OSGOOD CONSULTING

Lake and Watershed Planning and Analysis

Deer Lake Management Plan

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February 2004

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CONTENTS

ISSUES & CONCERNS

The Deer Lake Conservancy, in its request for proposals for the present study, indicated they were interested in conducting a more comprehensive lake study, which built upon previous studies. Specifically, there was interest by some board members to consider in-lake management methods such as aquatic plant removal and alum treatment to control nuisance aquatic plants and algae. In addition, the Deer Lake Conservancy was interested in conducting a detailed watershed modeling analysis, conducted as a separate study (JEO 2003), and specific management options for a 'barnyard runoff management system' (also known as Pond 1).

Deer Lake Owners Survey (2002)

A survey of the Deer Lake Owners was conducted in 2002. The survey was distributed to over 300 people and had a response of about 200. The survey asked respondents to 'list in order of priority (1, 2, 3), which of the following are most important:'

- Weeds
- Swimmer's itch
- Algae
- Safety
- Screening of Shoreline & Appearance
- Other

The results, ranked* from greatest to least order of priority, are:

PRIORITY	1	2	3	4	5
Weeds	65	33	28	6	1
Algae	24	46	31	12	5
Swimmer's Itch	22	37	32	8	7
Safety	24	18	19	24	4
Shoreline	7	5	14	10	29

*Ranking order determined by the sum of the first three priorities

The 'other' comments are not reported here.

Weeds, algae and swimmer's itch received the top three priority rankings by half or more of the respondents.

Deer Lake Improvement Association - 2003 Annual Meeting

The Deer Lake Improvement Association annual meeting was held on July 19, 2003. At that meeting, members expressed concerns with:

- Swimmer's itch control
- Fish kills
- High water levels and bank erosion and fallen trees
- Aquatic plant management
- Curlyleaf pondweed
- Copper sulfate treatment for filamentous algae control

Lake Management Concerns

Based on the charge given for this report as well as the input from the Deer Lake homeowners, here is a summary of lake management concerns for Deer Lake:

- Excessive Algae - Algae in the lake (planktonic) and filamentous algae (attached to rooted plants)

- Weeds - Curlyleaf pondweed control, native plant protection, swimming areas, channels to open water and exotic plant prevention

- Swimmer's itch - Control or elimination

- Fish kills - Prevention

- Safety

- Shoreline Appearance

- Water Level Control

The last three categories - safety, shoreline appearance and water level control - are beyond the scope of this study and will not be discussed in this report.

RESULTS

Watershed and Other Phosphorus Inputs

Barr Studies

The Barr studies (Barr 1993, 1995) estimated phosphorus inputs to Deer Lake from the watershed and related sources. These estimates were based on minimal field data and could be subject to error. The results (pounds of phosphorus per year) are as follows:

	1992	1994
Watershed	152	1,388
Septic	88	88
Groundwater	748	647
Atmosphere	405	388
	1,393	2,511

The differences between the two years are the result of 1992 being drier compared to 1994, which was near normal. The Barr studies did not precisely measure or estimate internal phosphorus inputs.

JEO Study

The JEO (2003) study was an analysis and modeling of earlier watershed sampling conducted by the Deer Lake Conservancy. The JEO (2003) study, along with follow-up analysis, found a 51% reduction in watershed total phosphorus loading resulting from the implementation of watershed management practices between 1996 and 2000. Annual phosphorus inputs to Deer Lake from watershed runoff during normal water years were modeled to be:

1996	5,199 pounds TP per year
2000	2,573 pounds TP per year
Reduction	2,626 pounds TP per year (51%)

These watershed inputs, because they are based on field measurement and have been normalized[1], are most appropriate for use in modeling water quality and analyzing Deer Lake management scenarios.

[1] Normalized refers to fitting field data to average rainfall amounts and allows comparisons of management practices between different years.

Additional watershed projects have been implemented or are planned. These projects and their estimated reductions in annual phosphorus inputs to Deer Lake are:

Project	Estimated Annual TP Reduction
Flagstad Farm Prairie (2003)	128 pounds TP per year
Flagstad Farm wetland restoration (2005)	300 pounds TP per year
W1 Pond Treatment (2004)	519 pounds TP per year

Internal Phosphorus Inputs

Sediment samples were collected from six locations in Deer Lake on August 20, 2003 (Figure 1). These samples were analyzed for total inorganic solids, inorganic dry weight, total phosphorus dry weight and percent moisture. In addition, phosphorus dry weight corrected for sample moisture, was calculated as follows:

TP dry weight = (TP wet weight / (% solids/100))

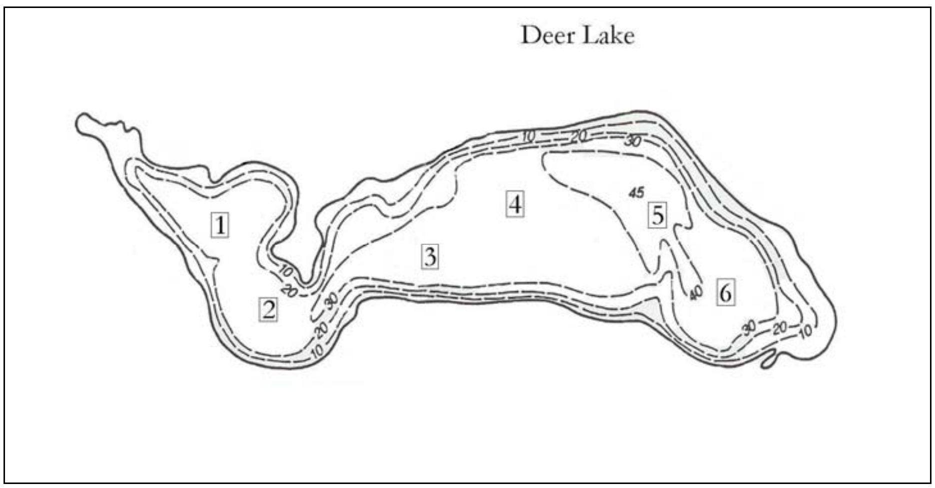


Figure 1. Deer Lake Sediment Sample Locations, August 20, 2003.

Table 1.

DEER LAKE SEDIMENT CONTENT
August 20, 2003

Station #	Depth (ft)	% Moisture	Total Solids (%)	% Inorganic	TP (mg/kg)	Dry Wt. TP (mg/g)
1	23.0	95	5.0	32	550	0.58
2	26.6	95	5.0	36	1000	1.05
3	31.2	96	4.0	35	1100	1.15
4	37.5	96	4.0	32	920	0.96
5	44.7	95	5.0	26	1300	1.37
6	38.6	96	4.0	32	960	1.00
					Average	**1.02**

Internal phosphorus release rate can be estimated using the following equation:

$$\text{Log RR} = 0.8 + 0.76 \log (\text{sediment TP})$$

From Nürnberg (1998)

where RR is the internal release rate ($mg/m^2/d$) and sediment TP is the dry weight TP (mg/g). For Deer Lake, the sediment release rate estimated using this formula, is 6.4 $mgP/ m^2/d$. This rate can be applied to the anoxic sediments in Deer Lake.

Water Quality

The Deer Lake Improvement Association has participated in Wisconsin's Self-Help Lake Monitoring program since 1987 (Secchi disk) and the Expanded Self-Help Lake Monitoring (phosphorus and chlorophyll) since 1991. Water quality, as indicated by phosphorus, chlorophyll and Secchi disk (summer averages), was the best measured in recent years (see Figures 2a-c). There is some indication Deer Lake water quality is improving in the last five years, providing evidence the reductions in watershed phosphorus inputs are having a positive impact.

Measurements of temperature and dissolved oxygen indicate the mid-summer thermocline depth fluctuates between 17 and 20 feet in both the East and West Basin of Deer Lake.

Figure 2a.

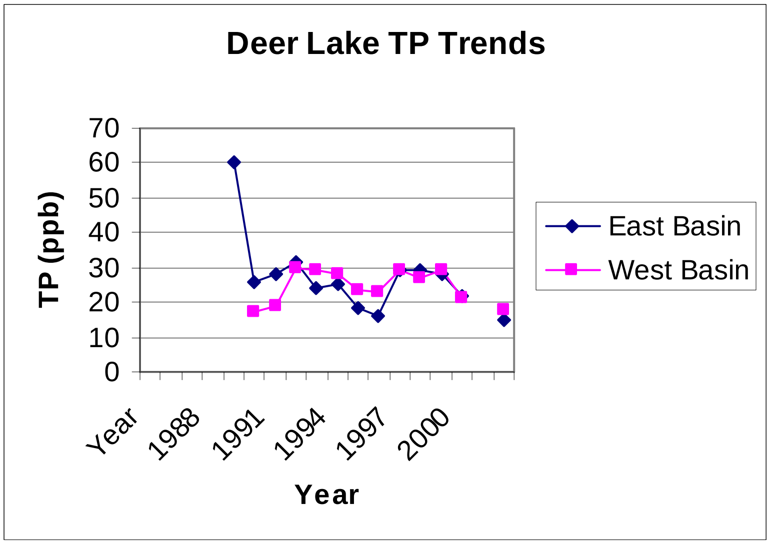


Figure 2b.

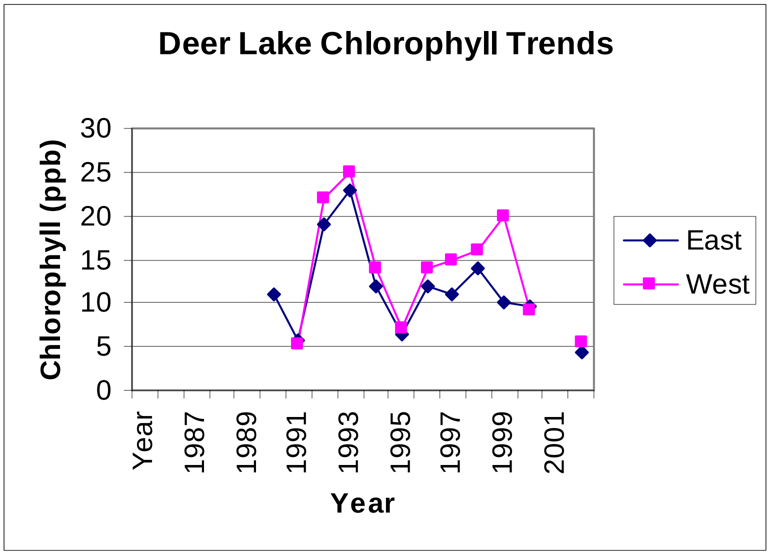
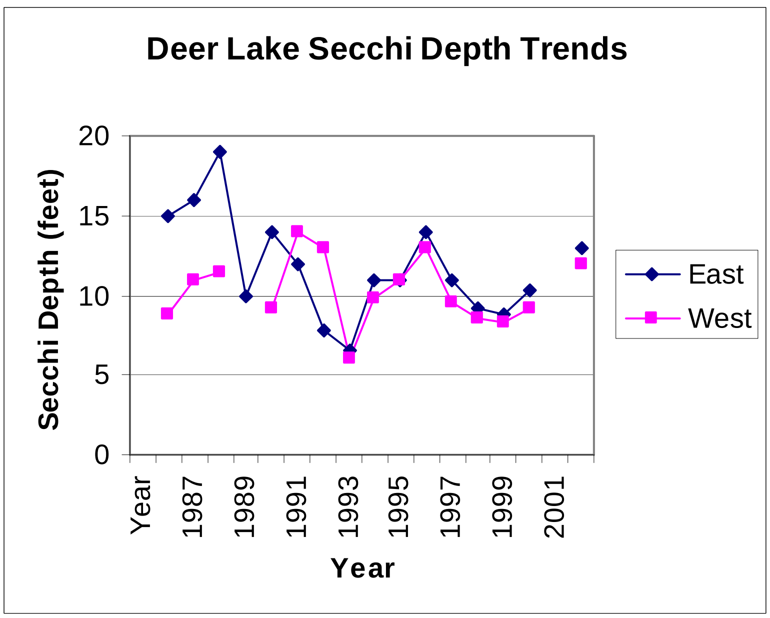


Figure 2c.



Aquatic Plants

Dragonfly Consulting Macrophyte Survey

An aquatic plant survey of Deer Lake was conducted in 2003 as part of this project (report in Appendix A). The plant survey found 17 species of rooted plants, including one exotic species, curlyleaf pondweed. There were also two other plants noted: chara, a type of algae that looks like a rooted plant and filamentous algae, the green slimy growths attached to other plants. Filamentous algae occurred in the greatest percentage of samples in the June survey.

There are three different approaches that can be used to estimate the extent of the curlyleaf pondweed (CWP) infestation in Deer Lake:

Method # 1

CWP found in 41/192 sites (21.4%)
The littoral area is 41% of the lake (Appendix x)
The lake area is 812 acres

CWP extent is 21% x 41% x 812 acres = 71 acres

Method #2

Each sampling point is from a 50 x 100 meter grid (1.235 acres)
CWP was found at 41 points

CWP extent is 41 x 1.235 acres = 51 acres

Method #3

Littoral depth is 6 meters or 20 feet (Appendix x)
Thus, littoral area is 812 - 519 = 293 acres (see below)
CWP found in 41/192 sites (21.4%)

CWP extent is 21.4% x 293 acres = 63 acres

Due to the limitations and imprecision of the sampling methods, no preference can be given to any of these three methods. Thus, the extent of curlyleaf pondweed in Deer Lake in 2003 is between 51 and 71 acres. As a practical matter, control options can be considered for 2004 at the earliest. At that time, the extent of curlyleaf pondweed will likely have changed. To be conservative, the greater acreage, 71 acres, should be used for planning purposes. Because the areal extent of curlyleaf pondweed will likely change from year-to-year, it is prudent to conduct a field inspection as soon as possible prior to future control efforts.

Except for the curlyleaf pondweed, the high diversity of native plants in Deer Lake indicates a healthy condition. The occurrence of filamentous algae, viewed as a nuisance by lakeshore owners, is an indication of a transitional condition between low nutrient/high clarity lake and a high nutrient/low clarity lake. Efforts to decrease the phosphorus levels in Deer Lake (discussed below), will tend to diminish the intensity of filamentous algae growth.

Aquatic Engineering Aquatic Plant Management Activities

A second aquatic plant evaluation is also available for Deer Lake in 2003[2]. Aquatic Engineering, Inc. conducted inspections, performed treatments and prepared an aquatic plant management program on behalf of the Deer Lake Improvement Association.

2003 Aquatic Plant Inspections

Inspections for Eurasian watermilfoil near the lake's two boat launches were conducted on June 5, July 8, August 4 & 29 and September 30. No Eurasian watermilfoil was found in Deer Lake. The entire littoral zone was inspected for filamentous algae on June 18 & 30, July 1, 8, 21 & 28, August 4, 12, 22 & 26 and September 23. Filamentous algae was noted and treated (see below).

2003 Herbicide Treatments

a. Treatments for Eurasian watermilfoil prevention

June 5 - mixture of Cutrine Plus, Reward & Aquathol K to 2 - 50x100' areas near launches
July 8 - Reward to 2 - 50x100' areas near launches

b. Treatments for filamentous algae (using copper sulfate and Cutrine Plus)

June 18	7.0 acres
July 1	12.4 acres
July 8	6.0 acres
July 21	10.5 acres
August 22	5.5 acres
August 26	6.9 acres

There was no indication whether the treatments areas overlapped from date-to-date.

2003 Aquatic Plant Management Program

The report lists two management objectives:

1. Prevent a Eurasian watermilfoil infestation in Deer Lake using aquatic herbicide treatments near boat launches.

2. Maintain recreational and aesthetic values of Deer Lake using aquatic herbicide treatments to alleviate the impacts of nuisance algae blooms.

The 2003 management program occurred in several phases which restate the specific treatments noted above.

[2] 2003 Deer Lake Aquatic Plant Management Technical Report. Aquatic Engineering, Inc. November 17, 2003.

The report stated the Eurasian watermilfoil prevention program successfully prevented the establishment in 2003, although there is not evidence that milfoil was introduced into the lake. The report also noted the frequent filamentous algae treatments were necessary to control nuisances in the near-term and that reducing lake phosphorus will control these nuisances in the long-term. The report also discussed concerns with curlyleaf pondweed and recommended early season herbicide treatments for a period of 3-5 years.

Lake Bathymetry

The bathymetry, or lake basin dimensions, of Deer Lake was calculated for this study. Earlier reports contained references to lake volume and mean depth, however, contours areas were not available. Bottom contour areas were measured from the lake map below (Figure 2). The results are:

Contour (feet)	Area (acres)
0 (Lake surface)	812
10	680
20	519
30	353
40	66
45 (maximum depth)	0

Using these contour measurements, these volumes are calculated:

Contour interval	Volume (acre-feet)
0 - 10 feet	7,450
10 - 20 feet	5,977
20 - 30 feet	4,333
30 - 40 feet	1,905
40 - 45 feet	110
TOTAL VOLUME	19,776

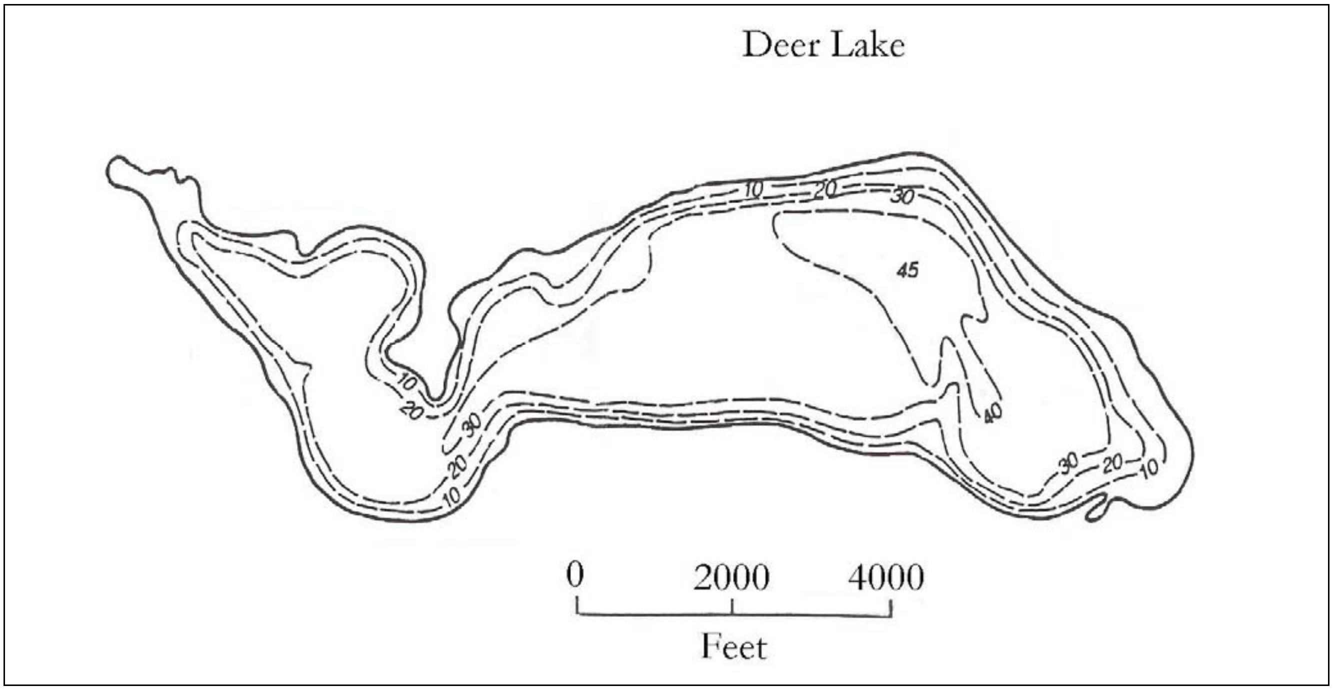


Figure 2. Deer Lake Bathymetric Map (from Barr 1993).

ANALYSIS

Water Quality Modeling

External Inputs

External inputs of water and phosphorus to Deer Lake must be determined to use in the lake phosphorus model (see below). For purposes of developing modeling and management scenarios, these inputs are derived from normal (average) precipitation years. Water enters Deer Lake from precipitation directly on the lake's surface as well as runoff from its tributary watershed, the combination of all subwatersheds. These amounts are:

Lake Surface Area	=	812 acres
Lake Volume	=	19,776 acre-feet
Mean Depth	=	24.4 feet
Watershed Area	=	4,607 acres
Average Annual Precipitation	=	27 inches per year

<u>Annual Water Inputs</u>

Precipitation on lake	=	2 ¼ feet x 812 acres	=	1,827 acre-feet
Runoff	=	2 ¼ feet x 4,607 acres x 0.25*	=	2,591 acre-feet
TOTAL			=	4,418 acre-feet

* Runoff coefficient

<u>Annual Phosphorus Inputs</u>

Precipitation on lake	=	(average reported in Barr 1995)	=	396 pounds
Runoff	=	(from Barr 1995; JEO 2003)	=	2,996 pounds
TOTAL			=	3,392 pounds

I have made judgments regarding different methods of estimating water and phosphorus inputs to Deer Lake. For example, the Barr (1995) study included terms for phosphorus inputs from septic systems and groundwater. Here, I included the septic inputs from the Barr report with the runoff estimate from the JEO report, but excluded the groundwater from the Barr report because it was estimated as a residual (difference), and could be 'double counted.' Finally, phosphorus inputs from the direct drainage around Deer Lake have been estimated and added.

Internal Phosphorus Inputs

Seasonal internal phosphorus release can be estimates using the average internal total phosphorus release rate from Deer Lake sediments and applying that over the anaerobic sediment surface. These values are:

Internal Total Phosphorus Release Rate	=	6.4 $mgP/m^2/d$
Lake Area Below the Thermocline (20 feet contour)	=	519 acres
Number of Days of Anoxia (July & August)	=	62 days

<u>Seasonal Internal P Input</u>

Estimated using the values presented above	=	1,833 pounds

Phosphorus Model

A phosphorus model has been developed that is useful for evaluating the impacts of changes in internal and external phosphorus inputs to Deer Lake (Nürnberg and LaZerte 2001). This model predicts lake phosphorus concentrations (summer surface average) based on inputs of annual water and phosphorus loads plus internal phosphorus loads. The model is:

$$((L_{ext} + L_{int}) / q_s) * (1 - R_p)$$

(Equation 7 in Nürnberg and LaZerte 2001)

where L_{ext} is the annual external phosphorus load normalized to lake surface area (mgP/m^2 yr), L_{int} is the internal phosphorus load normalized to lake surface area (mgP/m^2 yr), q_s is the water load (m/yr) and R_p is the phosphorus retention coefficient.

Using the external and internal inputs presented above, the model predicts a phosphorus concentration in Deer Lake of 24 ppb, which agrees with contemporary surface phosphorus measurements (see Figure 2a).

This model can be used to evaluate the impacts of internal and external phosphorus reductions to Deer Lake.

Water Quality

It appears Deer Lake water quality, as indicated by TP, CHL and SD (see figures 2a-c) has improved in the past several years. Furthermore, the modeling analysis presented above suggests this is the limit of the expected lake quality improvements. This is good news, as it provides evidence the watershed improvements implemented recently have resulted in real improvements in lake quality. However, further reductions in lake TP will be necessary to control filamentous algae that is observed growing in association with rooted plants.

Aquatic Plants

There are three identified problem areas associated with Deer Lake's aquatic plants:

- Curlyleaf pondweed infestation
- Dense plant growth at the lake's northwest end (near the public boat launch)
- Filamentous algae growing to rooted plants

These problems are counterbalanced by abundant native plants, which are indicative of and contribute to a healthy lake ecosystem. The management challenge for Deer Lake will be to control the aquatic plant nuisances without unduly damaging the native plants in the lake.

Other Management Concerns

Two other management concerns have been cited - fish kills and swimmers' itch. Neither this study nor previous studies have provided specific data or documentation on these problems. This is not to say these problems are not of concern, rather, there is little objective basis to evaluate them.

It is unlikely fish kills due to hypoxia have occurred in Deer Lake during the summertime. Winter fishkills can occur, but most often only in productive, shallow lakes. Deer Lake does not fit this profile. In light of substantial evidence that fishkills are not a concern[3], no specific management recommendation will be made at this time. Ongoing monitoring, which is recommended, should help to provide more specific information, should a fishkill occur in the future.

Swimmers' itch is difficult to monitor, except by after-the-fact complaints by infected swimmers. Furthermore, there are no effective lake-wide control options available. Small scale copper sulfate treatments are sometimes used to kill snails, the intermediate host for the swimmers' itch cercaria, in beach areas. However, these treatments are generally short-lived or ineffective. Educating Deer Lake residents about the risk of swimmers' itch as well as common sense methods to prevent becoming infected is the best available management approach at this time.

Lake and Watershed Management Goals

Based on the concerns expressed by the Deer Lake Association and the monitoring analysis provided in this report, the following management goals are suggested:

1. Reduce summer phosphorus concentration to 15 ppb
2. Control curlyleaf pondweed and filamentous algae
3. Protect native aquatic plants
4. Prevent additional exotic species introductions

Specific management actions are recommended (next section) to address these goals.

[3] Dead crappies have been observed in early summer, but these are the result of a common bacterial infection which does not normally result in significant reductions in their population (despite the significant visual impacts).

RECOMMENDATIONS

The following management actions or alternate management actions are recommended to address the goals presented above. Specific management actions are recommended in cases where there are no reasonable or feasible alternatives. Management alternatives are presented in other cases.

Management Action 1 **Deer Lake Alum Application**

Rationale: The watershed improvements that have been recently implemented have resulted in substantial reductions in phosphorus loading as well as significant improvements in lake quality. However, further water quality improvement is desired to better control nuisance algae, including filamentous algae. Controlling internal phosphorus inputs will result in further water quality improvements.

Analysis: A whole lake alum application will effectively reduce internal phosphorus loading, especially from the deep water areas. Appendix B more fully describes this method. Internal phosphorus loading accounts for 1,833 pounds per year. Alum dose was calculated using the methods of Kennedy et al. (1987) as modified by Eberhardt (1990). This method is based on net internal phosphorus release and is designed for a five-year dose. Because this method is designed to treat net phosphors release based on actual lake conditions and not the total available phosphorus pool, it can be underestimate the alum dose. I recommend using this method over the 'mobile P' method (Rydin and Welch 1999) because it is more conservative and allows for future adjustments, if needed.

The alum dose required for Deer Lake is 94,000 gallons of liquid alum.

Benefits: Assuming the alum will eliminate two thirds of the internal phosphorus load, the lake phosphorus model yields an expected lake phosphorus concentration of 18 ppb, a reduction of 25% compared to the modeled current lake concentration. Lower lake phosphorus concentrations will result in fewer, less intense algae blooms and clearer water. Because Deer Lake is already clear, the extent of rooted plant growth is not expected to increase significantly. However, filamentous algae growth on the rooted plants should diminish.

Estimated Cost: The recommended alum dose of 94,000 gallons is estimated to cost $1.10 per gallon applied, or $103,400. In addition, there will be costs associated with monitoring, permitting and evaluation.

Management Action 2 **W-1 Pond Alum Treatment**

Rationale: W-1 Pond remains a significant source of phosphorus and bacterial pollution to Deer Lake. It is impractical to treat the upstream source of these pollutants, so an alum treatment system in Pond A should be implemented to reduce these pollutants to an acceptable level.

Analysis: W-1 Pond has two inlets and an outlet to Deer Lake. The Pond's history of excess pollution as well as its continued pollution, means that the sediments are enriched and its overflow releases highly polluted (and stinky) water to Deer Lake. An alum system includes a sediment treatment plus a continuous dosing of alum. Because there is sketchy data available for the pond water and sediments as well as no ability to control pond levels or flow, it is not possible to estimate the performance of the alum applications with precision.

The Deer Lake Conservancy has been considering whether to control the pond level and outlet flow as a way to improve the efficiency of the alum treatment in the pond. I am recommending at this time that this consideration be suspended until the alum system is implemented and evaluated for two years because it is possible this system will result in adequate phosphorus removal without these modifications.

a. Sediment Alum Treatment. A sediment treatment is necessary to seal the nutrient-rich bottom sediments in the W-1 Pond. An alum dose of 460 pounds of dry alum applied as a bulk application is recommended.

b. Continuous Alum Applications. Following the sediment alum treatment, continuous alum applications are recommended to strip phosphorus from the water. Dry alum, mixed with water can be applied either automatically using an on site delivery system or with regular low dose bulk applications. Because the automatic system is more efficient, less alum is required.

- An alum injection system consists of a machine installed near the pond shore which delivers alum and compressed air in parallel lines to an injector resting on the pond bottom. The system requires electrical service and an operator to fill the reservoir with dry alum and make adjustments to flow rates. The recommended alum dose is 300 pounds of dry alum per season (April through September).

- Regular bulk alum applications are done manually using specialized equipment. Because these applications are scheduled in advance, it is not possible to anticipate flow into and out of the pond, so more alum is used. The recommended alum dose is 600 pounds of dry alum per season (May - August).

It will be necessary to 'fine tune' the operation of this system. Consulting services for this activity should be budgeted for two years. Following that, an operational plan can be developed for the volunteer operators.

The pros and cons of each method are listed below:

	Pros	**Cons**
Injection System	More efficient Dose can be adjusted Lower annual costs	Initial costs greater Maintenance required
Bulk Applications	No equipment costs No maintenance	Less efficient Higher annual costs

Benefits: The combined alum treatments of W-1 Pond will substantially reduce the effluent phosphorus going to Deer Lake. I anticipate a minimum phosphorus removal of 50% (a reduction of 519 pounds per year). With this annual phosphorus reduction, the lake phosphorus model yields an expected lake phosphorus concentration of 22 ppb, a reduction of 8% compared to the modeled current lake concentration.

Estimated Cost: The estimated costs for the alum treatments to W-1 Pond are:

	Alum[1]	Equipment	O & M
Sediment Treatment	$1,700	--	--
Continuous Application			
- **Injection system**	$ 330	$6,500	$ 500
- **Bulk applications**	$3,200	--	--
Operational Oversight[2]	--	--	$3,800
Monitoring & Evaluation	included in Management Action 6		

1. Include alum costs plus professional application services
2. First two years' consulting services for 'fine tuning'

Management Action 3 Other Watershed Projects

Two watershed projects should be considered. These are the Flagstad Farm Prairie (2003) and the Flagstad Farm wetland restoration (2005). Together these projects are estimated to result in the removal of 428 pounds TP per year. I have not specifically evaluated these projects here, but include them to provide an overall context for evaluating improvements to Deer Lake.

When all the phosphorus reduction projects are considered alone and in combination, it is possible to evaluate their impacts to the phosphorus concentration in Deer Lake. Based on the phosphorus model used in this study, the lake phosphorus concentrations under various management scenarios are:

Present Condition	24 ppb
Management Actions	
#1 Alum	18 ppb
#2 W1 Pond	22 ppb
#3 Other Watershed Projects	22 ppb
Combination of nos. 2 & 3	20 ppb
Combination of nos. 1-3	14 ppb

Management Action 4 Curlyleaf Pondweed Control

Rationale: Curlyleaf pondweed is an exotic invasive aquatic plant. Curlyleaf pondweed has become a nuisance in Deer Lake and anecdotal indications are that it is expanding. Deer Lake Association members are very concerned about the curlyleaf pondweed nuisance.

Analysis: There is no reliable treatment for the comprehensive, long-term control and reduction of curlyleaf pondweed. Several types of treatments, like harvesting or herbicides, are effective at controlling the immediate nuisance associated with curlyleaf pondweed, but none of these result in significant long-term control, meaning curlyleaf pondweed grows back the following season.

Individuals on Deer Lake already perform herbicide applications for nuisance aquatic plants. Some of the nuisances needing control involve native aquatic plants in addition to curlyleaf pondweed. To the extent desirable, these individual treatments should be coordinated to focus more on curlyleaf pondweed to have the greatest likelihood of accomplishing at least some long-term control incidental to the season's control. This strategy should increase control of curlyleaf pondweed and decrease the destruction of native aquatic plants.

I know the Deer Lake Association residents want to both control curlyleaf pondweed and aquatic plant nuisances adjacent to their individual lakeshore properties. There is no practical comprehensive control method available for curlyleaf pondweed. Unfortunately, curlyleaf pondweed as well as other invasive aquatic plants will more aggressively infest disturbed areas of the lake, such as those where native plant nuisances have been controlled. Because of this situation, I am advising that Deer Lake Association members exercise restraint in their control of native plants.

I recommend the Deer Lake Association coordinate the aquatic plant nuisance control activities of its members to emphasize as much control effort as possible on curlyleaf pondweed and minimize control of native plants. Further, I recommend that control activities for curlyleaf pondweed occur early in the season (in May) to take advantage curlyleaf pondweed's life cycle and the fact that turions (seeds) are not yet produced. Because native plants begin growing later, there will be a tradeoff (less control of native plant nuisances) when emphasizing curlyleaf pondweed control. The Deer Lake Association or the Deer Lake Conservancy should conduct an early-May survey to identify areas of heavy curlyleaf pondweed growth to guide the coordination of nuisance control activities.

Benefits: Focusing existing aquatic plant control activities on curlyleaf pondweed and away from native plants will increase the likelihood for comprehensive control of curlyleaf pondweed and increase the protection of native plants.

Estimated Cost: The cost, over-and-above the money already being spent by individuals for their own treatments, is for monitoring which is detailed in Management Action 6. It is assumed that coordinating the individual aquatic plant control activities will be done by volunteers, and therefore have no cost.

Management Action 5 **Exotic Species Prevention**

Rationale: Other aquatic exotic species, like Eurasian watermilfoil and zebra mussel, are in Wisconsin and Minnesota. Obviously, new exotic species are unwelcome, but specific prevention activities on Deer Lake are not occurring.

Analysis: Deer Lake, being close to a major highway as well as welcoming a large number of boaters, is at high risk for an exotic species introduction. Lakeshore resident education and access inspections will reduce the risk of an unwanted exotic species introduction to Deer Lake. There are many educational materials available from public sources. These materials should be gathered and assembled for distribution to Deer Lake residents. An access inspection program should be developed to 1) educate boaters entering Deer Lake, 2) provide a voluntary inspection and 3) allow for boat and trailer cleaning when contamination is observed or suspected. The Deer Lake Association should also develop contingencies and monitoring, including a budget, in the event an exotic species is discovered.

Preemptive Eurasian watermilfoil treatments, as were implemented in 2003, lack an objective method for identifying areas where Eurasian watermilfoil could become established and are therefore not effective. Simply, there is no way to know in advance where a Eurasian watermilfoil introduction may take hold. Furthermore, treating these areas will remove existing vegetation and create a habitat more inviting for the aggressive Eurasian watermilfoil. For these reasons, preemptive Eurasian watermilfoil treatments are not recommended.

Benefits: Taking positive steps to reduce the likelihood of an exotic species introduction.

Estimated Cost: Except for monitoring, which is detailed in Management Action 6, it is assumed the inspections will be conducted by volunteers, so the costs for this program will be negligible. If the inspections cannot be conducted by volunteers, there will be costs.

Management Action 6 **Monitoring & Evaluation**

Rationale: Monitoring and evaluation are a critical element to any lake management program. In addition, some of the management actions recommended above have a specific monitoring and evaluation element.

Analysis: General monitoring and evaluation activities as well as those required to support specific management actions are detailed here.

a. General Monitoring. The self-help monitoring that has been conducted in recent years should continue without change. The aquatic plant monitoring that was conducted in 2003 should continue each year. Some kind of assessment of user perceptions should be conducted each year.

b. Alum Evaluation. The lake water quality data from the self help monitoring should be evaluated annually.

c. W-1 Pond Monitoring. A regular sampling schedule should be established in W-1 Pond. Monitoring for total phosphorus and fecal coliform should be conducted every other week from

April through September. In addition, monitoring of the outlet may be required as a condition of a WI DNR permit.

d. Early Season Curlyleaf Pondweed Assessment. An early-May survey for curlyleaf pondweed should be conducted to guide and coordinate curlyleaf pondweed control activities. This assessment should map the locations of observable curlyleaf pondweed growths and note their nuisance level (light, medium or heavy).

e. Exotic Species Monitoring. Monitoring for likely exotic species should be an ongoing activity for the Deer Lake Association. This can be coordinated and conducted by volunteers.

Benefits: Knowledge is power.

Estimated Cost: The estimated annual costs for this program are:

	Volunteer	Lab/Analytical	Consultant
a. General Monitoring			
- Self-help WQ	X	X	--
- Aquatic Plants	--	--	$2,000
- Perceptions	X	--	--
b. Alum Evaluation	--	--	$2,500
c. W-1 Pond Monitoring	X	$450	--
d. Early Season CWP Assessment	--	--	$3,000
e. Exotic Species Monitoring	X	--	--

REFERENCES

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APPENDIX A

2003 DEER LAKE MACROPHYTE SURVEY

Macrophyte Survey

Deer Lake, Polk County Wisconsin

Summer 2003

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Introduction:

This report is presented as an analysis and summary of data collected in a macrophyte survey completed during the summer of 2003 on Deer Lake, Polk County Wisconsin. An early season sample was taken in mid-June and a late-season sample was taken in mid-August. All data presented here is available on request. The primary goals of the project were to establish a baseline for long-term monitoring of aquatic plant populations and to document and map the location of stands of non-native invasive aquatic plant species such as curly pondweed (*Potamogeton crispus*) and Eurasian water milfoil (*Myriophyllum spicatum*).

Field Methods

A point intercept method was employed for macrophyte sampling. A grid was generated that spaced the sampling points 50 meters running north/south and 100 meters running east/west. This spacing maximized the number of points in the bands of littoral vegetation that occur primarily on the north and south shores of the lake (Map 1 in Appendix). In addition, this provided approximately 200 sampling points (192 in actuality), a number recommended for a lake the size of Deer Lake. Global Positioning System (GPS) was used to locate sampling points in the field.

Once the sample location was found, the boat was anchored and the samples were taken. At each point, a specially designed rake was lowered and a 1-meter tow was completed on the shoreline side of the boat. A second sample was collected at each point using a bottom sampler with hinged jaws. All plants were emptied into shallow white tubs for analysis. All species identified in the sample were noted as "present." No quantitative data was recorded. Voucher specimens were collected, pressed, and dried to document the study. Water depth was also measured and recorded at each sample location. If no plants were collected, a depth was recorded. Most of the "too deep" samples were eliminated prior to data analysis and mapping.

Every other sample from the mid-June survey was relocated and resampled in mid-August. This was done to identify seasonal changes in the aquatic plant communities of Deer Lake. This was consistent with protocols outlined from similar survey/monitoring studies that have been done.

Data Analysis Methods

Data collected was entered into a spreadsheet for analysis. Average number of species per sample, average number of native species per sample, average number of non-native species, and frequency of each species were calculated. A Floristic Quality Assessment of the lake was also calculated using a method established by Dr. Stanley Nichols (Nichols 1999). This method is used to assess overall quality of aquatic plant communities within a lake and to gauge the response of these communities to disturbance such as development. The calculation is as follows:

I=average C X square root of N

I is the Floristic Quality Index, C is the average Coefficient of Conservatism for species documented in a particular lake and N is the number of species recorded for that lake. The Coefficient of Conservatism has been established for each aquatic plant species ranging from 0 to 10. Species that are highly tolerant to disturbance are assigned lower values while relatively sensitive species that are prone to adverse effects related to development and disturbance are assigned higher values. A higher Floristic Quality Index value is an indication of high quality aquatic plant communities in the lake while a low value is an indication of low quality aquatic plant communities related to a high level of disturbance.

The data was entered into ArcView for mapping purposes. The sample points (Map 1), area of the lake too deep to support aquatic plants (Map 2), samples which included curly pondweed (*Potamogeton crispus*), the only non-native species identified (Map 3), and the area of nuisance aquatic plant communities (Map 4) were mapped using ArcView.

Results

Seventeen vascular plant species and two categories of algae (filamentous algae and *Chara* sp.) were recorded during the mid-June survey (Table 1). White-stem pondweed (*Potamogeton praelongus*) and coontail *(Ceratophyllum demersum*) were the most frequently found species (46%). Northern milfoil (*Myriophyllum* sibericum), curly pondweed (*Potamogeton* crispus), flat-stemmed pondweed (*Potamogeton* zosteriformis) and water celery (*Vallisneria americana*) also had high frequencies.

Potamogeton (the pondweeds) was the most diverse vascular plant group by far, containing nearly half of the aquatic vascular plant flora found in Deer Lake (eight species).

Nineteen species were found during the mid-August sampling, including 15 vascular species documented during the mid-June sampling as well as the filamentous algae and *Chara* sp. (Table 2). No diverse-leaf pondweed (*Potamogeton diversifolius*) or sago pondweed (*Potamogeton pectinatus*), which were found in June, were found during the mid-August survey. Two species, wild rice (*Zizania palustris*) and greater duckweed (*Spirodela polyrhiza*) were found in mid-August but not during mid-June sampling. The increase in frequencies of coontail, flat-stemmed pondweed, and water celery are notable from mid-June to mid-August while the profound decrease in frequency of curly pondweed from 28% to 1% is striking.

The average number of species found per sample was 3.30 in mid-June and 3.41 in mid-August. The average number of native species found per sample was 3.03 in mid-June versus 3.39 in mid-August, the difference being entirely due to the near-complete senescence of curly pondweed between mid-June and mid-August. As a consequence, the average number of non-native species per sample decreased from 0.27 in mid-June to 0.01 in mid-August (Table 3). Curly pondweed was the only non-native species documented in Deer Lake during this study (there was no Eurasian water milfoil found).

The Floristic Quality Index for Deer Lake was 25.73, significantly higher than the 20.9 average for other lakes within the Northcentral Hardwoods Ecoregion (NCHE). Four of the aquatic species found in Deer Lake have Coefficents of Conservatism of eight, including *Potamogeton praelongus, P. robbinsii, P. diversifolius, and Bidens beckii.* As a result, Deer Lake has an exceptionally high average Coefficient of Conservativism of 6.24 compared with an average of 5.6 for lakes in the NCHE.

Summary:

<u>Plant Coverage</u>

Deer Lake is considered to be an excellent fishery. The primary reason for this is the abundance of high quality aquatic vegetation found in its littoral regions. Forty-one percent of Deer Lake is littoral, with a water depth that allows the growth of rooted aquatic vascular plants. The littoral zone is found as a continuous band around the margin of the lake. This zone extends toward the center of the lake in water greater than six meters deep in some areas, another indication of high water quality and an overall healthy ecosystem. Map 2 shows the portions of the lake that are too deep to support rooted aquatic plant growth. Very few portions of the littoral zone of Deer Lake would be characterized as having nuisance stands of aquatic plants. The exceptions, which may warrant some management action are areas supporting curly pondweed (Map 3) and the extremely dense stands of aquatic vegetation on the western end of the lake near the public boat landing (Map 4).

<u>Non-native species</u>

The only non-native species that was present was curly pondweed (*Potamageton crispus*) (see Map 3 for documented distribution of this species). No Eurasian water milfoil (*Myriophyllum spicatum*) was found. Curly pondweed was found in 41 of the 146 plant supporting samples taken in mid-June but only in one of the 73 samples analyzed in mid-August. This was not surprising given that fact that curly pondweed is a cool water species that is known to almost completely die back during the hot summer months.

Some of the curly pondweed stands were very thick and appeared to be "choking out" native plant species. The further spread of curly pondweed can result in more displacement of desirable native species and can produce local oxygen deficits and nutrient release during the midsummer die-back. Local control of the most dense stands followed by revegetation with warm water species such as coontail may be prudent to maintain the overall health of Deer Lake.

Table 1. List of species found during mid-June sampling and the frequencies of each species. Frequency of each species equals number of samples that the species was found in / total number of samples that contained aquatic plants (146 samples contained aquatic plants in the mid-June survey).

Species	Number of points sampled	Frequency
1. *Potamageton praelongus*	67	0.46 or 46%
2. *Potamageton amphlifolius*	17	0.12 or 12%
3. *Potamageton crispus**	41	0.28 or 28%
4. *Myriophyllum sibiricum*	45	0.31 or 31%
5. *Potamageton zosteriformis*	56	0.39 or 39%
6. *Vallisneria americana*	54	0.37 or 37%
7. Filamentous algae	96	0.66 or 66%
8. *Ceratophyllum demersum*	67	0.46 or 46%
9. *Lemna trisula*	16	0.11 or 11%
10. *Potamageton robbinsii*	10	0.07 or 7%
11. *Potamageton diversifolius*	8	0.055 or 5.5%
12. *Nymphaea odorata*	1	0.006 or 0.6%
13. *Potamageton pectinatus*	2	0.013 or 1.3%
14. *Chara spp.*	5	0.034 or 3.4%
15. *Potamageton pusillus*	4	0.028 or 2.8%
16. *Najas flexilis*	5	0.034 or 3.4%
17. *Bidens beckii*	2	0.013 or 1.3%
18. *Wolfia columbiana*	1	0.006 or 0.6%
19. *Lemna minor*	1	0.006 or 0.6%

*Non-native or exotic species in Wisconsin lakes

Table 2. List of species found during mid-August sampling and the frequencies of each species. Frequency of each species equals number of samples that the species was found in / total number of samples that contained aquatic plants (74 samples contained aquatic plants in the mid-August survey).

Species	Number of Points Sampled	Frequency
1. *Potamageton praelongus*	30	0.41 or 41%
2. *Potamageton amphlifolius*	10	0.14 or 14%
3. *Potamageton crispus**	1	0.01 or 1%
4. *Myriophyllum sibiricum*	25	0.34 or 34%
5. *Potamageton zosteriformis*	40	0.54 or 54%
6. *Vallisneria americana*	44	0.59 or 59%
7. Filamentous algae	18	0.24 or 24%
8. *Ceratophyllum demersum*	42	0.57 or 57%
9. *Lemna trisula*	10	0.14 or 14%
10. *Potamageton robbinsii*	8	0.11 or 11%
11. *Nymphaea odorata*	2	0.03 or 3%
12. *Potamageton pusillus*	6	0.08 or 8%
13. *Chara spp.*	6	0.08 or 8%
14. *Najas flexilis*	3	0.04 or 4%
15. *Bidens beckii*	2	0.03 or 3%
16. *Wolfia columbiana*	1	0.01 or 1%
17. *Lemna minor*	1	0.01 or 1%
18. *Zizania palustris*	2	0.03 or 3%
19. *Spirodela polyrhiza*	0	0.00 or 0%

*Non-native or exotic species in Wisconsin lakes

Table 3. Average number of species per sample, average number of native species per sample, and average number of non-native species per sample in Deer Lake in mid-June and mid-August.

	Mid-June	Mid-August
Avg. Number of Species/Sample	3.30	3.41
Avg. Number of Native Species/Sample	3.03	3.39
Avg. Number of Non-native Species/Sample	0.27	0.01

Table 4. Floristic Quality Index of Deer Lake and comparisons with average values from other lakes within the North Central Hardwoods Ecoregion (NCHE), using mid-June sampling data from Table 1.

	Deer Lake	NCHE Lakes Avg.	% of NSCE
Number of species	17	14	**121%**
Average conservatism	6.24	5.6	**111%**
Floristic quality	25.73	20.9	**123%**

Species diversity

Nineteen species of aquatic vascular plants were found during the study (Tables 1 and 2). This compares to an average of 14 for lakes in the NCHE (Table 4). All but one of these is native (the exception being curly pondweed) and no one plant seems to be dominating to the point of becoming a nuisance. The more diverse the ecosystem, the healthier it generally is. Based on aquatic plant diversity, Deer Lake appears to be a healthy lake ecosystem.

The most prevalent species sampled (other than filamentous algae) was coontail (*Ceratophyllum demersum*). This plant provides prime habitat for aquatic invertebrates and fish, especially in deeper waters as it can withstand low light conditions and cool temperatures. It also has the ability to pull large amounts of nutrients from the water. It can become a nuisance plant and require management, although this is not the case in Deer Lake. White stem pondweed (*Potamageton praelongus*) is also very common in Deer Lake. The high frequency of this plant is an indication of good water quality, as it tends to decrease in prominence with disturbance and degradation of water quality.

Other prominent native species, including cabbage weed (*Potamogeton amplifolius*), northern milfoil, flat stem pondweed, and water celery are present in healthy amounts and contribute favorably to the overall quality of the aquatic plant communities of Deer Lake. Most of the other species are relatively rare and found scattered throughout the lake and are of little ecological consequence.

Nuisance Stands Warranting Management Action

Only two areas approach nuisance status, which may warrant management action. The first is the far-western bay area of Deer Lake near the public boat landing (Map 4). During the early survey in June and the late survey in August this bay had plant growth that could be considered nuisance. This plant growth was thick enough to hinder boat use, swimming, and fishing. Localized mechanical harvest may alleviate some of the problems created by this dense vegetation.

Some of the curly pondweed stands, particularly on the north side of the lake were dense enough and extensive enough to be a concern, particularly if they continue to spread. These stands are thick enough to hinder recreational use. Further displacement of native aquatic species with curly pondweed will also degrade fisheries habitat and the overall health of the lake. It is also important to note that the curly pondweed does die back in the summer, and these stands eventually had only native plants that were not at nuisance levels (based on our mid-August sampling).

Recommendations:

Although the purpose of this survey was for data collection and not management suggestions, some observations were made that may need to be considered in a management plan.

First, Deer Lake supports healthy and diverse plant communities that are well-above average when compared to other lakes within the NCHE. However, the littoral zone, which supports all of the aquatic vegetation occurs in a relatively narrow band around the margins (covering 41% of the lake area total). When a management plan is established, this point should be considered. If a waterfront property owner sprays even a narrow region in front of their property, it could have very significant negative effects on healthy, desirable native stands of plants. Particularly, it can result in removal of the native aquatic plants that are responsible for the high water quality and excellent fisheries habitat associated with the lake while potentially hastening the spread of non-desirable non-native plants such as curly pondweed.

Curly pondweed is a potential problem in this lake. It has not spread throughout the lake yet, although the densities of some of the existing stands, particularly along the north shore (Map 3) are of immediate concern. We would recommend establishing a sound management plan to reduce the population of this plant in Deer Lake. If left unchecked, this plant could overtake desirable native plant communities in the lake and potentially lead to water quality problems. Haphazard, unregulated spraying of aquatic vegetation by property owners is more likely to increase the rate of spread of curly pondweed than it is to control it. Any removal through mechanical control or spraying should be done as part of a comprehensive management plan, which takes into consideration the entire lake ecosystem. It is our suggestion that it also be coupled with revegetation with warm water active species such as coontail to prevent its immediate return in treated areas. In other words, take advantage of its tendency to die back in the summer by establishing fast-growing species there after it has been killed.

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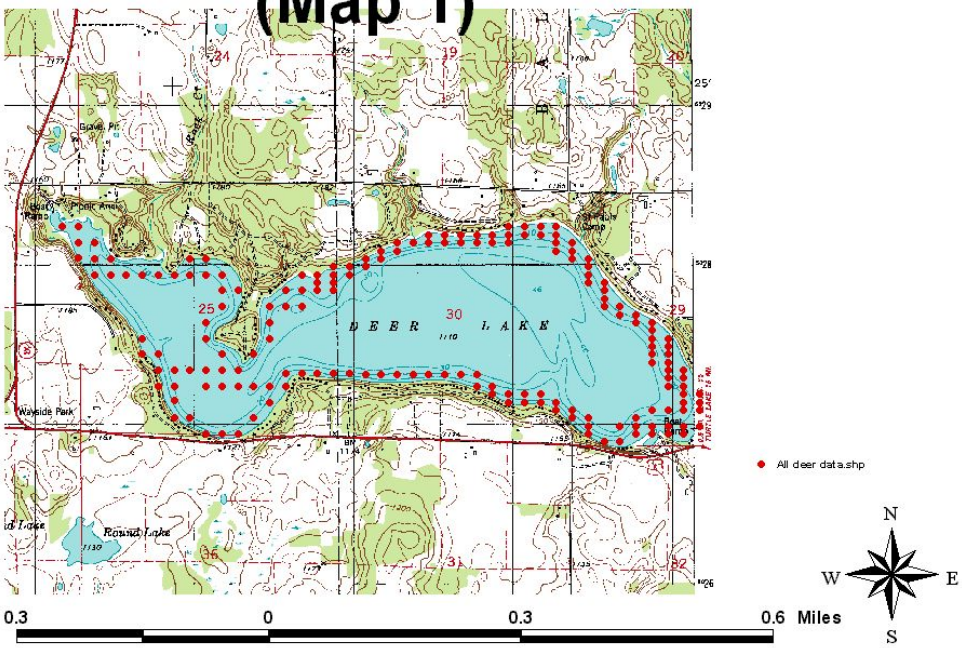
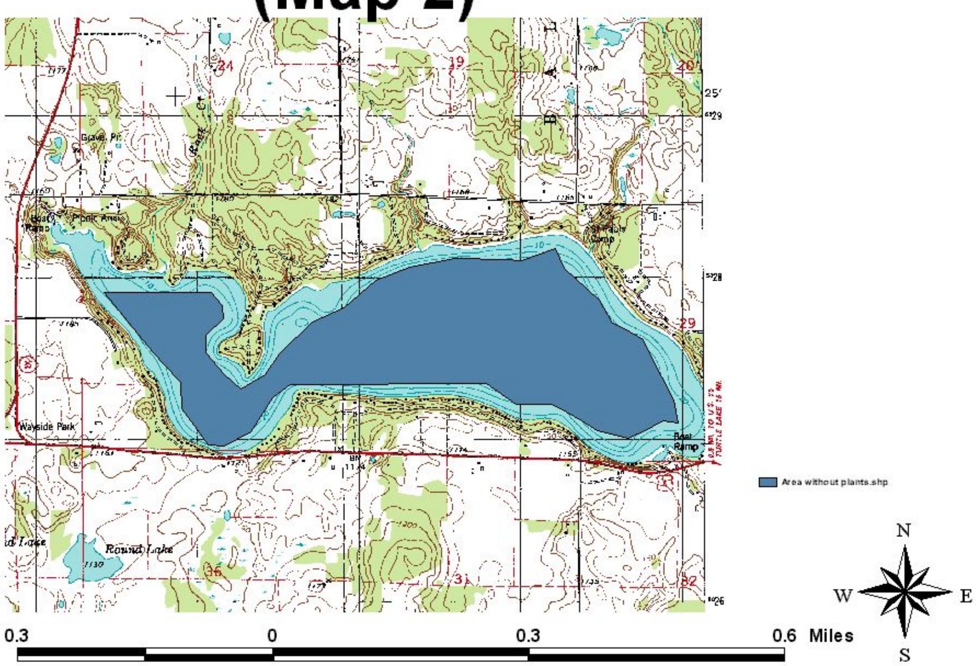
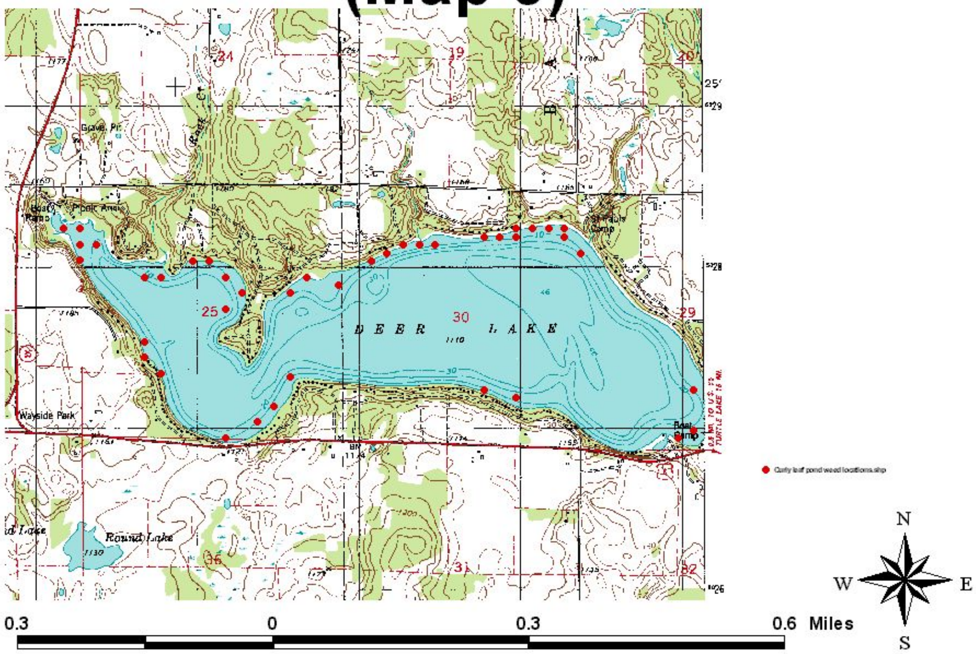
Sampling Points Plot
(Map 1)



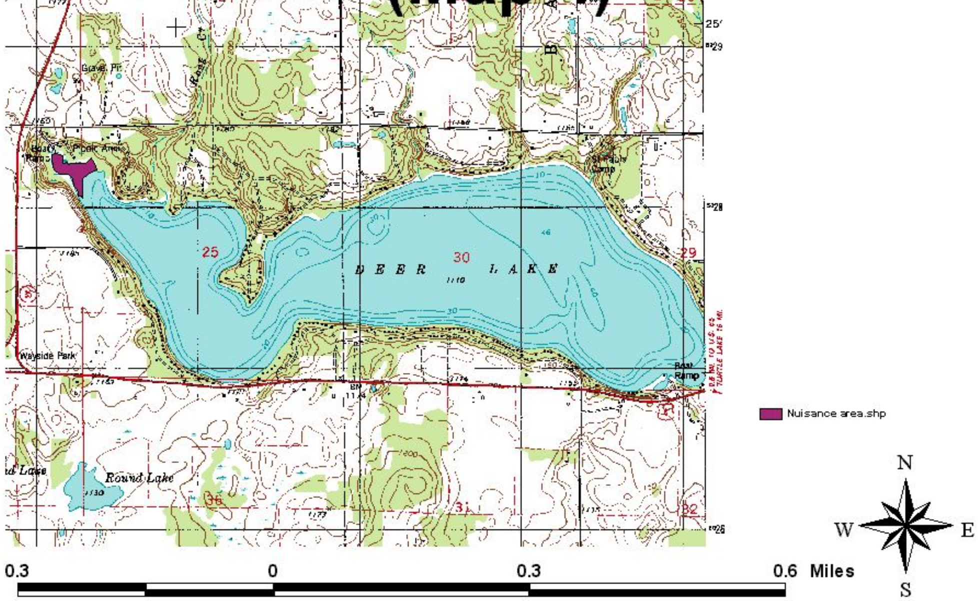
Area without plants
(Map 2)



Curly Leaf Pondweed Samples (Map 3)



Nuisance Growth of Macrophytes (Map 4)



APPENDIX B

HOW ALUM WORKS TO INACTIVATE PHOSPHORUS

Alum is applied to lake water as aluminum sulfate, or $Al_2(SO_4)_3 \cdot 14\ H_2O$. As aluminum sulfate is added to water, it forms aluminum ions, which are hydrated (combined with water):

$$Al^{+3} + 6\ H_2O \rightleftarrows Al\ (H_2O)_6^{3+}$$

In a series of chemical hydrolysis steps, hydrogen ions are liberated, which may lower the water pH, and ultimately forms aluminum hydroxide ($Al(OH)_3$), which is a solid precipitate:

$$Al^{3+} + H_2O \rightleftarrows \text{intermediate reactions} \rightleftarrows Al(OH)_3(s) + H^+$$

The solid precipitate forms a flocculent material, referred to as a floc, that has a high capacity to adsorb phosphates. At the pH of Deer Lake, these reactions occur quickly and the floc is stable. Aluminum hydroxide ultimately settles to the lake bottom where it remains stable and poses no toxicity to aquatic life.

If aluminum sulfate is applied as a bulk application, the aluminum hydroxide floc coagulates quickly. Bulk applications are thus intended to form an aluminum hydroxide layer on the lake bottom, which forms an effective barrier to the release of phosphates from the lake bottom sediments. The aluminum hydroxide layer may be disrupted by wind and wave action in shallow waters or become inefficient if the incoming phosphorus supplies remain unabated.

Alum can also be applied in lower doses directly to the incoming water or into the lake water. By this technique, aluminum hydroxide is injected into the lake or stream water as colloidal-sized (microscopic) particles that remain suspended for longer periods scavenging phosphates. Essentially, the alum uses (eliminates or inactivates) phosphates. In this way, the aluminum hydroxide particles compete with algae for available phosphates, thereby starving the algae. Eventually, the particles coagulate and settle to the lake bottom.