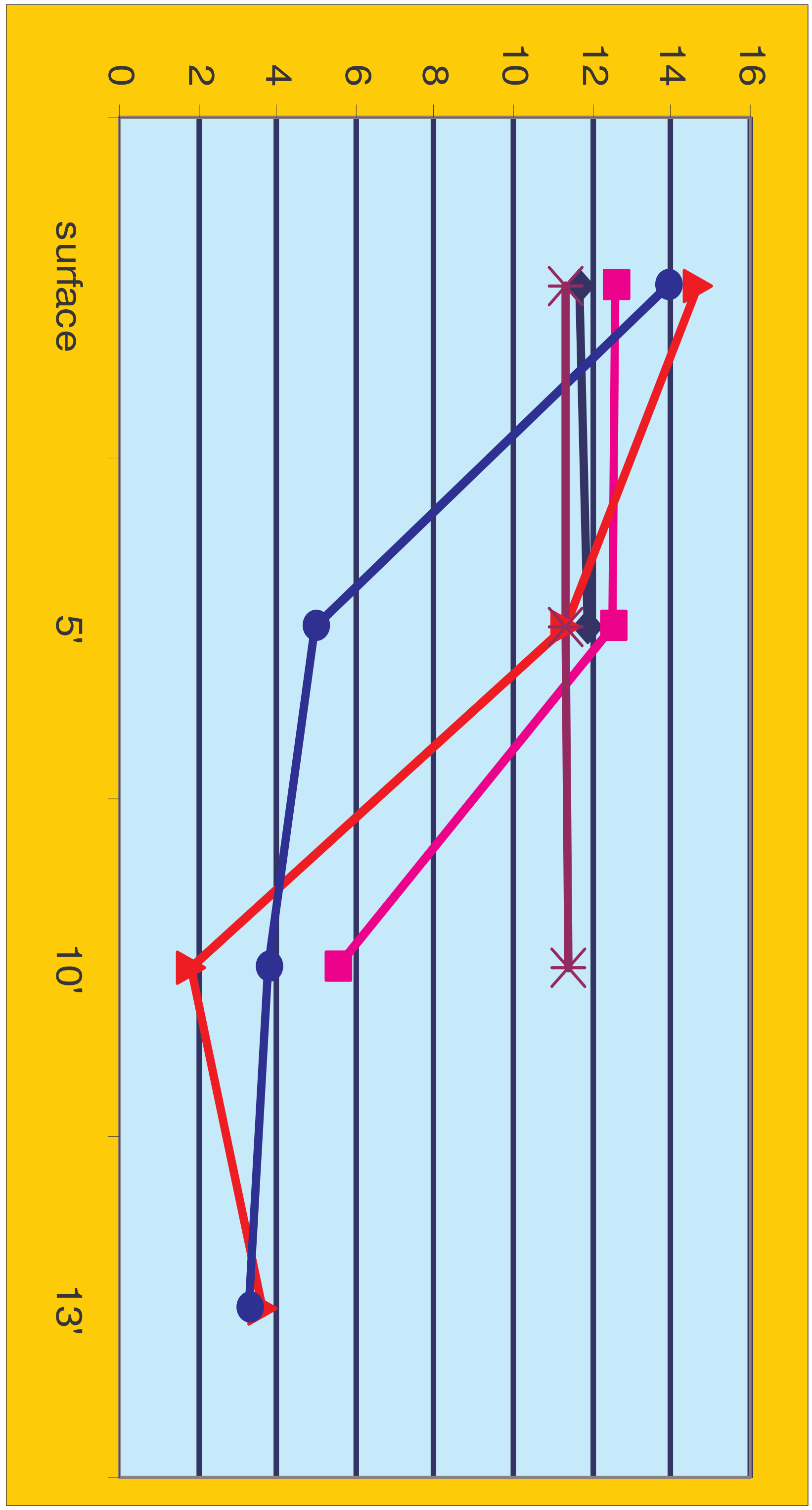


Figure 26a: Dissolved Oxygen Levels 2002-2003 in milligrams/liter

Figure 26b: Dissolved Oxygen Levels During 2004 Water Testing in milligrams/liter



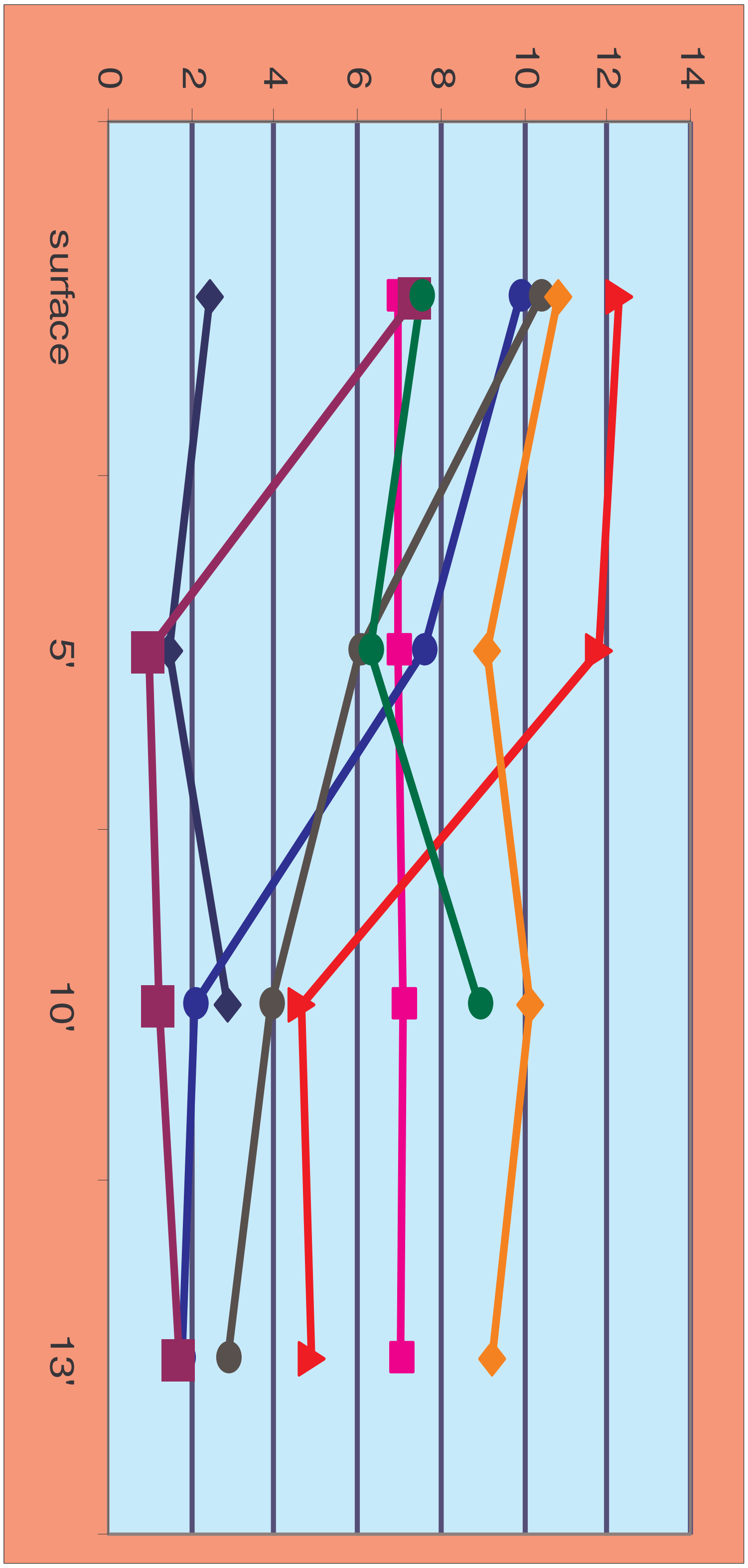


Figure 26c: Dissolved Oxygen Levels During 2005 Water Testing in milligrams/liter

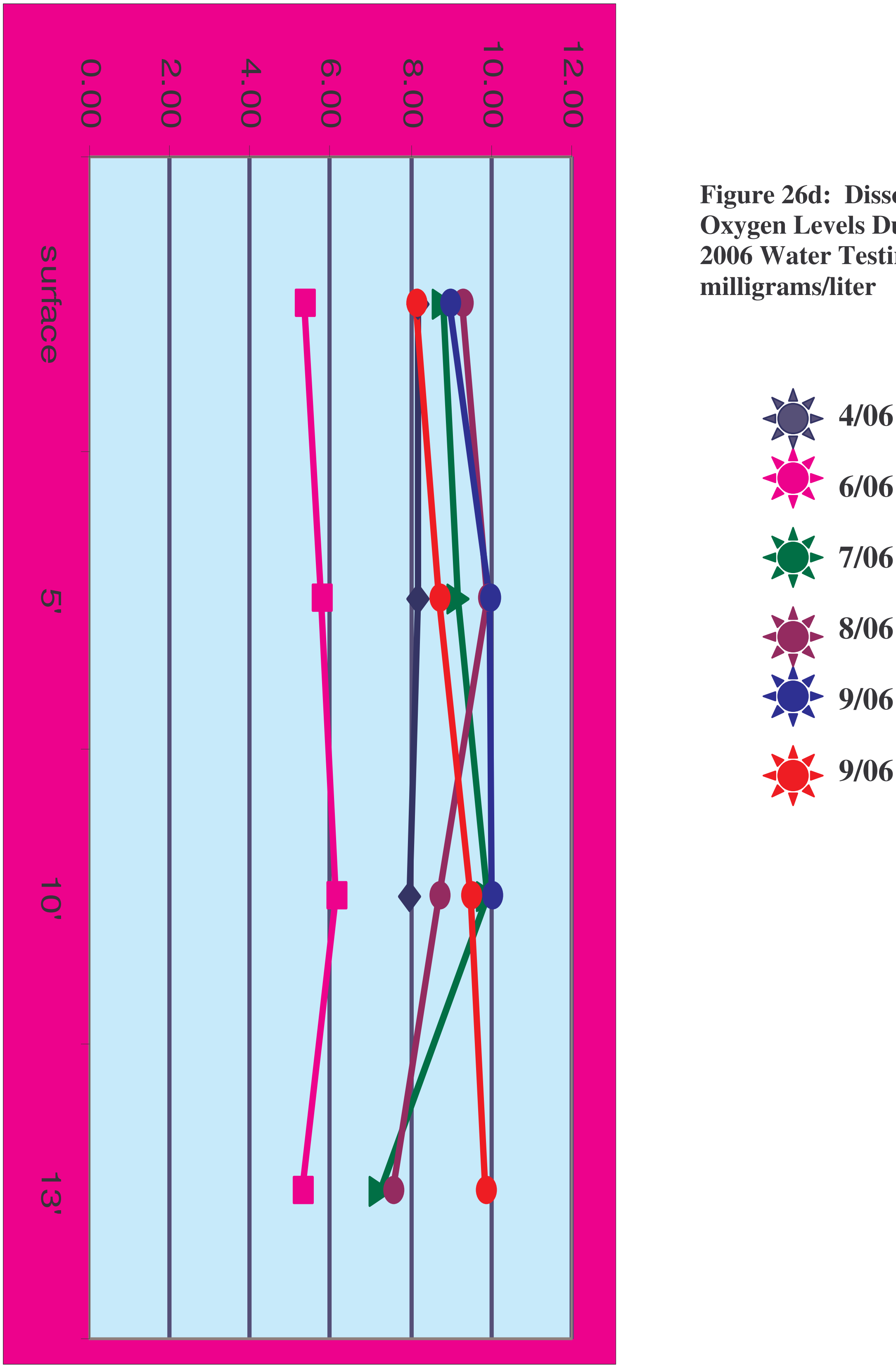


Figure 26d: Dissolved Oxygen Levels During 2006 Water Testing in milligrams/liter

In deeper lakes, when the surface waters have cooled in autumn and water density throughout the water column is the same, the water column mixes vertically, a process known as "fall turnover." Most of Peppermill Lake is shallow and does not stratify. However, in the deep holes of the lobes, the lake does stratify and turns over in the spring and fall.

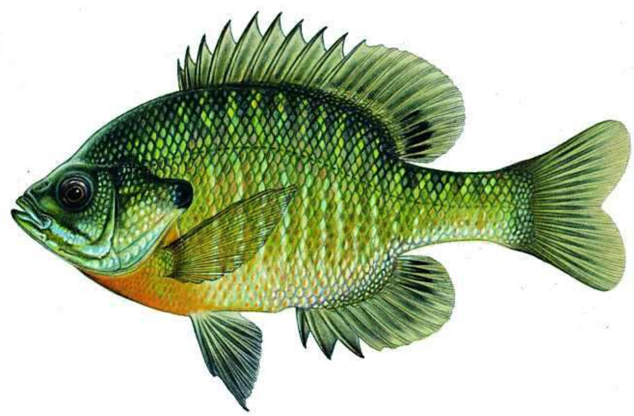


Figure 27a: Abundant fish in Peppermill Lake—Bluegill (*Lepomis macrochirus)*

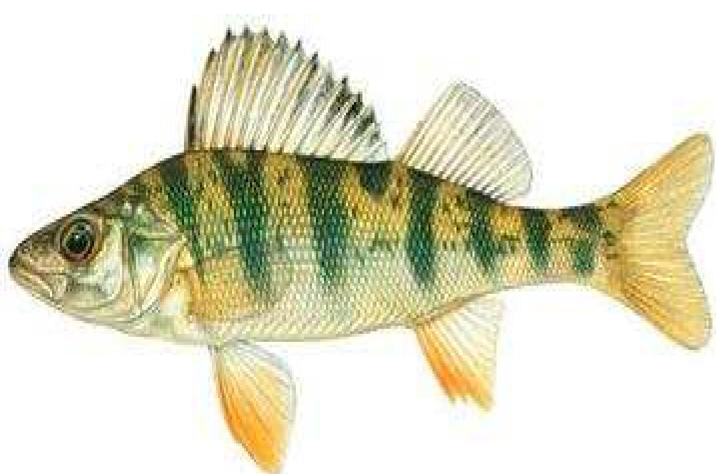


Figure 27b: Abundant Fish in Peppermill Lake—Yellow Perch (*Perca flavescens))*

Water Hardness, Alkalinity and pH

Testing done by Adams County LWCD on Peppermill Lake included annual testing for water alkalinity and water hardness. Hardness and alkalinity levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water & these materials.

Level of Hardness	Milligrams/liter CaCO3
SOFT	0-60
MODERATELY HARD	61-120
HARD	121-180
VERY HARD	>180

Figure 28: Hardness Table

One method of evaluating hardness is to test the water for the amount of calcium carbonate ($CaCO_3$) it contains. The surface water of all of the public access lakes in Adams County have water that is moderately hard to very hard, whether they are impoundments (man-made lakes) or natural lakes. In 2005 and 2006, random samples were also taken of wells around Peppermill Lake to measure the hardness of the water coming into the lake through groundwater. Hardness in the groundwater ranged from 140 (hard) to 304 (very hard), with an average of 203.64 milligrams/liter. This is slightly less than the surface water average of 198.67 milligrams/liter. The hardness in both surface and groundwater is likely due to the underlying bedrock in Adams County, which is mostly sandstone with pockets of dolomite and shale.

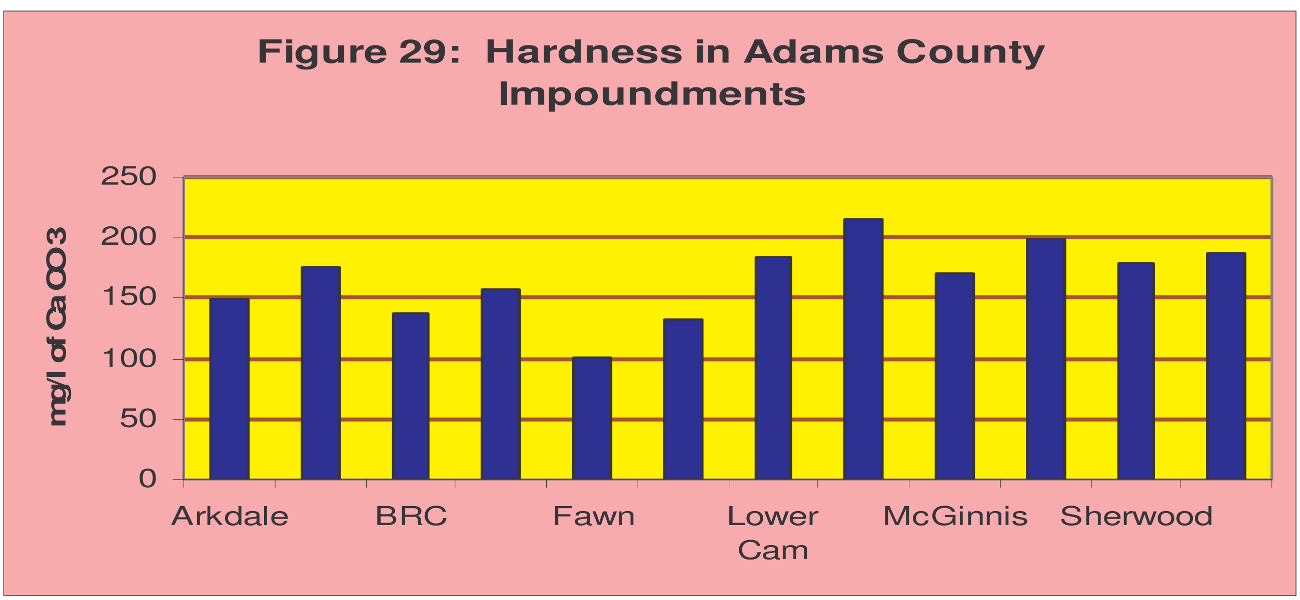


Figure 29: Hardness in Adams County Impoundments

As the graph (Figure 29) shows, Peppermill Lake surface water testing results showed "very hard" water (average 198.67 milligrams/liter CaCO3), considerably above the overall hardness average impoundments in Adams County of 166 milligrams/liter of Calcium Carbonate. Hard water lakes tend to produce more fish and aquatic plants than soft water lakes because they are often located in watersheds with soils that load phosphorus into the lake water.

Alkalinity is important in a lake to buffer the effects of acidification from the atmosphere. "Acid rain" has long been a problem with lakes that had low alkalinity level and high potential sources of acid deposition.

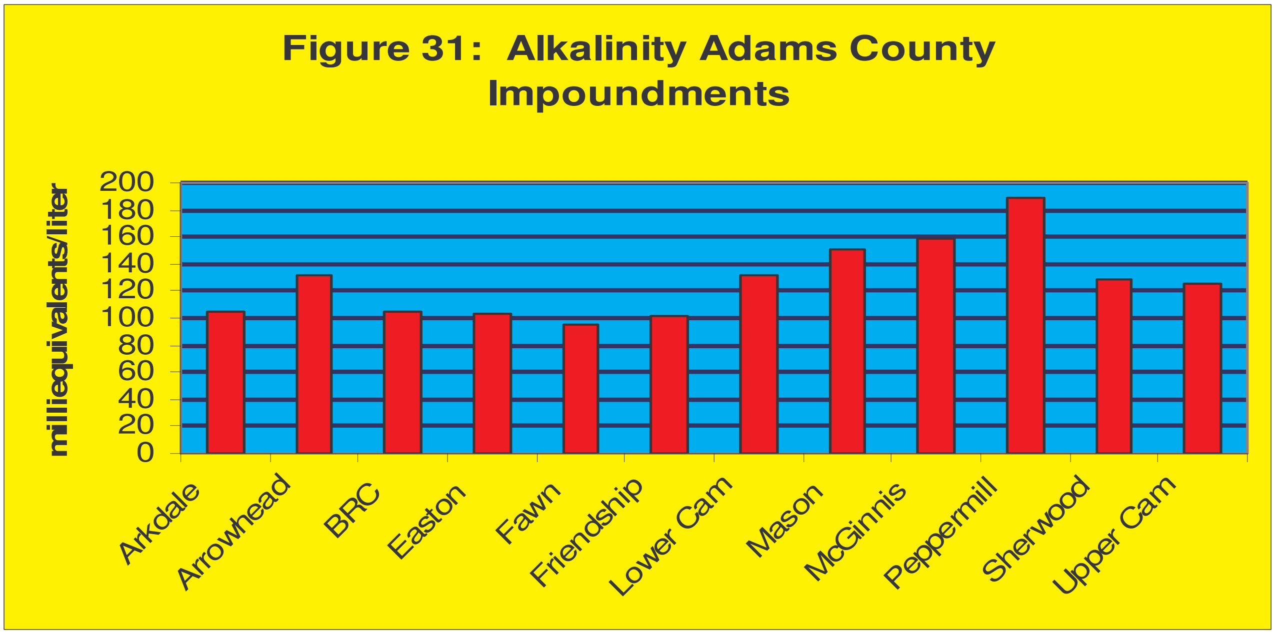
Acid Rain Sensitivity	ueq/l CaCO3
High	0-39
Moderate	49-199
Low	200-499
Not Sensitive	>500

Figure 30: Acid Rain Sensitivity

Peppermill Lake watersheds well water testing results ranged from 144 milliequavalents/liter to 284 milliequivalents/liter in alkalinity, with an average of 203.64 milliequivalents/liter. This is higher than the surface water alkalinity average of 187.2 milliequivalents/liter. Peppermill Lake's potential sensitivity to acid rain is moderate, but luckily for Adams County, the acid deposition rate is very low, probably due to the little industrialization in the county.

Alkalinity also affects the pH level of lake water. The acidity level of a lake's water regulates the solubility of many minerals. A pH level of 7 is neutral. The pH level in Wisconsin lakes ranges from 4.5 in acid bog lakes to 8.4 in hard water, marl lakes.

Some of the minerals that become available under low pH, especially the metals aluminum, zinc and mercury, can inhibit fish reproduction and/or survival. Even what seems like a small variance in pH can have large effects because the pH scale is set up so that every 1.0 unit change increases acidity tenfold, i.e., water with a pH of 7 is 10 times more acid than water with pH of 8. Mercury and aluminum are not only toxic to many kinds of wildlife; they can also be toxic to humans, especially those that eat tainted fish.



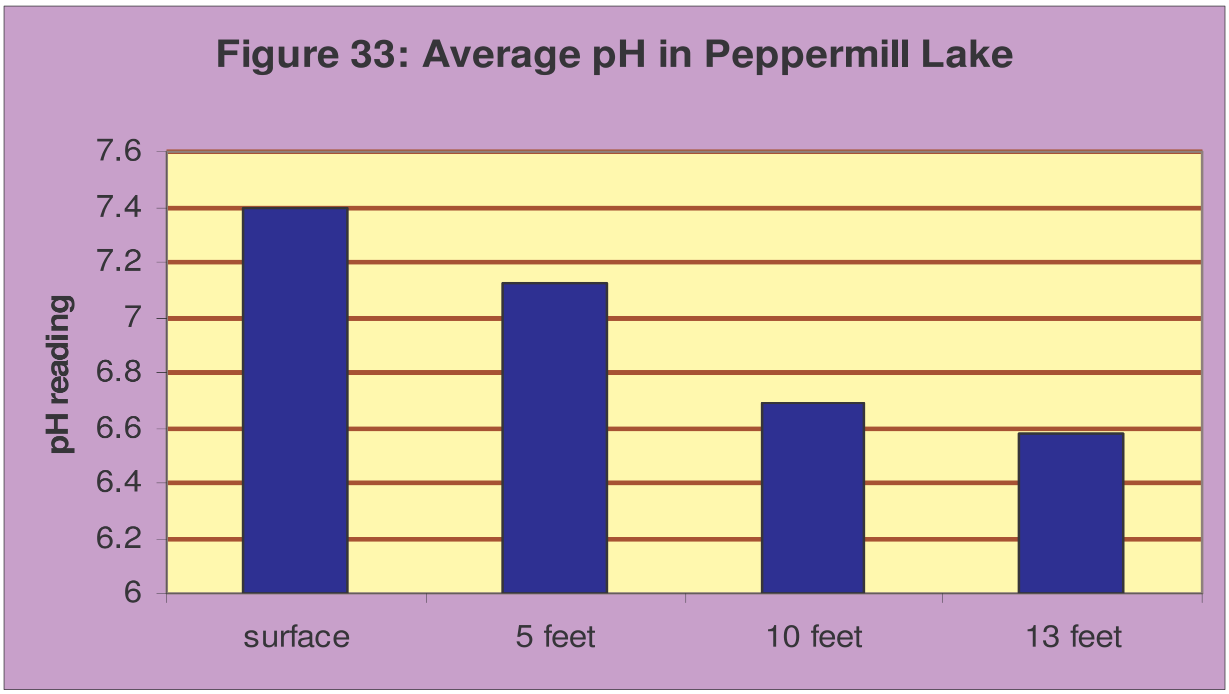
The testing occurring from 2004-2006 also included regular monitoring of the pH at several depths in Peppermill Lake. As is common in the lakes in Adams County, Peppermill Lake has pH levels starting at just under neutral (6.58) at 13 feet depth and increasing in alkalinity as the depth gets less, until the surface water pH averages 7.4. A lake's pH level is important for the release of potentially harmful substances and also affects plant growth, fish reproduction and survival. Most plants grow best at pH levels between 5.5 and 8.

More importantly for many lakes, fish reproduction and survival are very sensitive to pH levels. The chart below indicates the effect of pH levels under 6.5 on fish (Figure 32):

Figure 32: Effects of pH Levels on Fish

Water pH	Effects
6.5	walleye spawning inhibited
5.8	lake trout spawning inhibited
5.5	smallmouth bass disappear
5.2	walleye & lake trout disappear
5	spawning inhibited in most fish
4.7	Northern pike, sucker, bullhead, pumpkinseed, sunfish & rock bass disappear
4.5	perch spawning inhibited
3.5	perch disappear
3	toxic to all fish

No pH levels taken in Peppermill Lake between 2004-2006 fell below the pH level that inhibits walleye reproduction. A lake with a neutral or slightly alkaline pH like Peppermill Lake is a good lake for fish and plant survival. Natural rainfall in Wisconsin averages a pH of 5.6. This means that if the rain falls on a lake without sufficient alkalinity to buffer that acid water coming in by rainfall, the lake's fish cannot reproduce. That is not a problem at Peppermill Lake. Peppermill Lake has a good pH level for fish reproduction and survival.



Other Water Quality Testing Results

CHLORIDE: Chloride does not affect plant and algae growth and is not known to be harmful to humans. It isn't common in most Wisconsin soils and rocks, so is usually found only in very low levels in Wisconsin lakes. However, the presence of a significant amount of chloride over a period of time indicates there may be negative human impacts on the water quality present from septic system failure, the presence of fertilizer and/or waste, deposition of road-salt, and other nutrients. An increased chloride level is thus an indication that too many nutrients are entering the lake, although the level has to be evaluated compared to the natural background data for chloride. The average chloride level found in Peppermill Lake during the testing period was 2.4 milligrams/liter, below the natural level of chloride of 3 milligrams/liter in this area of Wisconsin

NITROGEN: Nitrogen is necessary for plant and algae growth. A lake receives nitrogen in various forms, including nitrate, nitrite, organic, and ammonium. In Wisconsin, the amount of nitrogen in a lake's water often corresponds to the local land use. Although some nitrogen will enter a lake through rainfall from the atmosphere, that coming from land use tends to be in higher concentrations in larger amounts, coming from fertilizers, animal and human wastes, decomposing organic matter, and surface runoff. For example, the growth level of the exotic aquatic plant, Eurasian Watermilfoil (*Myriophyllum spicatum*) has been correlated with fertilization of lake sediment by nitrogen-rich spring runoff.

Nitrogen levels can affect other aspects of water quality. The sum of water testing results for nitrate, nitrite and ammonium levels of over .3 milligrams/liter in the spring can be used to project the likelihood of an algal bloom in the summer (assuming sufficient phosphorus is also present). Peppermill Lake combination spring levels from 2004 to 2006 averaged 0.22 milligrams/liter, below the .3 milligrams/liter predictive level for nitrogen-related algal blooms. These elevations suggest that algal blooms on Peppermill Lake may be are probably not nitrogen-related.

CALCIUM and MAGNESIUM: Calcium is required by all higher plants and some microscopic lifeforms. Magnesium is needed by chlorophyllic plants and by algae, fungi and bacteria. Both calcium and magnesium are important contributors to the hardness of a lake's waters. Magnesium elevated about 125 milligrams/liter may have a laxative effect on some humans. Otherwise, no health hazards to humans and wildlife are known from calcium and magnesium. The average Calcium level in Peppermill Lake's water during the testing period was 38.85 milligrams/liter. The average Magnesium level was 23.76 milligrams/liter. Both of these are low-level readings.

SODIUM AND POTASSIUM: These elements occur naturally only in low levels in Wisconsin waters and soils. Their presence may indicate human-caused pollution. Sodium is found with chloride in many road salts and fertilizers and is also found in human and animal waste. Potassium is found in many fertilizers and also found in animal waste. The level of these two is generally not useful as a specific pollution indicator, but increasing levels or one or both of these elements can indicate possible contamination from damaging pollutants. High levels of sodium have also been found to influence the development of a large population of cyanobacteria, some of which can be toxic to animals and humans. Some health professionals have suggested that sodium levels over 20 milligrams/liter may be harmful to heart and kidney patients if ingested. Both sodium and potassium levels in Peppermill Lake are very low: the average sodium level was 1.91 milligrams/liter; the average potassium reading 0.55 milligrams/liter.

SULFATE: In low-oxygen waters (hypoxic), sulfate can combine with hydrogen and becomes the gas hydrogen sulfate, which smells like rotten eggs and is toxic to most aquatic organisms. Sulfate levels can also affect the metal ions in the lake, especially iron and mercury, by binding them up, thus removing them from the water column. To prevent the formation of hydrogen sulfate, levels of 10 milligrams/liter are best. A health advisory kicks in at 30 milligrams/liter. Peppermill Lake sulfate levels averaged 9.61 milligrams/liter during the testing period, below both the level for hydrogen sulfate formation and the health advisory level.

TURBIDITY: Turbidity reflects water clarity. The term refers to suspended solids in the water column—solids that may include clay, silt, sand, plankton, waste, sewage and other pollutants. Turbid water may mask the presence of bacteria or other pollutants because the water looks murky or muddy. In general, turbidity readings of less than 5 NTU are best. Very turbid waters may not only smell, but also tend to be aesthetically displeasing, thus curtailing recreational uses of the water. Turbidity levels for Peppermill Lake's waters were: 1.81 NTU in 2004, 1.81 NTU in 2005 and 1.89 NTU in 2006—all below the level of concern.

Figure 34: Examples of Very Turbid Water

HYDROLOGIC BUDGET

According to a recent bathymetric (depth) map, Peppermill Lake has 64.92 surface acres, and the volume of the lake is 280.21 acre-feet. 26.5% of the lake is less than 3 feet deep. The maximum depth is 14 feet.

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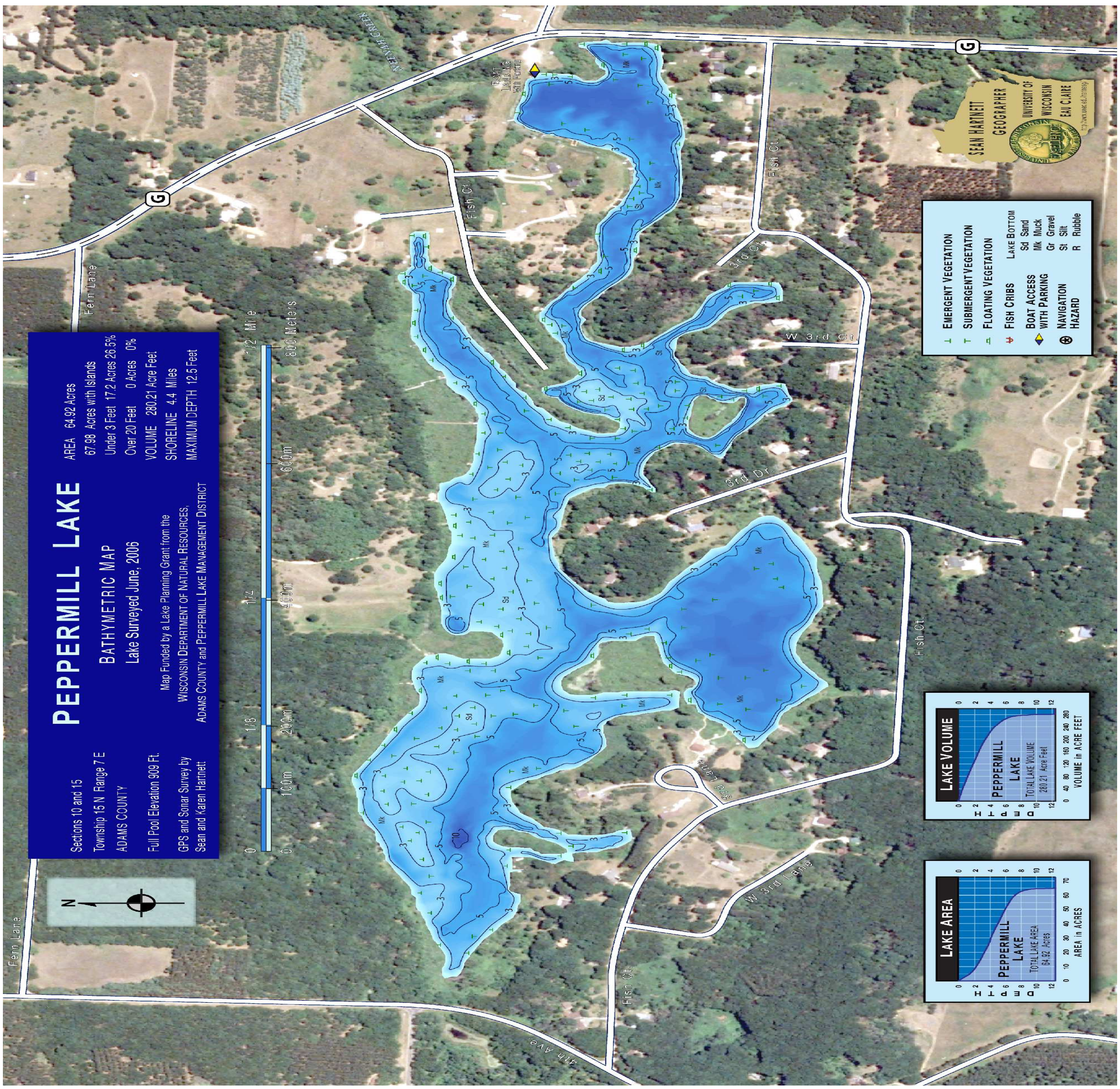
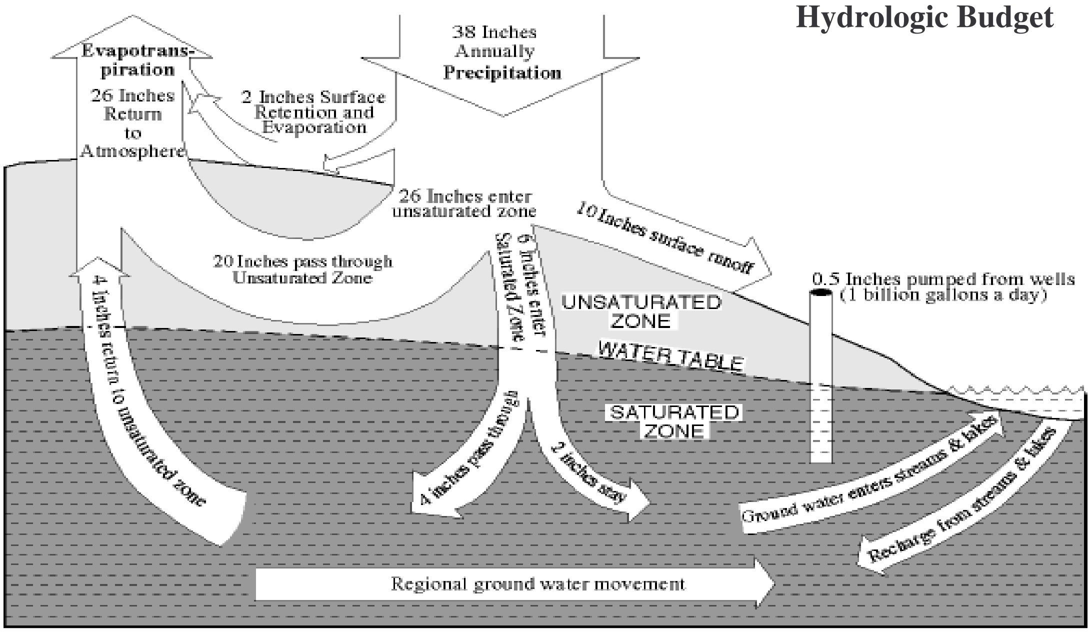
Figure 35: Bathymetric Map of Peppermill Lake



A "hydrologic budget" is an accounting of the inflow to, outflow from and storage in a hydrological unit (such as a lake). "Residence time" is the average length of time particular water stays within a lake before leaving it. This can range from several days to years, depending on the type of lake, amount of rainfall, and other factors. "Flushing rate" is the time it takes a lake's volume to be replaced. "Annual runoff volume", as used in WiLMS, is the total water yield from the drainage area reaching the lake. The "drainage area" is the amount of area (in acres) contributing surface water runoff and nutrients to the lake. The "areal water load" is the total annual flow volume reaching the lake divided by the surface area of the lake. "Hydraulic loading" is the total annual volume of all water sources (including precipitation, non-point sources & point sources) loading into the lake.

Using the data gathered from historical testing and that done by the Adams County LWCD from 2004-2006, the WiLMS model calculated the tributary drainage area for Peppermill Lake as 2625.3 acres. The average unit runoff for Adams County in the Peppermill Lake area is 9.4 inches. WiLMS determined the expected annual runoff volume as 2100.2 acre-feet/year. Anticipated annual hydraulic loading is 2113.2 acre-feet/year. Areal water load is 32.6 feet/year. Residence time is 0.13 year. Lake flushing rate is 7.54 1/year.

Figure 36: Example of Hydrologic Budget



TROPHIC STATE

The trophic state of a lake is one measure of water quality, basically defining the lake's biological production status (see Figure 37). **Eutrophic lakes** are very productive, with high nutrient levels, frequent algal blooms and/or abundant aquatic plant growth. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small populations of fish. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; often with a more varied fishery than either the eutrophic or oligotrophic lakes. In comparing water quality testing results with the prediction from the computer modeling of this modeling with the actual figures outlined above, the actual Trophic State of Peppermill Lake is what was predicted from the modeling. Modeling results predicted that the overall TSI for Peppermill Lake would be **46**. This score places Peppermill Lake's overall TSI at below average for impoundment lakes in Adams County (52.83)—which is good, since with TSI, the lower the score, the better.

Figure 37: Trophic Status Table

Peppermill Lake = 46 → 40-50

Score	TSI Level Description
30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth and occasional algal blooms; may have low oxygen levels near bottom in summer
50-60	**Mildly Eutrophic:** decreased water clarity; anoxic near bottom; may have heavy algal bloom and plant growth; high in nutrients; shallow eutrophic lakes may have winterkill of fish; rough fish common
60-70	**Eutrophic:** dominated by blue-green algae; algae scums common; prolific aquatic plant growth; high nutrient levels; rough fish common; susceptible to oxygen depletion and winter fishkill
70-80	**Hypereutrophic:** heavy algal blooms through most of summer; dense aquatic plant growth; poor water clarity; high nutrient levels

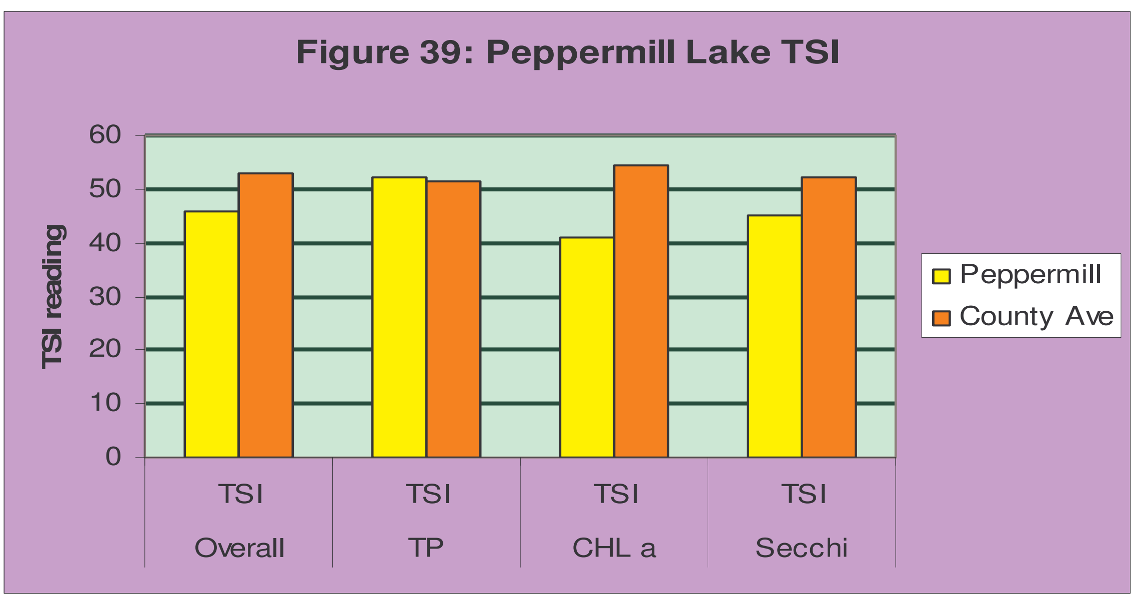
Phosphorus concentration, chlorophyll-a concentration and water clarity data are collected and combined to determine a trophic state. As discussed earlier, the average growing season epilimnetic total phosphorus for Peppermill Lake was 28.03 micrograms/liter. The average growing season chlorophyll-a concentration was 4.98

micrograms/liter. Growing season water clarity averaged a depth of 9.21 feet. Figure 40 shows where each of these measurements from Peppermill Lake fall in trophic level.

Figure 38: Peppermill Lake Trophic Status Overview

Trophic State	Quality Index	Phosphorus	Chlorophyll a	Sechhi Disk
		(ug/l)	(mg/l)	(ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	1 to 5	8 to 19
Mesotrophic	Good	10 to 30	5 to 10	**6 to 8**
	Fair	**30 to 50**	**10 to 15**	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Peppermill Lake		**33.91**	**14.15**	**7.19**

These figures show that Peppermill Lake has fair to good levels overall for the three parameters often used to described water quality: Secchi disk depths; average TP for the growing season; and chlorophyll a levels. It is normal for all of these values to fluctuate during a growing season. However, they can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events.



IN-LAKE HABITAT

Aquatic Plants

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in improving water quality, providing valuable habitat resources for fish and wildlife, resisting invasions of non-native species and checking excessive growth of the most tolerant species.

In 2006, a qualitative aquatic plant survey was done on Peppermill Lake by staff from WDNR and Adams County Land & Water Conservation Department. A prior survey was conducted by UWSP students in 2001.

The aquatic plant community is characterized by very good species diversity for both the North Central Hardwood Forest Region and all Wisconsin lakes The aquatic plant community in Peppermill Lake is in the category of those closer to disturbance and more tolerant of disturbance than the average lake in the North Central Hardwood Region and Wisconsin Lakes overall. Disturbances include invasions of exotic species, boat traffic, shoreline development, harvesting and past herbicide treatments.

Chara spp (muskgrass, a plant-like algae) and *Myriophyllum sibiricum* (northern milfoil) were the most frequently-occurring aquatic species in Peppermill Lake in 2006. The only other species that reached a frequency of 50% or greater was the invasive exotic, *Myriophyllum spicatum* (Eurasian watermilfoil). Since *Chara* spp. is only found in lakes with clear water, its presence at Peppermill Lake is a positive sign for the aquatic plant community there.

Chara spp was the densest aquatic species overall in Peppermill Lake and was the only species with more than average density of growth overall. Two other plants had a more than average density where present: *Najas flexilis* (bushy pondweed) and *Nymphaea odorata* (white water lily). This means these species exhibit a growth pattern of above average density, regardless of how frequently they occur in Peppermill Lake.

Based on dominance value, *Chara* spp was the dominant aquatic species overall in Peppermill Lake. There were no overall sub-dominant species. *Nymphaea odorata* was dominant in the 0-1.5 feet depth zone, with *Myriophyllum sibiricum* sub-dominant. *Chara* spp dominated in the 1.5 feet-5 feet depth zone, with *Myriophyllum sibiricum* sub-dominant. *Chara* spp. was also dominant in the 5 feet-10 feet depth zone, with *Myriophyllum spicatum* sub-dominant.

Figure 40. Peppermill Lake Aquatic Species--2006

Scientific Name	Common Name	Type
Acorus americanus	Sweet Flag	Emergent
Ascelpias incarnata	Swamp Milkweed	Emergent
Carex spp	Sedge	Emergent
Carex comosa	Bottlebrush Sedge	Emergent
Ceratophyllum demersum	Coontail	Submergent
Chara sp	Muskgrass	Submergent
Cicuta bulbifera	Water Hemlock	Emergent
Cornus stolonifera	Red-Osier Dogwood	Emergent
Elodea canadensis	Waterweed	Submergent
Impatiens capensis	Jewelweed	Emergent
Leersia oryzoides	Rice Cut-Grass	Emergent
Lemna minor	Lesser Duckweed	Free-Floating
Myriophyllum heterophyllum	Variable-Leaf Milfoil	Submergent
Myriophyllum sibiricum	Northern Milfoil	Submergent
Myriophyllum spicatum	Eurasian Watermilfoil	Submergent
Najas flexlis	Bushy Pondweed	Submergent
Nuphar variegata	Yellow Pond Lily	Floating-Leaf
Nymphaea odorata	White Water Lily	Floating-Leaf
Onoclea sensibilis	Sensitive Fern	Emergent
Physocarpus opulifolius	Common Ninebark	Emergent
Polygonum amphibium	Water Smartweed	Floating-Leaf
Potamogeton amplifolius	Large-Leaf Pondweed	Submergent
Potamogeton crispus	Curly-Leaf Pondweed	Submergent
Potamogeton foliosus	Leafy Pondweed	Submergent
Potamogeton friesii	Fries' Pondweed	Submergent
Potamogeton illinoensis	Illinois Pondweed	Submergent
Potamogeton natans	Floating-Leaf Pondweed	Submergent
Potamogeton pectinatus	Sago Pondweed	Submergent
Potamogeton zosteriformis	Flat-Stem Pondweed	Submergent
Rumex spp	Water Dock	Emergent
Sagittaria spp	Arrowhead	Emergent
Scirpus validus	Soft-Stem Bulrush	Emergent
Scutellaria laterifolia	Scullcap	Emergent
Sparganium spp	Burreed	Emergent
Spirodela polyrhiza	Greater Duckweed	Free-Floating
Utricularia vulgaris	Common Bladderwort	Submergent
Zosterella dubia	Water Stargrass	Submergent

100% of the sample sites were vegetated. Of the 36 species found in Peppermill Lake, 35 were native and 1 was an exotic invasives. In the native plant category, 15 were emergent, 2 were free-floating plants, 3 were floating-leaf rooted, and 15 were submergent types. One exotic invasive, *Myriophyllum spicatum* (Eurasian Watermilfoil) was also found. Filamentous algae were found at 48.15% of the sample sites. 36 species is more than double the 17 species found in 2001.

The highest total occurrence and total density of plant growth was recorded in the 0-1.5 feet depth zone. Total plant occurrence and density declined with increasing depth. The greatest species richness (mean number of species per site) was also found in the 0-1.5 feet depth zone.

The Simpson's Diversity Index for Peppermill Lake was 0.93, an excellent species diversity (the SI in 2001 was .90). A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for Simpson's Diversity Index readings for both the North Central Hardwood Forest Region and all Wisconsin lakes. The Aquatic Macrophyte Community Index for Peppermill Lake is 54, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes.

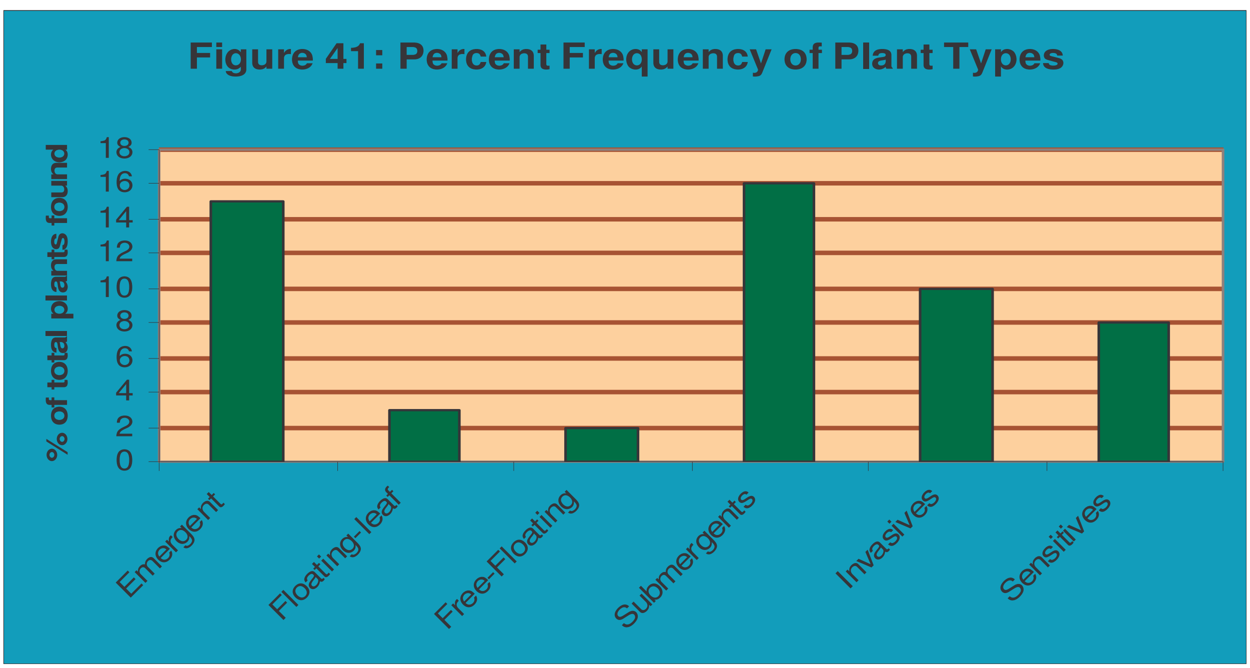
The presence of a highly invasive, exotic species like Eurasian Watermilfoil could be a significant factor in the future. Currently, EWM remains at high density and frequency, despite several years of chemical treatment and some mechanical harvesting. Its tenacity and ability to spread to large areas fairly quickly make it an ongoing danger to the diversity, habitat value and equality of Peppermill Lake's aquatic plant community.

The Average Coefficient of Conservatism and a Floristic Quality Index calculation were performed on the field results. Technically, the Average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Quality Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to the particular community.

Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often rare, endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

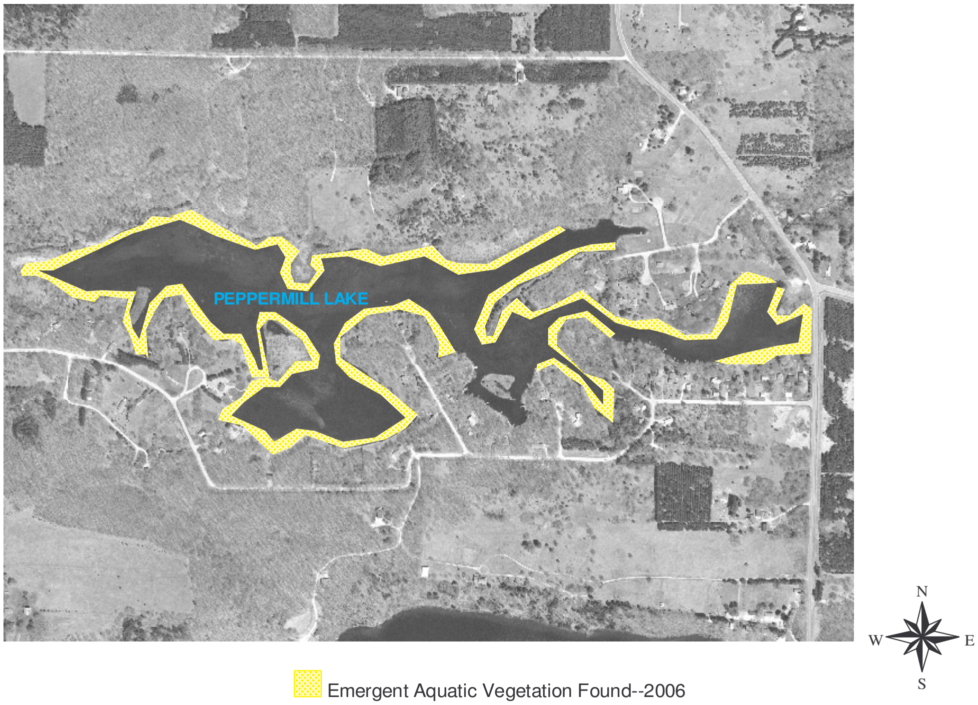
The Average Coefficient of Conservatism in Peppermill Lake in 2006 was 5.00. This makes it below average for Wisconsin Lakes (average 6.0) and for lakes in the North Central Hardwood Region average (average 5.6). The aquatic plant community in Peppermill Lake is in the category of those closer to disturbance and more tolerant of disturbance than the average lake in the North Central Hardwood Region and Wisconsin Lakes overall. The Average Coefficient of Conservatism in 2006 was up slightly from the 4.63 Coefficient found in the 2001 survey.

The Floristic Quality Index of the aquatic plant community in Peppermill Lake of 28.28 is above average for Wisconsin Lakes (average 22.2) and the North Central Hardwood Region (average 20.9). This suggests that the plant community in Peppermill Lake is closer to an undisturbed condition than the average lake in Wisconsin overall and in the North Central Hardwood Region. The FQI was also up from the 2001 figure of 19.6.



Since 100% of the lake bottom is vegetated, all the sediments in Peppermill hold sufficient nutrients to maintain aquatic plant growth. Due to the shallow depth of the lake, sunlight also encourages plant growth at all depths in the lake.

Figure 42a: Distribution of Emergent Plants in Peppermill Lake 2006



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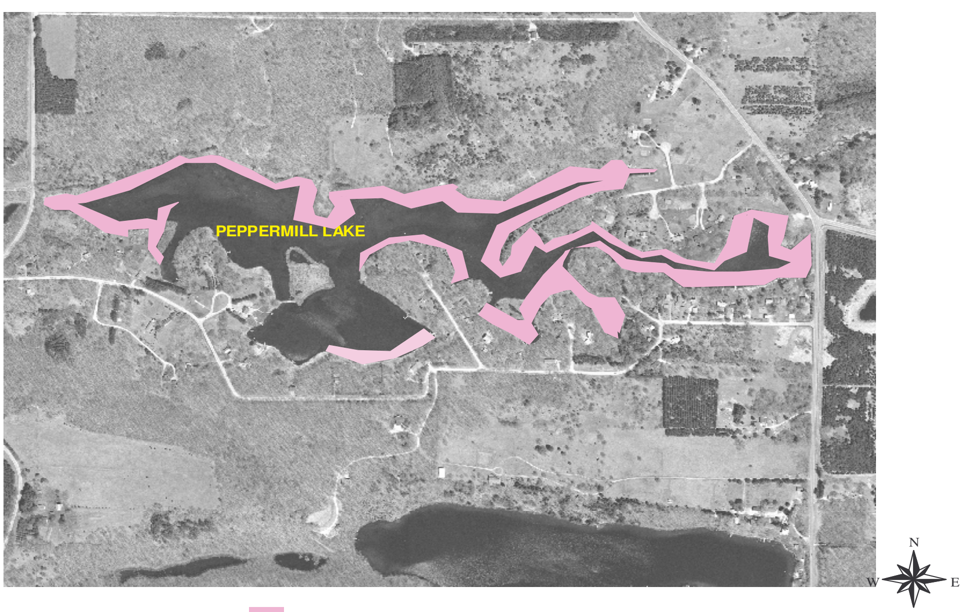
Emergent Aquatic Vegetation Found--2006

Figure 42b: Distribution of Free-Floating & Floating-Leaf Plants in Peppermill Lake 2006



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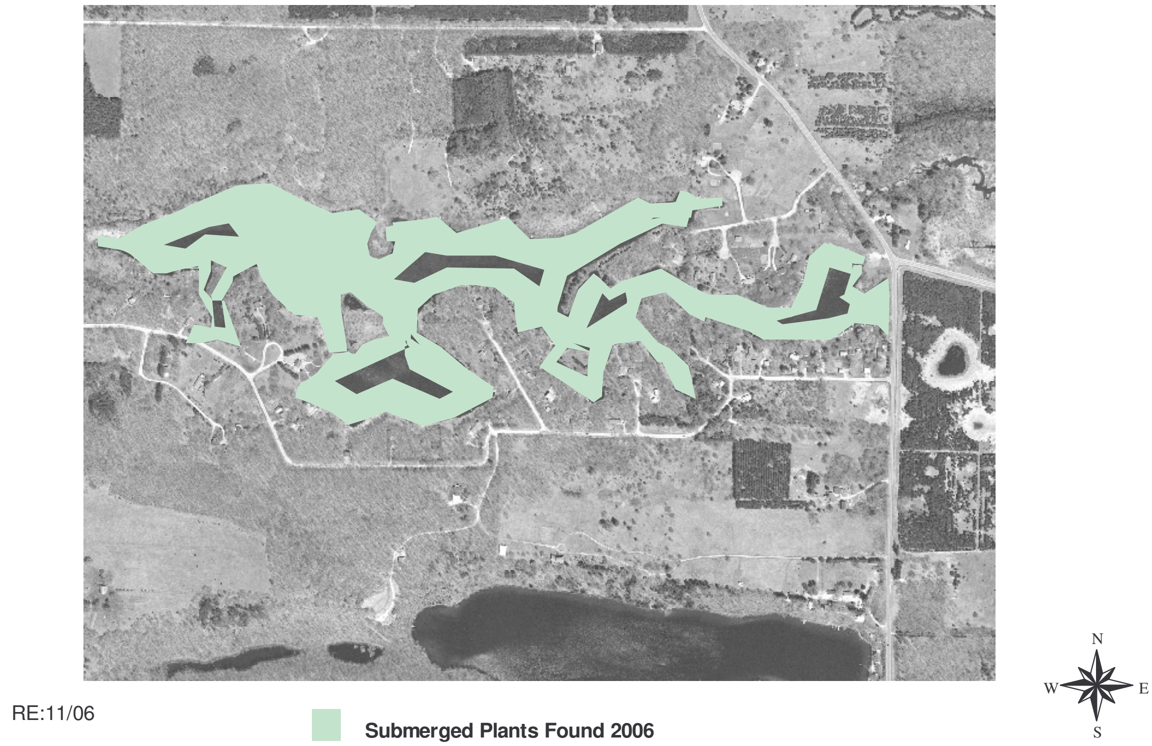
Floating Vegetation Found 2006

Figure 42c: Submergent Aquatic Plants in Peppermill Lake 2006



Some of the sample transects had an entirely native shore, although more sites had some disturbance by humans. Transect data was divided between natural and disturbed shores transects, then calculated as two separate lakes. This allowed a comparison of the two shore types on several criteria.

Figure 43: Natural v. Disturbed Shores

	Natural	Disturbed
Number of species	30	27
FQI	53.31	50.81
Average Coef. Of Cons	9.73	9.78
Simpson's Index	0.93	0.89
AMCI	49	47
Filamentous algae	51.85%	81.48%

Using these figures, the natural shores community supported more aquatic species, had a higher score for FQI, a higher Simpson's Diversity Index, and a higher Aquatic Macrophyte Community Index, as well as less filamentous algae. These results suggest that natural shores may have higher quality habitat and water quality than disturbed shores.

The 2001 aquatic plant survey used different transects and depths than the 2006 survey, so any comparison of the two surveys must be done with caution. However, the survey did not the plant species found, their frequencies of occurrence, and their density of occurrence. That survey also found that the plant-like algae, *Chara* spp, had the highest frequency, followed by *Myriophyllum sibiricum, Najas flexilis,* and *Potamogeton zosterformis* (flat-stemmed pondweed). Found at lesser frequencies were *Ceratophyllum demersum* (coontail)*, Elodea canadensis* (common waterweed)*, Lemna minor* (small duckweed)*, Myriophyllum spicatum, Nuphar advena* (yellow pond lily)*, Nymphaea odorata, Potamogeton amplifolius* (large-lead pondweed)*, Potamogeton pectinatus* (Sago pondweed)*, Potamogeton richardsoni* (clasping-leaf pondweed)*i, Scirpus validus* (soft-stemmed bulrush)*, Spirodela polyrhiza* (greater ducikweed)*, Typha latifolia* (wide-leaved cattail)*, Utricularia* spp.(bladderwort). *Chara* spp. was also the densest plant found. Of the 16 species found in 2001, two were emergent types, two were floating-leaf rooted species, two were free-floating species, and ten were submergent species. It is worth noting that the 2001 survey revealed only two emergent plants, while the 2006 survey resulted in fifteen emergent plants being found. The 2006 aquatic plant community appears to be gaining a more varied structure than was present during the 2001 survey.

The 2001 surveyors did calculate Coefficient of Conservatism, Floristic Quality Index, Simpson's Index of Diversity and the AMCI, i.e., standard methods of evaluating plant community health and diversity.

Figure 44: 2001 Survey v. 2006 Survey Results

	2001	2006
Number of Species	17	32
Aver. Coef. Of Cons	4.76	5.00
FQI	19.65	28.28
Simpson's Index	0.90	0.93
AMCI	43	54

All the measures discussed in this report used to determine the quality of an aquatic plant community were higher in 2006 than in 2001. *Chara* spp was the most frequently-occurring species in both 2001 and 2006, with *Myriophyllum spicatum* quite frequent in both years. It is likely that the high frequency of *Chara* spp assists in keeping the *Myriophyllum spicatum* less frequent. It appears that the efforts the Lake District is making to improve and/or maintain its lake water health are effective.

Efforts at controlling aquatic plant growth have included both chemical treatments and mechanical harvesting. 2006-2007 figures are not yet available, but other information is shown here. Chemical treatment records go back to 1999. Chemicals used were specific to dicotyledons and were used to eliminate or control Eurasian Watermilfoil.

Figure 45a: Table of Chemical Treatments 1999-2005

Year	Navigate	DMA-4 IVM
	(lbs)	(gal)
1999	300	
2000	700	
2001	1550	
2002	1400	
2003	352.23	5
2004	270	110
2005	300	
total	4872.23	115

Mechanical harvesting of aquatic plant started in 2003 and continued through 2007. The Lake District does not own a harvester, so a local contractor is hired to perform the machine harvesting.

Figure 45b: Table of Harvesting Removal 2003-2005

Year	Lbs Removed
2003	135,000
2004	114,000
2005	45,000
total	294,000

Ceratophyllum demersum
(Coontail)

Najas flexilis
(Bushy Pondweed)

Figure 46: Some Common Native Aquatic Species in Peppermill Lake

Myriophyllum sibiricum
(Northern watermilfoil)

Nymphaea odorata
(White Water Lily)

Aquatic Plant Management Recommendations from 2006 Report

(1) Because the plant cover in the littoral zone of Peppermill Lake is over the ideal (25%-85%) coverage for balanced fishery, the District should continue harvesting plan to reduce cover and open areas for fish. Dense vegetation removal by hand in shallow water can be removed to a maximum 30 feet channel out of 100 feet of shoreline at each property.

(2) Natural shoreline restoration and erosion control in some areas are needed. Biological shoreline restoration is preferred. If trees fall due to continued erosion, large portions of the banks will fall with them. The areas where there is undisturbed vegetated shore should be maintained and left undisturbed for water quality & habitat protection.

(3) To protect water quality, a buffer area of native plants should be restored on those sites that now have traditional lawns mowed to the water's edge. This is especially important because more than ¼ of the shoreline is currently impacted by disturbed shores.

(4) Buffers already installed around the lake should be maintained in their current condition.

(5) Stormwater management on the impervious surfaces around the lake is essential to maintain the high quality of the lake water. For example, County G runs near one edge of the lake, resulting in runoff from the pavement into the lake.

(6) No lawn chemicals should be used on properties around the lake. If they must be used, they should be used no closer than 50 feet to the shore.

(7) Septic systems around the lake should be regularly inspected and maintained properly.

(8) The integrated aquatic plant management plan within the Lake Management Plan should be followed. This plan includes mechanical harvesting and chemical spot treatment. The plan should include target harvesting for Eurasian Watermilfoil (EWM) to prevent further spread, as well as avoiding sensitive areas and beds of lily pads. Serious consideration should be given to increasing the presence of the native weevil that attacks and weakens Eurasian watermilfoil as an additional control method.

(9) The Peppermill Lake District may want to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

(10) No broad-scale chemical treatments of aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

(11) Peppermill Lake has long participated in the Self-Help Monitoring Program through the WDNR. Continued participation is recommended.

(12) Peppermill Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs.

(13) Critical habitat areas were formally determined in 2006, with a report due out later this year. The lake management plan should include recommendations for preserving these areas in its update.

(14) The Peppermill Lake District should make sure that its lake management plan takes into account all inputs from both the surface and ground watersheds and addresses the concerns of this lake community.

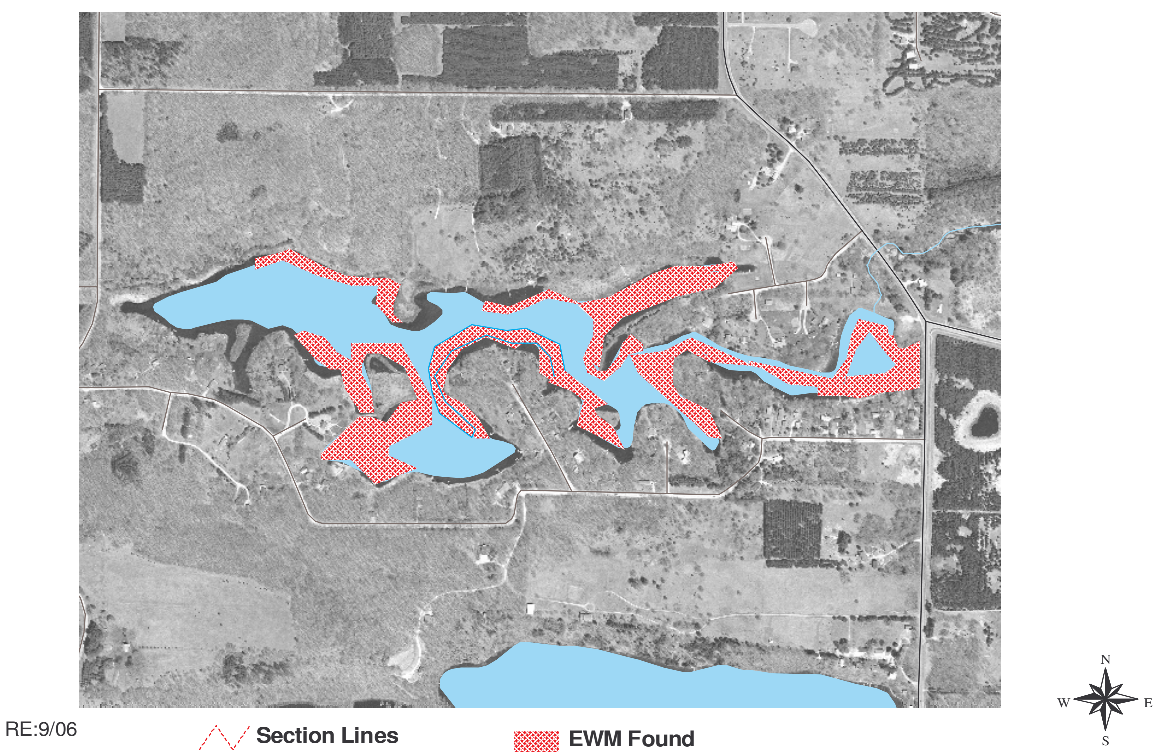
(15) Cooperation with the Town of Jackson in keeping the boat ramp in safe condition should help reduce any negative impacts caused by the heavy use of this public area.

Figure 47: Shore of Peppermill Lake showing emergent aquatic plants and floating-leaf rooted plants

Aquatic Invasives

Peppermill Lake has one known invasive aquatic species: *Myriophyllum spicatum* (EWM, Eurasian Watermilfoil). This invasive has continued to stay firmly entrenched in the aquatic plant community of Peppermill Lake. It is likely that the population of EWM would be greater if not for the significant amount of *Chara* spp. found in Peppermill Lake. Since *Chara* spp. uses much of the phosphorus in the lake, it keeps phosphorus out of the water column that would otherwise be available to other aquatic species, including EWM. In 2007, several lake citizens were trained to monitor the aquatic invasives and participate in the Clean Boats, Clean Waters boater education program. A survey was done on the lake in 2007 to determine the presence of the native weevil, *Euhrychiopsis lecontei*, which attacks and weakens Eurasian watermilfoil. Evidence of weevil presence was found, suggesting that Peppermill Lake has sufficient native habitat for the weevil to survive there.

Figure 48a: Distribution of Eurasian Watermilfoil in 2006



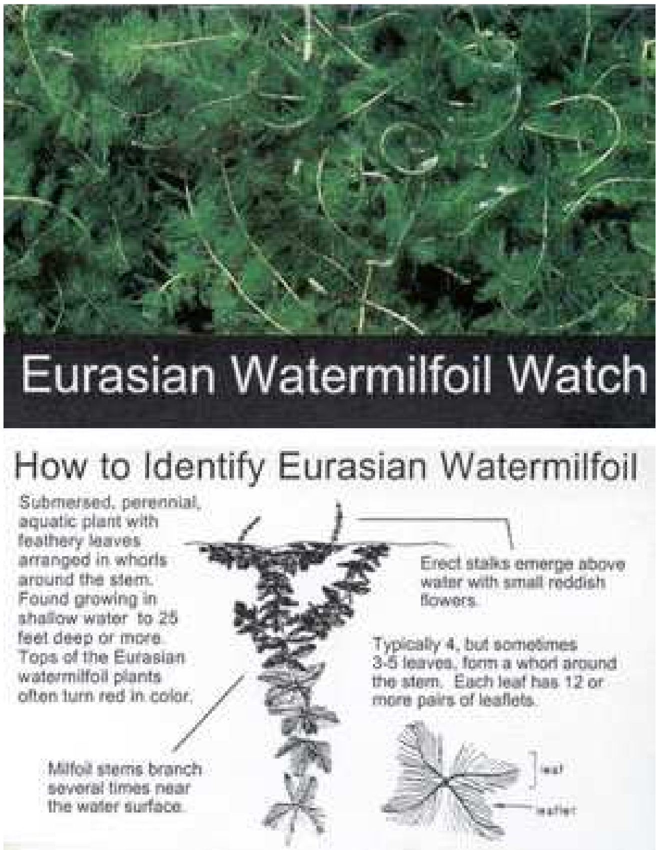


Figure 48b: The Invasive Aquatic Plants in Peppermill Lake

Myriophyllum spicatum
(Eurasian Watermilfoil)

Critical Habitat

Designation of critical habitat areas within lakes provides a holistic approach for assessing the ecosystem and for protecting those areas in and near a lake that are important for preserving the qualities of the lake. Wisconsin Rule 107.05(3)(i)(I) defines a "critical habitat areas" as: "areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water. Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, critical habitat areas often can provide the peace, serenity and beauty that draw many people to lakes.

Protection of critical habitat areas must include protecting the shore area plant community, often by buffers of native vegetation that absorb or filter nutrient & stormwater runoff, prevent shore erosion, maintain water temperature and provide important native habitat. Buffers can serve not only as habitats themselves, but may also provide corridors for species moving along the shore.

Besides protecting the landward shore areas, preserving the littoral (shallow) zone and its plant communities not only provides essential habitat for fish, wildlife, and the invertebrates that feed on them, but also provides further erosion protection and water quality protection.

Field work for a critical habitat area study was performed on October 4, 2006, on Peppermill Lake, Adams County. The study team included: Scot Ironside, DNR Fish Biologist; Deborah Konkel, DNR Aquatic Plant Specialist; and Reesa Evans, Adams County Land & Water Conservation Department. Areas were identified visually, with GPS readings and digital photos providing additional information. Input was also sought from Terry Kafka, DNR Water Regulation; Jim Keir, DNR Wildlife Biologist; and Buzz Sorge, DNR Lake Manager. Two areas on Peppermill Lake were determined to be appropriate for critical habitat designation.

Critical Habitat Areas--Peppermill Lake

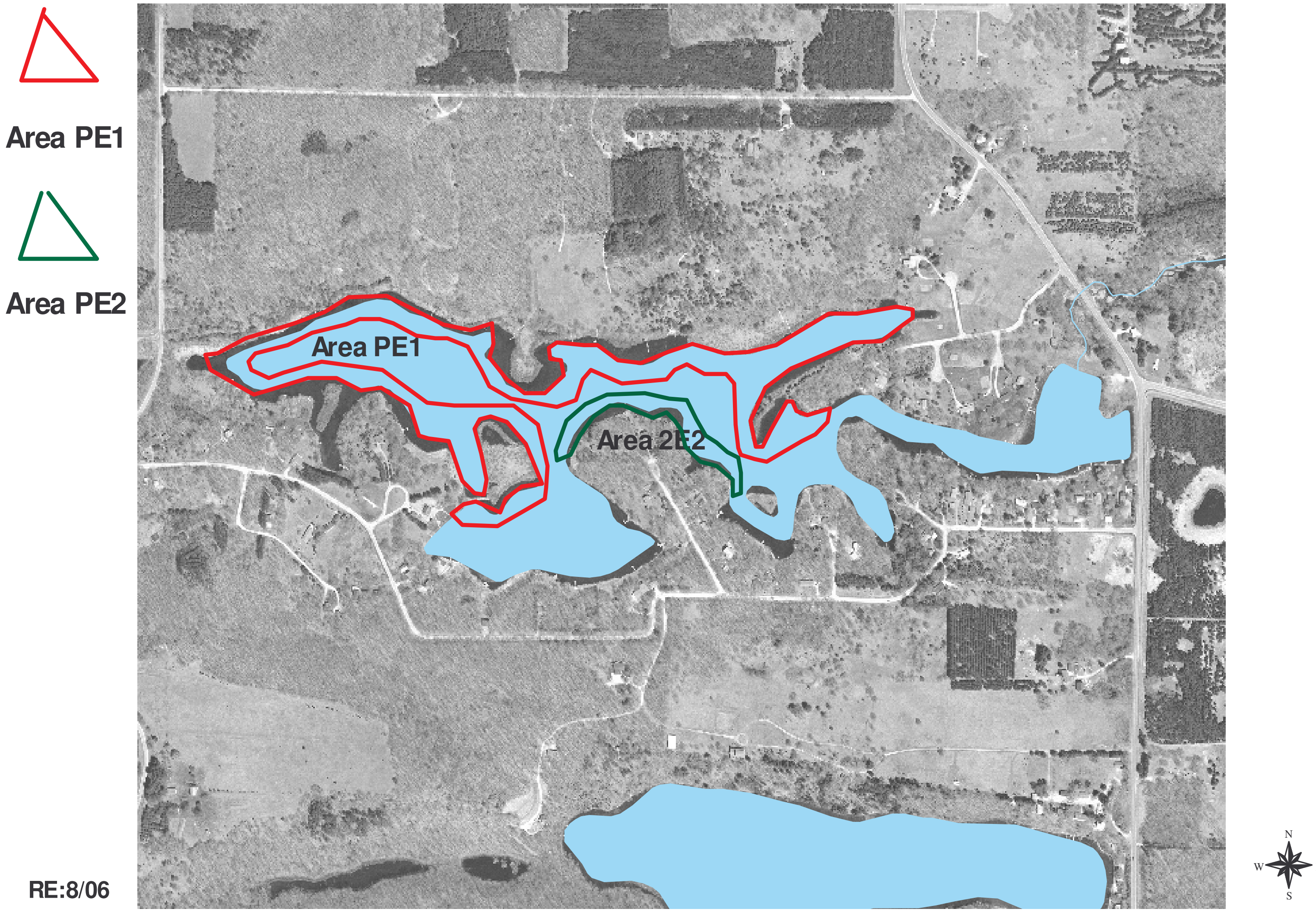


Figure 49: Map of Critical Habitat Areas on Peppermill Lake

Critical Habitat Area PE1

This area extends along approximately 7000 feet of the shoreline up to the ordinary high water mark, comprised of about 2/3 of the northern shore of the lake and the southwest shore of the lake. 12% of the shore is wooded; 61% has shrubs; 27% is native herbaceous cover. Shrub-carr is found along part of the shore. Large woody cover is common for habitat. With minimal human disturbance along this shoreline, the area has natural scenic beauty.

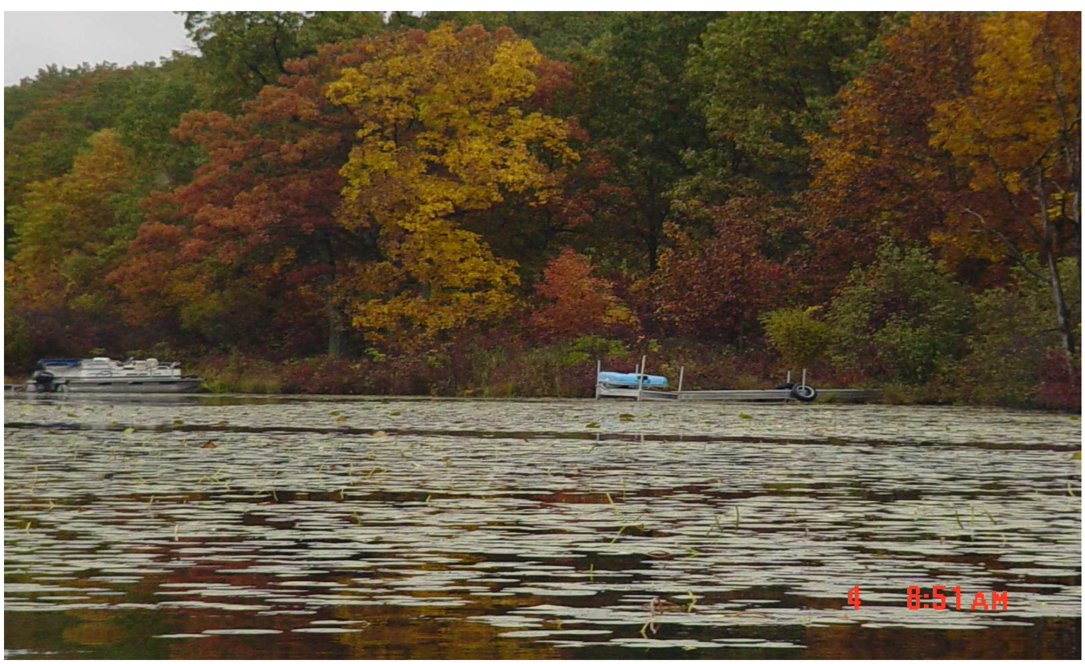
This area of large woody cover, emergent aquatic vegetation, submergent and floating vegetation provides spawning and nursery areas for many types of fish: northern pike; largemouth bass; rock bass; bluegill; pumpkinseed; yellow perch; black crappie; bullhead; white suckers, and other panfish. All of these fish also feed and take cover in these areas. No exotic aquatic wildlife was noted in this area, i.e, no carp, smelt or rusty crayfish were seen.

Muskrat and mink are also known to use this habitat for cover, reproduction and feeding. Seen during the field survey were various types of songbirds. Frogs and salamanders are known to use this area for shelter/cover, nesting and feeding. Turtles and snakes also use this area for cover or shelter in this area, as well as nested and fed in this area. Upland wildlife feed and nest here as well. Since human disturbance is light in PE1, it provides quality habitat for many types of wildlife. The wildlife biologist indicated that should this shoreline become more developed, its habitat value will be limited.

Maximum rooting depth of aquatic vegetation in PE1 was 7.5 feet. Eight species of emergent aquatic plants were found in this area. Emergents provide important fish habitat and spawning areas, as well as food and cover for wildlife. Two species of free-floating plants and three species of floating-leaf rooted plants were also present. These provide cover for fish and invertebrates and are eaten by fish and waterfowl. Floating-leaf rooted vegetation also provides cover and dampens waves, protecting the shore. Filamentous algae were common in this area. Eleven species of submergent aquatics were found in PE1.

The only exotic invasive plant found in this area was Eurasian Watermilfoil. Most of the aquatic vegetation in this area has multiple uses for fish and wildlife. Because this site provides all three structural types of vegetation, the community has a diversity of structure and species that supports even more diversity of fish and wildlife.

Figure 50: Sections of PE1



Critical Habitat Area PE2

This area extends along approximately 800 feet of the shoreline along the middle south part of the lake. 35% of the shore is wooded; 10% is native herbaceous cover; the remaining shore is cultivated lawn and a little hard structure. Shallow marsh covers part of the shore. Large woody cover is common for habitat.

This area of abundant large woody cover, emergent aquatic vegetation, submergent and floating vegetation provides spawning and nursery areas for many types of fish: northern pike; largemouth bass; rock bass; bluegill; pumpkinseed; yellow perch; black crappie; bullhead; white suckers, and other panfish. All of these fish also feed and take cover in these areas. No exotic aquatic wildlife was noted in this area, i.e, no carp, smelt or rusty crayfish were seen. Some shore development was present in PE2.

Maximum rooting depth in PE2 was 8 feet. No threatened or endangered species were found in this area. One exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil), was found in this area. Filamentous algae were present, especially near the shores. Only two types of emergents were found here. Two species of floating-leaf rooted plants were present. Two free-floating plants were also at this site. The remaining five aquatics in this area were submergents. A diverse submergent community can provide many benefits. All of these plants have multiple fish and wildlife uses.

Figure 51: Area of PE2

Recommendations for Critical Habitat Areas

(1) Maintain current habitat for fish and wildlife.
(2) Do not remove fallen trees along the shoreline.
(3) No alteration of littoral zone unless to improve spawning habitat.
(4) Seasonal protection of spawning habitat.
(5) Maintain snag/cavity trees for nesting.
(6) Install nest boxes.
(7) Maintain or increase wildlife corridor.
(8) Maintain no-wake lake designation.
(9) Allow no further development of PE1.
(10) Protect and, if possible, enhance emergent vegetation.
(11) Minimize aquatic plant and shore plant removal to maximum 30' wide viewing/access corridor or for navigational purposes only. Leave as much vegetation as possible to protect water quality and habitat.
(12) Use forestry best management practices.
(13) No use of lawn products.
(14) No bank grading or grading of adjacent land.
(15) No additional pier placement, boat landings, development or other shoreline disturbance in the shore area of the wetland corridor.
(16) No additional pier construction or other activity except by permit using a case-by-case evaluation and using light-penetrating materials.
(17) No installation of pea gravel or sand blankets.
(18) No bank restoration unless the erosion index scores moderate or high.
(19) If the erosion index does score moderate or high, bank restoration only using biologs or similar bioengineering, with no use of riprap or retaining walls.
(20) Placement of swimming rafts or other recreational floating devices only by permit.
(21) Maintain buffer of shoreline vegetation where present. Install buffer where there is currently cultivated lawn.
(22) Maintain aquatic vegetation in undisturbed condition for wildlife habitat, fish use and water quality protection.
(23) Maintain sign for exotic species alert at boat landing

FISHERY/WILDLIFE/ENDANGERED RESOURCES

WDNR fish stocking for Peppermill Lake occurred mainly in the 1990s and consisted of northern pike and largemouth bass. A fish inventory recorded in 1970 found that largemouth bass, bluegills, pumpkinseeds and white suckers were common, with northern pike and rock bass present. By 1999, bluegills were abundant, but had stunted growth. A threatened fish species, *Fundulus diaphanous* (red-banded killifish), was found in the lake in 1995.

A number of efforts to improve fish habitat have been made on Peppermill Lake over the years. These include the installation of pea gravel spawning beds, installation of fish cribs; installation of aerators; stocking largemouth bass, northern pike and yellow perch; feeding the fish; and aquatic plant control.

An October 2001 inventory done as part of the UWSP study found that bluegills, black crappie and largemouth bass were abundant; crappie, green sunfish, yellow perch, northern pike, pumpkinseed and rock bass were common; brown bullheads were scarce. The report on that inventory indicated that bluegill structure and size were poor due to their high density, low predatory density and slow growth That report noted that the average fish length had decreased for most of the fish species. The report indicated that nutrient loading might be coming from both the lake bed and shore development. The report expressed the concern that the "extreme abundance" of chara, which it attributed to internal loading of phosphorus from the lake bed, reduced the amount of free phosphorus in the water column, keeping down phytoplankton, which in turn kept down the zooplankton that small fish eat, reducing the growth and survival of larval fish. The report concluded that the Peppermill Lake fish community was unbalance, with large numbers of bluegill and low numbers of predators. The report made the following recommendations: (1) mechanical harvesting be used to remove aquatic plants; (2) stocking should continue of largemouth bass and pike; (3) consideration of prohibiting the harvest of bass and northern pike for 5 years to help decrease the bluegill population and increase predation; (4) use of restrictive size limits on predator catches to increase the number of predators.

An updated fishery inventory was performed in October 2006 by the WDNR. That survey found that largemouth bass and bluegills were abundant; northern pike was common; and black crappie, pumpkinseed and yellow perch were present. Largemouth bass average 13.4 inches long, while bluegills average 4.3 inches long. The average northern pike was 18.3 inches long. Black crappie, pumpkinseed and yellow perch averaged 11.2 inches, 6.8 inches and 5.7 inches respectively.

Muskrat are also known to use Peppermill Lake for cover, reproduction and feeding. Seen during the field survey were various types of waterfowl, songbirds, and turkey. Frogs and salamanders are known, using the lake shores for shelter/cover, nesting and feeding. Turtles and snakes also use this area for cover or shelter in this area, as well as nested and fed in this area. Upland wildlife feed and nest here as well.

Endangered resources reported in the Peppermill Lake watersheds include ***Anemone nemorosa*** (Early Anemone) and ***Plantanthera hookeri*** (Hooker's orchid).

Figure 52: Endangered Resources at Peppermill Lake

Early Anemone

Hooker's Orchid

*information courtesy of Wisconsin Department of Natural Resources

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Figure 53: Part of Shore of Peppermill Lake