Lily Lake Watershed Land Use and Water Quality Study (Phase II)

Town of Eaton, Brown County, Wisconsin

Funding for this study was provided in part by the Wisconsin Department of Natural Resources through a Large-Scale Lake Planning Grant.

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Lily Lake Watershed Land Use and Water Quality Study

Prepared for the Town of Eaton by the Brown County Planning Commission with funding provided through a Large-Scale Lake Planning Grant from the Wisconsin Department of Natural Resources.

The Brown County Planning Commission would like to gratefully acknowledge the assistance of Mr. Jim Reyburn with the Wisconsin Department of Natural Resources, and Mr. Doug Hartman with the Brown County Facility and Park Management Department in preparing the study.

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CHAPTER 1

Introduction

Introduction and Background

The project area includes Lily Lake in the southwestern part of the Town of Eaton Brown County, Wisconsin. Lily Lake and the smaller Middle and Third Lakes (Lily Lake System) are the only natural lakes within Brown County. Lily Lake is approximately 43 acres in area with a maximum depth of 21 feet. The entire shoreline is buffered by woodlands and wetlands and contains a county park at its northern end. Lily Lake is described as mesotrophic with a mean summer Secchi reading of about 14 feet. Due to the generally shallow nature of the lake, periodic winterkills of fish have occurred. An aerator is now utilized to increase dissolved oxygen levels during the winter months.

Located about ten miles southeast of the City of Green Bay, Lily Lake receives a lot of usage for fishing and passive outdoor recreation. Facilities at Lily Lake County Park include picnic and play areas, an arboretum, nature trails, two fishing docks (one ADA accessible), a boat launch, an open air shelter, and parking. The lake is popular for day fishing trips either from the fishing docks or from a non-motorized (except electric trolling motors) watercraft.

Purpose and Intent

The Lily Lake Land Use and Water Quality Study is intended to inventory and analyze the Lily Lake watershed from a watershed perspective in order to ascertain potential land use related causes for extensive late summer aquatic plant growth. All three lakes are fed exclusively by groundwater seepage, and only the smallest of the three lakes, Third Lake, has an intermittent outlet. There land use activities around the lakes have a direct impact on the water quality and recreational usage of all three lakes.

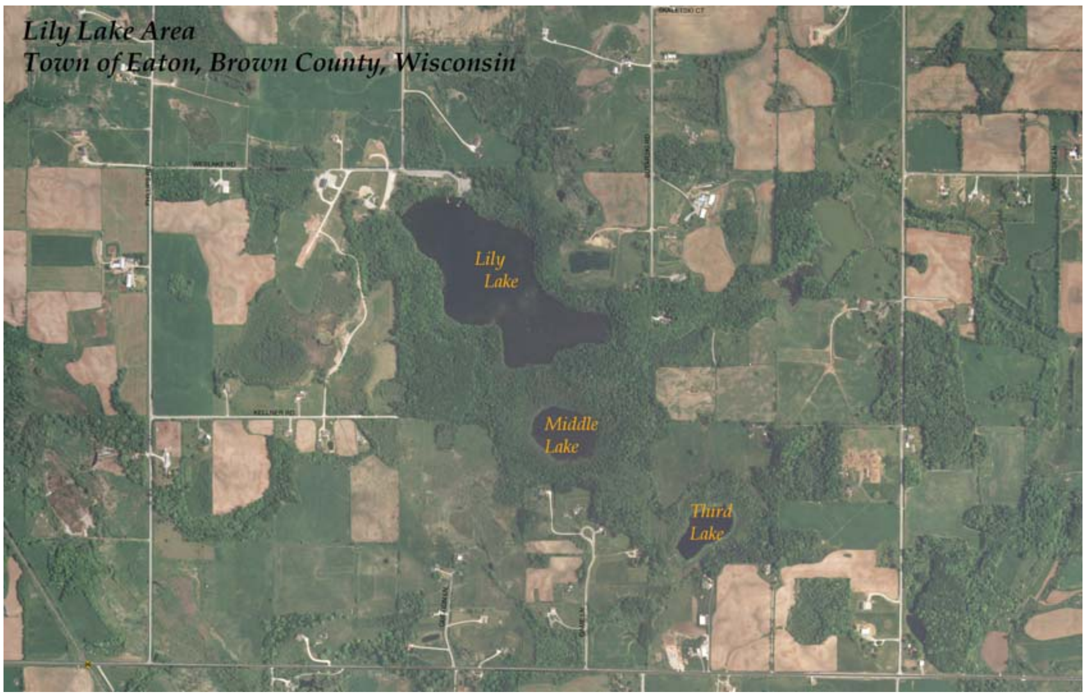
This report will analyze the physical and chemical components that most directly affect the overall water quality of a freshwater lake. Although “water quality” is often determined by human uses of a surface water resource, emphasis will be placed on biological, physical and chemical criteria. Both qualitative and quantitative measurements were taken throughout the summer and fall of 2008. Specific examinations included water clarity (Secchi disc) readings, an aquatic vegetation survey, and water sample collection and analysis.

It is expected that the resulting data and analyses contained within the report will be utilized by the Town of Eaton and Brown County specifically to implement measure to ensure the Lily Lake system remains a healthy and vital components of the Town of Eaton's landscape and the Brown County Parks System.

Study Area

Although the previous phase of this ongoing study focused on the entire Lily Lake watershed, this study is restricted to Lily Lake. See Figure 1-1 for an aerial photograph of Lily Lake. All sampling and monitoring were conducted in Lily Lake between May and November 2008.

Figure 1-1: Lily Lake



Source: Brown County Planning Commission (BCPC), 2005

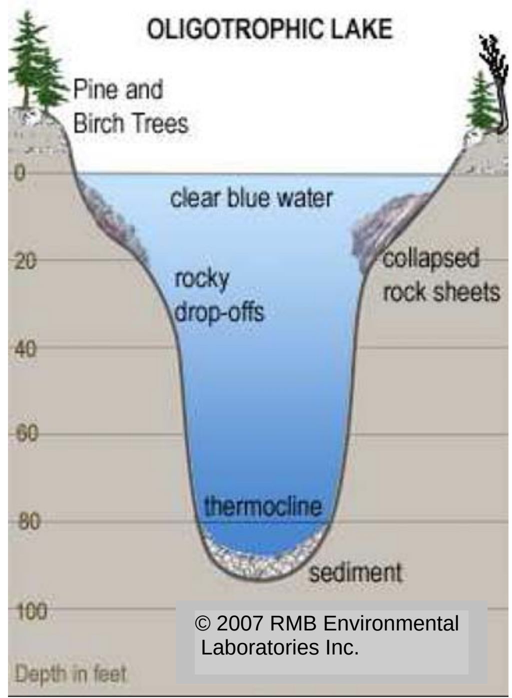
Limnology

Limnology is the division of hydrology that studies fresh water. Limnology covers lakes, ponds, reservoirs, streams, rivers, wetlands, and estuaries. Limnologists recognize that lakes are complex ecological systems physically and chemically connected with its surroundings. Scientists use biological, physical, chemical, and geological characteristics of the surface water to determine a lake's overall "health."

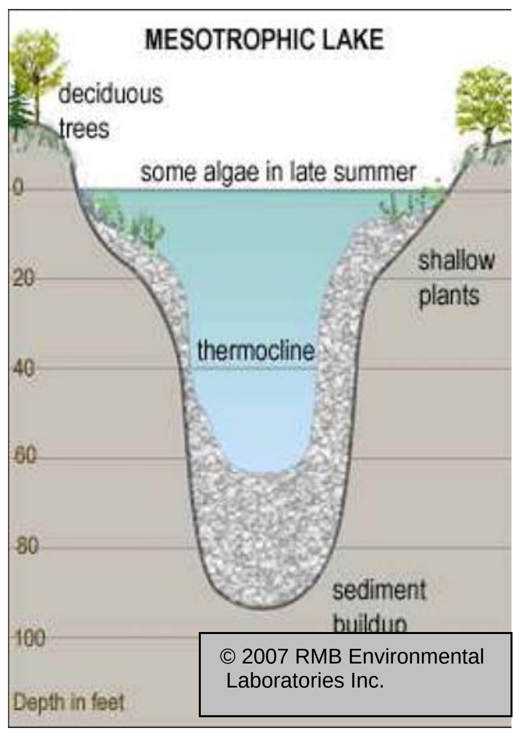
Trophic Status

Lakes are classified according to their "trophic status" depending on the amount of nutrients present in the lake. Lakes are classified as either oligotrophic, mesotrophic, or eutrophic.

Oligotrophic lakes have little or few nutrients. They are generally deep lakes within generally U-shaped basins. Temperatures are often cold, and oxygen levels are high throughout the water column. Since cold water can hold more oxygen, they often hold healthy trout populations.



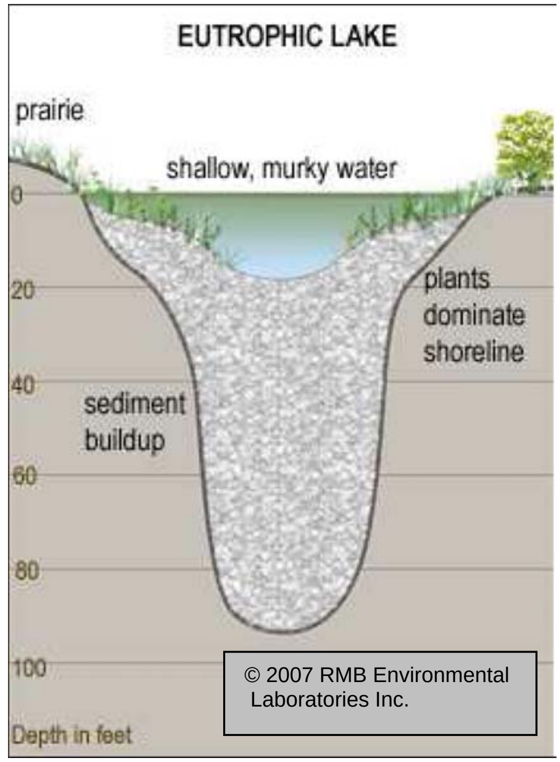
Eutrophic lakes have highly enriched nutrient levels. Such lakes are often shallow V-shaped bottoms. The bottoms are often mucky and soft-bottomed. Deeper portions of the lakes are often anoxic, or devoid of oxygen, during a large part of the year. In very shallow lakes, the entire lake may become anoxic. The high nutrient concentrations allow high plant and algae growth. In less eutrophic lakes, game fish populations such as bass, pan fish, and northern pike thrive. In more eutrophic lakes, rough fish such as carp and catfish survive.



Mesotrophic lakes have an intermediate nutrient concentration. Mesotrophic lakes support higher fish diversities than either oligotrophic or eutrophic lakes. As a result, they often support excellent fisheries. Mesotrophic lakes are unique because they display stratification, or layering of water. As the sun warms the surface layers, water temperatures rise and the density decreases. Since sunlight may not penetrate to the bottom, deeper water becomes colder and denser than surface waters. This differentiation between water causes noticeable layering. Since the layers do not mix, oxygen levels deplete as algae and other organisms die, settle to the bottom, and decay. Most lakes throughout Wisconsin are mesotrophic.

A natural aging process occurs in all lakes causing them to change from oligotrophic to eutrophic over time. Each year plants uproot in the fall and sink to the bottom. Although some of the material decomposes, lakes will eventually start to fill in. People can accelerate the eutrophication process by allowing nutrient rich runoff to enter lakes from lawns, agricultural fields, septic systems, or urban storm drains.

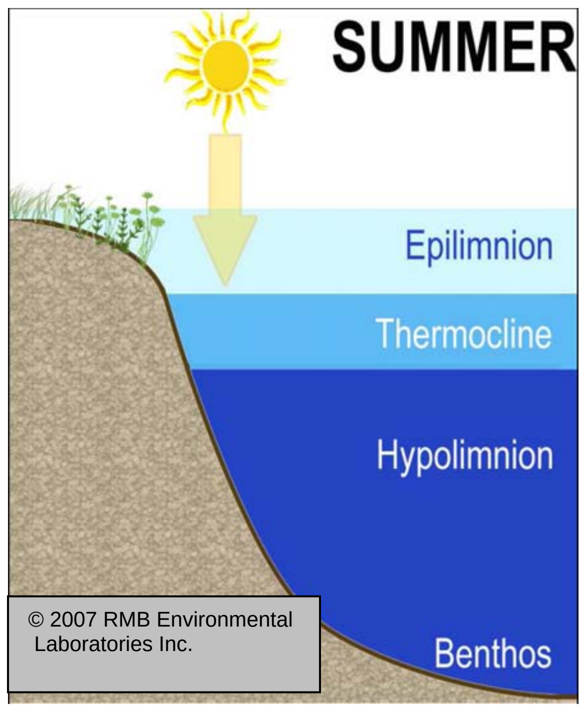
One drawback of defining trophic states within the trophic state index is that lakes vary. The trophic state of a particular lake depends on numerous factors including depth, surface area, watershed size, adjacent land use, and climate. There is some overlap between the trophic classifications. Trophic states should be considered a general definition of lakes condition.



Lake Cycles

Most inland lakes undergo an annual cycle as seen in Figure 1-2. The cycle begins at the spring thaw and repeats itself annually. The length of each stage in the cycle can change the lake's chemical and physical properties throughout the year. During summer, lakes more than 20 feet deep usually experience stratification, or layering. A lakes water quality and ability to support fish are affected by the extent to which the water mixes.

The mixing is caused by the evening of water temperatures throughout the water column. When a lake mixes, cold bottom water is brought to the surface and the warmer surface water is mixed downward.



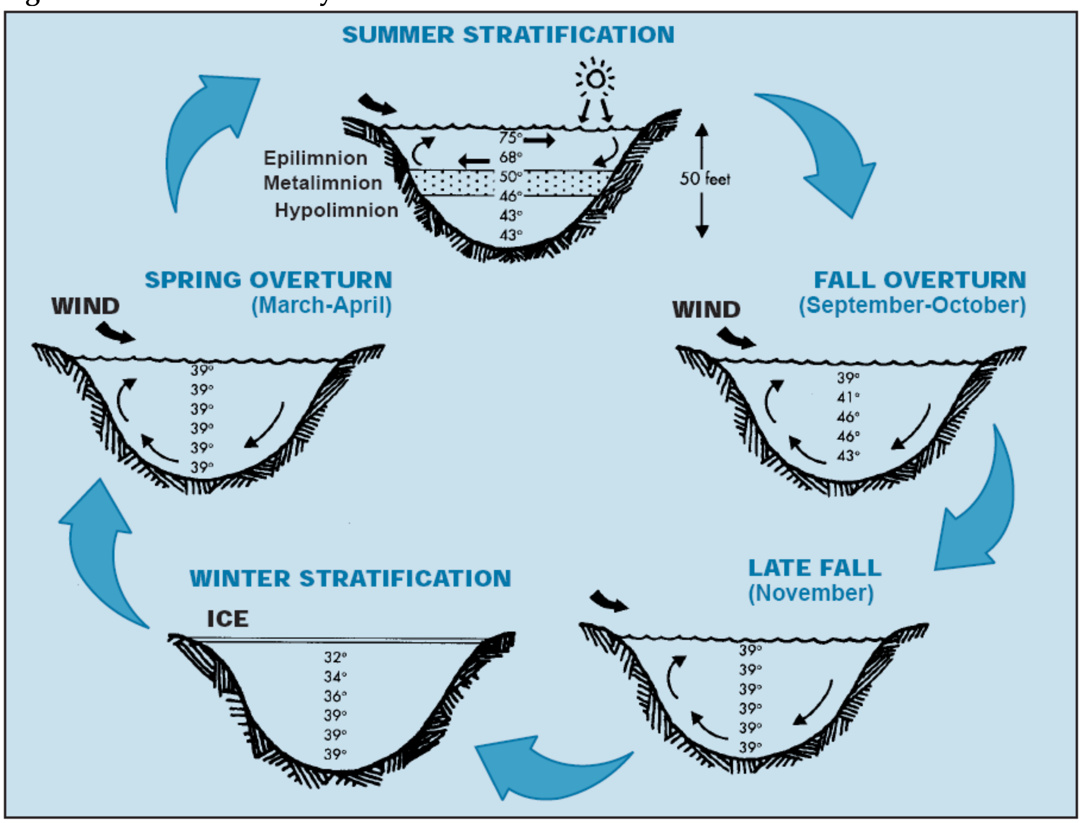
Stratification is influenced by lake depth and lake orientation. Shallow lakes can be mixed all year by wind or waves. In larger lakes, the wind may continuously mix the water to a depth of 30 feet. Lake shallows do not form layers, though deeper areas may stratify. Winds will sweep over the water surface causing mixing. Lakes with numerous bays may not be thoroughly mixed.

Water density is highest at 39°F (4°C). It is lighter at both warmer and colder temperatures. When ice melts in early spring, the temperature and density of lake water will be almost uniform from the surface to the bottom. The uniform density allows the lake to mix completely, recharging the bottom with oxygen and bring nutrients to the surface. The mixing is called the spring overturn. Natural mixing can occur to depths of 30 feet.

As the summer lengthens, the sun warms the upper layers. Typically the warming is observed to the depth at which sunlight penetrates. As the surface water temperature is warmed, three distinct layers form: the epilimnion (warm surface layer), the metalimnion (transition zone), and hypolimnion (cold bottom water). The metalimnion also known as the thermocline is a zone of rapid change. The temperature usually drops several degrees within a few feet. In some lakes, the metalimnion may be extremely thin preventing mixing of water between the upper and bottom layers.

The circulation of nutrients, food, and other components in stratified lakes are restricted to within a single layer. The bottom layers of productive lakes (those with significant plant growth) become oxygen depleted as temperatures water rise and bacterial respiration increases. With insufficient oxygen, fish kills can occur.

Figure 1-2: Annual Lake Cycles and Stratification



Source: Wisconsin Department of Natural Resources, 2007

In the fall, surface waters cool until the temperature evens out from top to bottom. The evening temperatures allow a second mixing to take place. Nutrients such as phosphorous are re-distributed through the lake. As a result, some lakes may experience a fall algal bloom. There is little variation in temperature and dissolve oxygen after mixing is completed.

Stratification is less noticeable during the winter. Temperature variations only reach 7°F. Ice cover will prevent water from mixing and temperatures will be uniform throughout the winter months. If insufficient oxygen is re-circulated or algal blooms result in increased bacterial decomposition before the water freezes, dissolved oxygen levels will be lower. Fish kills can also occur when ice cover prevents mixing of dissolved oxygen.

Water Quality Testing

Researchers use various methods to calculate the trophic status of lakes. Common characteristics used to make a determination are total phosphorous concentration, chlorophyll a concentration, Secchi disc readings, temperature, dissolved oxygen readings, and color. Other tests such as specific conductivity and pH give clues on the overall chemical composition of a lake.

Total Phosphorous Concentration

Phosphorous is the main nutrient which plants and algae need to grow. Phosphorous occurs is several forms. Not all forms are available for biological activity; the total amount available is dependent on several chemical and physical parameters.

Phosphorous is measured in micrograms per liter (μg/L) which is equivalent to parts per billion (ppb). Typical total phosphorous concentrations for each trophic index are found in Table 1-1. Lakes that have phosphorous concentrations higher than 20 μg/L are susceptible to periodic algal blooms.

Table 1-1: Water Quality Parameters by Trophic Classification

Water Quality Parameter	Oligotrophic	Mesotrophic	Eutrophic
Secchi (feet)	> 16.4	6.5 - 16.4	< 6.5
Total Phosphorus (μg/L)	< 10	10 - 30	> 30
Chlorophyll a (μg/L)	< 2	2 -5	> 5

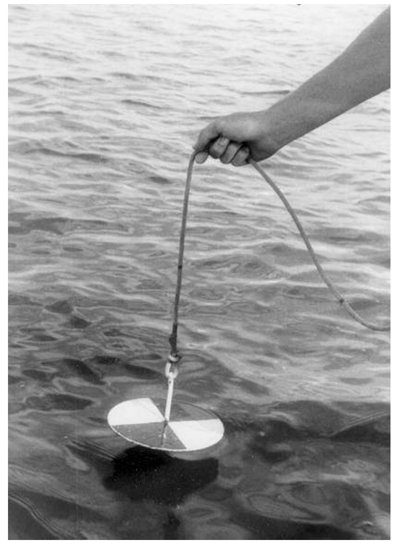
Source: Mackie, 2001

Chlorophyll a Concentration

Chlorophyll is the pigment that makes algae and other plants green. At least four types of chlorophylls are known. Chlorophyll a is the most common and is present in all plants. It is the primary photosynthetic pigment and receives light energy from most other pigments.

Chemical instrument is used to quantify how much algae is in the water. A chlorophyll reading of less than 5 g/L is very good or excellent. A chlorophyll reading of greater than 30 g/L is very poor. Chlorophyll concentrations for the trophic indexes are found in Table 1-1.

Secchi Disc Readings



The Secchi disc is arguably the most useful device and easily performed test in water quality analysis. The instrument is a 20 cm disc with black and white quadrants. An eye bolt is fastened to the center of the disc and a rope is attached to it. The rope is marked in one foot increments. The Secchi disc is lowered into the water until the white quadrants disappear from view. The depth at which the disc disappears is referred to as the Secchi depth.

Secchi readings measure the relative depth of light penetration. It is a relative measurement because readings vary from individual to individual or moment to moment. Factors such as algae concentrations, turbidity, water color, cloud cover, or the amount of shaded cast by the boat affect the reading. Algae absorb sunlight and reduce the depth to which it will penetrate. Suspended sediment stirred up by wind or boat motors will cloud the water. "Stained" water may result if tannic acids or other naturally occurring chemicals are present in the water. Secchi data for the trophic index is located in Table 1-1.

Temperature and Dissolved Oxygen

Measuring the temperature of a lake at different depths will determine the influence it has on the physical, biological, and chemical aspects of the lake. Lake temperature can affect the rate of decomposition, nutrient recycling, lake stratification, and dissolved oxygen contents near the bottom. Temperature changes can also affect the distribution of fish species throughout a lake. The dissolved oxygen content of lake water is vital in determining the fishery present.

Dissolved oxygen also has a strong influence on the chemical and physical conditions of a lake. The amount of dissolved oxygen is dependent on the water temperature, atmospheric pressure, and biological activity. Oxygen levels are increased by aquatic plant production but reduced by bacterial consumption for decomposition and respiration of fish and aquatic invertebrates.

The amount of dissolve oxygen available in a lake, particularly in the deeper parts of a lake, is critical to overall health. Colder water holds more oxygen than warm water. Thus shallower lakes have the tendency to hold less dissolved oxygen.

Both temperature and dissolved oxygen data are collected simultaneously with specialized probes at the end of a 25 foot cord. Readings are taken at the deepest point of the lake. Measurements were taken at the surface and at two foot intervals until the dissolved oxygen content reached 0°C. Measurements were recorded at one foot intervals near the thermocline. The purpose behind collecting profile data is to show how water characteristics change with depth. The profile is taken at the deepest point of the lake because it is the best indicator of lake health.

Color

The color of a lake bottom often affects our perception of the water color. In general bluish or black lakes indicate oligotrophic lakes. The lack of nutrients creates clear water. Brownish lakes indicate mesotrophic or eutrophic lakes. Greenish lakes are typically eutrophic; the green color is a direct result of large concentration of algae and other microscopic plant material.

Specific Conductivity

Electric conductivity is a measure of water's ability to conduct electricity, and therefore a measure of the water's ionic activity. Increasing conductivity is a direct result of higher dissolved ion concentrations. Conductivity is affected by the temperature.

Specific conductance (SC) is measure using two probes one squared centimeter in area separated by one centimeter. The probes measure the electrical current created by ions in the water. SC is measured in µS/cm.

pH

The pH of a lake indicates whether it is an acidic or basic environment. The pH scale ranges from 0 to 14. A pH value of seven is neutral. As the pH decreases (closer to 0), the water is more acidic; as the pH increases (closer to 14), the water becomes more basic.

A wide range of pH values is encountered in different lakes. The pH is influenced by the geology of the underlying soils and the resulting ions that are dissolved in the water. The pH can regulate various chemical cycles that occur in lakes and directly influence the plant and fish communities present. Furthermore, the temporal and vertical patterns of pH in lake are mediates through the overall dynamics of photosynthetic consumption and respiratory/decomposition production of carbon dioxide (CO2). Photosynthesis by algae and other plants will increase the pH, while decomposition and respiration make the pH more acidic.

Aquatic Vegetation

Aquatic vegetation is an important indicator in the overall health of a lake. Since phosphorous is the primary "food" source for plants, high nutrient concentrations can lead to an abundance of plant growth or algal blooms. In addition, the chemical parameters of a lake can limit what species of plants can grow.

Freshwater plant monitoring is completed by natural resource agencies to track aquatic plant community changes over time. In addition, these programs help identify whether invasive species have been introduced into a lake.

Invasive species are non-native plants that have been introduced to Wisconsin either accidentally or on purpose by humans. Many invasive plants were originally used in either the aquarium industry or landscaping. Invasive species typically originated in foreign countries. Once introduced, they live in an environment which lacks natural predators such as plant-eating insects or disease that normally keeps their growth in check. The lack of natural controls, combined with the plants high reproductive rates, allows the plants to thrive and out-compete native desire species.

CHAPTER 2

Sampling Methodology

Methods

Each lake has a unique set of physical and chemical characteristics which determine its overall water quality. This study explores several limnilogical parameters in order to determine a baseline health status of Lily Lake. The study utilizes Secchi readings, an aquatic plant survey, and advanced chemical analyses to determine an overall trophic status for Lily Lake.

One of the components of the grant application to the WDNR was to participate in the Wisconsin Citizens Lake Monitoring Programs (CLMN). Water quality testing was performed utilizing the procedures outlined in the Wisconsin Citizen Lake Monitoring Manual. The results were entered into the WDNR's Surface Water Integrated Monitoring System (SWIMS) database to continue a recorded water quality monitoring effort on Lily Lake.

Aquatic Vegetation Survey

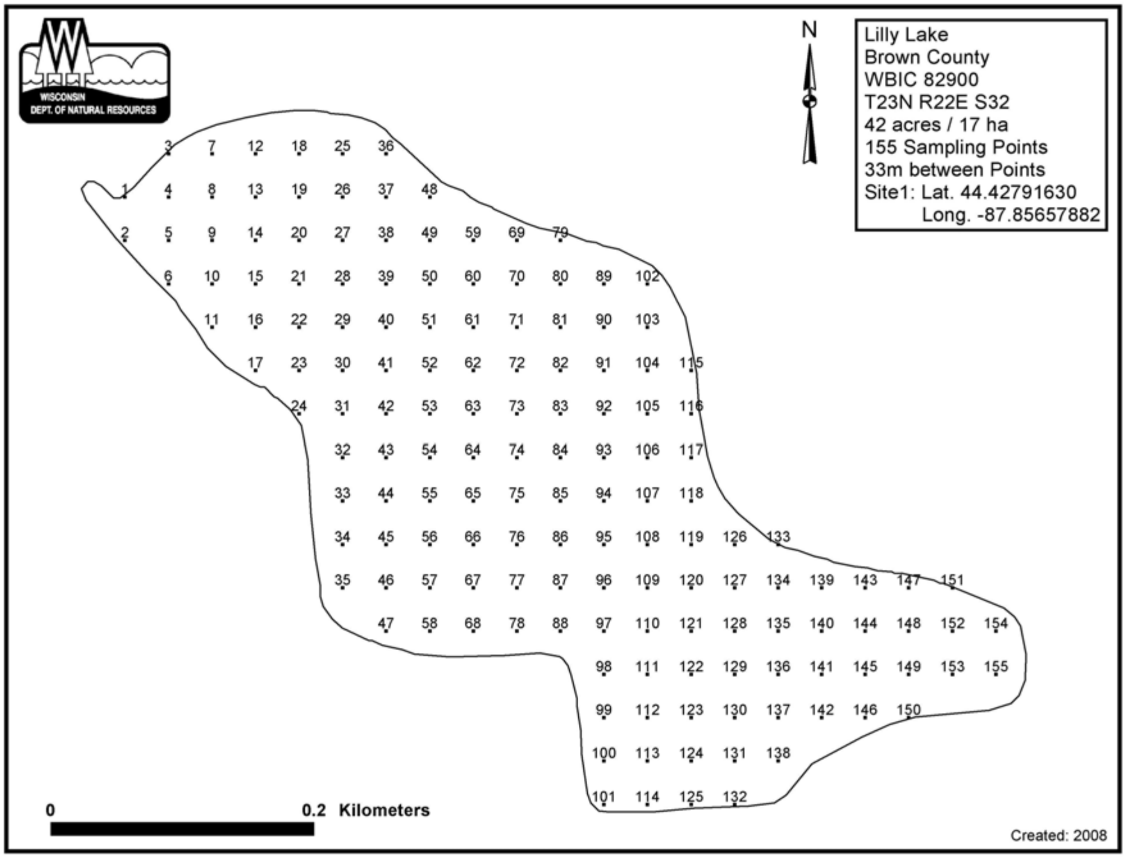
A point-intercept vegetation survey of Lily Lake was conducted between July 23, 2008, and July 31, 2008, following the methodology described by Madsen (1999). Sample points were established across Lily Lake by using a 33 meter by 33 meter grid. This resulted in a total of 155 sample points as seen in Figure 2-1. Specific GPS coordinates for the points is located in Appendix A.

A Garmin GPSMAP 60CX GPS unit was used to navigate the boat to each sample point. One side of the boat was designated as the sampling area. At each site, water depth was recorded using a measured weighted rope. A double-headed, weighted garden rake, attached to a rope was lowered into the water. At depths less than eight feet, the rake was spun in two complete circles to entwine plant material; at depths greater than eight feet, the rake was swung like a pendulum to tangle plant material. Emergent vegetation surrounding the lake not identified at the sampling points were noted and identified to species where possible. Samples points that fell on land were noted in the field and not included in the overall analysis.

All vegetation was identified to a species level where possible utilizing dichotomous keys utilizing nomenclature followed by Vosters (1972). When necessary, plants were identified to their genus.

Data was entered into an Access database and frequency of occurrence was calculated for each species as the number of sites in which a species occurred as a percentage of the total sites sampled. Water depths for each observed species were identified and distribution maps for each species were created.

Figure 2-1: Lily Lake Point-Intercept Sampling Map



Source: WDNR, 2008

Bathymetry

Bathymetry is the study of underwater depth. The double-headed rake utilized in the plant survey was marked at one foot intervals. The depth at each of the 155 sampling points was noted. The depths were entered into ArcView 9.2, and a contour map was created. The ArcView software was also utilized to create a three-dimensional model of Lily Lake.

Secchi Disc

Secchi readings were taken twice monthly between May and November 2008. All Secchi readings occurred between 10:00 a.m. and 4:00 p.m. to ensure optimal lighting conditions. Where possible, no more than 14 days lapsed between recording Secchi data. There were instances where this varied due to staff scheduling conflicts and weather. The readings were entered into the SWIMS database as a part of an ongoing study.

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen profiles were obtained monthly at the deepest part of Lily Lake. A Hydrolab Quanta probe was lowered through the water column. Temperature, dissolved oxygen, specific conductivity, and pH were measured at the surface and at two foot intervals until the probe hit the bottom of the lake or the dissolve oxygen content reached zero. Measurements were also recorded at one foot intervals at the thermocline.

Per CLMN requirements, three temperature/dissolved oxygen profiles were to be collected during the growing season (June 15 – September 15). To better understand the annual cycle of Lily Lake, profiles were collected each month. In addition, monthly temperature/dissolved oxygen profiles were collected monthly during the winter to analyze the efficiency of the aerator used by the Brown County Parks Department. Winter profiles were collected only as safety conditions warranted.

Chemical Instrumentation

Water samples were collected by hand at the deepest part of Lily Lake. Plastic bottles obtained from the Wisconsin State Lab of Hygiene (SLOH) were rinsed three times with lake water. The bottles were inserted upside-down and extended to an arm's length depth below the water surface. The bottle was inverted and filled to the neck. The bottle was capped, labeled with a unique identifying number, and treated with chemical preservatives where appropriate. All water samples were stored in individual ziploc bags in a refrigerator until shipping. Water samples were shipped on ice to the SLOH in Madison for analysis. The sampling schedule for Lily Lake water quality monitoring is summarized in Table 2-1.

Table 2-1: Water Quality Sampling Schedule - 2008

Parameter	May	June	July	August	September
Nutrients					
Total Phosphorous, all levels	X		X	X	X
Total Kjeldahl Nitrogen				X	
Nitrate plus Nitrite-N				X	
Wet Chemistry					
Automated conductivity			X	X	X
pH			X	X	X
Alkalinity			X	X	X
Chlorophyll a			X	X	X
True color				X	
Metals					
Calcium, total				X	
Magnesium, total				X	

Source: Wisconsin State Lab of Hygiene

Historic Comparisons

Limited data on historic water quality sampling performed in 1995 and 1996 was available for Lily Lake in the SWIMS Database. The data was used to re-create and graphically display the aforementioned information. Historical comparisons were made for Secchi readings; temperature and dissolved oxygen profiles, and chemical analyses (total phosphorous and chlorophyll a). The historical data is able to develop some long-term trends.

CHAPTER 3

Results

Aquatic Vegetation

A total of 18 native species and one non-native plant species were recorded in Lily Lake. The survey focused on in-lake vegetation, and the majority 68 percent of the species found was submerged. Submergent species accounted for 87 percent of all vegetation found as seen in Table 3-1.

Table 3-1: Plants Identified in Lily Lake

Scientific	Common	Number of Sites Observed	Visual Observations
Ceratophyllum demersum	Coon's-tail	36	
Chara spp.	Muskgrass	18	
Elodea canadensis	Canadian waterweed	5	
Lemna minor	Common duckweed	1	
Myriophylum sibiricum	Common water-milfoil	21	
Najas flexis	Northern water-mint	17	
Nymphea odorata	American white water-lily	26	
Potamogeton crispus	Curly-leaved pondweed	68	
Potamogeton illinoensis	Illinois pondweed	8	
Potamogeton natans	Floating leaved pondweed	2	
Potamogeton praelongeous	White-stemmed pondweed	39	
Potamogeton richardsonii	Richardson's pondweed	12	
Potamogeton robbinsii	Robbin's pondweed	42	
Potamogeton zosteriformis	Flat-stemmed pondweed	12	
Spirodela polyrhiza	Greater duckweed	1	
Stuckenia pectinata	Sago pondweed	46	
Vallisneria americana	Water-celery	37	
Eupatorium maculatum	Joe-pye-weed		X
Nuphar variegata	Bull-head pond-lily		X
Typha latifolia	Broad-leaved cattail		X

Source: BCPC, 2008

The plant community was dominated by the invasive curly-leafed pondweed (*Potamogeton crispus*) and sago pondweed (*Stuckenia pectinata*). Curly-leafed pondweed was found in 44 percent of all sample points. Other common submersed species included water-celery (*Vallisernus americanus*), coon's tail (*Ceratophyllum demersum*), and white-stemmed pondweed *(Potamogeton praelongus*).

Emergent species accounted for less than one percent of all vegetation. Although not sampled in the point-intercept survey broadleaf cattails (*Typha latifolia*) and Joe-Pye weed (*Eupatorium maculatum*) were common along the edges of the shallow bays.

Floating leaf species made up approximately 13 percent of the plant community. The most common species was American white water lily (*Nymphea odorata*). Free-floating pondweed (*Potamogeton natans*) was found at one location and bull-head pond lily (*Nuphar variegata*) was observed at several points on the lake which were not included as sampling points. Free-floating vegetation was found at only one sample point. Two species of duckweed were observed.

Bathymetry

A three dimensional model of Lily Lake was created. The deepest recorded depths were 21 feet. This was recorded at two different "deep holes in the lake". The first is located approximately 50 meters southeast of the easterly fishing dock (Sample Point Lily019). The second "deep hole" is located 300 meters southeast of the fishing dock (Sample Points Lily053 and Lily 054). Figure 3-1 shows a three dimensional view of Lily Lake. All water quality sampling was performed between sample point Lily053 and Lily054.

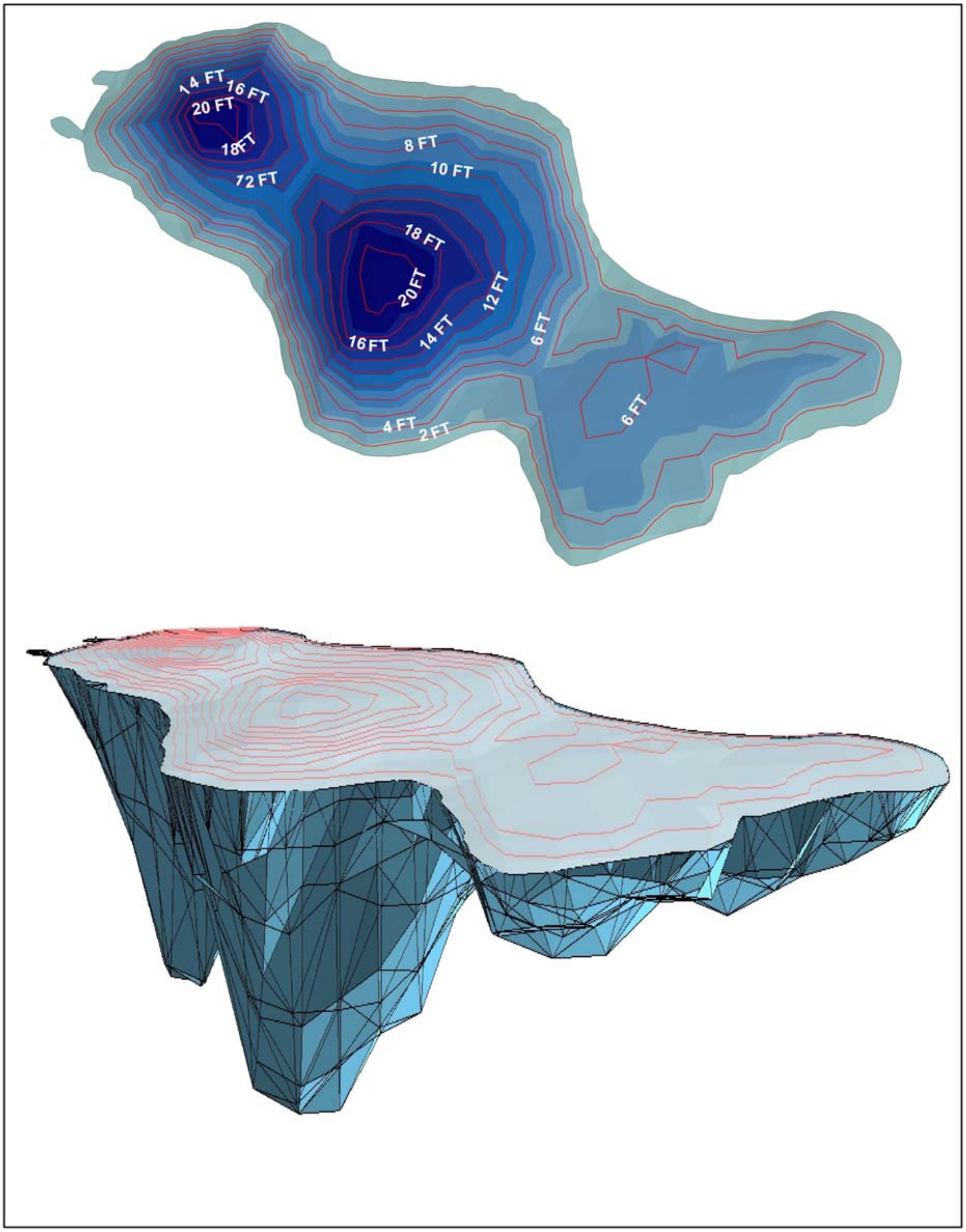
Six coordinates of the point-intercept sampling method were located on dry land. These points were not incorporated into the overall analysis.

Secchi Readings

Secchi readings were taken both in summer 2007 and throughout 2008 as seen in Figure 3-2. Four readings were taken in 2007. Secchi readings were taken twice a month in between April 22 and December 2008. Secchi depths varied from four feet on May 9, 2008 to 13 feet on October 29, 2008. The maximum Secchi depth recorded in the 2007 and 2008 growing seasons was 12.5 feet on August 12, 2008.

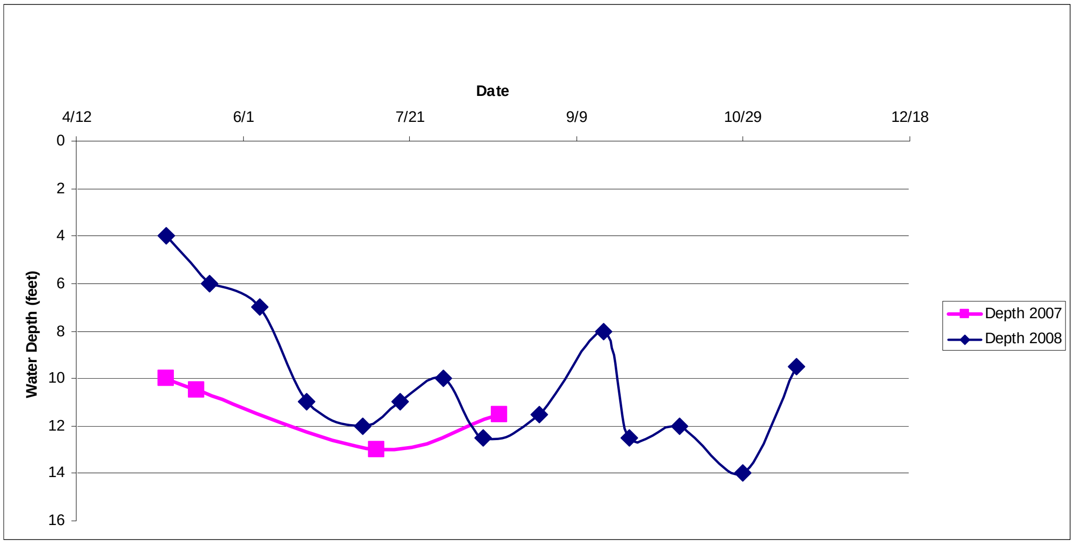
Water clarity was the lowest shortly after ice out in May. As the water column became increasingly clear as the growing season progressed. Water clarity began to decrease in November. Several episodes of decreased water clarity occurred throughout the summer. These readings were taken within a day or two after significant rainfalls during the summer.

Figure 3-1: Lily Lake Contour Map and Bathymetry



Source: BCPC, 2008

Figure 3-2: Current Secchi Depths at Lily Lake



Source: Brown County Planning Commission (BCPC), 2007-2008

Phosphorous

Water samples were collected in May, July, August, and September 2008. The specific dates are listed in Table 3-2. Individual water samples were sent to the Wisconsin State Lab of Hygiene (SLOH) for analysis.

Table 3-2: Lily Lake Phosphorous Concentrations

Date	Concentration (µg/L)
May 22	20
July 18	20
August 29	20
September 25	11

Source: SLOH, 2008

Chlorophyll a

Water samples were collected in July, August, and September 2008. The specific dates are listed in Table 3-3. Results were unable to be processed in July. Individual water samples were sent to the SLOH for analysis.

Table 3-3: Lily Lake Chlorophyll a Concentrations (µg/L)

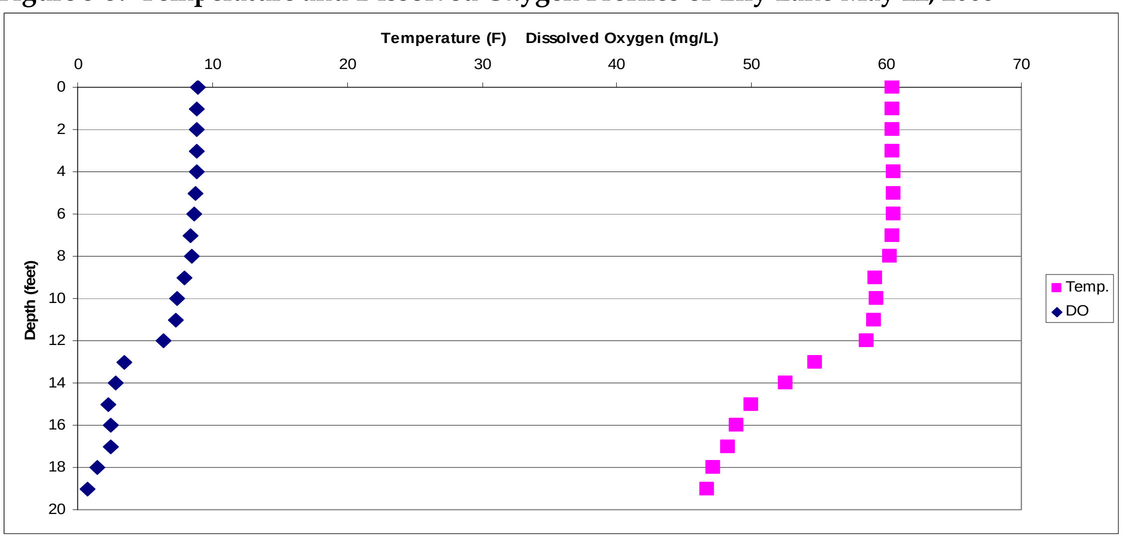
Date	Concentration (µg/L)
July 18	-
August 29	1.57
September 25	3.39

Source: SLOH, 2008

Dissolved Oxygen and Temperature

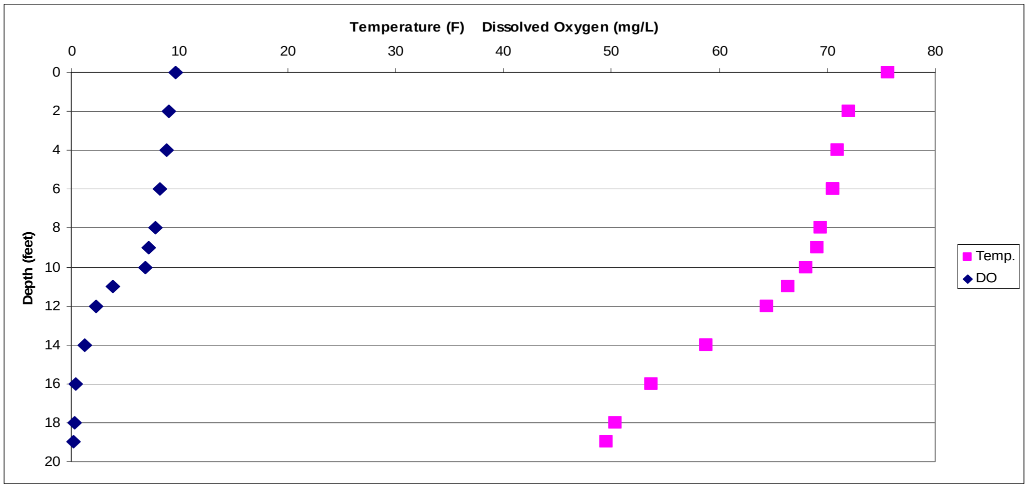
Dissolved oxygen (DO) and temperature (Temp) profiles were collected in May, June, July, August, September, and October in Lily Lake. The individual profiles as seen in Figures 3-3 to 3-8 demonstrate that Lily Lake undergoes an annual stratification cycle as discussed in Chapter 1. The warmer, less dense water is separated into a single layer, an epilimnion, at the surface of the lake. The colder waters have settled below this layer to form another distinct layer, the hypolimnion. Each lake also has a region in which the temperature dropped rapidly; this phenomenon is called the thermocline. This thermocline occurs in the metalimnion. As summer progressed, the top layers warmed significantly. The bottom layers showed signs of anoxia (oxygen depletion) as early as June.

Figure 3-3: Temperature and Dissolved Oxygen Profiles of Lily Lake May 22, 2008



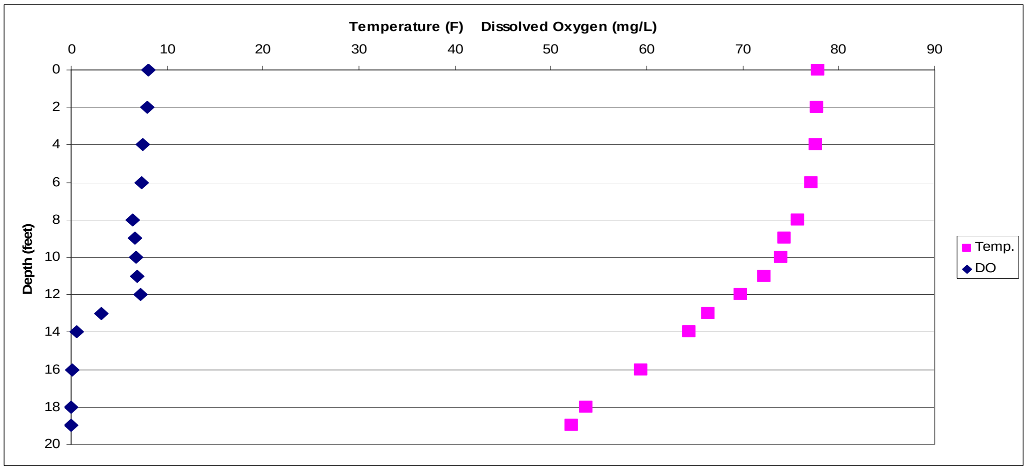
Source: BCPC, 2008

Figure 3-4: Temperature and Dissolved Oxygen Profiles of Lily Lake June 20, 2008



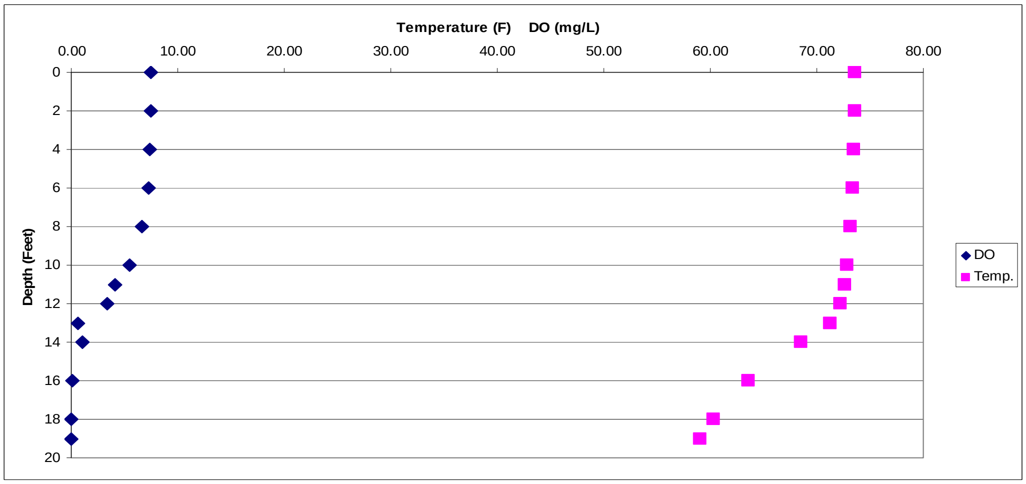
Source: BCPC, 2008

Figure 3-5: Temperature and Dissolved Oxygen Profiles of Lily Lake July 18, 2008



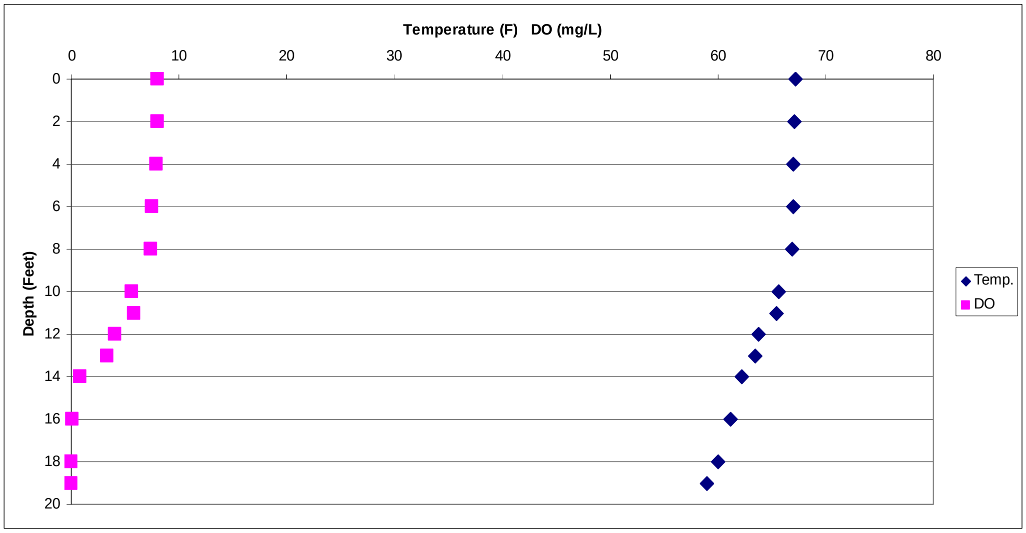
Source: BCPC, 2008

Figure 3-6: Temperature and Dissolved Oxygen Profiles of Lily Lake August 29, 2008



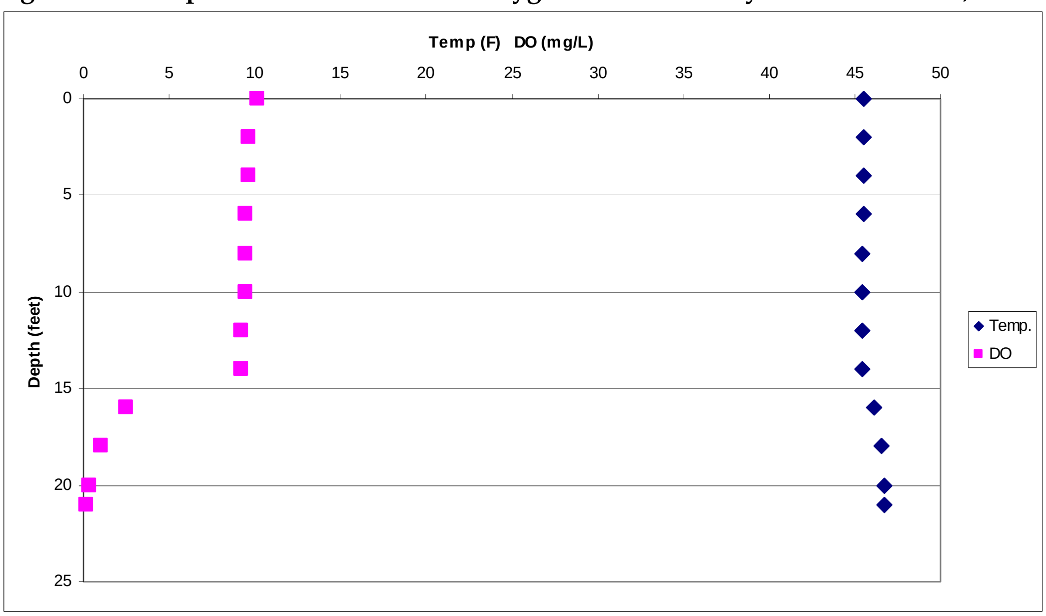
Source: BCPC, 2008

Figure 3-7: Temperature and Dissolved Oxygen Profiles of Lily Lake September 24, 2008



Source: BCPC, 2008

Figure 3-8: Temperature and Dissolved Oxygen Profiles of Lily Lake October 29, 2008



Source: BCPC, 2008

Chemical Instrumentation

Although phosphorous is the primary nutrient which contributes to plant growth, other elements can affect the overall plant growth. Nitrogen can be a growth-limiting factor to plants in some aquatic systems, especially those that are extremely oligotrophic or extremely eutrophic. Mineral abundances can also affect the overall pH of a lake. The pH, in turn, has a significant impact on the type of plants that can grow.

All water samples were collected in bottles provided by the SLOH as discussed in the Methodology Chapter. Specific tests performed were indicated in Wisconsin Citizen Lake Monitoring Manual. All samples were analyzed by the SLOH.

Nitrogen

Nitrogen is a secondary nutrient in limiting plant growth. Two tests were completed to analyze nitrogen content in the water. They were the Kjeldahl Nitrogen and Nitrate + Nitrite Tests. Results for both analyses are located in Table 3-4.

Table 3-4: Lily Lake Nitrogen Analyses

Test	Concentration (mg/L)
Nitrogen Kjeldahl (mg/L)	1.03
Nitrogen (Nitrate + Nitrite	*

*Not detectable

Source: SLOH, 2008

Water Hardness

The overall water hardness is determined by the amount of dissolve minerals such as calcium, magnesium, and to some extent iron present in surface water. The overall concentration of metal cations was analyzed see Table 3-5.

Table 3-5: Lily Lake Metal Concentrations

Metals	Concentration (mg/L)
Calcium	28.8
Magnesium	20.3

Source: SLOH, 2008

Alkalinity

Alkalinity is a measure of the ability of water to resist a change in pH. Water resists changes in pH due to the presence of anions of carbonates, bicarbonates, and hydroxides. The total alkalinity is the sum of the concentrations of these anions. Alkalinity is summarized in Table 3-6. Alkalinity is expressed in terms of equivalents of calcium carbonated ($CaCO_3$) per liter of water.

Table 3-6: Lily Lake Alkalinity

Alkalinity Total $CaCO_3$	Concentration (mg/L)
July 18	144
August 29	144
September 25	151

Source: SLOH, 2008

Specific Conductivity

Specific conductivity is a measure of the overall dissolved ion concentration. Elements who ionic forms can contribute to the overall SC measure include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}). Other ions which contribute include bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), and chloride (Cl^{-}). Conductivity was measured both at the SLOH and by Brown County staff. The conductivity was measured by a pair of probes on the dissolved oxygen/temperature probe. Results from the SLOH are found in Table 3-7. Results obtained by Brown County staff are in Appendix B.

Table 3-7: Specific Conductivity in Lily Lake

Date	Conductivity (μs/cm)
July 18	326
August 29	323
September 25	342

Source: SLOH, 2008

pH

The pH scale measures the overall acidity or causticity of liquids. Both the SLOH and Brown County staff measured pH. The pH levels were measured monthly by a probe on the dissolved oxygen/temperature meter. With the exception of May and October, all pH readings in the epilimnion exceeded 8.2. Results from the SLOH are found in Table 3-8; Brown County results are listed in Appendix B.

Table 3-8: Lily Lake pH Levels

Date	pH
May 22	7.1
July 18	8.49
August 29	8.26
September 25	8.36

Source: SLOH, 2008

CHAPTER 4

Analysis and Discussion

Aquatic Vegetation Survey

Aquatic vegetation was sampled at 143 of the 155 sample points as seen in Table 4-1. Six of the predetermined points were on land; the remaining points lacked vegetation. Vegetation was found to a depth of 18.5 feet.

Species richness or the number of species present in a lake is a commonly used parameter to quantify the overall "healthiness" of a lake. Typically, the higher the diversity of aquatic plants, the healthier the lake is. The aquatic vegetation survey indicated that 19 species of plants were present in Lily Lake. An average of 2.85 species was found at each site; of these, 2.47 were native species. Species richness was greatest in shallower water as seen in Table 4-1. The southeastern portions of Lily Lake had the highest species richness where as many as six species were found at a single sample point. A brief discussion of the most prevalent species follows below.

Table 4-1: Aquatic Vegetation Species Richness Analysis

Total number of sample points	155
Total number of points sampled	150
Total number of sites with vegetation	137
Total number of sites shallower than maximum depth of plants	137
Average number of species present per site (veg. sites only)	2.85
Average number of native species present per site (veg. sites only)	2.47
Species Richness	16
Species Richness (Including visuals)	19
Number of native species	18
Number of invasive species	1

Source: BCPC, 2008

Only one invasive species of plant was located. Curly-leaf pondweed was identified at 44 percent of sites on Lily Lake. Due to the observed proliferation of Curly-leafed pondweed, proactive steps must be taken to create an eradication and management program for the invasive plant.

Curly-leaf Pondweed (*Potamogeton Crispus*)

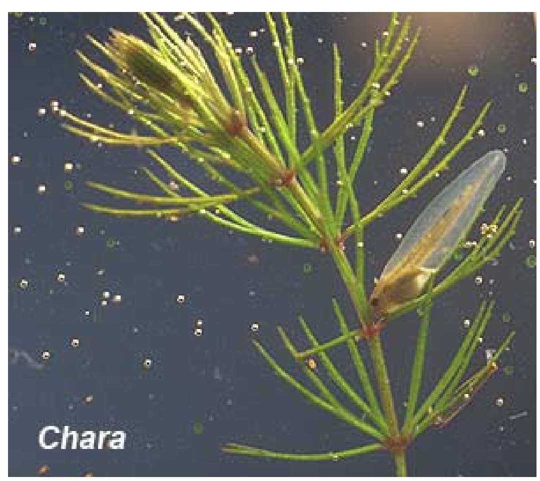
Curly-leafed pondweed is an invasive perennial that is native to Eurasia, Africa, and Australia. It was accidentally introduced to United States waters in the mid-1880s by the aquarium industry. The approximately three inch long leaves are reddish-green, oblong, and distinct wavy edges that are finely toothed. The stem of the plant is flat, reddish-brown and grows up to three feet long.

In Wisconsin, curly-leaf pondweed usually is fully grown by the end of July. The summering bud (called a turion) breaks off from the plat, falls to the bottom of the lake, and lies submerged and dormant. The turions begin to sprout in fall, responding to the shortening day length and cooling water temperatures. The new plantlets continue to grow throughout the winter. The early growing start allows the plant to crowd out other more desirable native species. Curly-leafed pondweed is one of the predominant species within Lily Lake.

Turions and plant fragments can be carried on boats, trailers and fishing gear from one water body to another. Since its introduction into Lily Lake, it has spread rapidly. Control methods for this species are varied and the best options will be explored further in the lake management study.

Although many people perceive Lily Lake as weedy, many beneficial species of aquatic plants are present throughout the lake. These species provide invaluable cover and food sources for fish and land animals alike. A brief discussion of the major plant families found in Lily Lake follows.

Muskgrass



Most members of the genus Chara are commonly called “muskgrass”. Although these common lake inhabitants look similar to many underwater plants, they are actually related to algae. Muskgrass species are green or gray-green and grow completely submersed in shallow water. Individuals can very greatly in size from a few inches to over three feet in length. The main “stem” of the stonewort bears whorls of branchlets, clustered at regularly spaced joints. When growing in hard water such as Lily Lake, they sometimes become coated with lime giving them a gritty feel.

Pondweeds (Potamogeton spp.)

Pondweeds are a large family of widely distributed aquatic vegetation. Over 30 species are found in Wisconsin. Plants are mostly perennial and typically produce rhizomes (undergrounds running roots). Many species also produce over-wintering buds called turions. In many species, the thin leaves are submersed and float easily within the current. Those species with floating leaves tend to be more leathery.

Water Celery (*Vallisneria Americana*)

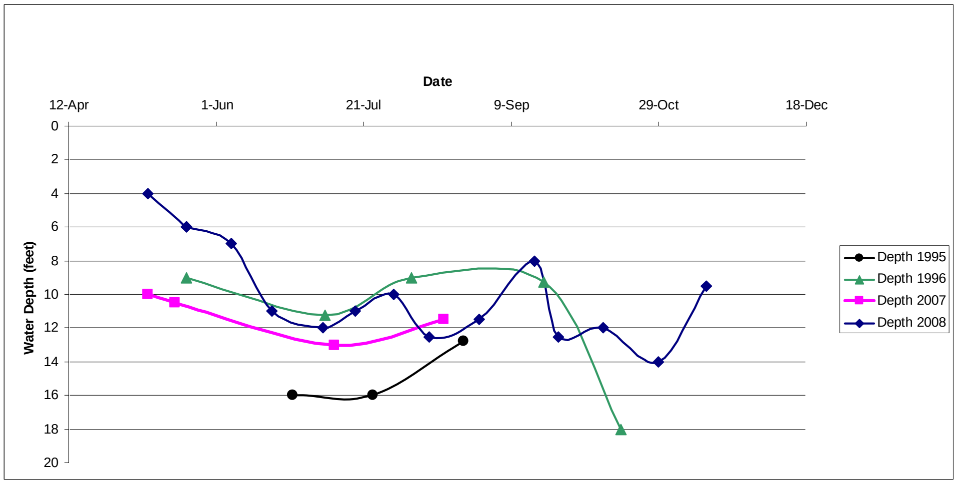
Water celery is an attractive plant. It has long ribbon-like leaves that grown from a root-stock anchored in the lake bottom. The leaves can grow up to six feet in length. There is a prominent red mid-vein which runs the entire length of the plant. The plant is usually submersed, but leaves will float on the surface in shallow waters. The plant reproduces by extending a small flower to the water surface on a cork screw stem. Male plants produce a stomach-shaped tuber. In the fall after reproduction is complete, the plant rises to the surface and floats to shore in large mats. Water celery provides important cover for fish, and the tubers are leaves that are a delicacy for waterfowl.

Secchi Readings

Figure 4-1 displays all Secchi readings available in the SWIMS database. Historical observations were completed in 1995 and 1996, although limited historical information is available, several trends can be seen. Over time, the overall Secchi depth, and thus, water clarity have decreased.

The variation in readings observed gives a snapshot of how the water quality of a lake is affected by outside pollution sources and the natural cycle of turnovers and stratification. Readings tended to be lower at turnover due to the increase of sediment and algae which was recycled to the surface. Water clarity increased during the summer as sediment settled and was trapped in lower layers of the lake. Several "spikes" in decreased water quality were observed during 2008. These readings were taken less than two days after significant storm events. The direct input of water and runoff from adjacent uplands mixes with the lake water at the surface. The mixing redistributes algae within the epilimnion resulting in reduced water clarity.

Figure 4-1: Historical Secchi Depth Comparisons at Lily Lake



Source: WDNR, 1995-1996, 2007; BCPC, 2008

Table 4-2: Average Historical Secchi Depths

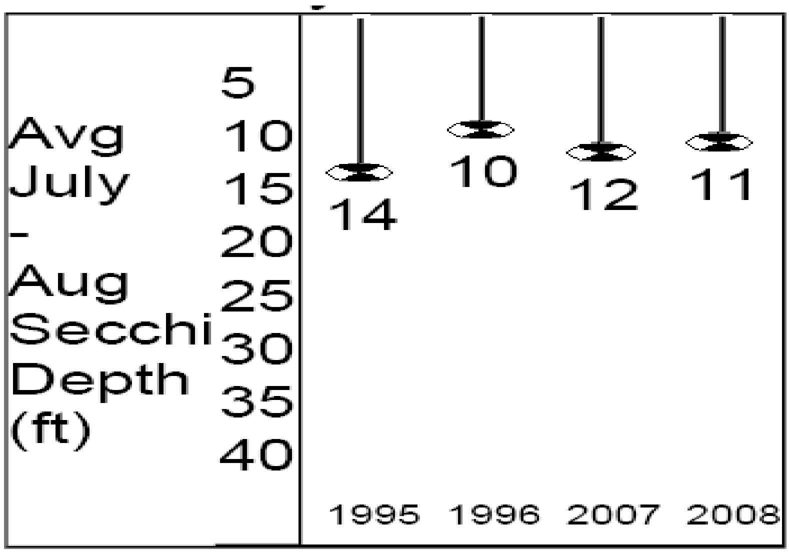
Year	Mean Depth (ft)	Min. Depth (ft)	Max. Depth (ft)	Number of Readings
1995	14.4	12.75	16	2
1996	10.1	9	11.25	2
2007	12.3	11.5	13	2
2008	11.4	10	12.5	5

Source: WDNR 1995, 1996, 2007, 2008

Secchi readings cannot be averaged over an entire year. Instead, readings between June and August are averaged as this is the growing season and predominant period for algal blooms. Secchi readings are not typically taken after a lake has frozen. Snow cover and the overall "cloudiness" of the ice significantly impact light penetration into a lake. Thus, winter Secchi readings do not properly indicate overall water clarity or quality.

Table 4-2 and Figure 4-2 detail the average Secchi reading during the growing season July and August for Lily Lake. Between 2007 and 2008, the average Secchi depth decreased by one foot. This indicates an approximately eight percent decrease in water clarity. Although this may seem significant, the increased number of Secchi readings in 2008 may have altered these results. Since Secchi readings will be taken during the 2009 growing season, a more exact comparison will be made next year. Over time, however, water clarity has decreased even more significantly. Between 1995 and 2008, Secchi depths have decreased by over 20 percent. This indicates that water clarity has decreased significantly. This is most likely due to increased levels of algal blooms in the lake. The increased levels of phosphorous as discussed in the previous section would provide additional food resources for plant growth.

Figure 4-2: Average Secchi Readings



Source: WDNR, 1995-1996, 2007; BCPC, 2008

Phosphorous

In more than 80 percent of Wisconsin's lakes, phosphorous is the key nutrient affecting aquatic plant and algae growth. There are both naturally occurring and anthropogenic (man-made) sources of phosphorous occur. Very few sources of phosphorous such as soil and bedrock are naturally occurring. Man-made sources of phosphorous are quite varied and include septic systems; detergents; animal waste; farmland and storm sewer runoff; soil erosion; and fertilizers for lawns, gardens, and agriculture.

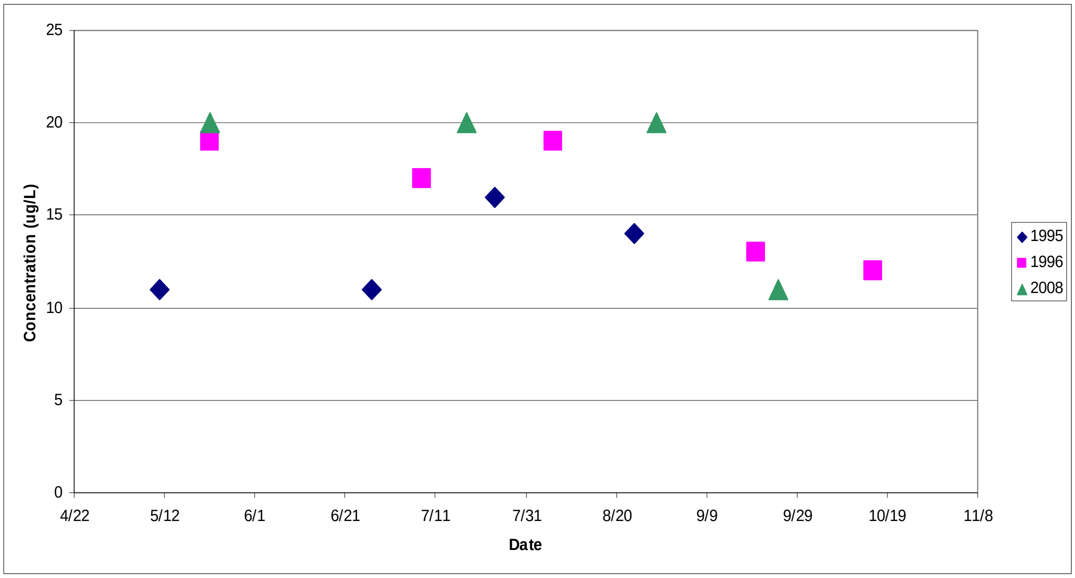
Once in a lake system, phosphorous levels are difficult to reduce, so limiting phosphorous input is essential. Phosphorous levels above 30 µg/L can lead to increased plant growth or foster the growth of nuisance exotic plants. Historically, phosphorous levels have ranged from 10 – 20 µg/L as show in Figure 4-3.

Current phosphorous levels indicate that Lily Lake is mesotrophic as previously seen in Table 1-1. However, it is important to note that phosphorous concentrations have, on average, doubled in since 1995. This indicates that eutrophication is currently occurring within Lily Lake.

The soils within the Lily Lake basin are predominantly Carbondale muck. Although it is high in organic material, its phosphorous content is very low. This means that a fair portion of all phosphorous inputs into Lily Lake will be manmade.

Manmade phosphorous inputs of phosphorous will be limited to the developed areas around Lily Lake. Lawn fertilizers applied at either Lily Lake County Park or the Polish League of American Veteran Park would contribute to increasing phosphorous levels. In addition, additional phosphorous runoff may be contributed to runoff from the parking lots. Phosphorous may be mobilized from sources within the lake such as dead plant material and the underlying bedrock. Under the anoxic (oxygen depleted) conditions during the summer stratification, additional phosphorous can be released from natural sources. Hence, phosphorus mobilization increases as lakes become more eutrophic. Normally occurring lake cycles may increase phosphorous concentrations and the eutrophication rate.

Figure 4-3: Historic Phosphorous Concentrations in Lily Lake



Source: WDNR, 1995-1996, 2007; BCPC, 2008

Since the lake is already infested with curly-leaf pondweed, implementing protective onshore measures become increasingly important in controlling phosphorous loading in Lily Lake.

Chlorophyll a

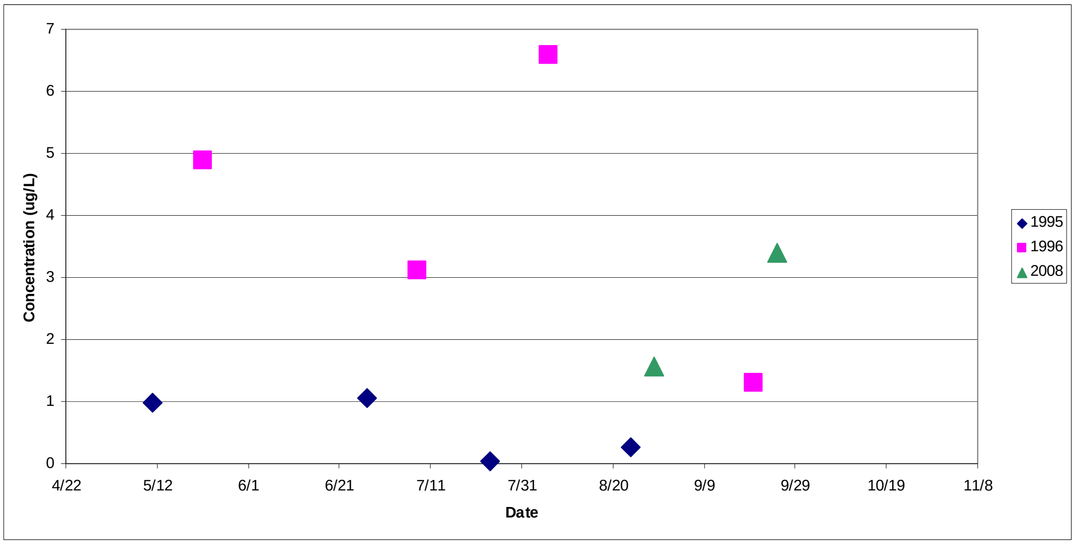
Chlorophylls are the greenish pigments which give plants there characteristic color. Chlorophyll a is the primary substance which is responsible for photosynthesis, the process of converting sunlight into food. The amount of chlorophyll a is correlated with the amount of green plant material in the water. The higher the chlorophyll a concentration, the more active plant material that is present. With lakes, chlorophyll a is typically present in algae.

Chlorophyll a is the primary indicator for nutrient pollution in lake systems. Excess nutrients result in increased algal growth. Chlorophyll a analyses reveal that it has been as high as 7 µg/L as seen in Figure 4-4.

Currently chlorophyll levels indicate that Lily Lake is a mesotrophic lake as previously seen in Table 1-1. However, since 1995, the overall chlorophyll a concentrations have been increasing in Lily Lake. This indicates that algae content of Lily Lake is increasing.

This indicates that nutrient enrichment can and is occurring within the watershed. Chlorophyll a readings as high as 7 μg/L indicated that Lily Lake experiences periodic algal blooms. Steps should be taken to minimize and eliminate sources of additional phosphorous inputs into Lily Lake.

Figure 4-4: Historic Chlorophyll a Concentrations in Lily Lake



Source: WDNR, 1995-1996, 2007; BCPC, 2008

Temperature and Dissolved Oxygen

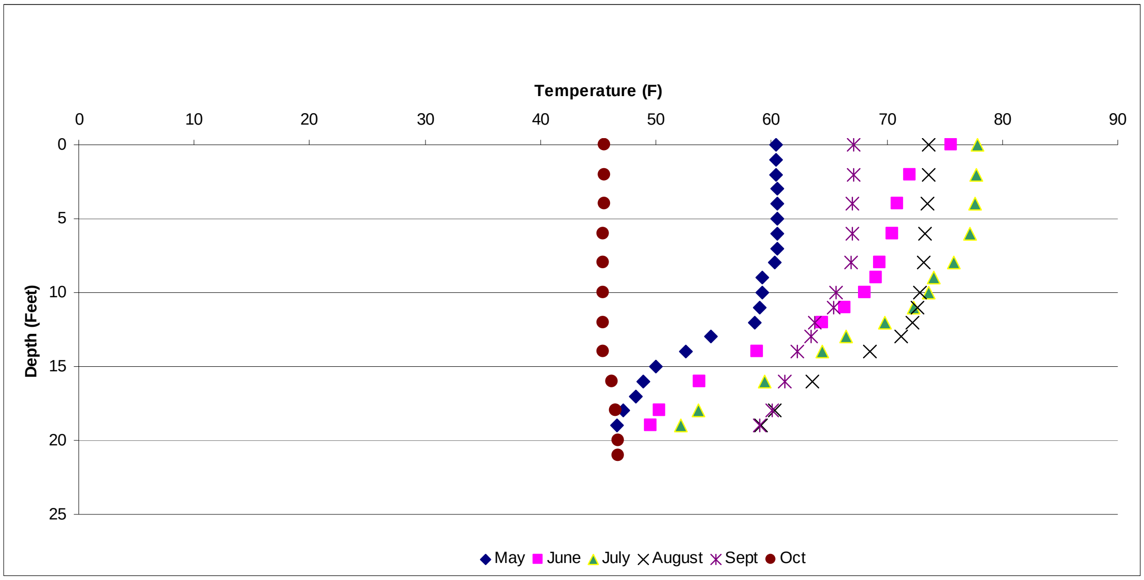
Lily Lake undergoes stratification as discussed in Chapter 1. The surface layers had temperatures which were significantly higher than the bottom layers. This held true between May and September. Temperatures were constant after the fall turnover in October as seen in Figure 4-5. A temperature increased was observed in the hypolimion.

The water column displayed a clinograde profile as seen in Figure 4-6. Oxygen levels in the epilimnion (surface layer) near complete saturation and are greatly reduced in the hypolimnion (lower layers). Clinograde profiles show a curve which descends and curves to the left. This pattern was observed each month from May until the fall turnover in October.

There are two primary sources of oxygen in aquatic systems: the atmosphere and photosynthetic production. In most aquatic systems, oxygen is predominantly created by the photosynthetic activities of plants. Plants utilize carbon dioxide in the water and convert it to sugars; oxygen is given off as a waste by-product.

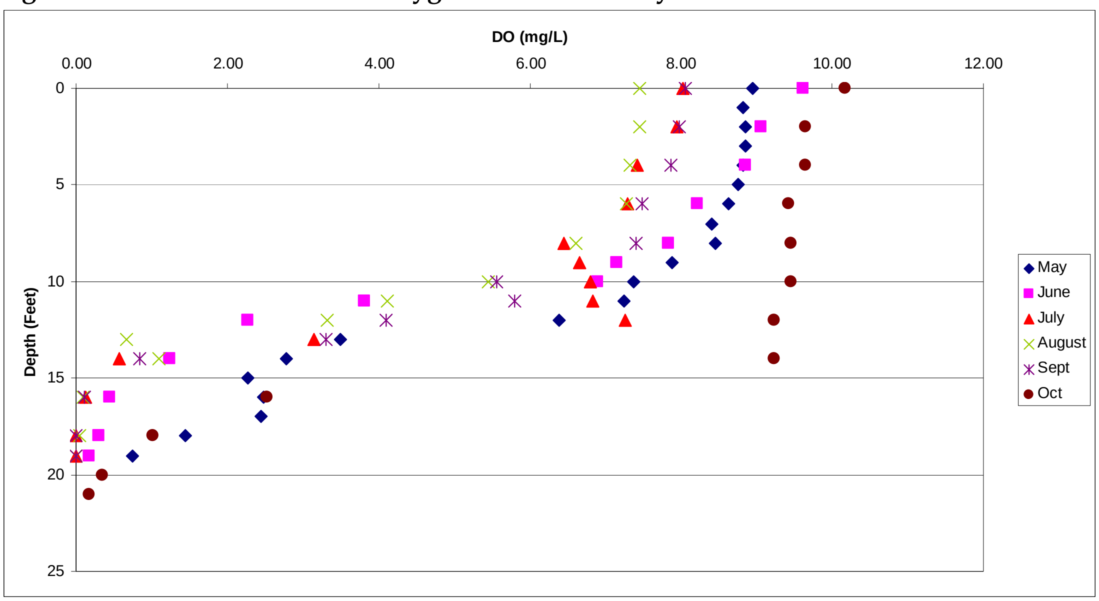
Oxygen is introduced into water from the atmosphere in several ways. First it can diffuse across the air-water interface. This is a slow process. Other physical factors such as mixing accelerate the atmospheric deposition of oxygen. Oxygen mixes more rapidly into rough, or choppy, water than calm water because waves and ripples create additional surface area for interactions. Fast moving streams tend to be the most oxygenated systems because the turbulent waters are naturally aerated. Since Lily Lake is a predominantly "calm" lake, atmospheric oxygen is slowly diffused from the air into the water.

Figure 4-5: Seasonal Temperature Profiles for Lily Lake



Source: BCPC, 2008

Figure 4-6: Seasonal Dissolved Oxygen Profiles for Lily Lake



Source: BCPC, 2008

The amount of oxygen in the water is also influenced by the temperature and air pressure. As temperatures increase, the solubility of oxygen decreases. Molecules in a solution such as water are "held together" by small intermolecular forces. Higher temperatures provide additional energy to the individual molecules. As the energy levels increase, it becomes easier for gases to escape into the atmosphere. An open bottle of soda provides an excellent example. When left at room temperature, soda will go "flat" faster than if left refrigerated because the carbon dioxide bubbles escape faster. In addition, gases naturally expand as the temperature increases. This expansion will cause oxygen to leave the water as temperatures increase.

Historical trends of the overall dissolved oxygen levels within Lily Lake were examined. Historical data was available in June, July, and August 1995 as well as May, July, August, September, and October 1996. A month by month comparison indicated 2008 dissolved oxygen levels were lower than historical levels in all months.

Since oxygen concentrations vary according to the temperature of the water, it is also necessary to examine the saturation levels present. Percent saturation indicates the amount of oxygen that is dissolved in water compared to the maximum amount. The percent saturation can give key to various chemical and biological processes that may be occurring within a lake system.

Percent saturation levels were compared at a depth of six feet as seen in Table 4-3. In 1995 and 1996, Lily Lake oxygen levels were completely saturated 100 percent. In 2008, percent saturation was normally below 90 percent. This means that biological and chemical processes within Lily Lake are consuming oxygen necessary to support fish and other life.

Table 4-3: Percent Saturation Levels for DO in Lily Lake

Percent Saturation	Year		
Month	1995	1996	2008
May		100	87
June	100		98
July	100	100	87
August	100	100	84
September		92	80
October		100	77

Source: BCPC, 2008

A major concern expressed by Lily Lake users is predominant algal blooms in the summer and fall. Algal blooms can occur throughout the water column. Although algae produce oxygen, the increase may be short lived. As the algal die and fall to the bottom, bacterial decomposition will consume oxygen and produce excess carbon dioxide. In addition, zooplanktons (microscopic animals) consume oxygen throughout the entire summer; they respire carbon dioxide as a waste product. As a result, oxygen levels fell below the saturation level as oxygen is displaced by carbon dioxide.

Finally, data gathered indicate that an anoxic layer in Lily Lake is present throughout the year. Anoxia is the complete removal of oxygen from a portion of the water column.

The anoxic layer is most likely present due to increased bacteria decomposition from increased phosphorous loading throughout the year. An alternative hypothesis is that the spring and fall mixing in Lily Lake are limited to less than 20 feet due to the size of Lily Lake. Although this phenomenon is usually restricted to extremely deep lakes, it may occur it shallower lakes (Wüest etal, 1992).

Oxygen levels must be continually monitored within a lake. If a lake's dissolved oxygen levels decrease significantly, fish kills may occur or fish species composition may shift to those with lower oxygen needs.

Methodologies utilized for this study varied slightly from CLMN protocol for temperature and dissolved oxygen. The CLMN protocol called for measurements at three foot intervals. Brown County staff felt better data could be obtained by increasing the sampling frequency. The varying scales utilized in the 1990s and 2000s will not affect the overall analysis as both sampling methods provided profiles with enough detail to analyze changes in the water column.

Unlike dissolved oxygen levels, historical temperature differences did not show any significant trends. Lake temperatures are directly affected by atmospheric conditions and will vary annually according to existing weather patterns.

Chemical Instrumentation

Nitrogen

Nitrogen is the most abundant gas in the atmosphere. Approximately 50 percent of the gas in freshwater is nitrogen. The upper layers of water are usually saturated with nitrogen. Nitrogen is introduced into the water column through diffusion at the water's surface. Many organisms require nitrogen to live, but they cannot directly use nitrogen gas dissolved in the water. Nitrogen must first be fixed into usable forms by specialized bacteria. The major forms available to aquatic life are ammonium and nitrate. Total Kjeldahl Nitrogen (TKN) measures the total amount of organic nitrogen available. Nitrogen in organic materials is converted to ammonium. Nitrates (NO_3^-) and nitrites (NO_2^-) are the predominant inorganic forms of nitrogen. Nitrate + nitrite analysis measures the total inorganic nitrogen. Total nitrogen measures the total concentration of the organic and inorganic forms.

The results for the Kjeldahl nitrogen analysis are within acceptable limits. Natural systems can have ammonium concentrations up to 10 mg/L. Inorganic nitrogen was not detected within water samples submitted to the SLOH. This could be explained by one of two reasons. First, staff did not preserve the sample with nitric acid as required by lab protocol. This may have lead to a "decayed" sample. Second, nitrate levels are typically lower in the epilimnion during the summer because algae utilize it for tissue growth. It is important to know the overall ammonium (NH_4^+) concentration as it can be converted to ammonia. Further testing completed in 2009 will allow for a better determination of both inorganic and total nitrogen concentrations in Lily Lake.

Nitrogen cycling through a lake is a complex process. It is important to monitor nitrogen levels because high nitrogen levels can adversely affect water quality. Oxidized forms of nitrogen (NO_3^- and NO_2^-) can only exist in oxygenated layers. Increased nitrate levels can lead to algae blooms. The decomposition of the increased plant material leads to oxygen depletion. Bacterial decomposition of ammonia is toxic to fish and other aquatic life. In addition, natural biological processes which convert ammonia to ammonium ions consume dissolved oxygen.

Water Hardness

Calcium, magnesium, and iron are the three major elements which cause hard water. Iron accounts for less than one percent of all dissolved minerals in "hard water" lakes. Thus, it is typically not analyzed by analytical laboratories.

The concept of water hardness originated because the salts form complexes with soaps which can be seen on various hard surfaces such as watercraft and bathroom surfaces. Since magnesium and calcium form similar salts, they are expressed as one unit, milligram $CaCO_3$ per liter ($CaCO_3$ mg/L). Hard water is classified as 120 – 240 mg $CaCO_3$/L. Lily Lake is classified as hard water.

Dissolved minerals present in lakes can lead to the development of marl, or solid calcium carbonated deposits. This happens at pH levels higher than 8.2. Marl tends to deposit on plants giving them a "gritty" feel. Marl was observed on plant samples throughout the lake. If the marl concentration is high enough, it can also lead to decreased lake clarity.

Alkalinity

Alkalinity is a measure of the buffering capacity of water. A buffer is a solution to which an acid can be added without changing the overall pH of the solution. In most natural water bodies, the buffering system is comprised of carbonate (CO_3^{2-}) and bicarbonate ions (HCO_3^-). In addition, several other negatively charge ions contribute to the overall alkalinity of water. Since calcium carbonate is present in the highest concentration, it is used as the overall measuring unit.

Water bodies with high metal carbonate concentrations are less susceptible to rapid pH changes. This is important as it protects fish and other aquatic life.

For protection of aquatic life, the buffering capacity should be at least 20 mg/L. Analyses completed by the SLOH indicated that Lily Lake had at least a 144 mg/L buffering capacity, well above the minimum threshold.

Specific Conductivity

Conductivity is important because it can indicate the overall concentration of total dissolve solids (TDS) in a lake. The exact ions present can affect the overall pH, and thus, fish habitat suitability of the water. In addition, the specific ions present can indicate how healthy the lake is, as some are increased by manmade sources. As discussed in previous water hardness and alkalinity sections, there are high concentrations of basic ions present in Lily Lake leads to noticeable levels of conductivity.

Considering the chemical composition of Lily Lake, the higher values seem to reflect the naturally occurring makeup of the lake. Conductivity was constant throughout the summer averaging approximately 320 – 330 µs/cm. Lily Lake is highly mineralized, especially when compared with rain water (50 µs/cm) (NWFWMD, 2006). Values increased as the summer progressed. As lake levels decreased, the concentrations rose due to a decrease in the overall volume of water. Deeper depths (≥ 16 feet) had noticeably higher levels. No explanation is hypothesized for this phenomenon.

pH

The pH of a lake affects many chemical parameters in a lake. pH levels control the solubility (amount that can be dissolved in water) and the biological availability (amount that can be used by aquatic life) of nutrients such as phosphorous and nitrogen. Aquatic life functions best at a pH between six and nine.

Fortunately, lake water is complex. A complex array of chemical reactions is simultaneously occurring. The basic ions such as carbonate, calcium, magnesium, and other form a buffer solution. Small or localized changes in pH will be quickly neutralized by the high buffering capacity in Lily Lake.

Trophic Status Index

Phosphorous, Chlorophyll a, and Secchi depth are interrelated measurements. When additional phosphorous is introduced into a lake, it provides a food source for algae. The increased algal blooms result in an increase in chlorophyll a concentrations. The increased algae content, in turn, results, in lower water clarity. The interactions between these parameters are a complex and dynamic process. As an alternate to analyzing each parameter separately, the Trophic State Index (TSI) can be calculated for each parameter.

The Trophic State Index was developed by Carlson (1977) to alleviate the difficulties in communicating the overall health of a lake system utilizing the traditional oligotrophic, mesotrophic, and eutrophic classification system.

Since not all lakes with the same trophic classification are not identical, TSI quantitatively describes the trophic status with a numerical range form 0 – 110 see Table

4-4. Shallow Secchi measurements correspond to higher TSI numbers. Higher TSI numbers indicate more eutrophic lakes. An increase of ten on the TSI scale correlates to a doubling of lake algal biomass and halving of water Clarity (Carlson, 1997).

Chlorophyll a and total phosphorous concentration may also be used to calculate TSI. Both can be used to measure overall lake productivity. Higher chlorophyll a and total phosphorous concentrations translate into higher TSI values.

The Wisconsin Department of Natural Resources has developed its own TSI scale based upon chlorophyll a concentrations. Since chlorophyll a is directly correlated to the overall biomass present, it is a better indicator than Secchi depth.

The SWIMS database calculates TSI indices for all available parameters as seen in Figure 4-7. Currently, the TSI for chlorophyll a is in the high 50's. Since 1995, the TSI for chlorophyll a has increased by 10 units indicating a doubling in plant biomass present. TSI indices for phosphorous have remained relatively stable in the mid-60's; TSI Secchi readings have increased slightly to the high 50's. Overall, the TSI indices reveal that Lily Lake is becoming more nutrient rich.

Table 4-4: TSI Index

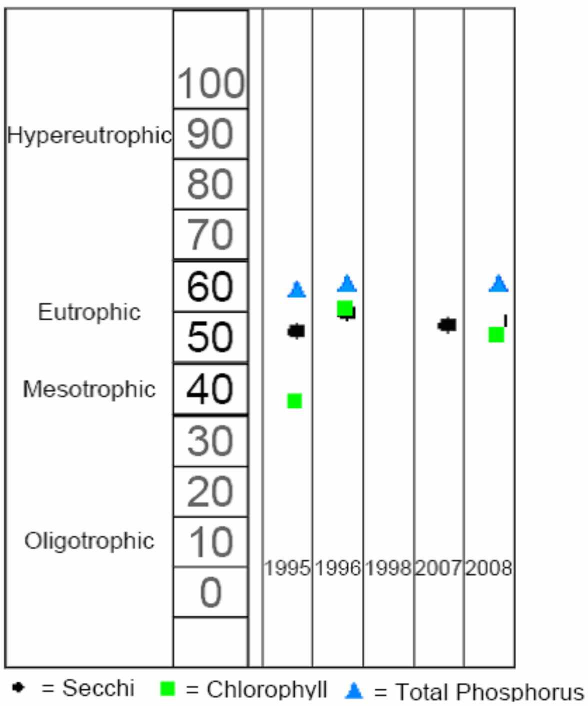
TSI	TSI Description
< 30	Classical oligotropy, clear water, many algal species, oxygen present throughout the year in bottom water, cold water, oxygen-sensitive fish species in deep lakes. Excellent water quality.
30 - 40	Deep lakes still oligotrophic, but bottom water of some shallower lake will become oxygen depleted during the summer.
40 - 50	Water moderately clear, but increasing chance of low dissolved oxygen in deep water during the summer.
50 - 60	Lakes becoming eutrophic: decreased clarity, fewer algal species, oxygen-depleted waters during the summer, plant overgrowth evident, warm-water fisheries (pike, perch, bass, etc.) only.
60 - 70	Blue-green algae become dominant and algal scums are possible, extensive plant overgrowth problems possible.
70 - 80	Becoming very eutrophic. Heavy algal blooms possible throughout the summer, dense plant beds, but extent limited by light penetration (blue-green algae block sunlight).
> 80	Algal scums, summer fish kills, few plants, rough fish dominant. Very poor water quality.

Source: WDNR, 2008

All lakes undergo a natural eutrophication process. During this process, sediment and plant material accumulate at the bottom. The additional plant material leads to not only a decrease in overall depth, but the biological oxygen demand also increases. While these changes may be naturally slow, human intervention can accelerate the eutrophication process. Lily Lake is no exception.

Although Lily Lake is still an excellent resource, evidence of accelerated eutrophication is obvious. Increased sedimentation was observed around the edges of the lake. Over the past 12 years, Lily Lake has been classified as a mesotrophic lake. Much of the recorded data such as Secchi readings, phosphorous concentrations, and chlorophyll a levels indicate that Lily Lake is still considered a mesotrophic lake. However, the TSI indicates that Lily Lake is more biomass (plant life) is accumulating in Lily Lake. The increased biomass classifies Lily Lake as a eutrophic lake.

Figure 4-7: TSI Indices



Source: WDNR, 1995-1996, 2007; BCPC, 2008

CHAPTER 5

Summary and Recommendations

As noted at the beginning of the report, Lily Lake is a wonder natural amenity located mere minutes from the Green Bay metropolitan area. The fact that almost its entire shoreline is located within a county park means that development pressure will be very limited. However, development pressures from continued usage may continue to contribute to the eutrophication of Lily Lake.

Since Lily Lake is a small, isolated watershed, minute changes in water chemistry may have significant impacts on the overall ecological health of the lake. Based upon the scientific analyses contained within this report, it is evident that the limnological characteristics are changing. Definite signs of eutrophication have been observed during 2008. A second year of water quality testing is scheduled for the 2009 calendar year to further assess the degree of ongoing change. However, it is necessary to proactively plan for various policy objectives and facility upgrades to better protect the continued health of Lily Lake. The following recommendations will provide a starting point for the responsible government agencies to prepare and ensure that Lily Lake remains a tranquil, natural retreat in a rapidly urbanizing area.

Facility Recommendations

- Develop a catch basin or bio-retention system at the Lily Lake boat launch to capture stormwater runoff that may be laden with fertilizers, sediments, pesticides, grease, and oil from the parking lot rather than allowing it to directly enter Lily Lake.

- Plant native grasses and shrubbery to create a buffer between Lily Lake and the grassed picnic area to filter out sediments prior to reaching Lily Lake's shoreline.

- Work with the PLAV to plant native vegetations at their lake access point to create a buffer for sediments carried by stormwater to filter out prior to reaching the lake.

- Prepare an update to the Brown County Parks and Outdoor Recreation Plan to identify future facilities for Lily Lake Park that meet the needs of Town of Eaton and Brown County residents.

Policy Recommendations

- Eliminate fertilizer usage within Lily Lake Park and the PLAV property, or when it must be applied, utilize phosphorus-free fertilizers only.

- Support Brown County's regulations related to surface water protection through the Brown County Land Conservation Department and Brown County Planning Commission.

- When development is proposed around Lily Lake, encourage conservation subdivisions to minimize stormwater runoff and the visual impact of development on the lands outside of Lily Lake Park.

Program Recommendations

- Monitor dissolved oxygen levels in the lake during winter to determine the effectiveness of the aerator.

- Continue to monitor water clarity with continued Secchi readings and submittal to the WDNR.

- Create an educational program for visitors to Lily Lake Park so that they learn to appreciate the uniqueness of Lily Lake in Brown County and its sensitivity to nutrients and other pollution.

- Create an educational program for visitors regarding invasive species and steps to take to prevent the further spread in Lily Lake.

- Monitor plant growth under the ice to determine the overall extent of curly leaf pondweed (*Potamogeton crispus*) growth and research possible control methodologies.

- Research methodologies to remove phosphorous from Lily Lake and determine the overall feasibility of implementing such programs.

- Should the PLAV property ever be placed on the market, Brown County Park and Facility Management, in cooperation with the Town of Eaton, should attempt to purchase it.

- Future chemical analysis should measure the total oxygen deficit within Lily Lake. The observed difference between observed oxygen concentrations and the saturation level at the spring turnover is called the absolute oxygen deficit.

- Develop an overall lake management plan for Lily Lake that includes lake chemistry, a general plant inventory, and recommendations for future usage or improvements.

- The Wisconsin Department of Natural Resources performed a fish census in Lily Lake in 2008. Preliminary results indicated the majority of the fish population is compromised of largemouth bass. The full results of this study will be included in the lake management plan in 2009.

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Appendix A

Sample-Intercept Survey GPS Coordinates

Point	Latitude	Longitude		Point	Latitude	Longitude		Point	Latitude	Longitude
LILY001	44.42792	-87.8566		LILY040	44.42698	-87.8541		LILY079	44.42754	-87.8524
LILY002	44.42762	-87.8566		LILY041	44.42668	-87.8541		LILY080	44.42724	-87.8525
LILY003	44.42821	-87.8562		LILY042	44.42639	-87.8541		LILY081	44.42695	-87.8525
LILY004	44.42791	-87.8562		LILY043	44.42609	-87.8542		LILY082	44.42665	-87.8525
LILY005	44.42761	-87.8562		LILY044	44.42579	-87.8542		LILY083	44.42635	-87.8525
LILY006	44.42731	-87.8562		LILY045	44.42549	-87.8542		LILY084	44.42606	-87.8525
LILY007	44.4282	-87.8557		LILY046	44.4252	-87.8542		LILY085	44.42576	-87.8525
LILY008	44.4279	-87.8558		LILY047	44.4249	-87.8542		LILY086	44.42546	-87.8525
LILY009	44.4276	-87.8558		LILY048	44.42786	-87.8537		LILY087	44.42517	-87.8525
LILY010	44.42731	-87.8558		LILY049	44.42756	-87.8537		LILY088	44.42487	-87.8525
LILY011	44.42701	-87.8558		LILY050	44.42727	-87.8537		LILY089	44.42724	-87.852
LILY012	44.42819	-87.8553		LILY051	44.42697	-87.8537		LILY090	44.42694	-87.8521
LILY013	44.42789	-87.8553		LILY052	44.42667	-87.8537		LILY091	44.42664	-87.8521
LILY014	44.4276	-87.8553		LILY053	44.42638	-87.8537		LILY092	44.42635	-87.8521
LILY015	44.4273	-87.8554		LILY054	44.42608	-87.8537		LILY093	44.42605	-87.8521
LILY016	44.427	-87.8554		LILY055	44.42578	-87.8538		LILY094	44.42575	-87.8521
LILY017	44.42671	-87.8554		LILY056	44.42549	-87.8538		LILY095	44.42546	-87.8521
LILY018	44.42818	-87.8549		LILY057	44.42519	-87.8538		LILY096	44.42516	-87.8521
LILY019	44.42789	-87.8549		LILY058	44.42489	-87.8538		LILY097	44.42486	-87.8521
LILY020	44.42759	-87.8549		LILY059	44.42756	-87.8533		LILY098	44.42456	-87.8521
LILY021	44.42729	-87.8549		LILY060	44.42726	-87.8533		LILY099	44.42427	-87.8522
LILY022	44.42699	-87.855		LILY061	44.42696	-87.8533		LILY100	44.42397	-87.8522
LILY023	44.4267	-87.855		LILY062	44.42667	-87.8533		LILY101	44.42367	-87.8522
LILY024	44.4264	-87.855		LILY063	44.42637	-87.8533		LILY102	44.42723	-87.8516
LILY025	44.42817	-87.8545		LILY064	44.42607	-87.8533		LILY103	44.42693	-87.8516
LILY026	44.42788	-87.8545		LILY065	44.42578	-87.8533		LILY104	44.42664	-87.8517
LILY027	44.42758	-87.8545		LILY066	44.42548	-87.8534		LILY105	44.42634	-87.8517
LILY028	44.42728	-87.8545		LILY067	44.42518	-87.8534		LILY106	44.42604	-87.8517
LILY029	44.42699	-87.8545		LILY068	44.42489	-87.8534		LILY107	44.42574	-87.8517
LILY030	44.42669	-87.8546		LILY069	44.42755	-87.8529		LILY108	44.42545	-87.8517
LILY031	44.42639	-87.8546		LILY070	44.42725	-87.8529		LILY109	44.42515	-87.8517
LILY032	44.4261	-87.8546		LILY071	44.42696	-87.8529		LILY110	44.42485	-87.8517
LILY033	44.4258	-87.8546		LILY072	44.42666	-87.8529		LILY111	44.42456	-87.8517
LILY034	44.4255	-87.8546		LILY073	44.42636	-87.8529		LILY112	44.42426	-87.8517
LILY035	44.42521	-87.8546		LILY074	44.42606	-87.8529		LILY113	44.42396	-87.8517
LILY036	44.42817	-87.8541		LILY075	44.42577	-87.8529		LILY114	44.42367	-87.8518
LILY037	44.42787	-87.8541		LILY076	44.42547	-87.8529		LILY115	44.42663	-87.8512
LILY038	44.42757	-87.8541		LILY077	44.42517	-87.8529		LILY116	44.42633	-87.8512
LILY039	44.42728	-87.8541		LILY078	44.42488	-87.853		LILY117	44.42603	-87.8513

Source: WDNR, 2008

Appendix A

Sample-Intercept Survey GPS Coordinates

Point	Latitude	Longitude	Point	Latitude	Longitude	Point	Latitude	Longitude
LILY118	44.42574	-87.8513	LILY131	44.42395	-87.8509	LILY144	44.42482	-87.8496
LILY119	44.42544	-87.8513	LILY132	44.42365	-87.8509	LILY145	44.42452	-87.8497
LILY120	44.42514	-87.8513	LILY133	44.42542	-87.8505	LILY146	44.42422	-87.8497
LILY121	44.42485	-87.8513	LILY134	44.42513	-87.8505	LILY147	44.4251	-87.8492
LILY122	44.42455	-87.8513	LILY135	44.42483	-87.8505	LILY148	44.42481	-87.8492
LILY123	44.42425	-87.8513	LILY136	44.42453	-87.8505	LILY149	44.42451	-87.8492
LILY124	44.42396	-87.8513	LILY137	44.42424	-87.8505	LILY150	44.42421	-87.8493
LILY125	44.42366	-87.8513	LILY138	44.42394	-87.8505	LILY151	44.4251	-87.8488
LILY126	44.42543	-87.8509	LILY139	44.42512	-87.85	LILY152	44.4248	-87.8488
LILY127	44.42514	-87.8509	LILY140	44.42482	-87.8501	LILY153	44.4245	-87.8488
LILY128	44.42484	-87.8509	LILY141	44.42453	-87.8501	LILY154	44.42479	-87.8484
LILY129	44.42454	-87.8509	LILY142	44.42423	-87.8501	LILY155	44.42449	-87.8484
LILY130	44.42424	-87.8509	LILY143	44.42511	-87.8496			

Source: WDNR, 2008

Appendix B

Lily Lake Specific Conductivity and pH Measurements

Depth (Feet)	May 22, 2008	June 22, 2008	July 18, 2008	August 29, 2008	September 24, 2008	October 29, 2008
0	0.331	0.321	0.308	0.312	0.325	0.342
1	0.331					
2	0.331	0.320	0.308	0.312	0.325	0.342
3	0.331					
4	0.331	0.321	0.308	0.312	0.326	0.343
5	0.331					
6	0.331	0.322	0.308	0.312	0.326	0.342
7	0.336					
8	0.332	0.322	0.314	0.314	0.325	0.343
9	0.333	0.323	0.313			
10	0.333	0.324	0.314	0.317	0.327	0.342
11	0.334	0.331	0.318	0.318	0.327	
12	0.334	0.334	3.280	0.321	0.327	0.343
13	0.334		0.335	0.327	0.329	
14	0.333	0.333	0.337	0.338	0.332	0.343
15	0.332					
16	0.332	0.333	0.343	0.367	0.353	0.403
17	0.332					
18	0.340	0.348	0.363	0.400	0.524	0.598
19	0.343	0.354	0.385	0.403	0.578	
20						0.600
21						0.600

Source: BCPC, 2008

Appendix B

Lily Lake Specific Conductivity and pH Measurements

Depth (Feet)	May 22, 2008	June 22, 2008	July 18, 2008	August 29, 2008	September 24, 2008	October 29, 2008
0	8.17	7.98	8.39	8.39	8.26	7.82
1	8.16					
2	8.16	7.92	8.34	8.34	8.23	7.82
3	8.16					
4	8.15	7.86	8.26	8.32	8.21	7.81
5	8.15					
6	8.15	7.91	8.24	8.31	8.21	7.81
7	8.05					
8	8.06	7.81	8.00	8.22	8.20	7.80
9	7.96	7.92	8.20			
10	7.96	7.65	8.07	8.00	7.77	7.81
11	7.84	7.45	8.11	7.88	7.86	
12	7.59	7.17	7.95	7.70	7.72	7.81
13	7.15		7.34	7.36	7.53	
14	7.02	7.01	7.13	7.24	7.29	7.79
15	6.90					
16	6.88	6.88	6.97	6.91	7.04	6.78
17	6.75					
18	6.72	6.82	6.90	6.70	6.67	6.70
19	6.70	6.84	6.81	6.68	6.65	
20						6.69
21						6.70

Source: BCPC, 2008