LITTLE HILLS LAKE

WAUSHARA COUNTY, WISCONSIN

COMPREHENSIVE LAKE MANAGEMENT PLAN

Prepared for

Little Hills Lake Management District

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SUMMARY

A comprehensive study of Little Hills Lake, Waushara County, Wisconsin (Figure 1) was completed during 2002 and 2003. The study was completed to provide information concerning the lake and its watershed so a comprehensive lake management plan could be written for the lake. Funding for this study and the development of the plan was provided by the Wisconsin Department of Natural Resources Lake Management Grant Program and the Little Hills Lake Management District.

Data from this study were analyzed with data collected during past studies and yielded the following major results:

- Current and historic water quality analysis indicates that the water quality of Little Hills Lake has fluctuated over the past few years, but has always been good or very good.
- The current trophic state of Little Hills Lake is on the lower to mid mesotrophic level.
- Little Hills Lake only weakly stratifies during the summer and winter months which does not allow the hypolimnion to become anoxic; therefore, fishkills are not a concern nor is internal phosphorus loading.
- Although Little Hills Lake does not have a highly diverse plant community that is indicative of an undisturbed system, Floristic Quality Assessment analysis indicates that it is of higher quality than most lakes in the ecoregion and state.
- Although there are a number of emergent and floating-leaf aquatic species found in and around Little Hills Lake, their infrequency throughout the entire lake is likely the result of a combination of shoreland development and recreational boating.
- A hybrid between exotic Eurasian water-milfoil and the native northern water-milfoil was found in Little Hills Lake during the summer of 2002; however, only a small plant was able to be located during a site visit in July of 2003. This reduction was likely the result of the efforts of a small group of District members that manually removed the plants that were located during the summer of 2002.
- Watershed analysis and modeling indicated that most of the Little Hills Lake watershed is currently forested and that natural, atmospheric fallout and precipitation to the lake surface is likely the biggest contributor to the lake's phosphorus load; followed closely by the contributions of the nearby golf course and runoff from developed properties.

Major recommendations to the Little Hills Lake Management District include the following:

- The best way to protect the water quality of Little Hills Lake is to minimize the external sources that feed phosphorus to the lake.
- Continued monitoring of both the aquatic plants and water quality was highly recommended.
- Creating a permanent slow-no-wake zone within the small bay where the boat landing is located was recommended to slow the potential spread of the hybrid milfoil and to help protect and possibly enhance the existing floating-leaf and emergent aquatic plant communities.

- The creation of buffer zones of native plants between the lake and maintained lawns of lakeshore properties was recommended to reduce phosphorus runoff from these areas.
- A ban on use of fertilizers containing phosphorus (phosphate) on lakeshore properties was recommended to reduce phosphorus loading to Little Hills Lake.
- Continued lake user education was also stressed as a means to raise awareness of everyone's role in protecting Little Hills Lake as an important natural resource.

INTRODUCTION

Little Hills Lake, located in south central Waushara County, is an 81acre seepage lake with a maximum depth of 23 feet. Self-Help Lake Monitoring data from 2000 indicates that Little Hills is a high-quality, oligotrophic/mesotrophic lake. In 1999, the Little Hills Lake Association was granted its petition to form the Little Hills Lake Management District (LHLMD). The District was formed over concerns of possible Eurasian water-milfoil (*Myriophyllum spicatum*) (EWM) infestation. These concerns are validated by the facts that EWM has spread to 16 water bodies in Waushara County in the last 20 years and four of those lakes are within three miles of Little Hills Lake. The LHLMD has worked hard to combat this possible invasion by placing signs at the public access, through continuing education of lake users and property owners, and by performing periodic, visual lake plant inspections.

The LHLMD also has concerns about changes in the land uses within the lake's watershed, the effects of increased recreational boating, and variations in the lake's aquatic plant community. In answer to these concerns, the LHLMD elected to develop a comprehensive lake management plan aimed to 1) assess the current conditions and processes within Little Hills Lake and its watershed, and 2) develop feasible alternatives to protect the lake as a natural and important ecosystem. More specifically, the goal of the management plan would be to protect and enhance the lake and its watershed in an effort to maintain or improve the trophic status of the lake.

The purpose of the project reported on here was to collect additional information concerning lake water quality, aquatic vegetation, and influences of the lake's watershed. These data along with the data previously collected were then used to create a lake management plan specific to the needs of Little Hills Lake and the LHLMD. This document is a combination of the final report and the lake management plan.

Notes on the Format of this Document

This document serves two purposes; 1) it fulfills the requirements for final reporting of a study that was partially funded through a Wisconsin Department of Natural Resources (WDNR) Lake Planning Grant, and 2) it is the Lake Management Plan for Little Hills Lake. Care has been taken to keep the technical aspects of the document on laymen's terms as much as possible. To facilitate the ease of reading, certain topics are expanded upon and technical terms are defined in a glossary. Furthermore, the reporting of specific data is kept to a minimum within the text, but is wholly contained within the appendices. The appendices also contain the glossary mentioned above (terms contained in the glossary are italicized within the text).

The study contained four major components, watershed analysis, aquatic vegetation, water quality, and education. Each section of the report and plan are generally separated into these four components.

For ease of reading and document compilation, the large format (11"x17") maps are contained near the end of this report.

RESULTS AND DISCUSSION

Lake Water Quality

Judging the quality of lake water can be difficult because lakes display problems in a multitude of ways. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region, and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water. To complete this task, three water quality parameters are focused upon:

1. **Phosphorus** is a nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both *algae* and *macrophytes*. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the growth rates of the plants within the lake.
2. **Chlorophyll-*a*** is the pigment in plants that is used during *photosynthesis*. Chlorophyll-*a* concentrations indicate algal abundance within a lake.
3. **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring lake health. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural, Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water.

Each of these parameters is also directly related to the *trophic state* of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: *oligotrophic*, *mesotrophic*, and finally *eutrophic*. Every lake will naturally progress through these states; however, under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in most Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the health of their lake over time. Yet, classifying a lake into one of three trophic states does not give clear indication of where a lake really exists in its trophic progression. To solve this problem, the parameters measured above can be used in an index that will indicate a lake's trophic state more clearly and provide a means for which to track it over time.

The complete results of these three parameters and the other chemical data that were collected at Little Hills Lake can be found in Appendix A. The results and discussion of the analysis and comparisons described above can be found in the paragraphs and figures that follow.

Comparisons with Other Datasets

Lillie and Mason (1983) is an excellent source for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Waushara County lakes are included within the study's Central Region and are among 44 lakes randomly picked from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide means, historical, current, and average data from Little Hills Lake are displayed in Figures 2-4. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August) in the deepest location in the lake (Figure 1). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments (see section on internal nutrient loading).

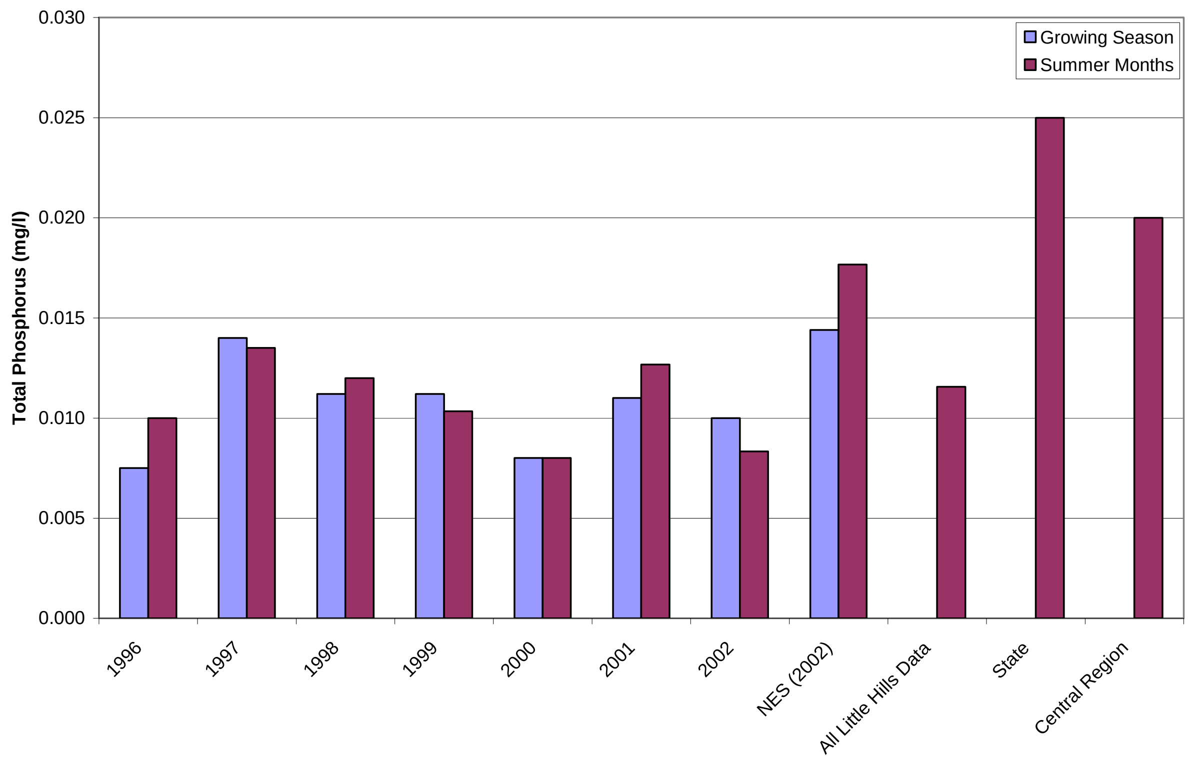

Figure 2. Mean total phosphorus concentrations from Little Hills Lake, state and central region. All means were calculated from surface samples. Growing season includes April-October measurements

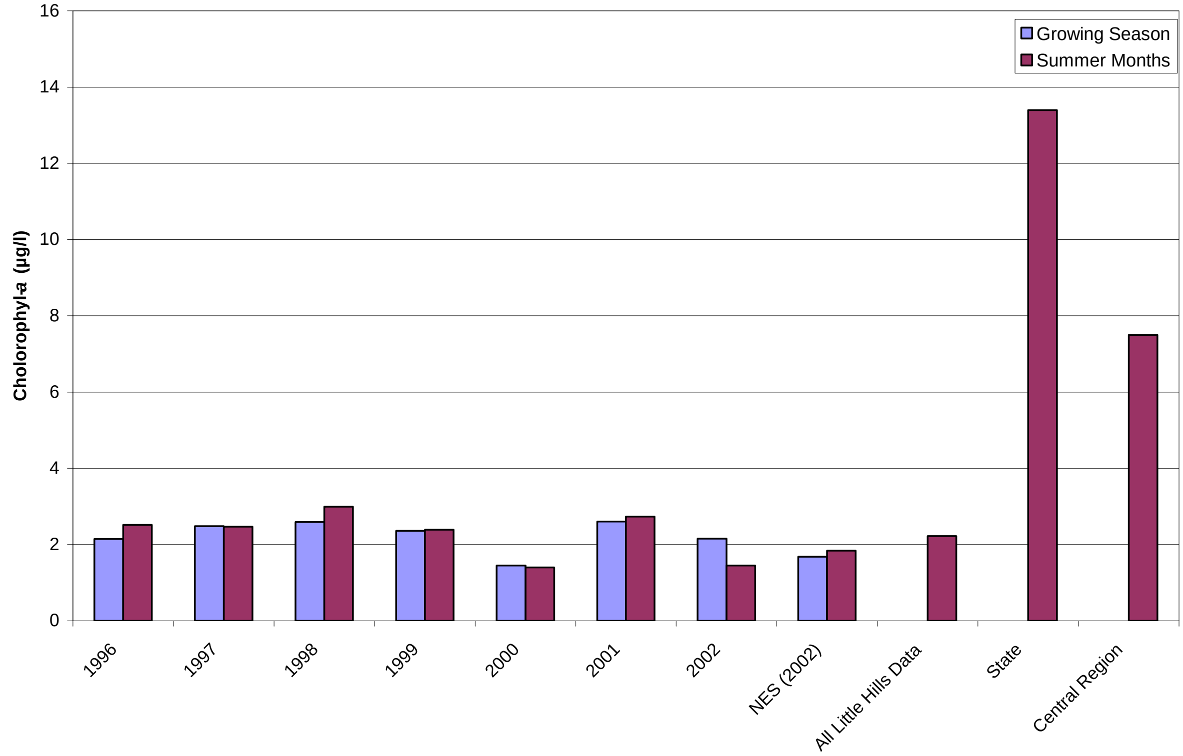

Figure 3. Mean chlorophyll-*a* concentrations from Little Hills Lake, state and central region. All means were calculated from surface samples. Growing season includes April-October measurements

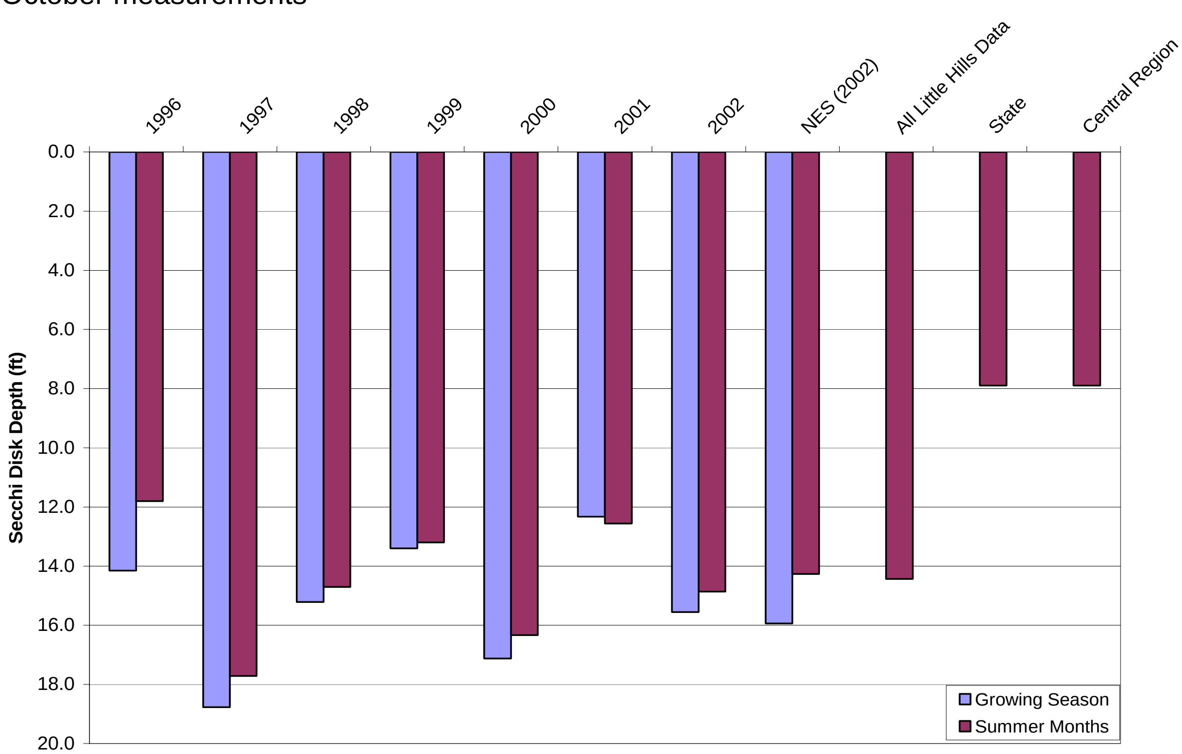

Figure 4. Mean Secchi disk transparencies from Little Hills Lake, state and central region. Growing season includes April-October measurements

Examination of the graphs reveals that although all three parameters fluctuate from year to year, they all fall in the "Good" to "Very Good" range within the Water Quality Index (WQI) developed by Lillie and Mason (1983) (Table 1). Fluctuations and even occasional spikes are normal within these parameters because so many factors affect them. Precipitation, cloud-cover, nutrient forms (particulate, dissolved), lake use, and among others, all determine the concentration of chlorophyll-*a* and phosphorus and affect water clarity. Even the timing of the samples can lead to slight differences within a season, as indicated by the differences that were found between phosphorus samples collected by NES and those collected by the LHLMD Self-Help Volunteer. The differences are not unusual, but are an excellent example of how parameter values can fluctuate and amplify how important a long-term data set is to the management of a lake.

Table 1. Water Quality Index (WQI) developed by Lillie and Mason (1983) for Wisconsin Lakes. Multiply meters (m) by 0.305 to get feet and divide mg/m^3 by 1000 to get mg/l.

	Approximate Equivalents				
WQI	**Water Clarity (m)**	**Water Clarity (ft)**	**Chlorophyll-a (µg/l)**	**Total Phosphorus (mg/m^3)**	**WTSI***
Excellent	>6	>19.7	<1	<1	>34
Very Good	3.0-6.0	9.8-19.7	1-5	1-10	34-44
Good	2.0-3.0	6.6-9.8	5-10	10-30	44-50
Fair	1.5-2.0	4.9-6.6	10-15	30-50	50-54
Poor	1.0-1.5	3.3-4.9	15-30	50-150	54-60
Very Poor	<1.0	<3.3	>30	>150	<60

*Calculated from water clarity values.

Overall, when compared to the WQI values in Table 1, the data found in Figures 2-4 indicate that the water quality of Little Hills Lake is quite good and that there is no clear evidence of changes in water quality over the past 7 years. These data also indicate that, in general, the phosphorus and chlorophyll-*a* concentrations within Little Hills Lake are well below those found in the state and the central region. Comparisons of water transparency show the water of Little Hills Lake has been consistently much clearer than that found in other lakes within the region and state. These consistently good values are likely attributable to two factors:

1. The small amount of land that drains surface water to Little Hills Lake.
2. The fact that the residencies around Little Hills Lake are part of the Silver Lake Sanitary District.

Both of these factors work in favor of the lake's water quality and are explained in more detail in the Watershed Analysis Section.

Lake Trophic State and Limiting Nutrient

Figure 5 contains the Wisconsin Trophic State Index (WTSI) (Lillie, et al. 1993) values calculated from average surface levels of chlorophyll-*a*, total phosphorus, and Secchi disk transparencies measured during the summer months in Little Hills Lake. The WTSI is based upon the widely used Carlson Trophic State Index (TSI) (Carlson 1977), but is specific to Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Self-Help Volunteers.

Based upon total phosphorus concentrations, the trophic state of Little Hills Lake remains well within the mesotrophic level; however, examination of the WTSI values calculated with chlorophyll-*a* concentrations and Secchi disk depths indicate that Little Hills Lake is on the lower side of the mesotrophic level and upper end of the oligotrophic state. As described above, the three parameters used to calculate the WTSI are very much interrelated; however, the long-term data from Little Hills Lake exhibits slight variation from these relationships. For instance, the data collected for this study during the summer of 2002 resulted in some of the highest total phosphorus levels recorded at the lake. However, the chlorophyll-*a* and clarity values remained low during the same timeframe. One possible explanation may be that phosphorus is not actually the *limiting nutrient* within Little Hills Lake. Yet, this cannot be the case because the nitrogen to phosphorus ratio found during the current study was above 67:1, indicating a very strong phosphorus limitation. Actually, a portion of the phenomenon likely occurs because some of the phosphorus is actually bound to calcium product called marl and is unusable by the algae.

Carlson (1977) suggests that for TSI calculations using summer samples, as ours do, that chlorophyll-*a* produces the best indication of lake trophic status. With that in mind, we would have to conclude that Little Hills Lake is on the lower end of mesotrophic.

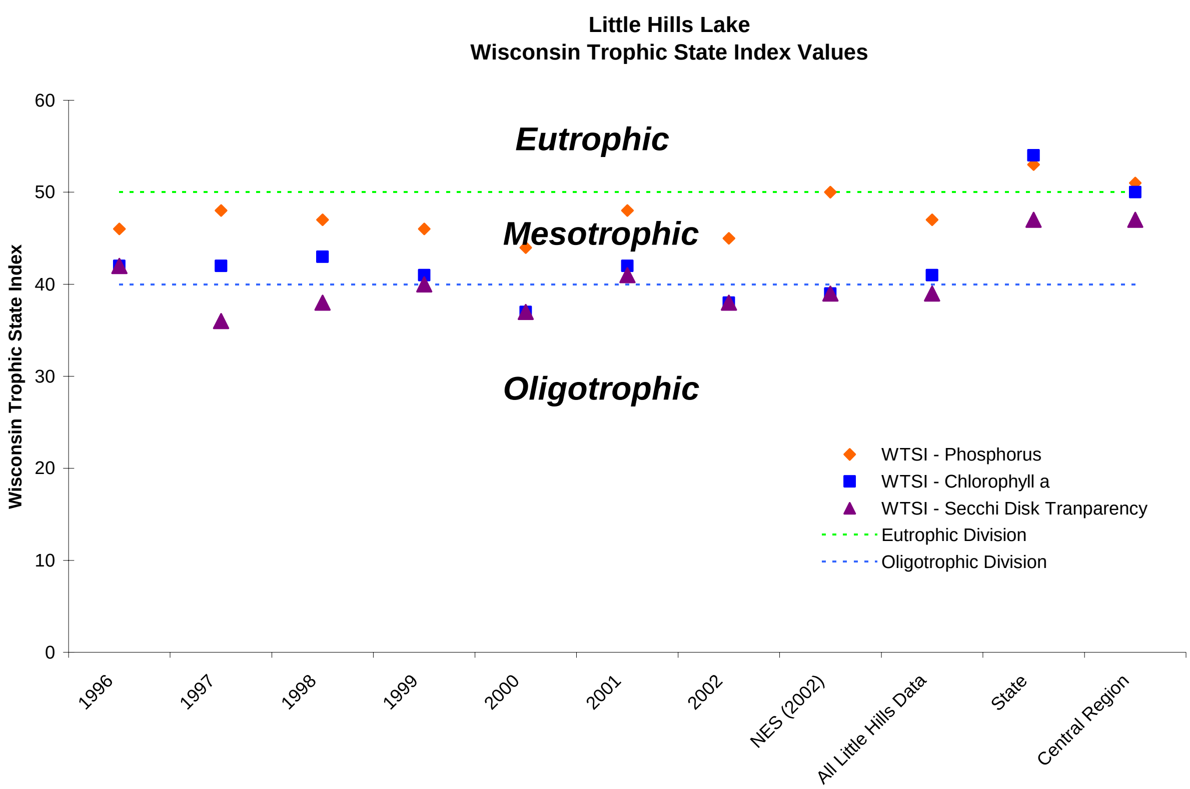

Figure 5. Wisconsin Trophic State Index results for Little Hills Lake.

Internal Phosphorus Loading

In lakes that have strong stratification, the hypolimnion, can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae. This cycle continues year after year and is termed "internal phosphorus loading;" a phenomenon that can support nuisance algae blooms decades after external sources are controlled. Internal nutrient loading is especially troubling in seepage lakes such as Little Hills Lake because the nutrients are not flushed out of the system, but remain to be recycled every year.

The Phosphorus Prediction and Uncertainty Analysis Module of the Wisconsin Lake Modeling Suite (WiLMS) indicates that when considering the land uses around the lake, there is much less phosphorus in Little Hills Lake than would be expected. This was particularly true for the Nurnberg modeling results, which was designed to model lakes that mix often and do not support an *anoxic hypolimnion* such as Little Hills Lake. In fact, this model showed over 100% variation between observed and modeled phosphorus levels, indicating that the current phosphorus levels in Little Hills Lake are quite low. The modeling results, coupled with the fact that Little Hills Lake only weakly stratifies and does not exhibit an *anoxic* hypolimnion leads to the conclusion that internal phosphorus loading is currently not significant.

Temperature and Dissolved Oxygen

The temperature and dissolved oxygen profiles performed at Little Hills Lake show the lake only weakly stratified during a short period in early spring (Figure 6). The profiles also indicate that the lake holds oxygen well throughout the winter as indicated by the January 14, 2003 profile that was taken through the ice.

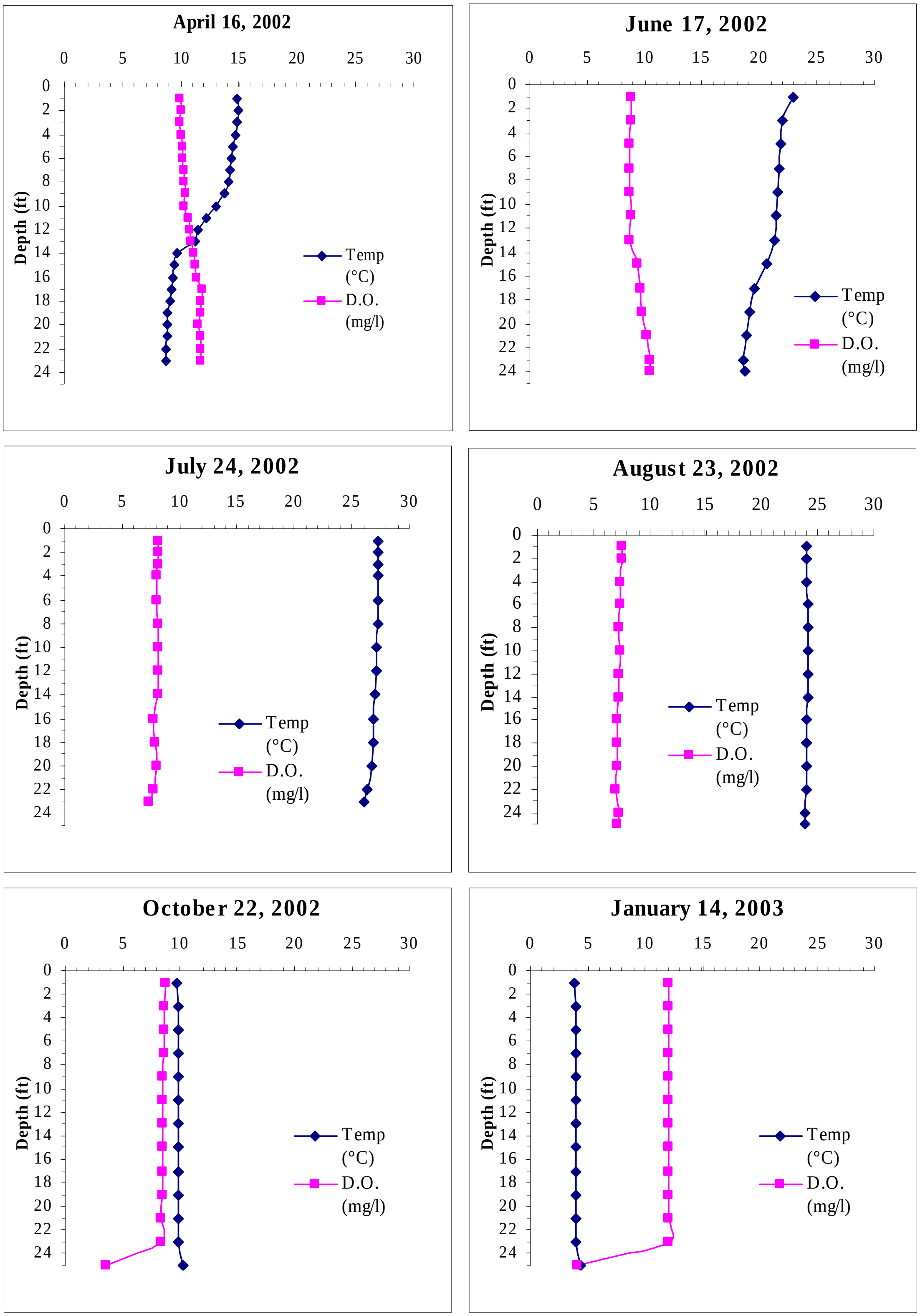

Figure 6. Results of temperature and dissolved oxygen profiles for Little Hills Lake.

Aquatic Vegetation

Although many lake users consider aquatic macrophytes to be "weeds" and a nuisance to the recreational use of the lake, they are actually an essential element in a healthy, functioning lake ecosystem. It is very important that the lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative affects on it.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Zizania palustris*) both serve as excellent food sources for ducks and geese. In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the *periphyton* attached to them as their primary food source. The plants also provide cover for feeder fish and *zooplankton*, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas were plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

Under certain conditions, plant populations may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced numbers of predator fish and a stunted pan-fish population. *Exotic* plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing *native* plants and reducing *species diversity*. These *invasive* plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant biomass negatively affects the lake ecosystem and limits the use of the resource, plant management may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods.

Aquatic Plant Management and Protection

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, grass carp (*Ctenopharyngodon idella*) are illegal in Wisconsin and rotovation is not commonly used. Unfortunately, there are no "wonder drugs" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below. Although all of these techniques may not be applicable to Little Hills Lake, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why they are or are not applicable.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many new aquatic plant management regulations. The rules for the new regulations have been set forth by the WDNR as NR 109. A major change includes is that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now; including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet along the shoreline and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within the 30 feet. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban

landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects. The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a *shoreland buffer zone.* The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping.

Enhancement activities also include additions of *submergent*, *emergent*, and *floating-leaf* plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic and shoreland plant restorations is highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), measures used to protect the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,050.

- The single site used for the estimate indicated above has the following characteristics:
  - An upland buffer zone measuring 35' x 100'.
  - An aquatic zone with shallow-water and deep-water areas of 10' x 100' each.
  - Site is assumed to need little invasive species removal prior to restoration.
  - Site has a moderate slope.
  - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
  - Plant spacing for the aquatic zone would be 3 feet.
  - Each site would need 100' of biolog to protect the bank toe and each site would need 100' of wavebreak and goose netting to protect aquatic plantings.
  - Each site would need 100' of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
  - There is no hard-armor (rip-rap or seawall) that would need to be removed.

Advantages

Improves the aquatic ecosystem through species diversification and habitat enhancement.
Assists native plant populations to compete with exotic species.
Increases natural aesthetics sought by many lake users.
Decreases sediment and nutrient loads entering the lake from developed properties.
Reduces bottom sediment resuspension and shoreline erosion.
Lower cost when compared to rip-rap and seawalls.
Restoration projects can be completed in phases to spread out costs.
Many educational and volunteer opportunities are available with each project.

Disadvantages

Property owners need to be educated on the benefits of native plant restoration before they are willing to participate.
Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in.
Monitoring and maintenance are required to assure that newly planted areas will thrive.
Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings.

Manual Removal

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not taken out, rather the plants are cut similar to mowing a lawn. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The other cutting method entails a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent rerooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1200 to $11,000.

Advantages

Very cost effective for clearing areas around docks, piers, and swimming areas.
Relatively environmentally safe if treatment is conducted after June 15th.
Allows for selective removal of undesirable plant species.
Provides immediate relief in localized area.
Plant biomass is removed from waterbody.

Disadvantages

Labor intensive.
Impractical for larger areas or dense plant beds.
Subsequent treatments may be needed as plants recolonize and/or continue to grow.
Uprooting of plants stirs bottom sediments making it difficult to harvest remaining plants
May disturb *benthic* organisms and fish-spawning areas.
Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant recolonization on top of the screen.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation costs vary greatly depending on the size of the area to be covered and the depth of overlaying water.

Advantages

Immediate and sustainable control.
Long-term costs are low.
Excellent for small areas and around obstructions.
Materials are reusable.
Prevents fragmentation and subsequent spread of plants to other areas.

Disadvantages

Installation may be difficult over dense plant beds.
Installation in deep water may require SCUBA.
Not species specific.
Disrupts benthic fauna.
May be navigational hazard in shallow water.
Initial costs are high.
Labor intensive due to the seasonal removal and reinstallation requirements.
Does not remove plant biomass from lake.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive.

Advantages

Inexpensive if outlet structure exists.
May control populations of certain species, like Eurasian water-milfoil for up to two years.
Allows some loose sediments to consolidate.
May enhance growth of desirable emergent species.

Other work, like dock and pier repair and/or dredging may be completed more easily and at a lower cost while water levels are down.

Disadvantages

May be cost prohibitive if pumping is required to lower water levels.
Drastically upsets lake ecosystem with significant effects on fish and other aquatic wildlife.
Adjacent wetlands may be altered due to lower water levels.
Disrupts recreational, hydroelectric, irrigation and water supply uses.
May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).
Unselective.

Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 10 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor.

Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the later route is chosen, it is very important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages

Immediate results.
Plant biomass and associated nutrients are removed from the lake.
Select areas can be treated, leaving sensitive areas intact.

Plants are not completely removed and can still provide some habitat benefits.
Opening of cruise lanes can increase predator pressure and reduce stunted fish populations.
Harvested plant materials produce excellent compost.

Disadvantages

Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.
Multiple treatments may be required during the growing season because lower portions of the plant and root systems are left intact.
Many small fish, amphibians and invertebrates may be harvested along with plants.
There is little or no reduction in plant density with harvesting.
Invasive and exotic species may spread because of plant fragmentation associated with harvester operation.
Larger harvesters are not easily maneuverable in shallow water or near docks and piers.
Bottom sediments may be resuspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

1. *Contact herbicides* act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment; so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Irrigation restrictions apply.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*).

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on to foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothal (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothal (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, Aqua-Kleen®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions apply.

Advantages

Herbicides are easily applied in restricted areas, like around docks and boatlifts.
If certain chemicals are applied at the correct dosages, they can selectively control certain invasive species, such as Eurasian water-milfoil.
Some herbicides can be used effectively in spot treatments.

Disadvantages

Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.
Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them.
Many herbicides are nonselective.
Most herbicides have a combination of use restrictions that must be followed after their application.
Many herbicides are slow-acting and may require multiple treatments throughout the growing season.

Cost

Herbicide application charges vary greatly between $250 to $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin. Other states have also used insects to battle invasive plants, such as waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, Wisconsin's climate is a bit harsh for these two invasive plants, so we do not use either biocontrol insect. However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water-milfoil. Wisconsin is also using two species of leaf-eating beetles

(*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These biocontrol insects are not covered here because purple loosestrife is predominantly a wetland species.

Advantages

Milfoil weevils occur naturally in Wisconsin.
This is likely an environmentally safe alternative to controlling Eurasian water-milfoil.

Disadvantages

Stocking and monitoring costs are high.
This is an unproven and experimental treatment.
There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Cost

Stocking with adult weevils costs about $1.00/weevil and they are usually stocked in lots of 1000 or more.

Nutrient Reduction

Every plant, whether it is algal or vascular, requires nutrients to grow. The three primary, macronutrients include phosphorus, nitrogen, and carbon. Under normal conditions, lakes in Wisconsin are phosphorus limited and occasionally, nitrogen limited. In other words, one of these nutrients is in short enough supply that it controls plant growth. If more of the nutrient is added to the system, the plant population expands; if the nutrient is taken away, the plant population decreases. However, rooted, vascular plants will not respond to nutrient reductions in the open water as quickly as algal populations will because they have the ability to take up nutrients from the sediment, and unfortunately, there is not a method currently available that will reduce or deactivate phosphorus and nitrogen in lake sediments. Nevertheless, it should be the goal of every lake organization to promote the minimization of all sources of nutrients and pollution entering the lake, whether they are in the form of a *nonpoint-source pollution* like runoff from agricultural and residential lands or *point-source pollution*, like an agricultural drain tile or storm sewer outfall. The reduction of these pollutants will slow the filling of the lake and reduce plant growth in the long-term.

Analysis of Current Aquatic Plant Data

The Floristic Quality Assessment (FQA) (see Methods Section) indicates that Little Hills Lake has a relatively high quality plant community that is made up of many species that are normally found in somewhat disturbed systems. Essentially, the FQA uses species conservatism, or a species' likelihood of occurring in an undisturbed system, along with the number of native species found in the lake to calculate the system's Floristic Quality Index (FQI). The average species conservatism for the survey data from this study is slightly lower than those calculated for the ecoregion and the state (Figures 7 and 8). This means that the species that were located in the lake are likely to be found in more disturbed systems – systems with development and other forms of *anthropogenic* influences. However, the great variety of species found during the 2002 survey resulted in a high FQI for the lake, indicating that although the lake is moderately disturbed, it still supports an aquatic plant community of higher quality.

Unfortunately, although there is a great variety of aquatic plants associated with Little Hills Lake (Table 2), the occurrences of most plants within the lake are quite low (Figure 9) as are their coverages (Figure 10). Considering that the substrate types and water depths of the *littoral zone* are very similar for the entire lake and that the lake does not experience a great deal of wind-driven wave action, it would be expected that these species would occur in greater frequencies throughout the lake instead of just a few locations (Figure 11) in limited numbers. Anecdotal information from long-term lake residents indicate that there were greater occurrences of emergent and floating-leaf species in the lake at one time. The apparent decline is likely the result of recreational boating and shoreland development and has lead to an aquatic plant community dominated by only a few submergent species. This is unfortunate because many fish species, including, northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*), use emergent and floating-leaf areas for spawning and nursery habitat. Reductions in these areas have likely affected the fisheries of the lake.

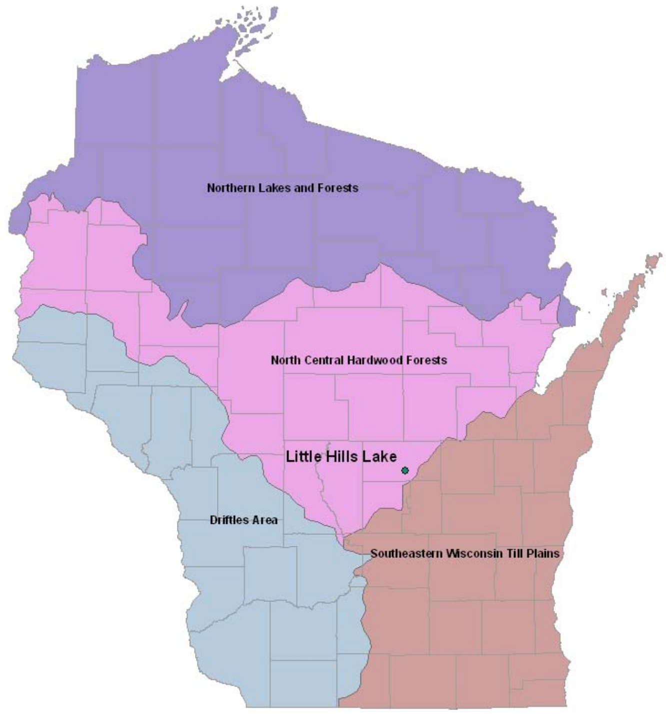

Figure 7. Location of Little Hills Lake relative to the ecoregions of Wisconsin after Nichols 1999 and Omernick and Gallant 1988.

Exotic Species

In recent years, researchers from the University of Connecticut discovered a hybrid milfoil has developed from an *interspecific* cross between the native northern water-milfoil (*Myriophyllum sibiricum*) and the exotic Eurasian water-milfoil (*M. spicatum*). For the time being, the WDNR is treating the hybrid as if it is an exotic species because it seems to have the same invasive nature as Eurasian water-milfoil.

During the summer of 2002 aquatic plant survey, a milfoil species was found adjacent to the boat landing at Little Hills Lake. Later that summer, the same species was located by district members (Figure 11). The species exhibited mixed characteristics of both the native and exotic milfoils. Samples were sent to experts within the WDNR, the University of Wisconsin, and the Wisconsin Geological and Natural History Survey. Mixed results were received so it was assumed to be the exotic species. During early fall of that same year, district members hand-removed as much of the milfoil as they could find. The following summer, NES ecologists returned to Little Hills Lake to collect samples for genetic analysis. The areas where the plants were found the previous summer were searched for nearly an hour by two ecologists using snorkeling equipment and resulted in one small fragment being collected (Figure 11). That fragment was sent to the University of Connecticut for genetic analysis and was determined to be the hybrid species.

Table 2. Aquatic plant species occurring in Little Hills Lake during 2002 survey. Species are broken into community type and include coefficients of conservatism used in Floristic Quality Assessment. FL = Floating-leaf.

	Scientific Name	Common Name	Coefficient of Conservatism (C)	Notes
Emergent	*Verbena hastata*	Blue vervain	5.9	Incidental
	Calamagrostis canadensis	Blue-joint grass	5.9	
	Carex comosa	Bristly sedge	5	
	Polygonum careyi	Carey's heartsease	5.9	
	Typha latifolia	Broad-leaf cattail	1	Incidental
	Eupatorium perfoliatum	Common boneset	5.9	
	Euthamia graminifolia	Flat-top goldenrod	5.9	
	Scirpus acutus	Hardstem bulrush	5	
	Eleocharis acicularis	Needle spikerush	5	
	Juncus effusus	Soft stemmed rush	5.9	
	Scirpus validus	Softstem bulrush	4	
	Asclepias incarnata	Swamp Milkweed	5.9	Incidental
	Scirpus americanus	Three-square	5	
	Dulichium arundinaceum	Three-way sedge	9	
	Iris versicolor	Wild blueflag	5.9	
FL	*Polygonum amphibium*	Water smartweed	5	
	Nymphaea odorata	White water lily	6	
Submergent	*Potamogeton richardsonii*	Clasping-leaf pondweed	5	
	Potamogeton illinoensis	Illinois pondweed	6	
	Myriophyllum sp.	Hybrid water-milfoil	N/A	Exotic/Incidental
	Potamogeton nodosus	Long-leaf pondweed	7	
	Chara sp.	Muskgrasses	7	
	Potamogeton pectinatus	Sago pondweed	3	
	Najas flexilis	Slender naiad	6	
	Potamogeton pusillus	Small pondweed	7	
	Potamogeton gramineus	Variable pondweed	7	
	Bidens beckii	Water marigold	8	
	Zosterella dubia	Water stargrass	6	

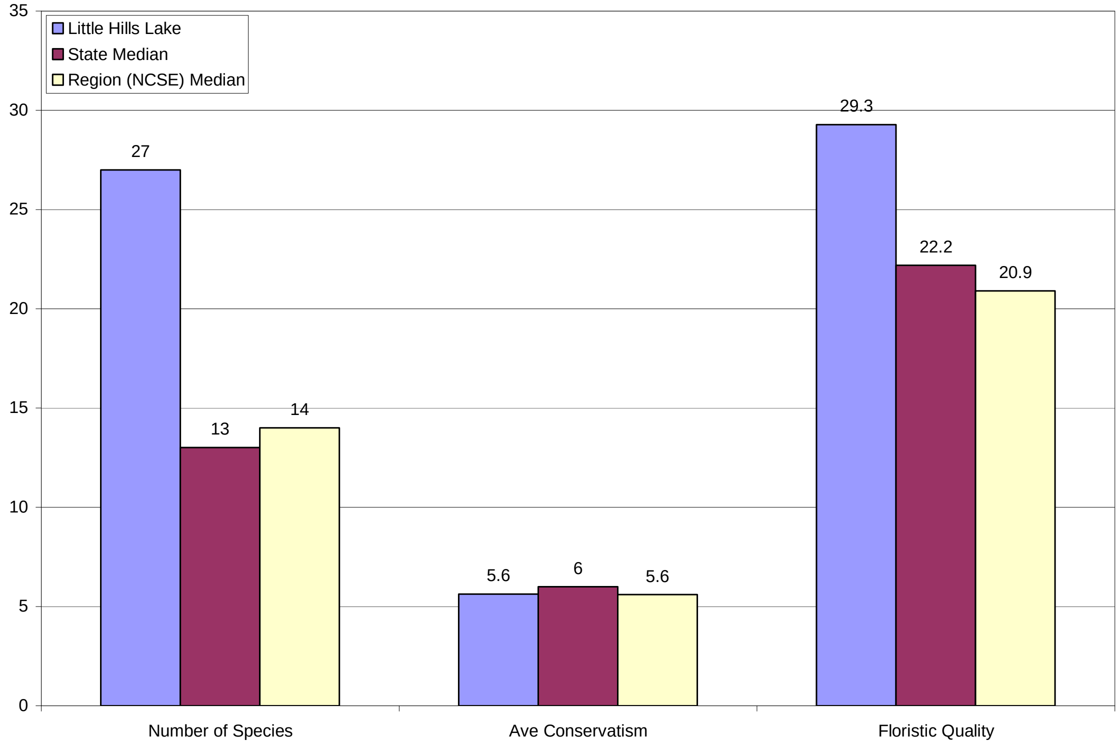

Figure 8. Floristic Quality Assessment (FQA) results for the current dataset of Little Hills Lake, the ecoregion and state. The ecoregion results shown are a combination of results from the North Central Hardwood Forest and Southeastern Wisconsin Till Plains ecoregions (Nichols 1999). Number of species only includes native species.

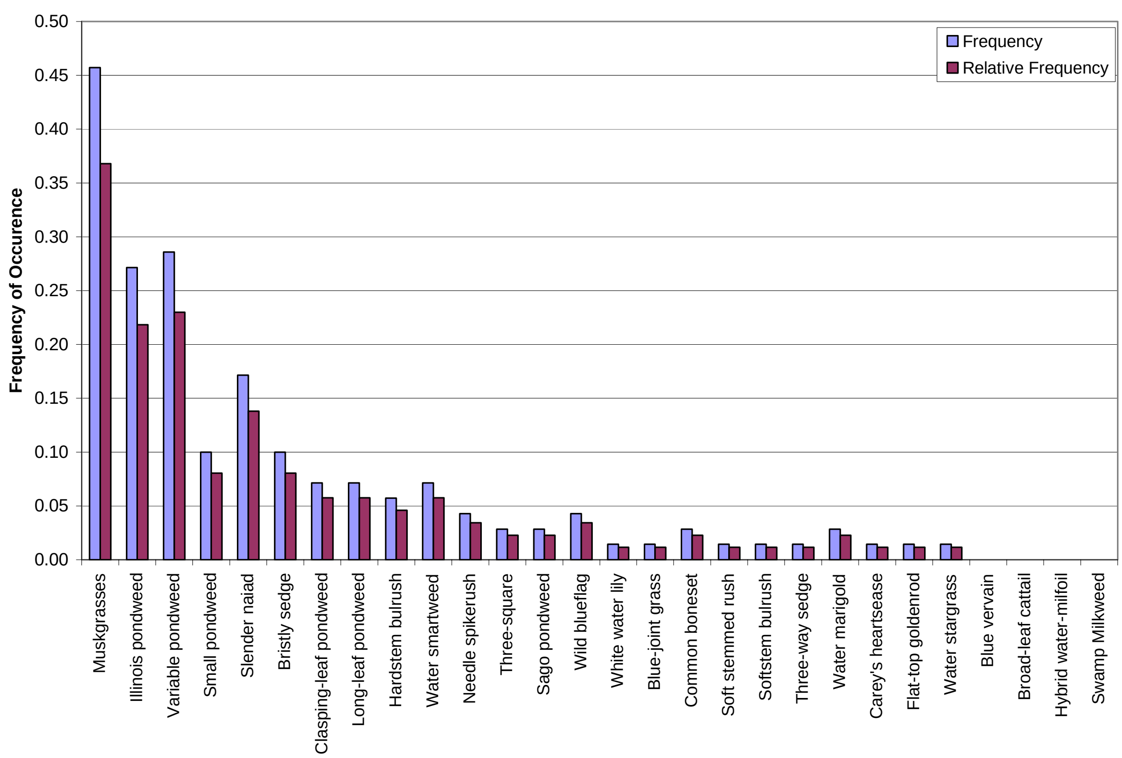

Figure 9. Frequency results for current vegetation survey at Little Hills Lake. Species with zero values were incidentals.

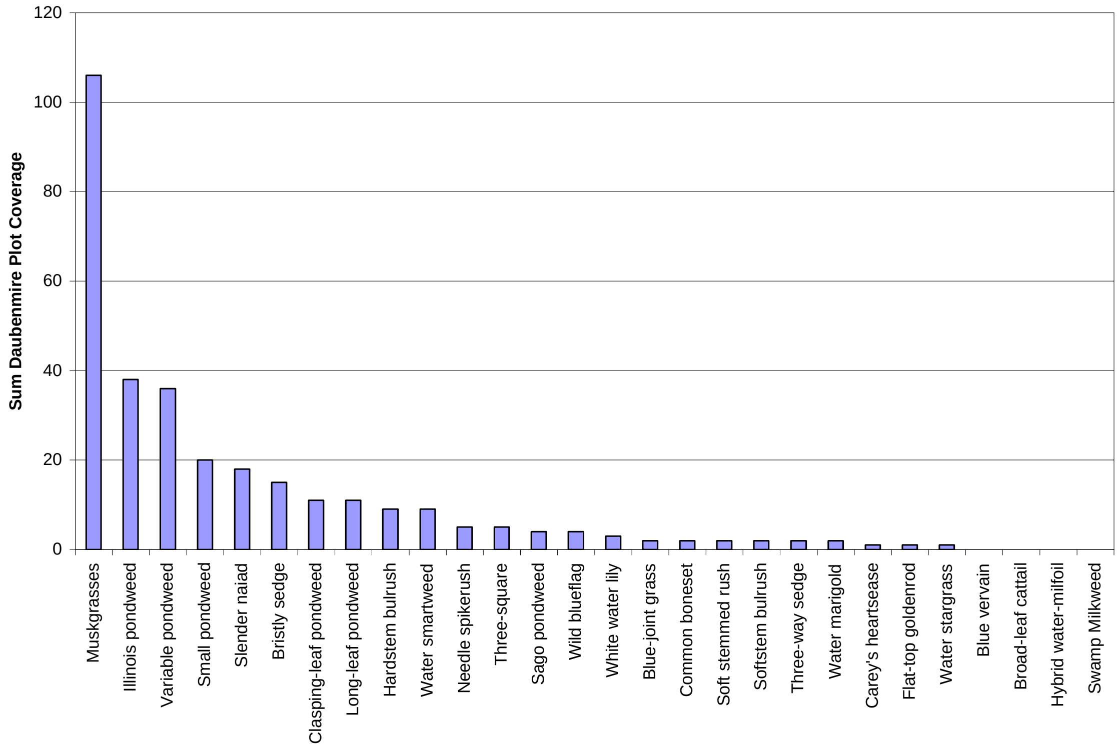

Figure 10. Total Daubenmire coverage results for current survey results at Little Hills Lake. Species with zero values were incidentals.

Watershed Analysis

The Little Hills Lake watershed is approximately 114 acres, which yields a highly favorable watershed to lake area ratio of 1.4:1. In general, lakes with a ratio greater than 10:1 tend to have management problems that revolve around excessive amounts of phosphorus and/or sediments that enter the lake from its drainage basin. This is true because as the drainage area increases, so does the amount of nutrients and sediments that are delivered to the lake. This is not to say that every lake with a watershed to lake area ratio greater than 10:1 experiences problems, because the amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to infiltrate into the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas reduce infiltration and increase surface runoff. The increased surface runoff associated with these land coverage types leads to increased pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

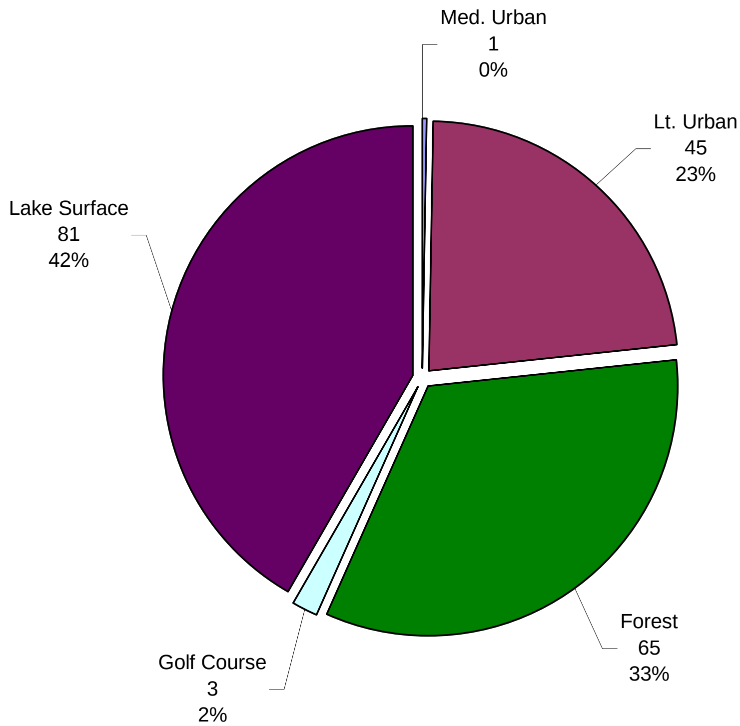

Figure 13. Land use types and associated acreages within the Little Hills Lake watershed. Percentages indicate percent of total watershed acreage.

Field-verified land use data for the Little Hills Lake watershed are displayed in Figures 12 and 13. Currently, the majority of land within the Little Hills Lake watershed is forested. As mentioned above, fully vegetated areas produce very little surface runoff; in fact, these areas allow 60-80% or greater of the precipitation that falls on them to infiltrate the ground. Having a large proportion of the watershed in this land use type does a great deal to prevent excessive phosphorus loading to the Little Hills Lake.

Modeling results of the land use types listed are shown in Figure 14. Atmospheric fallout and precipitation is the largest contributor of phosphorus followed by contributions from the nearby golf course and the light urban development around the lake.

The soils around Little Hills Lake consist primarily of Plainfield Sands (USDA 1989); a soil that drains well, but does little to remove containments from septic field effluent before it enters the groundwater. Considering its small watershed, it is obvious that groundwater plays a major role in the hydrology of Little Hills Lake. The combination of these two factors means that private septic systems were likely the largest contributors of phosphorus to Little Hills Lake before the public sanitary system was brought through. The decision to attach the shoreland properties of the lake to the Silver Lake Sanitary District has probably led to a substantial slowdown in the eutrophication of Little Hills Lake.

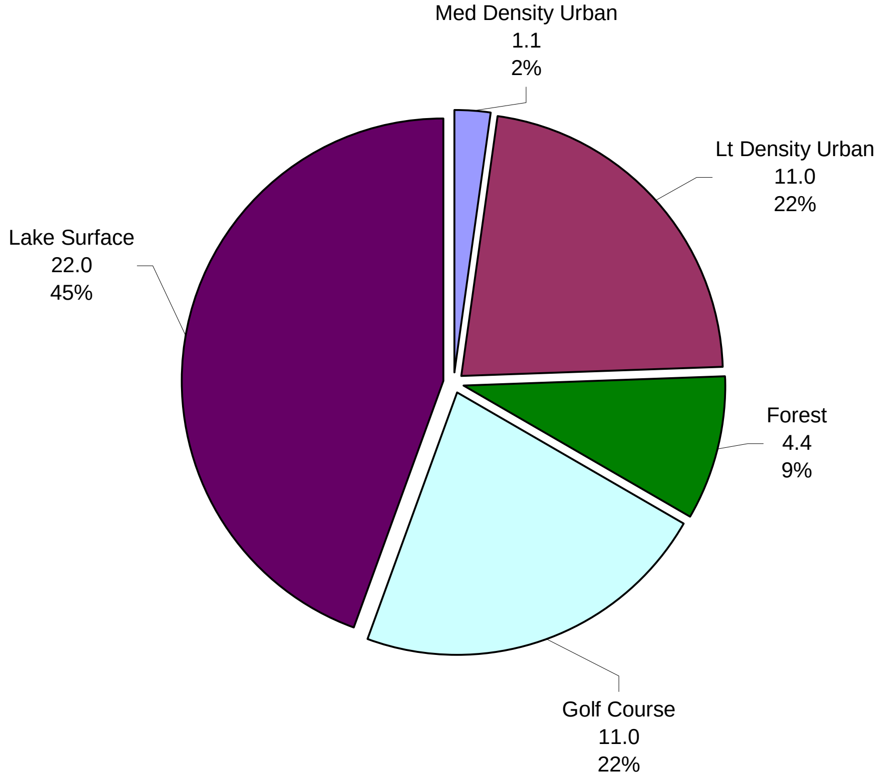

Figure 14. Estimated phosphorus loading values for the Little Hills Lake watershed. Loads are listed in lbs/yr of phosphorus. Percentages indicate percent of total external phosphorus load.

RECOMMENDATIONS

Lake Water Quality

Water Quality Protection

As outlined in the Results and Discussion Section, the water quality of Little Hills Lake appears to have remained consistently good to very good over the past 7 years; therefore, there are no steps that need to be taken to correct in-lake problems. The most appropriate plan is to protect the current water quality of the lake through implementation of the recommendations stated in the Watershed and Aquatic Vegetation sections.

Water Quality Monitoring

Continuous water quality monitoring is an essential component in any lake management plan. Long-term datasets help lake managers detect subtle trends in water quality that cannot be detected with only a year or season's worth of data. Important parameters to include are, chlorophyll-*a*, total phosphorus, and Secchi disk transparency, which are currently being collected on an annual basis through the efforts of the District's Self-Help Volunteers and should definitely continue.

Aquatic Vegetation

There are two primary concerns with the aquatic plant community of Little Hills Lake: 1) the limitation of emergent and floating-leaf habitat to only a few locations within the lake, and 2) the occurrence of the hybrid water-milfoil. These concerns are equally important because both can severely affect the lake.

Aquatic plants are excellent indicators of the health of a lake and are an incredibly important component in the lake ecosystem. They provide habitat to fish, amphibians, and insects, while tying up phosphorus that may otherwise be used by algae. The fact is that high-speed boating and shoreland development have detrimental affects on aquatic plants. These detrimental affects are seen on many of the lakes in Wisconsin, and as described in the results section, is likely occurring at Little Hills Lake.

The hybrid identified in Little Hills Lake has been found in other lakes within Waushara County. For the time being, the WDNR is managing the plant as if it were Eurasian water-milfoil because it exhibits many of its competitive characteristics. Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 15). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead, it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and hampering recreational activities such as swimming, fishing, and boating.

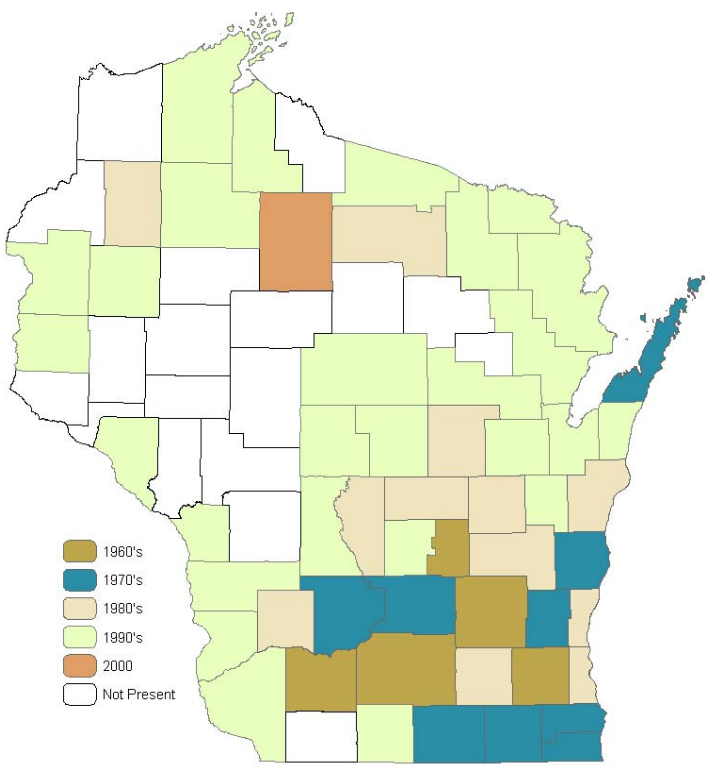

Figure 15. Eurasian water-milfoil spread in Wisconsin counties. Data from Wisconsin DNR.

In order to provide an opportunity for the existing native floating-leaf and emergent species to expand their area of establishment and to slow the potential spread of the hybrid water-milfoil to other areas of the lake, we strongly recommend that the LHLMD move to have the small, southern bay containing the boat landing deemed a permanent slow-no-wake zone. Eliminating high-speed boating from this area would likely allow the existing aquatic plants within the bay to spread and establish themselves throughout the area resulting in an increase of habitat value for the entire lake. Furthermore, fragmentation and subsequent spread of the hybrid water-milfoil to other areas of the lake would be slowed if the colonies of the plant still exist or would be reintroduced in the future.

Should the LHLMD decide to pursue the implementation of the slow-no-wake zone, they should contact both the WDNR and the Town of Marion. In the end, it would be the town that would adopt the ordinance that would set the slow-no-wake area. The WDNR would be essential in providing advice on enforcement and signage.

The District should also consider actively enhancing the newly created slow-no-wake area by planting emergent and floating-leaf species. Please note that the District would need to notify the WDNR for approval of their planting plan before the plants were installed.

We also recommend that the LHLMD conduct annual surveys to monitor for milfoil colonization. The surveys should be completed in mid July and could consist of District members canoeing around the lake looking for milfoil plants. If plants are found, a temporary buoy should be placed to mark the location and a sample should be collected for identification by the area WDNR aquatic plant specialist. If it is determined or suspected to be the hybrid or Eurasian water-milfoil, the plants, including roots, should be removed by hand and disposed of well away from the lake or any other waterbody. If a larger colony is found, the District could consider the use of a sediment blanket to smother the colony. Finally, in the unlikely event that the survey should find a very large colony (0.25 acres or more), the District may need to consider a herbicide treatment. In any event, the WDNR should be apprised of all aquatic plant management in the lake.

Watershed

The fact that the majority of the watershed is currently forested or in grassland/pasture helps to assure that excess runoff, carrying phosphorus and other pollutants to the lake, will be minimal. However, there should be concern over runoff entering the lake from developed shoreland properties. With the exception of converting the forested areas to residential lots or agricultural use, continued and/or increased loading from shoreland properties will likely have the greatest impact on the health of Little Hills Lake.

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development, a decrease in water quality and wildlife habitat has occurred. Many people that move to or build on shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects. The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife. The removal of fallen trees and other woody debris from shoreline areas in an attempt to maintain a clean appearance also removes habit and food for aquatic and terrestrial flora and fauna. Combined, these actions have helped lead to noticeable decreases in the quality of Wisconsin's lakes.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values and water quality by restoring portions of their shoreland to its unaltered state before it was developed. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a *shoreland buffer zone.* The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping.

NES ecologists pay particular attention to the condition of a lake's shorelands during our site visits, especially during the vegetation surveys. There are many properties along the shores of Little Hills Lake which are maintained as unnatural landscapes that are not appropriate for these delicate areas. This includes both lawns that are maintained to the water's edge and properties that still have many large trees, but are void of the understory and herbaceous layers that naturally occur in woodlands.

We recommend that all property owners restore a shoreland buffer zone on their properties The benefits to the lake ecosystem and the property owners are numerous and far outweigh the costs of the restorations. Creating a contiguous buffer zone around Little Hills Lake would do much to preserve it. Partial (75%) funding for these projects could be obtained through a WDNR Lake Protection Grant with the remaining monies coming form the property owners.

We also recommend that the District pass a resolution allowing the use of only phosphorus-free fertilizers on shoreland properties. It is true that enforcing this type of resolution would be difficult if not impossible, but the fact is that if the District formally passed the resolution and notified its members of it, there would likely be a significant reduction in the use of fertilizers containing phosphorus.

A small portion of the golf course is also believed to be draining to Little Hills Lake. Golf courses are notorious for utilizing large amounts of fertilizers in their maintenance activities. The LHLMD should consider expanding its water quality monitoring program to occasional sampling of the water that flows from the golf course and under Cree Dr. It is likely that there may only be sufficient flows for sampling during substantial rain events, so we recommend that the District visually monitor the flows through the culverts during the spring, summer, and fall of 2004 to determine if there are sufficient flows to warrant concern and monitoring. If the District should find that there are noticeable flows through the culverts that make their way to the lake, they should contact the WDNR to expand their monitoring program to include phosphorus samples from the culvert flows.

Please note that collecting grab samples without associated discharge data (volume per unit of time – cubic feet per minute, gallons per minute, etc) does not give a complete picture of how much phosphorus is actually entering the lake. If high concentrations are found to be occurring, further study may be warranted that could guide the District and the golf course to methods that would minimize the loadings.

Education

Education is an incredibly important aspect of any lake management plan. Informing District members about District activities is very important, but the education of its members is as important, if not more important. Educational topics should include:

- Lake Stewardship
  - A lake steward understands his or her affect on the lake ecosystem and takes measures to protect and enhance it. Lake stewards also understand that protecting the ecosystem as a natural resource and not just a recreational resource is important to all lake uses, including fishing, swimming, boating, and enjoying the aesthetics of the lake.
- Property Management
  - This topic can be tied to lake stewardship and should include information on the use of lawn fertilizers, and methods of blending structures with the natural landscape. This topic should also include information on natural buffer strips that can be used to minimize soil erosion and nutrient loading to the lake from shoreland properties.
- Exotic and Invasive Plants
  - Education should stress the fact that prevention and early detection are paramount in the battle against these organisms. The District could take this even further by developing a *Volunteer Watercraft Inspection Program*. More information on the program can be obtained by contacting the UW-Extension Lakes Program at (715) 346-3366.
- Native Aquatic Plants
  - This topic should include discussions on the importance of aquatic plants to the health of the lake ecosystem, including fish and other wildlife.

METHODS

Lake Water Quality

Water Quality Monitoring

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Little Hills Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake. Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B), and occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following normal protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included:

	Spring		**June**		**July**		**August**		**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●						
Chlorophyll-*a*	●	●	●		●		●		●			
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●			●	●	●	●	●	●	●	●
Calcium	●	●			●							

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 4.

Aquatic Vegetation

Transect Surveys and Macrophyte Community Mapping

A quantitative aquatic vegetation survey was conducted on July 18, 2002 by sampling 18 transects located along the shoreline of the lake (Figure 12). Sampling was completed via boating, wading, and snorkeling. In order to map the macrophyte communities and to assist in determining the frequency and location of transects, visual inspections were completed throughout the lake using a combination of sketches and notes created on hardcopy maps and position data recorded with a Trimble GeoExplorer 3 GPS/Data Collector. On each transect, a ten-foot diameter circle was sampled within each of four different depth ranges (Table 3). The maximum depth of sampling was determined through field observation of the approximate maximum depth of aquatic vegetation growth. At each sampling location, substrate type and species composition were recorded.

Table 3. Depth codes and ranges sampled during transect surveys.

Depth Code	Depth Range (feet)
1	0.0-1.5
2	1.5-3.0
3	3.0-5.0
4	5.0-10.0

A visual estimate of percent foliage cover for each species was also recorded at the sampling locations. Coverage is determined as the perpendicular projection to the substrate from the outline of the aerial parts of the plant species and is typically reported as the percent of total area (e.g., substrate or water surface) covered (Brower et al. 1990). For emergent and floating-leaf vegetation, the percent of water surface covered was used in the visual estimate, and for submergent vegetation the percent of substrate covered was used. After the collection of field data, the Daubenmire Classification Scheme (Mueller-Dumbois and Ellenberg 1974) was used to rank each species observed according to estimated foliage cover (Table 4). By providing a range of percent foliage cover for each rank, the Daubenmire Classification Scheme helps to minimize errors due to observer bias, visual estimation, etc.

Table 4. Daubenmire Classification Scheme cover ranking system.

Percent Foliage Cover	Rank
0-5	1
5-25	2
25-50	3
50-75	4
75-95	5
95-100	6

The collected transect data were used to estimate frequency of occurrence and relative frequency of occurrence for each species observed. The frequency of occurrence is defined as the number of times a given species occurred on the total plots of all transects sampled. The relative frequency of occurrence is the frequency of that species divided by the sum of the frequencies of all species in the community (Brower et al. 1990). Sum coverage is the total Daubenmire cover found for each plant.

Floristic Quality Assessment

A Florist Quality Assessment (FQA) was applied to the aquatic vegetation species lists generated for Little Hills Lake using the methodology of Nichols (1999). FQA is a rapid assessment metric used to assist in evaluating the floristic and natural significance of a given area. The assessment system is not intended to be a stand-alone tool, but is valuable as a complementary and corroborative method of evaluating the natural floristic quality of a lake ecosystem.

The primary concept in FQA is species conservatism. Each native species found in the lake was assigned a coefficient of conservatism (*C*) ranging from 0 to 10. The coefficient of conservatism estimates the probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be pre-settlement condition. A *C* of 0 indicates little fidelity to a natural community, and a *C* of 10 is indicative of restriction to high quality, natural areas. The FQA was applied by calculating a mean coefficient of conservatism for all species observed in the lake. The mean *C* was then multiplied by the square root of the total number of species to yield a

Floristic Quality Index (FQI). Examination of the floristic quality index within the context of statewide and regional trends was used to provide an overall evaluation of the floristic quality of Little Hills Lake.

Watershed Analysis

The watershed analysis began with an accurate delineation of Little Hills Lake's drainage area using U.S.G.S. topographic survey maps. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land use data supplied by Waushara County, were then combined to determine the preliminary watershed land use classifications. The watershed delineation and land use classifications were field verified during the fall of 2002.

The preliminary data were then corrected with the field verified data within the GIS and watershed area and acreages for each land use type were calculated. These data, along with historic and current water quality data were inputted into the Wisconsin Lake Modeling Suite (WiLMS) to determine potential phosphorus loads to the lake.

Education

Educational components were accomplished through a "Kick-off Meeting" held in May 2002, project updates created for inclusion in the District's newsletter, an article that appeared in the Oshkosh Northwestern, and a "Project Completion Meeting" at which the final report and recommendations were presented to the District. All of these materials are included in Appendix D.

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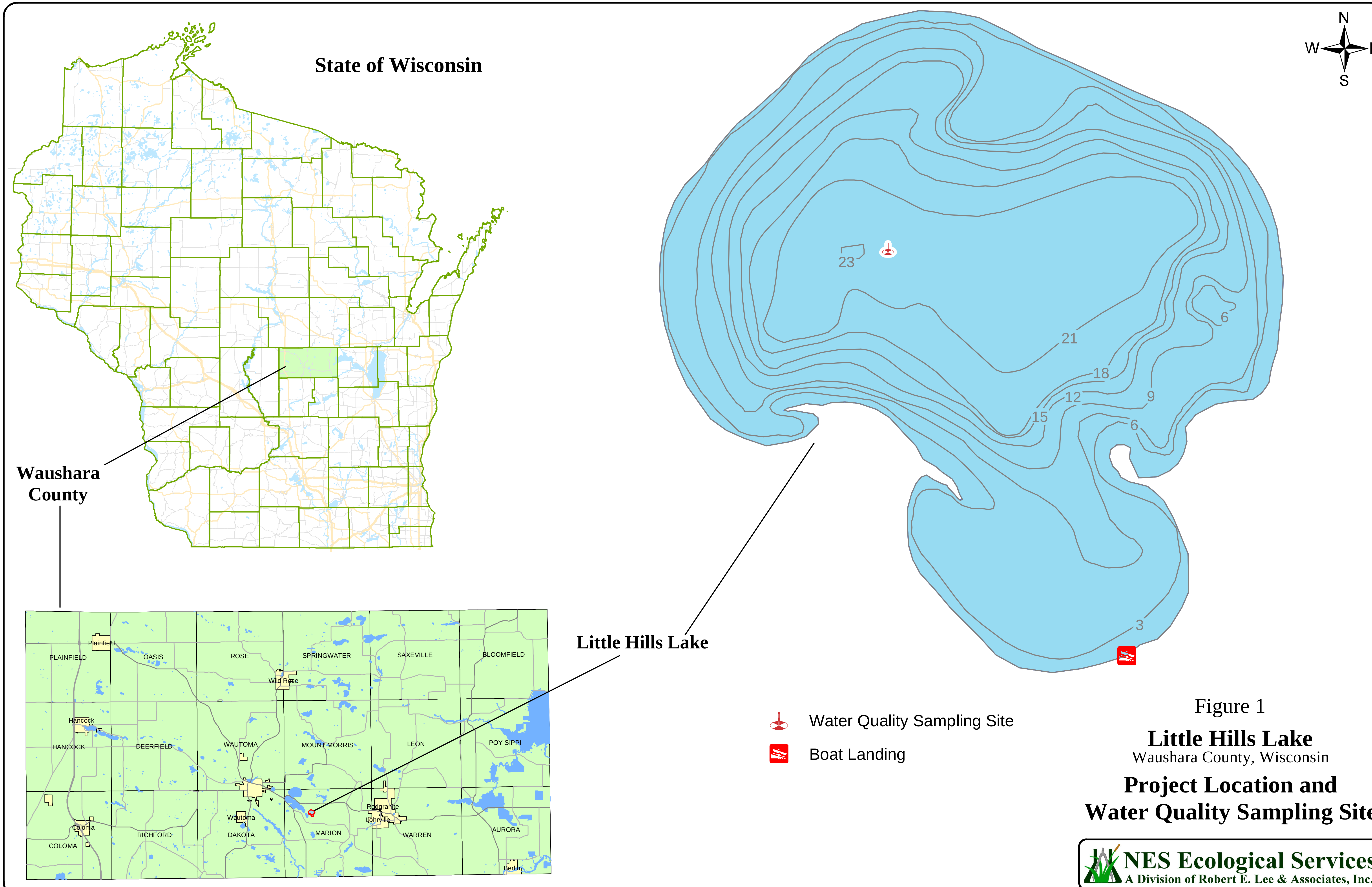

Figure 1

Little Hills Lake

Waushara County, Wisconsin

Project Location and Water Quality Sampling Site

NES Ecological Services

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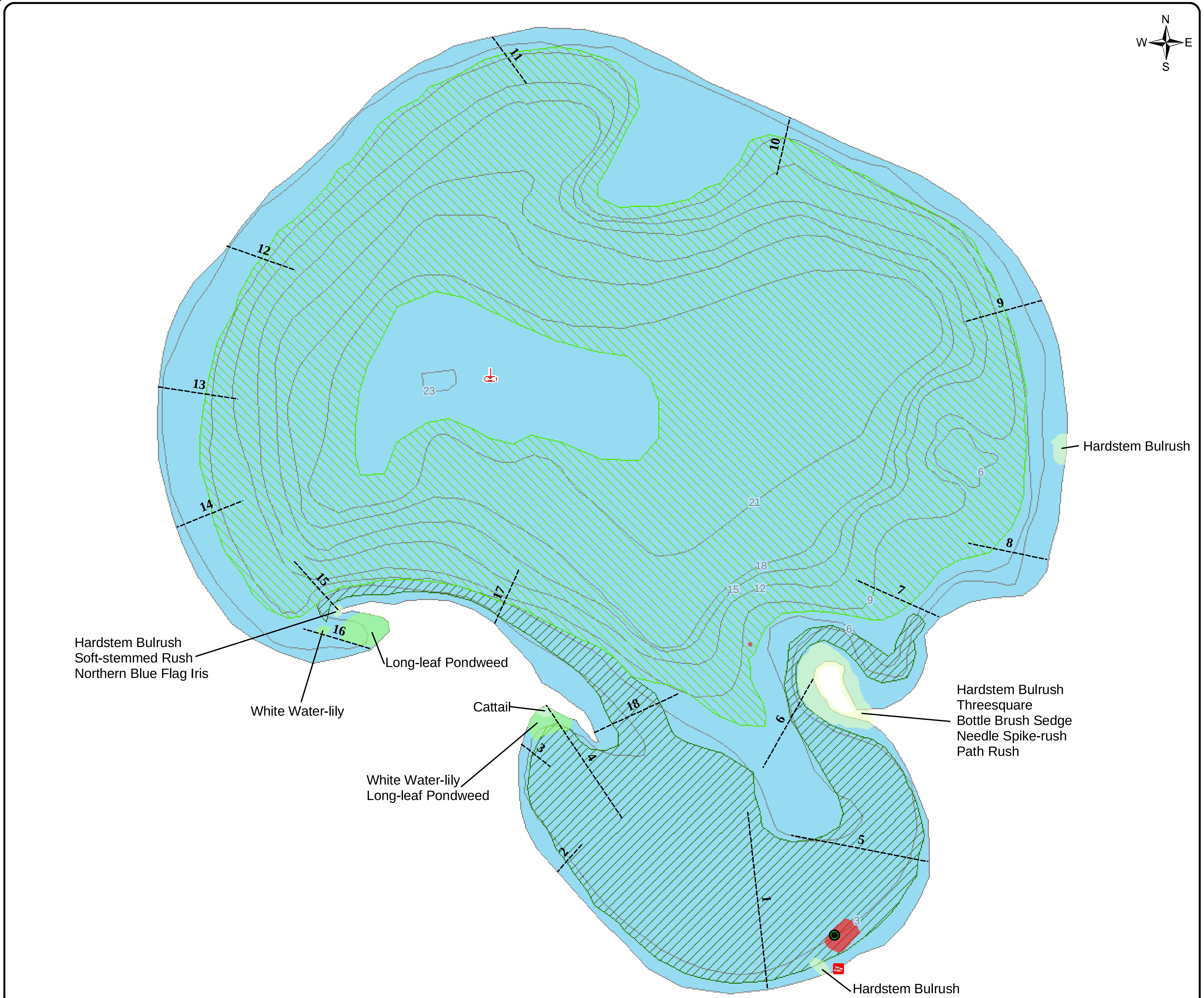

Figure 11

Little Hills Lake

Waushara County, Wisconsin

Aquatic Plant Communities and Eurasian Water-milfoil Locations

- Emergent Plant Community
  Dominant Species Indicated
- Floating-leaf Plant Community
  Dominant Species Indicated
- Submergent Plant Community
  Dominated by:
  Muskgrass
  Illinois Pondweed
  Variable Pondweed
  Small Pondweed
- Submergent Plant Community
  Dominated By:
  Muskgrass
- Eurasian Water-milfoil Location
- Aquatic Plant Survey Transect
- Water Quality Sample Site
- Eurasian Water-milfoil Collection Location
- Boat Landing

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Figure 12

Little Hills Lake

Waushara County, Wisconsin

Watershed Land Use Classifications

WiLMS Land Use Classification

- Forest
- Golf Course
- Lake Surface
- Light Density Urban
- Medium Density Urban

Boat Landing

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A

APPENDIX A

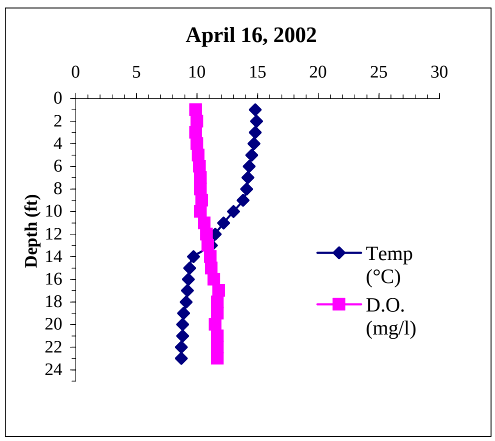
Water Quality Dataset Collected During 2002-2003

Little Hills Lake

Date:	**04-16-02**			**Max Depth (ft):**	24.2
Time:	16:40			**LHLS Depth (ft):**	3.0
Weather:	80, Partly Cloudy			**Depth (ft):**	21.0
Ent:	BGN	**Verf:**	BN/JE	**Secchi Depth (ft):**	20.8

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	14.8	9.9	8.5	214
2.0	14.9	10.0	8.5	215
3.0	14.8	9.9	8.5	215
4.0	14.7	10.0	8.5	215
5.0	14.5	10.1	8.5	215
6.0	14.3	10.2	8.5	215
7.0	14.2	10.3	8.5	215
8.0	14.1	10.3	8.5	215
9.0	13.8	10.4	8.5	216
10.0	13.0	10.3	8.5	214
11.0	12.2	10.6	8.5	216
12.0	11.5	10.8	8.5	214
13.0	11.2	10.9	8.5	215
14.0	9.7	11.1	8.5	213
15.0	9.4	11.2	8.5	213
16.0	9.3	11.4	8.6	212
17.0	9.2	11.8	8.6	212
18.0	9.1	11.7	8.6	213
19.0	8.9	11.7	8.6	213
20.0	8.8	11.5	8.6	212
21.0	8.8	11.7	8.6	212
22.0	8.7	11.7	8.6	212
23.0	8.7	11.7	8.6	212

Parameter	LHLS	LHLB
Total P (mg/l)	0.012	0.008
Dissolved P (mg/l)	0.000	0.000
Chl a (µg/l)	<1	<1
TKN (mg/l)	0.640	0.600
NO_4+NO_3-N (mg/l)	0.038	0.033
NH_3-N (mg/l)	0.076	0.038
Total N (mg/l)	0.678	0.633
Lab Cond. (µS/cm)	252	252
Lab pH	8.4	8.49
Alkal (mg/l $CaCO_3$)	116	116
Total Susp Sol (mg/l)	152	136
Calcium (mg/l)	22.6	22.4



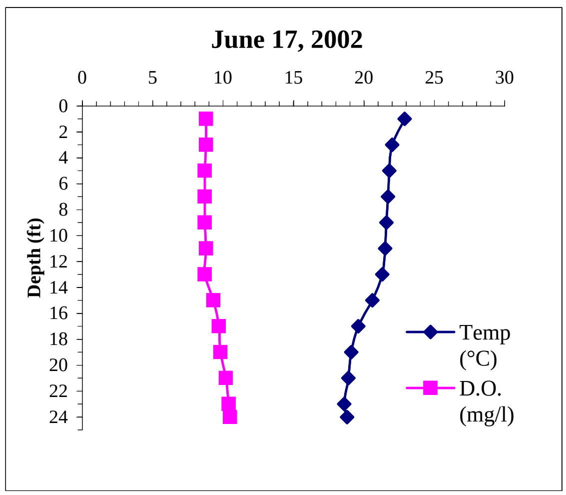
Notes:

Little Hills Lake

Date:	**06-17-02**	**Max Depth (ft):**	24.6
Time:	14:00	**LHLS Depth (ft):**	3.0
Weather:	high clouds 76	**)epth (ft):**	21.0
Ent:	BGN **Verf:** BN/JE	**Secchi Depth (ft):**	19.2

Depth (ft)	**Temp (°C)**	**D.O. (mg/l)**	**pH**	**Sp. Cond (µS/cm)**
1.0	22.9	8.8	8.7	242
3.0	22.0	8.8	8.7	241
5.0	21.8	8.7	8.7	241
7.0	21.7	8.7	8.7	242
9.0	21.6	8.7	8.7	241
11.0	21.5	8.8	8.7	241
13.0	21.3	8.7	8.7	241
15.0	20.6	9.3	8.7	244
17.0	19.6	9.7	8.7	244
19.0	19.1	9.8	8.6	244
21.0	18.9	10.2	8.7	245
23.0	18.6	10.4	8.7	245
24.0	18.8	10.5	8.7	244

Parameter	**LHLS**	**LHLB**
Total P (mg/l)	0.021	0.011
Dissolved P (mg/l)		
Chl a (µg/l)	<1	
TKN (mg/l)		
NO_4+NO_3-N (mg/l)		
NH_3-N (mg/l)		
Total N (mg/l)		
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
'otal Susp Sol (mg/l)		
Calcium (mg/l)		



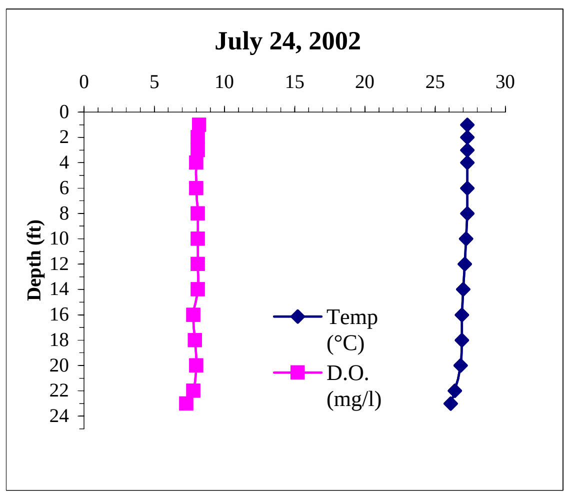
Notes:

Little Hills Lake

Date: 07-24-02 **Max Depth (ft):** 25.8
Time: 13:24 **LHLS Depth (ft):** 3.0
Weather: 74, breezy partly cloudy **)epth (ft):** 21.0
Ent: BGN **Verf:** BN/JE **Secchi Depth (ft):** 15.8

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	27.3	8.2	8.9	231
2.0	27.3	8.1	8.9	230
3.0	27.3	8.1	8.9	230
4.0	27.3	8.0	8.9	231
6.0	27.3	8.0	8.9	230
8.0	27.3	8.1	8.9	230
10.0	27.2	8.1	8.9	230
12.0	27.1	8.1	8.9	230
14.0	27.0	8.1	8.9	230
16.0	26.9	7.8	8.9	231
18.0	26.9	7.9	8.9	231
20.0	26.8	8.0	8.8	234
22.0	26.4	7.8	8.7	237
23.0	26.1	7.3	8.6	245

Parameter	LHLS	LHLB
Total P (mg/l)	0.016	0.011
Dissolved P (mg/l)	0.000	
Chl a (µg/l)	0.76	
TKN (mg/l)	0.620	0.530
NO_4+NO_3-N (mg/l)	0.645	0.016
NH_3-N (mg/l)	0.072	0.033
Total N (mg/l)	1.265	0.546
Lab Cond. (µS/cm)	236	237
Lab pH	8.8	8.78
Alkal (mg/l $CaCO_3$)	108	109
'otal Susp Sol (mg/l)	0	0
Calcium (mg/l)	20.4	



Notes:

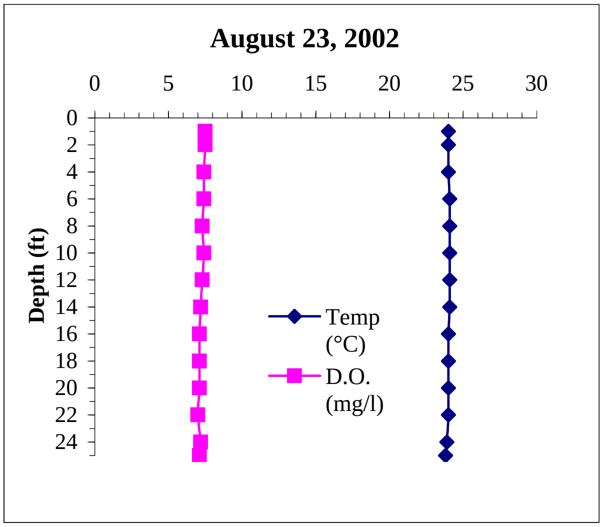
Little Hills Lake

Date: **08-23-02**
Time: 13:43
Weather: misting 65
Ent: BGN **Verf:**

Max Depth (ft): 26.0
LHLS Depth (ft): 3.0
Depth (ft): 23.0
Secchi Depth (ft): 7.8

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	24.0	7.5	9.0	237
2.0	24.0	7.5	9.1	238
4.0	24.0	7.4	9.1	237
6.0	24.1	7.4	9.3	237
8.0	24.1	7.3	9.3	238
10.0	24.1	7.4	9.2	238
12.0	24.1	7.3	9.1	238
14.0	24.1	7.2	9.0	238
16.0	24.0	7.1	9.0	239
18.0	24.0	7.1	8.9	238
20.0	24.0	7.1	8.9	238
22.0	24.0	7.0	8.9	238
24.0	23.9	7.2	8.9	238
25.0	23.8	7.1	8.8	238

Parameter	LHLS	LHLB
Total P (mg/l)	0.016	0.019
Dissolved P (mg/l)		
Chl a (µg/l)	4.27	
TKN (mg/l)		
NO_4+NO_3-N (mg/l)		
NH_3-N (mg/l)		
Total N (mg/l)		
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
Total Susp Sol (mg/l)	4	4
Calcium (mg/l)		



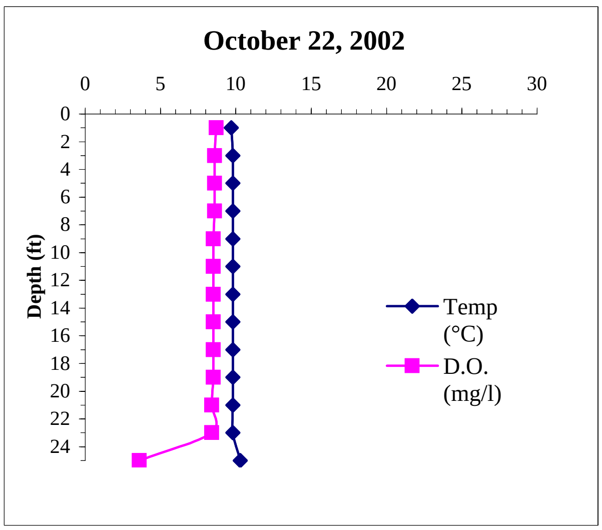
Notes:

Little Hills Lake

Date: **10-22-02** **Max Depth (ft):** 26.1
Time: 13:45 **LHLS Depth (ft):** 3.0
Weather: Overcast, 40, Breezy **Depth (ft):** 23.0
Ent: tsn **Verf:** **Secchi Depth (ft):** 16.1

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	9.7	8.7	8.8	244
3.0	9.8	8.6	9.0	244
5.0	9.8	8.6	9.0	244
7.0	9.8	8.6	9.0	244
9.0	9.8	8.5	9.0	244
11.0	9.8	8.5	9.0	244
13.0	9.8	8.5	8.9	244
15.0	9.8	8.5	8.9	244
17.0	9.8	8.5	8.8	244
19.0	9.8	8.5	8.8	244
21.0	9.8	8.4	8.8	244
23.0	9.8	8.4	8.8	244
25.0	10.3	3.6	7.2	302

Parameter	LHLS	LHLB
Total P (mg/l)	0.007	0.007
Dissolved P (mg/l)		
Chl a (µg/l)	2.38	
TKN (mg/l)		
NO_4+NO_3-N (mg/l)		
NH_3-N (mg/l)		
Total N (mg/l)		
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
Total Susp Sol (mg/l)	2	0
Calcium (mg/l)		



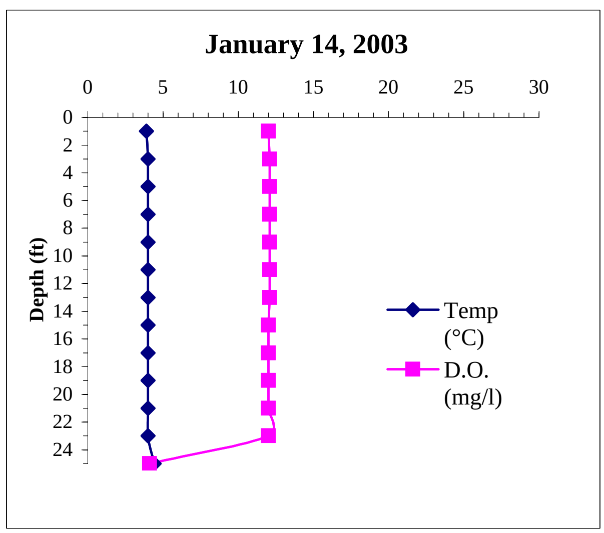
Notes: Data at 25.0 is a probable bottom reading

Little Hills Lake

Date:	**01-14-03**	**Max Depth (ft):**	26.7
Time:	10:30	**LHLS Depth (ft):**	3.0
Weather:	7F, Sunny, Breezy	**Depth (ft):**	23.0
Ent:	TSN **Verf:**	**Secchi Depth (ft):**	23.8

Depth (ft)	Temp (°C)	D.O. (mg/l)	pH	Sp. Cond (µS/cm)
1.0	3.9	12.0	8.5	258
3.0	4.0	12.1	8.6	258
5.0	4.0	12.1	8.6	257
7.0	4.0	12.1	8.6	257
9.0	4.0	12.1	8.6	258
11.0	4.0	12.1	8.6	258
13.0	4.0	12.1	8.6	258
15.0	4.0	12.0	8.6	257
17.0	4.0	12.0	8.6	258
19.0	4.0	12.0	8.6	257
21.0	4.0	12.0	8.6	258
23.0	4.0	12.0	8.6	257
25.0	4.4	4.1	7.0	321

Parameter	LHLS	LHLB
Total P (mg/l)	0.010	0.012
Dissolved P (mg/l)		
Chl a (µg/l)		
TKN (mg/l)	0.460	0.430
NO_4+NO_3-N (mg/l)	0.036	0.035
NH_3-N (mg/l)	0.117	0.096
Total N (mg/l)	0.496	0.465
Lab Cond. (µS/cm)		
Lab pH		
Alkal (mg/l $CaCO_3$)		
Total Susp Sol (mg/l)	0	0
Calcium (mg/l)		



Notes: Ice thickness = 0.55'

B

APPENDIX B

Comprehensive Aquatic Vegetation Survey Data

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover
1	1	sandy	eutgr	1		Euthamia graminifolia	Flat-top goldenrod	1
1	1	sandy	cxcom	1		Carex comosa	Bristly sedge, bottle brush sedge	1
1	1	sandy	bidbe	1		Bidens beckii	Water marigold	1
1	1	sandy	euppe	1		Eupatorium perfoliatum	Common boneset	1
1	1	sandy	sciac	5		Scirpus acutus	Hardstem bulrush	2
1	1	sandy	elosp	5		Elodea sp	Waterweeds	2
1	1	sandy	potpus	1		Potamogeton pusillus	Small pondweed	1
1	2	sandy	sciac	10		Scirpus acutus	Hardstem bulrush	2
1	2	sand	potpus	60		Potamogeton pusillus	Small pondweed	4
1	3	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1
1	3	silty	sciac	30		Scirpus acutus	Hardstem bulrush	3
1	3	silty	chasp	1		Chara sp.	Muskgrasses, stoneworts	1
1	3	silty	potpus	80		Potamogeton pusillus	Small pondweed	5
1	4	silty marl	potil	10	99	Potamogeton illinoensis	Illinois pondweed	2
2	1	sandy	potgr	1	99	Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1
2	2	sandy	chasp	60		Chara sp.	Muskgrasses, stoneworts	4
2	3	mucky sand	chasp	80		Chara sp.	Muskgrasses, stoneworts	5
2	4	silty	potil	1		Potamogeton illinoensis	Illinois pondweed	1
2	4	silty	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
2	4	silty	chasp	70		Chara sp.	Muskgrasses, stoneworts	4
3	1	sandy	calca	10		Calamagrostis canadensis	Blue-joint grass	2
3	1	sandy	polam	25	99	Polygonum amphibium	Water smartweed, water knotweed	3
3	1	sandy	cxcom	30		Carex comosa	Bristly sedge, bottle brush sedge	3
3	2	sandy	polam	1		Polygonum amphibium	Water smartweed, water knotweed	1
3	3	silty	najfl	20		Najas flexilis	Slender naiad, bushy pondweed	2
3	3	silty	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
3	3	silty	potil	10		Potamogeton illinoensis	Illinois pondweed	2
3	3	silty	chasp	60		Chara sp.	Muskgrasses, stoneworts	4
3	4	silty	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
3	4	silty	potil	5		Potamogeton illinoensis	Illinois pondweed	2
3	4	silty	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
4	1	mucky sand	irive	1		Iris versicolor	Wild blueflag	1
4	1	mucky sand	polam	10		Polygonum amphibium	Water smartweed, water knotweed	2
4	1	mucky sand	sciva	5		Scirpus validus	Softstem bulrush	2
4	1	mucky sand	cxcom	5		Carex comosa	Bristly sedge, bottle brush sedge	2
4	2	mucky sand	polam	10		Polygonum amphibium	Water smartweed, water knotweed	2
4	2	mucky sand	eleac	10		Eleocharis acicularis	Needle spikerush, hairgrass	2
4	2	mucky sand	nymod	30		Nymphaea odorata	White water lily, fragrant water lily	3
4	2	mucky sand	potno	40		Potamogeton nodosus	Long-leaf pondweed	3
4	3	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1
4	3	silty	potil	20		Potamogeton illinoensis	Illinois pondweed	2
4	3	silty	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
4	3	silty	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
4	3	silty	potpus	40		Potamogeton pusillus	Small pondweed	3
4	4	silty	potil	30	99	Potamogeton illinoensis	Illinois pondweed	3
5	1	sandy	noveg			NO VEG	NO VEG	0
5	2	sandy	potpus	10		Potamogeton pusillus	Small pondweed	2
5	2	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
5	3	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1
5	3	silty	potil	5		Potamogeton illinoensis	Illinois pondweed	2
5	3	silty	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
5	3	silty	chasp	30		Chara sp.	Muskgrasses, stoneworts	3
5	4	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1
5	4	silty	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1
5	4	silty	potil	10	99	Potamogeton illinoensis	Illinois pondweed	2
6	1	sandy	cxcom	5		Carex comosa	Bristly sedge, bottle brush sedge	2
6	1	sandy	junsp	30		Juncus sp	Rushes	3
6	1	sandy	sciam	30		Scirpus americanus	Three-square, chairmaker's rush	3
6	2	rocky sand	sciam	10		Scirpus americanus	Three-square, chairmaker's rush	2
6	3	rocky sand	chasp	5		Chara sp.	Muskgrasses, stoneworts	2
6	4	silty	potil	5	99	Potamogeton illinoensis	Illinois pondweed	2
7	1	rocky	scisp	1		Scirpus sp	Bulrushes	1
7	2	rocky	noveg			NO VEG	NO VEG	0
7	3	silty sand	potgr	20		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
7	3	silty sand	chasp	50		Chara sp.	Muskgrasses, stoneworts	4
7	4	silty	chasp	60		Chara sp.	Muskgrasses, stoneworts	4
8	1	sandy	noveg			NO VEG	NO VEG	0
8	2	sandy	noveg			NO VEG	NO VEG	0

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover
8	3	sandy	potil	5		Potamogeton illinoensis	Illinois pondweed	2
8	4	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1
8	4	silty	potil	5		Potamogeton illinoensis	Illinois pondweed	2
8	4	silty	chasp	30		Chara sp.	Muskgrasses, stoneworts	3
9	1	sandy	noveg			NO VEG	NO VEG	0
9	2	sandy	noveg			NO VEG	NO VEG	0
9	3	sandy	potgr	20		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
9	3	sandy	chasp	50		Chara sp.	Muskgrasses, stoneworts	4
9	4	silty	potri	5		Potamogeton richardsonii	Clasping-leaf pondweed	2
9	4	silty	chasp	80	22-23	Chara sp.	Muskgrasses, stoneworts	5
10	1	sandy w/cobble	noveg			NO VEG	NO VEG	0
10	2	sandy w/cobble	potil	1		Potamogeton illinoensis	Illinois pondweed	1
10	3	sandy silt	potgr	20		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
10	3	sandy silt	potil	25		Potamogeton illinoensis	Illinois pondweed	3
10	3	sandy silt	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
10	4	silty	potil	25		Potamogeton illinoensis	Illinois pondweed	3
10	4	silty	chasp	30		Chara sp.	Muskgrasses, stoneworts	3
11	1	sandy	salsp	1		Salix sp	Willows	1
11	1	sandy	bidbe	1		Bidens beckii	Water marigold	1
11	1	sandy	euppe	1		Eupatorium perfoliatum	Common boneset	1
11	1	sandy	polca	1		Polygonum careyi	Carey's heartsease	1
11	1	sandy	eleac	5		Eleocharis acicularis	Needle spikerush, hairgrass	2
11	1	sandy	cxcom	40		Carex comosa	Bristly sedge, bottle brush sedge	3
11	2	sandy	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1
11	3	sandy	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1
11	3	sandy	potgr	20		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
11	3	sandy	chasp	30		Chara sp.	Muskgrasses, stoneworts	3
11	4	silty	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2
11	4	silty	potri	40		Potamogeton richardsonii	Clasping-leaf pondweed	3
11	4	silty	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
12	1	sandy	noveg			NO VEG	NO VEG	0
12	2	sandy w/detritus	potno	10		Potamogeton nodosus	Long-leaf pondweed	2
12	2	sandy w/detritus	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
12	2	sandy w/detritus	chasp	10		Chara sp.	Muskgrasses, stoneworts	2
12	3	silty	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
12	3	silty	potil	20		Potamogeton illinoensis	Illinois pondweed	2
12	3	silty	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2
12	3	silty	chasp	80		Chara sp.	Muskgrasses, stoneworts	5
12	4	silty	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
13	1	sandy	eleac	1		Eleocharis acicularis	Needle spikerush, hairgrass	1
13	1	sandy	potpe	20		Potamogeton pectinatus	Sago pondweed	2
13	2	sandy	zosdu	1		Zosterella dubia	Water stargrass	1
13	2	sandy	potpe	10		Potamogeton pectinatus	Sago pondweed	2
13	2	sandy	potil	25		Potamogeton illinoensis	Illinois pondweed	3
13	3	silty	najfl	1		Najas flexilis	Slender naiad, bushy pondweed	1
13	3	silty	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
13	3	silty	chasp	50		Chara sp.	Muskgrasses, stoneworts	4
13	4	silty	chasp	60		Chara sp.	Muskgrasses, stoneworts	4
14	1	sandy	cxcom	10		Carex comosa	Bristly sedge, bottle brush sedge	2
14	2	sandy	noveg			NO VEG	NO VEG	0
14	3	sandy silt	potgr	1		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	1
14	3	sandy silt	chasp	10		Chara sp.	Muskgrasses, stoneworts	2
14	3	sandy silt	potil	5		Potamogeton illinoensis	Illinois pondweed	2
14	4	silty	potri	20	99	Potamogeton richardsonii	Clasping-leaf pondweed	2
14	4	silty	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
15	1	rocky sand	irive	1		Iris versicolor	Wild blueflag	1
15	1	rocky sand	junef	15		Juncus effusus	Soft stemmed rush	2
15	1	rocky sand	sciac	20		Scirpus acutus	Hardstem bulrush	2
15	2	gravelly sand	noveg			NO VEG	NO VEG	0
15	3	sandy gravel	chasp	5		Chara sp.	Muskgrasses, stoneworts	2
15	4	silty	potri	1		Potamogeton richardsonii	Clasping-leaf pondweed	1
15	4	silty	chasp	60	99	Chara sp.	Muskgrasses, stoneworts	4
16	1	sandy	polam	1		Polygonum amphibium	Water smartweed, water knotweed	1
16	1	sandy	potno	10		Potamogeton nodosus	Long-leaf pondweed	2
16	1	sandy	irive	10		Iris versicolor	Wild blueflag	2
16	1	sandy	cxcom	10		Carex comosa	Bristly sedge, bottle brush sedge	2
16	1	sandy	dular	5		Dulichium arundinaceum	Three-way sedge	2
16	1	sandy	junsp	40		Juncus sp	Rushes	3

Transect	Depth Range	Substrate	Acronym	Aerial Cover	Max Veg Z	Species	Common Name	Daubenmire Cover
16	2	sandy	potno	1		Potamogeton nodosus	Long-leaf pondweed	1
16	2	sandy	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
16	3	sandy silt	chasp	10		Chara sp.	Muskgrasses, stoneworts	2
16	3	sandy silt	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2
16	3	sandy silt	potno	40		Potamogeton nodosus	Long-leaf pondweed	3
16	3	sandy silt	potpus	60		Potamogeton pusillus	Small pondweed	4
16	4	silty	potil	1	99	Potamogeton illinoensis	Illinois pondweed	1
16	4	silty	potpus	1		Potamogeton pusillus	Small pondweed	1
16	4	silty	najfl	5		Najas flexilis	Slender naiad, bushy pondweed	2
16	4	silty	potgr	5		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
16	4	silty	chasp	80		Chara sp.	Muskgrasses, stoneworts	5
17	1	sand w/cobble	noveg			NO VEG	NO VEG	0
17	2	sandy gravel	najfl	10		Najas flexilis	Slender naiad, bushy pondweed	2
17	2	sandy gravel	potgr	10		Potamogeton gramineus	Variable pondweed, grass-leaved pondweed	2
17	2	sandy gravel	chasp	40		Chara sp.	Muskgrasses, stoneworts	3
17	3	mucky gravel	chasp	10		Chara sp.	Muskgrasses, stoneworts	2
17	4	silty	potri	30		Potamogeton richardsonii	Clasping-leaf pondweed	3
17	4	silty	chasp	70		Chara sp.	Muskgrasses, stoneworts	4
18	1	sandy	noveg			NO VEG	NO VEG	0
18	2	sandy	noveg			NO VEG	NO VEG	0

C

APPENDIX C

Lake Term Glossary

Algae	Microscopic plants that use sunlight as an energy source. Algae can be unicellular (Diatoms), filamentous (many green or blue-green species), colonies in a gelatinous mass (many blue-greens) or more complicated colonies like *Chara sp.*
Anthropogenic	An occurrence caused or produced by the action of humans.
Anoxic	Devoid of dissolved oxygen.
Benthic	Pertaining to a river bed or lake floor
Contact Herbicide	A plant specific pesticide which causes extensive cellular damage exclusively to the areas of the target which come in contact with the herbicide (Affects contacted area only)
Ecosystem	The interaction of a community of organisms with each other and with the characteristics that make up their environment (Aquatic ecosystem, Northern Boreal Forest)
Emergent	An aquatic plant having most of its vegetative parts above the water surface (Cattail, Common Arrowhead)
Epilimnion	The upper most layer of water within a stratified lake. During the summer, this layer holds the warmest water and during the winter it holds the coldest water. This layer continuously circulates.
Exotic	A non-native organism that has been introduced into an area (Purple Loosestrife, Eurasian Water Milfoil)
Floating-leaf	Plants rooted in the sediment or free-floating with leaves lying flat on the water surface (Duckweed, White Water Lilly)
Hypolimnion	The deepest layer of water within a stratified lake. In the winter it holds the warmest water and in the summer it holds the coldest water.
Interspecific	Between two or more distinct species.
Invasive	An organism which readily colonizes a disturbed area and tends to take it over by out-competing other plants. These can be native (Cattail) or exotic species (Purple Loosestrife).
Limiting Nutrient	The nutrient, usually phosphorus, which is in shortest supply and controls the growth rate of algae and macrophytes.
Littoral Zone	Pertaining to the shallow water zone of a lake that has sufficient light penetration to support macrophytes.
Macrophyte	A multicelled plant, usually with roots, stems, and leaves. A vascular plant (Cattail, Eurasian water-milfoil, pondweeds)
Median Value	A value in a set which has an equal number of observations above it and below it
Metalimnion	This is the layer between the epilimnion and the Hypolimnion that has the greatest range of temperature change with depth. The metalimnion contains the thermocline, but is not the same thing.
Native	An organism that is naturally occurring to an area (White Water Lilly, Northern Water-milfoil)

Nitrogen to Phosphorus Ratio	Results of this ratio indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 16:1, the lake is considered phosphorus limited; if it is less than 16:1, it is considered nitrogen limited. The key ratio of 16:1 is related to the normal nitrogen to phosphorus ration found in most algae.
Non-Point Source Pollution	A source of pollution that comes from an indirect point of discharge (Overland flow)
Periphyton	A community of algae, and fragments of algae, which are attached to submerged objects such as plants and stones
Photosynthesis	The process in which chlorophyll producing organisms convert CO2 and water into sugar and oxygen, using sunlight as an energy source
Phytoplankton	Free-floating (not attached) algae.
Point Source Pollution	A source of pollution that comes from a direct point of discharge (Drain Tile Outfall)
Senesce	To complete a life cycle; to die off
Shoreland Buffer Zone	A buffer of native plants and habitat that occurs between the lake and developed property. The buffer zone serves to filter sediment and nutrients that wash off of a developed area before they reach the lake.
Species Diversity	An index that relates the number of species to their relative abundances. A community with many species with similar numbers (abundances) is more diverse than a community with the same number of species, but only a few of the species dominate the area with their abundances.
Species Richness	The total number of species occurring in a community
Submergent	An aquatic plant growing entirely under the water surface (Coontail, Large-leaf pondweed, Eurasian water-milfoil)
Systematic Herbicide	A plant specific pesticide which causes systematic cellular damage after coming in contact with the target. These herbicides spread through the entire plant.
Water Residence Time	The average amount of time water resides in a lake. Usually measured in years or days. A lake with a long residence time would have a slow flushing rate.
Zooplankton	Microscopic animals that are free-floating with in a water body. Many prey on algae and are an important food source for young fish.

D

APPENDIX D

Education Component Material

Little Hills Lake Management District

Timothy A. Hoyman, CLM

NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

Presentation Outline

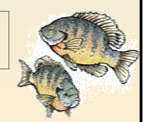
Comprehensive Lake Management Plan Development Project
- Goals and Objectives
- Components
- Timeline

NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

Current Project

Project Goals and Objectives

Why should we develop a lake management plan?



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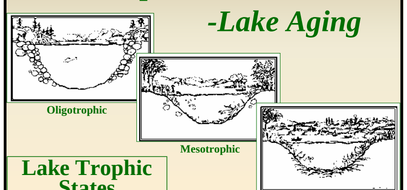
Goals and Objectives

Eutrophication -Lake Aging



Lake Trophic States

NES Ecological Services
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Goals and Objectives

Protection of Little Hills Lake

- Sensitive Area Designation
- Exotic Species Education
  - Signs
  - Literature Handouts
- Motor Boat Limitations
  - Slow-no-wake Areas
  - Restricted Hours
- Baseline & Long-term Monitoring
- New Property Owner Education
- Watershed Management

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Goals and Objectives

Enhancement of Little Hills Lake

- Habitat
- Shoreland Restoration
- Watershed Management

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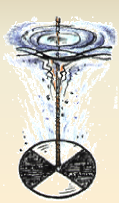
Current Project

Project Components

- Public Participation
- Watershed Assessment
- Water Quality
- Aquatic Vegetation Survey



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Current Project

Project Timeline

NES Ecological Services
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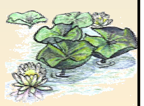
Current Project

Your Participation is Important to the Success of this Project



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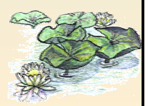
Current Project

- Concerns
- Observations
- Questions



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Thank You

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UW Extension

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NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

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NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

Lake management under way in Waushara

BY PATRICIA WOLFF
OF THE NORTHWESTERN

BERLIN – A little purple loosestrife here. A little Eurasian water-milfoil there. Some zebra mussels over here.

The spread of non-native, invasive plants and animal species are a threat to lakes all over Wisconsin, said Tim Hoyman, an aquatic ecologist with NES Ecological Services.

Many lake districts in the state are waging war against those threats.

Hoyman's Green Bay company is working with four lake districts in Waushara County to develop lake management plans aimed at correcting problems that are already there and avoiding new ones.

Managing a lake district is a lot like managing your health or your pocketbook, Hoyman said.

With all three, an ounce of prevention is worth a pound of cure.

"When it comes to health and finances, the person who starts early does better than the person who waits until he's 55. It's the same with lakes. It's better to keep them healthy," Hoyman said.

That was the idea that convinced the boards of directors of the Alpine Lake Protection and Rehabilitation District, the Little Hills Management District, the Marl Lake District and the Big Hills Lake Protection and Rehabilitation District to go after state grants to help with their planning.

The DNR's Lake Management Grant program pays up to 75 percent of the cost of planning projects. The average lake management plan costs roughly $10,000 and takes many months to complete, Hoyman said.

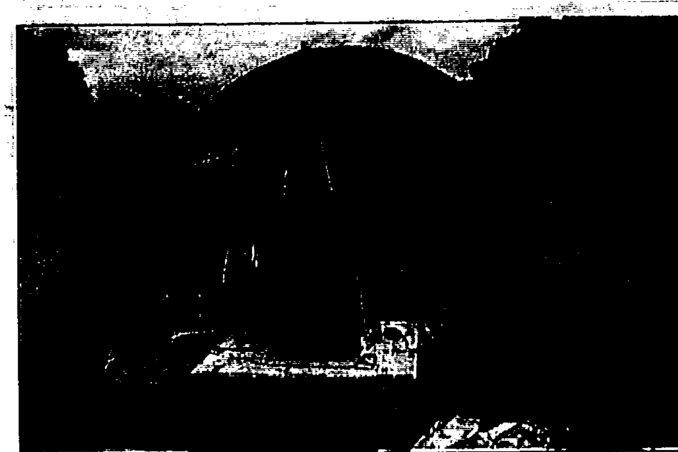
The people in the Marl-Lake District in the town of Deerfield got into planning to update a 1995 plant study.

"We wanted to see if we have Eurasian water-milfoil. So far, we have none. We have a healthy lake," Barry Wilson said.

He'd like to keep it that way. NES Ecological Services will help, Wilson said.

Wilson has been spending time on the 40-acre Marl Lake six miles west of Wautoma since 1946. Thirty-three prop-

LAKES, PAGE C2 ▶



SPECIAL TO THE NORTHWESTERN

JAMES HAVEL, an ecologist with NES Ecological Services of Green Bay, records aquatic plant survey data at Alpine Lake in Waushara County.

Lakes: DNR will prepare list of recommendations for lake districts once studies are complete

FROM PAGE C1

erty owners have homes on the lake, popular for swimming, boating and fishing. Fishermen and women ply the waters for bass, northern, bluegills, crappie and perch, Wilson said.

Wilson, who is retired, said he enjoys watching the wildlife that live around the lake. "Turkeys come down to drink. We see blue herons, ducks, everything you can think of," he said.

Each of the four lakes being studied is different and each requires a specific management plan to protect and improve it, Hoyman said.

"Lake Alpine has historically had aquatic plant problems, both in the form of rooted aquatic plants and algae," Hoyman said.

"Marl Lake and Little Hills Lake are not dealing with specific problems, but Big Hills Lake does support a healthy population and potentially problematic plant, Eurasian water-milfoil," he said.

Eurasian water-milfoil is a non-native plant that inhabits many of Wisconsin's lakes and occurs in lakes in most counties in the state. As of 2001, the plant had shown up in 15 of Waushara County's 100 lakes.

Eurasian water-milfoil is a problem because it grows earlier in the spring than other native plants, creating a canopy that blocks light from reaching other plants. At its worst, it can nearly take over a lake, causing navigation and swimming problems and upsetting the ecosystem to harm fish and other aquatic organisms, Hoyman said.

Once NES Ecological Services and the DNR have finished studying the four lakes, they will prepare a list of recommendations for the lake districts to implement.

In addition to the invasion of non-native species, people in lake districts are concerned about sediments, nutrients and other pollutants from watersheds getting into lakes. Development of homes around lakes contributes to the problem when property owners remove native vegetation and put in turf grass. This destroys habitat around the lake, Hoyman said.

"The best way for a lake to stay healthy is to let it function as a natural ecosystem," Hoyman said.

Patricia Wolff: (920) 361-0770 or pwolff@smgpo.gannett.com

Little Hills Lake Comprehensive Management Plan Project Update

Little Hills Lake Management Dist. Aug. 2002

The Little Hills Lake project is moving along as planned. Many of the tasks that we discussed during the Kick-off meeting have been completed and the associated data awaits analysis this fall. Three lake water quality samples have been collected including one during the spring and two during this summer. Three additional samples will be collected including an August sample, and one during the fall and winter. The sample analyses that we have received back from the State Lab of Hygiene do not indicate anything out of the ordinary; however, the water clarity has been good considering the wet and hot weather the lake has received over the past months. Many of the lakes in the area are experiencing algal blooms, however, Little Hills Lake is still exhibiting good water clarity as indicated by the 15.8-foot Secchi disk depth that was recorded the fourth week of July.

A very diverse area containing floating-leaf, emergent, submergent plant species, located on the northwest shore of the bay near the boat landing.

The aquatic plant survey has also been completed with a long day's worth of work on July 18th. The inventory went well and has lead us to believe that Little Hills Lake has a relatively diverse plant community. In fact, we found two plants that we have not found in other lakes. Our data analyses this fall will tell us more.

We have also received a great deal of data concerning the Little Hills Lake watershed through the much-appreciated cooperation of Waushara County and the East Central Regional Planning Commission. The data they supplied will help us determine the affects the watershed has on the lake and will be critical for the development of the lake management plan.

The importance of your participation was stressed during our discussions at the Kick-off meeting held in May. To date, we have not received any comments or questions from any of the lake residents (with the exception of your commissioners). Please remember that your comments are important and greatly appreciated, so please do not hesitate to provide comments or ask questions on the form that has been provided.

For more information, please contact Tim Hoyman, NES Ecological Services. t.hoyman@releeinc.com
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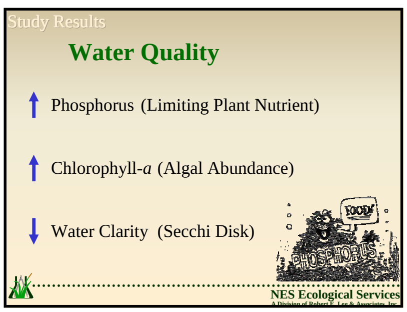
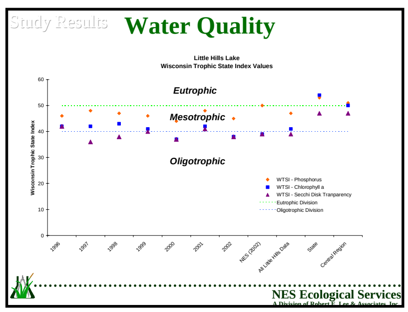
www.releeinc.com/NES

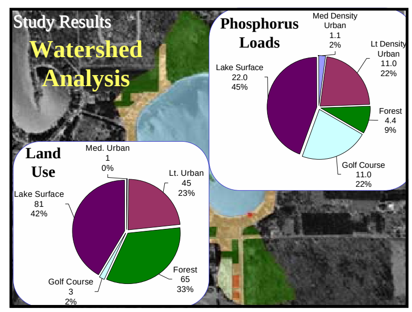

Little Hills Lake
Management District
Little Hills Lake
Comprehensive Lake
Management Plan
September 13, 2003
Timothy A. Hoyman, CLM
NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.

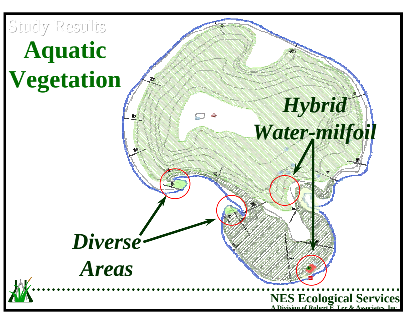

Presentation Outline
• Project Objectives
• Study Results
• Management Recommendations
NES Ecological Services

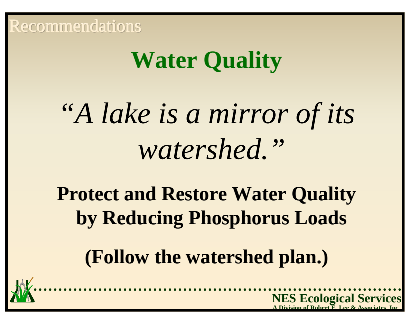

Project Objectives
• Data Collection and Analysis
– Watershed
– Aquatic Plants
– Water Quality
• Develop Comprehensive Management Plan
NES Ecological Services

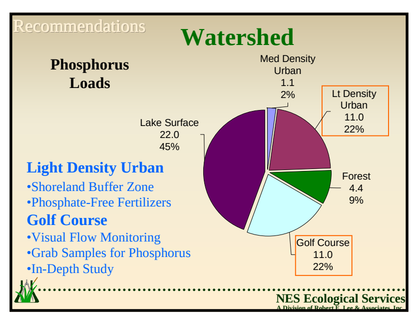

Study Results
Water Quality
Phosphorus (Limiting Plant Nutrient)
Chlorophyll-a (Algal Abundance)
Water Clarity (Secchi Disk)
FOOD!
PHOSPHORUS
NES Ecological Services


Study Results
Water Quality
Little Hills Lake
Wisconsin Trophic State Index Values
Wisconsin Trophic State Index
Eutrophic
Mesotrophic
Oligotrophic
WTSI - Phosphorus
WTSI - Chlorophyll a
WTSI - Secchi Disk Tranparency
Eutrophic Division
Oligotrophic Division
0
10
20
30
40
50
60
1996
1997
1998
1999
2000
2001
2002
NES (2002)
All Little Hills Data
State
Central Region
NES Ecological Services


Study Results
Watershed Analysis
Phosphorus Loads
Med Density Urban 1.1 2%
Lt Density Urban 11.0 22%
Lake Surface 22.0 45%
Forest 4.4 9%
Golf Course 11.0 22%
Land Use
Med. Urban 1 0%
Lt. Urban 45 23%
Lake Surface 81 42%
Forest 65 33%
Golf Course 3 2%


Study Results
Aquatic Vegetation
Hybrid Water-milfoil
Diverse Areas
NES Ecological Services


Recommendations
Water Quality
"A lake is a mirror of its watershed."
Protect and Restore Water Quality by Reducing Phosphorus Loads
(Follow the watershed plan.)
NES Ecological Services

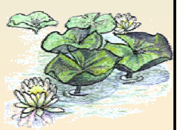

Recommendations
Watershed
Phosphorus Loads
Med Density Urban 1.1 2%
Lt Density Urban 11.0 22%
Lake Surface 22.0 45%
Forest 4.4 9%
Golf Course 11.0 22%
Light Density Urban
•Shoreland Buffer Zone
•Phosphate-Free Fertilizers
Golf Course
•Visual Flow Monitoring
•Grab Samples for Phosphorus
•In-Depth Study
NES Ecological Services

Aquatic Vegetation

Two Primary Concerns:

Hybrid Water-milfoil

Native Emergent & Floating-leaf Species



Aquatic Vegetation

Prevention - *Education*

Monitoring - *Annual Survey*

Protection & Enhancement

Aquatic Vegetation

Protection & Enhancement

Preserve Diverse Areas

Re-Establishment of Historic Communities

Slow Potential Spread of Exotic Milfoils

Slow-No-Wake

Thank You

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