White Ash Lake (South) and North White Ash Lakes Macrophyte Surveys and Management Plan

Prepared for
White Ash Lake Protection and Rehabilitation District

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Executive Summary

Macrophyte surveys were completed in White Ash Lake (South) and North White Ash Lake during July and August of 1997. The surveys evaluated plant coverage, density, and species composition. The results indicate the total area of macrophyte (i.e., aquatic plant) coverage in White Ash Lake (South) was approximately 78 acres (i.e., 51 percent of lake surface area) during July and 70 acres (i.e., 46 percent of lake surface area) during August. The total area of macrophyte (i.e., aquatic plant) coverage in North White Ash Lake was approximately 117 acres (i.e., 98 percent of lake surface area) during July and August. Plant diversity in both lakes was relatively high when compared with 46 other Wisconsin lakes (Nichols, 1997). A total of 23 species was found in White Ash Lake (South) and 21 species in North White Ash Lake. Approximately 11 species were found in each sample transect during July and approximately seven or eight species were found in each sample transect during August. Although individual species generally occurred in a relatively low density, the concurrent growth of many species at each sample location resulted in an overall plant growth of high density.

Macrophytes in White Ash Lake (South) and North White Ash Lake consisted primarily of native species. Only one exotic species (i.e., not native to this region), *Potamogeton crispus* (curly-leaf pondweed), was found. Exotic or non-native species are undesirable because their natural control mechanisms are not introduced with the species. Consequently, exotic species frequently exhibit rapid unchecked growth patterns, which eliminate native species. The total area of White Ash Lake (South) containing curly-leaf pondweed was 75 acres during July and 2 acres during August. The total area of North White Ash Lake containing curly-leaf pondweed was 57 acres during July and 6 acres during August. In general, curly-leaf pondweed occurred concurrently with several native species.

The survey results were used to develop a macrophyte management plan for White Ash Lake and North White Ash Lake. The eight aquatic plant management goals for the lakes are:

- Improve navigation within the lakes through areas containing dense plant beds
- Improve recreational attributes of the lakes
- Remove or limit current exotic plants (i.e., curly-leaf pondweed)

- Preserve native species and prevent introduction of additional exotic species
- Preserve and/or improve fish and wildlife habitat
- Protect and/or improve quality of the resources for all to enjoy (i.e., people, fish, wildlife)
- Minimize disturbance of sensitive areas (i.e., fish and wildlife)
- Reduce long-term sedimentation from decaying macrophytes

The macrophyte management plan includes three parts:

- Harvesting program to create navigation channels, fish cruising lanes, and increased edge in areas with excessive macrophyte growth (i.e., total of approximately 14 acres will be harvested to create navigation channels in areas of dense growth -- 8.7 acres for North White Ash Lake and 5.3 acres for White Ash Lake);
- Education of lake homeowners;
- Prevent the establishment of other exotic species in the lake (e.g., Eurasian watermilfoil).

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Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

White Ash Lake (South) and North White Ash Lake in Polk County, Wisconsin are valued by riparian owners, area residents, Polk County, and the Wisconsin Department of Natural Resources (WDNR) for their fisheries and for recreational uses (see Figure 1). However, the lakes have experienced problems with aquatic plant beds and algal blooms for more than 20 years. Concern for the lakes resulted in the formation of a Lake District in 1976, and a subsequent request for WDNR technical and financial assistance.

The WDNR responded to the request by completing a study of the lakes and their watersheds during 1980. The study concluded that aquatic plant growth occurred in both lakes. Vegetation growth was noted in the entire north lake. In the south lake, macrophyte growth was limited to areas having water depths of less than six feet. Density of submerged macrophytes (i.e., aquatic plants) ranged from moderate to dense in both lakes. Emergent species, such as wild rice and floating-leafed species were noted in both lakes (WDNR, 1980).

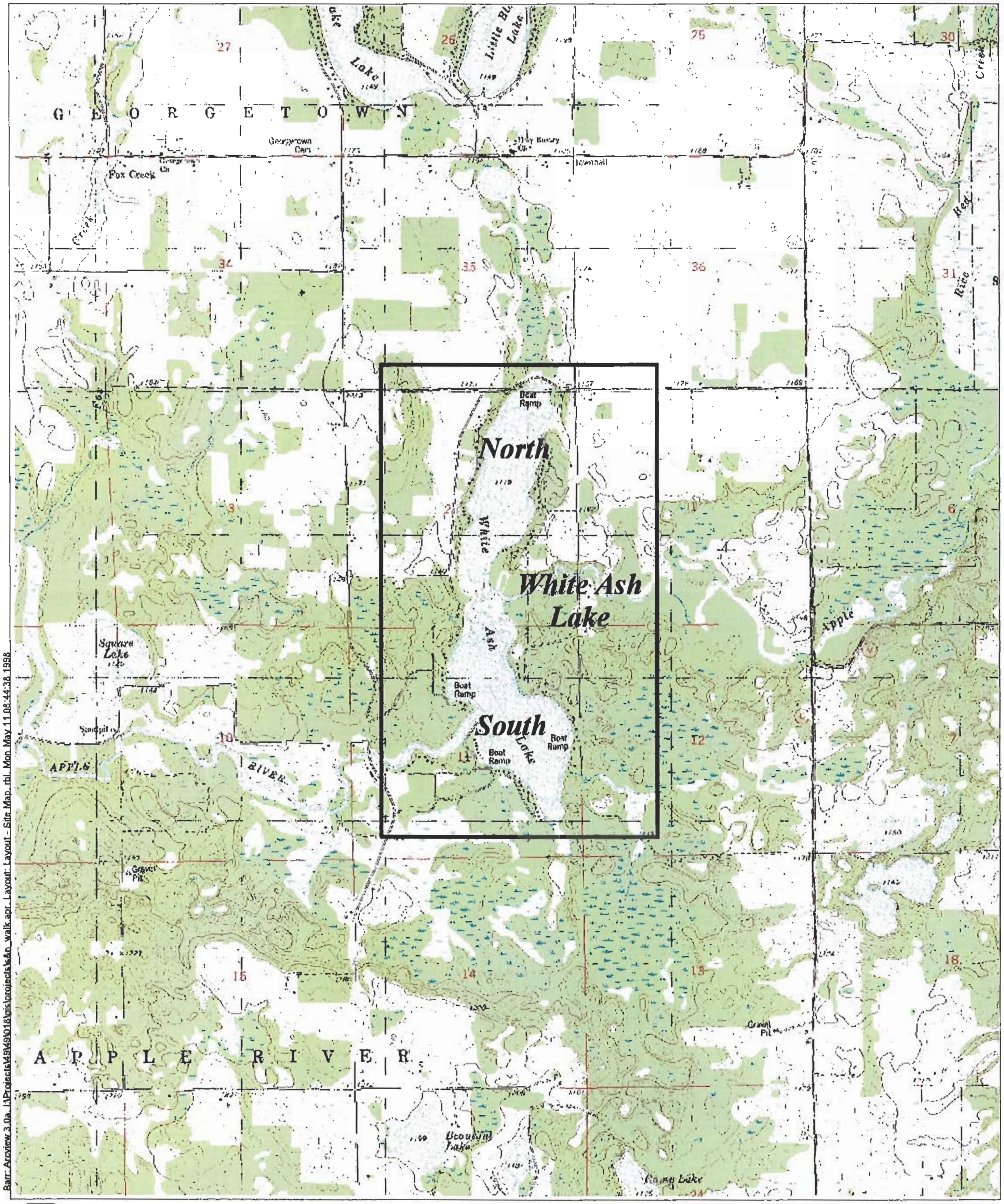
Following completion of the 1980 lake study, the District determined that harvesting would best meet the macrophyte management needs of the lakes. During the early 1980s, a private harvesting company was hired to create navigation channels within the lakes. The White Ash Lake Protection and Rehabilitation District paid some costs and individual lot owners provided the additional funding to harvest in front of their respective lots. Harvesting only occurred in front of riparian owners participating in the District cost-sharing program. This proved unsatisfactory as not all of the shore owners participated, resulting in a patchwork of cut and uncut areas.

The District purchased a harvestor during 1985 and initiated a harvesting program to create navigation channels in the lakes. The District has been satisfied with its harvesting program. However, the aging harvestor needs to be replaced because of escalating maintenance costs and declining reliability. During 1996, representatives from the District approached the WDNR to receive information regarding a cost sharing program for the replacement harvestor. The WDNR indicated a macrophyte management plan must be completed prior to application for harvestor cost sharing.

Macrophyte surveys of White Ash Lake (South) and North White Ash Lake were completed during 1997. This report presents the macrophyte management plan for the lakes. The report discusses:

- Overview of macrophyte growth in lakes

- Compilation and assessment of existing information
- The methodology of the 1997 White Ash Lake (South) and North White Ash Lake membership and aquatic plant surveys
- Results and discussion of the 1997 White Ash Lake (South) and North White Ash Lake membership and aquatic plant surveys
- Developing a macrophyte management plan
- Macrophyte management plan for White Ash Lake (South) and North White Ash Lake
- Recommended equipment purchase and estimated cost
- Field operation and maintenance
- Record keeping and evaluation



Barr Engineering Company

N

0 1500 3000 4500 Feet

Figure 1
Site Map
White Ash Lake

2.0 Overview of Macrophyte Growth in Lakes

The basis of the following text on macrophyte growth in lakes is Minnesota Department of Natural Resources (MDNR) *A Guide to Aquatic Plants Identification and Management* (1994).

2.1 Location of Aquatic Plant Growth Within Lakes and Impoundments

Within a lake, pond, or impoundment, aquatic plants grow in the area known as the littoral zone—the shallow transition zone between dry land and the open water area of the lake. The littoral zone extends from the shore to a depth of about 15 feet, depending on water clarity. The littoral zone is highly productive. The shallow water, abundant light, and nutrient-rich sediment provide ideal conditions for plant growth. Aquatic plants, in turn, provide food and habitat for many animals such as fish, frogs, birds, muskrats, turtles, insects, and snails. Protecting the littoral zone is important for the health of a lake's fish and other animal populations.

The width of the littoral zone often varies within a lake and among lakes. In places where the slope of the lake bottom is steep, the littoral area may be narrow, extending several feet from the shoreline. In contrast, if the lake is shallow and the bottom slopes gradually, the littoral area may extend hundreds of feet into the lake or may even cover it entirely. Impoundments frequently note extensive littoral areas in the upper portion due to sedimentation and shallow depths. In contrast, the lower portions of impoundments may have little littoral area.

Cloudy or stained water, which limits light penetration, may restrict plant growth. In lakes where water clarity is low all summer, aquatic plants will not grow throughout the littoral zone, but will be restricted to the shallow areas near shore.

Other physical factors also influence the distribution of plants within a lake or pond. For example, aquatic plants generally thrive in shallow, calm water protected from heavy wind, wave, or ice action. However, if the littoral area is exposed to the frequent pounding of waves, plants may be scarce. In a windy location, the bottom may be sand, gravel, or large boulders--none of which provides a good place for plants to take root. In areas where a stream or river enters a lake, plant growth can be variable. Nutrients carried by the stream may enrich the sediments and promote plant growth; or, suspended sediments may cloud the water and inhibit growth.

2.1.1 Categories of Aquatic Plants

Aquatic plants are grouped into four major categories:

- Algae have no true roots, stems, or leaves and range in size from tiny, one-celled organisms to large, multi-celled plant-like organisms, such as *Chara*. Plankton algae, which consist of free-floating microscopic plants, grow throughout both the littoral zone and the well-lit surface waters of an entire lake. Other forms of algae, including *Chara* and some stringy filamentous types (such as *Cladophora*), are common only in the littoral area.

- Submerged plants have stems and leaves that grow entirely underwater, although some may also have floating leaves. Flowers and seeds on short stems that extend above the water may also be present. Submerged plants grow from near shore to the deepest part of the littoral zone and display a wide range of plant shapes. Depending on the species, they may form a low-growing "meadow" near the lake bottom, grow with lots of open space between plant stems, or form dense stands or surface mats.

- Floating-leaf plants are often rooted in the lake bottom, but their leaves and flowers float on the water surface. Water lilies are a well-known example. Floating leaf plants typically grow in protected areas where there is little wave action.

- Emergent plants are rooted in the lake bottom, but their leaves and stems extend out of the water. Cattails, bulrushes, and other emergent plants typically grow in wetlands and along the shore, where the water is less than 4 feet deep.

2.1.2 Value of Aquatic Plants

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. In lakes, life depends—directly or indirectly—on water plants. They are the primary producers in the aquatic food chain, converting the basic chemical nutrients in the water and soil into plant matter, which becomes food for all other aquatic life. Aquatic plants serve many important functions, including:

- ***Provide fish food***—More food for fish is produced in areas of aquatic vegetation than in areas where there are no plants. Insect larvae, snails, and freshwater shrimp thrive in plant beds. Sunfish eat aquatic plants besides aquatic insects and crustaceans.

- ***Offer fish shelter***—Plants provide shelter for young fish. Because bass, sunfish, and yellow perch usually nest in areas where vegetation is growing, certain areas of lakes are protected and posted by the DNR as fish spawning areas during spring and early summer. Northern pike use aquatic plants, too, by spawning in marshy and flooded areas in early spring.

- ***Improve water quality***—Certain water plants, such as rushes, can actually absorb and break down polluting chemicals.

- ***Protect shorelines and lake bottoms***—Aquatic plants, especially rushes and cattails, dampen the force of waves and help prevent shoreline erosion. Submerged aquatic plants also weaken wave action and help stabilize bottom sediment.

- ***Provide food and shelter for waterfowl***—Many submerged plants produce seeds and tubers (roots), which are eaten by waterfowl. Bulrushes, sago pondweed, and wild rice are especially important duck foods. Submerged plants also provide habitat to many insect species and other invertebrates that are, in turn, important foods for brooding hens and migrating waterfowl.

- ***Improve aesthetics***—The visual appeal of a lakeshore often includes aquatic plants, which are a natural, critical part of a lake community. Plants such as water lilies, arrowhead, and pickerelweed have flowers or leaves that many people enjoy.

- ***Provide economic value***—As a natural component of lakes, aquatic plants support the economic value of all lake activities. Wisconsin has a huge tourism industry centered on lakes and the recreation they support. Residents and tourists spend large sums of money each year to hunt, fish, camp, and watch wildlife on and around the state's lakes.

3.0 Compilation and Assessment of Existing Information

3.1 Physical Characteristics (Morphometry)

White Ash Lake (South) and North White Ash Lake are located in Polk County in northwestern Wisconsin, approximately 6 miles east of the Village of Balsam Lake. The general physical characteristics of the lakes are as follows (Wisconsin Department of Natural Resources, 1980):

Parameter	White Ash Lake (South)	North White Ash Lake
Surface area (acres)	153	119
Maximum depth (feet)	9	9
Mean depth (feet)	6	5
Volume (acre-feet)	924	595
Watershed Area (acres)	21,000*	700**
Ratio of Watershed to Lake	137:1	6:1
Hydraulic Retention Time (days)	20	70

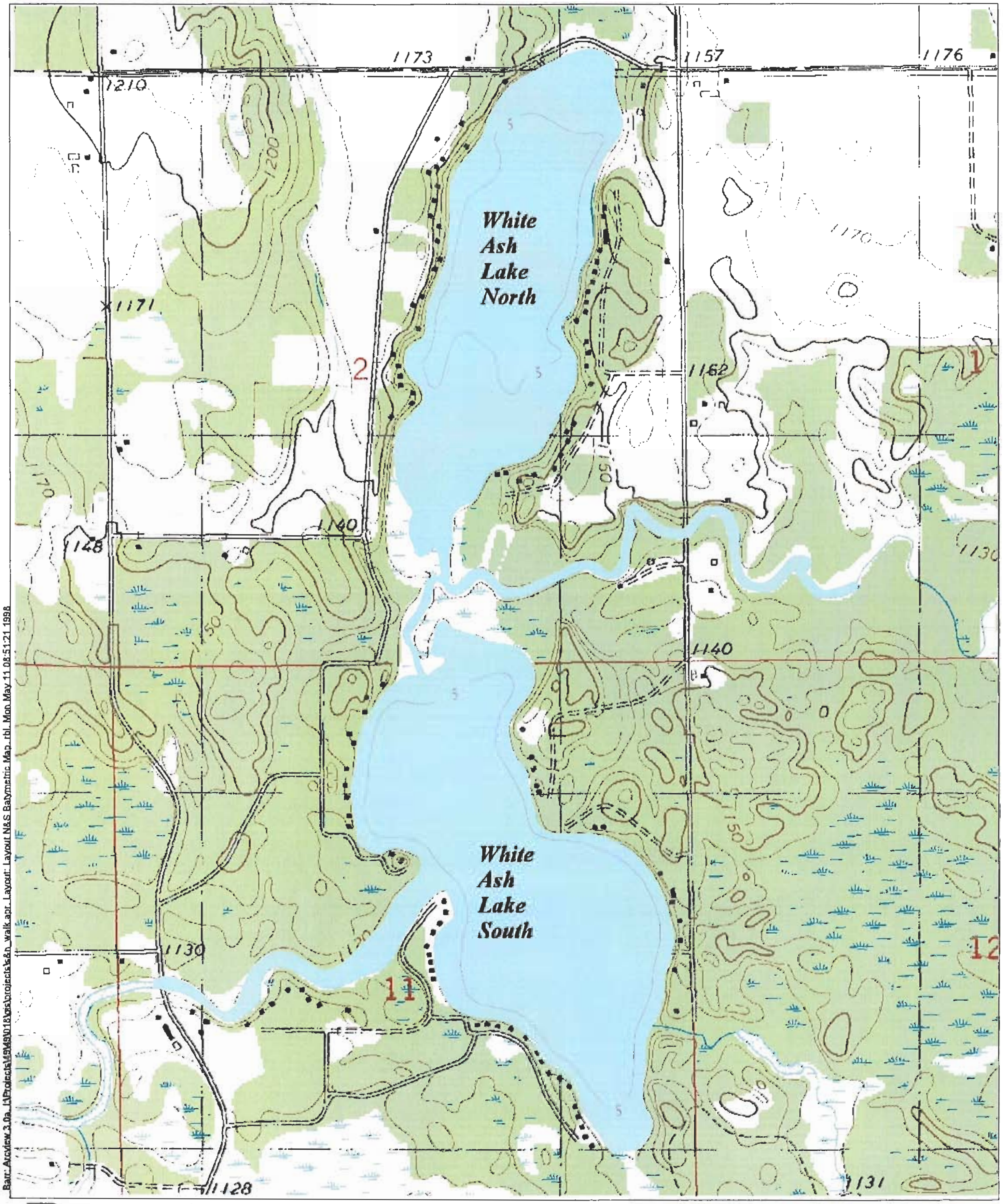
*Includes the basin's direct drainage area and the entire drainage area of the Apple River.

**At times the lake receives waters from the Apple River. Consequently, at times the lake's drainage area is approximately 21,000 acres and includes the entire drainage area of the Apple River.

A bathymetric map of the lakes is presented in Figure 2.

3.2 Water Quality

Results of a 1980 WDNR study of White Ash Lake (South) and North White Ash Lake indicated both lakes were moderately eutrophic (i.e., nutrient rich). The determination was based upon a Trophic State Index (TSI) that relates total phosphorus (a measure of lake fertility), chlorophyll *a*



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N

0 600 1200 1800 Feet

Depth Contour (feet)

Figure 2
Bathymetric
(Depth Contour) Map
White Ash Lake

(a measure of algal biomass), and Secchi disc transparency (a measure of water transparency) to water quality and the trophic state of a given lake.

Secchi disc measurements of White Ash Lake (South) were completed by a riparian resident during 1996 under the WDNR Self Help Monitoring Program. Summer measurements ranged from 8 feet (i.e., on June 15) to 3.25 feet (i.e., on August 9). The average summer Secchi disc measurement was 4.9 feet, indicating the lake was moderately eutrophic.

Study results indicate 1996 recreational-use impairment ranged from minimal to severe and was, on average, moderate. The determination is based upon the results of a survey completed by the Metropolitan Council (Osgood 1989) correlating the perceptions and expectations of people using a lake with its water quality. Survey results revealed the following relationship between a lake's recreational-use impairment and Secchi disc transparencies:

- No impairment occurs at Secchi disc transparencies greater than 4 meters;
- Minimal impairment occurs at Secchi disc transparencies of 2 to 4 meters;
- Moderate impairment occurs at Secchi disc transparencies of 1 to 2 meters;
- Moderate to severe use-impairment occurs at Secchi disc transparencies less than 1 meter (3.3 feet).

3.3 Fishery

Results of a 1980 WDNR study of White Ash Lake (South) indicated the lake had a gamefish population composed primarily of largemouth bass and northern pike, with small numbers of muskellunge present. Natural reproduction of bass and northern pike was good, and preservation of areas of emergent vegetation was determined to be vital to northern pike and muskellunge spawning. Bluegills and black crappies were common and reached a very desirable size. Other species present included yellow perch, rock bass, pumpkinseeds, white suckers and bullheads (WDNR 1980).

Results of a 1980 WDNR study of North White Ash Lake indicated the lake contained the same fish species as the south lake. However, its fishery was more variable due to periodic, partial winterkill conditions. Following winterkills, the fishery of the north lake was dominated by northern pike, yellow perch and bullheads and other species were present in fewer numbers.

Movement of fish into the north lake from the south lake likely occurs to some extent following winterkills (WDNR 1980).

3.4 Sediments

During the 1980 study of the lakes, the WDNR estimated the original volumes of White Ash Lake (South) and North White Ash Lake were 2,700 acre feet and 2,000 acre feet, respectively. The WDNR estimated the volumes of the basins during 1980 were 900 acre-feet (i.e., south lake) and 600 acre-feet (i.e., north lake). It is estimated that the reduction in volumes of over 65 percent has occurred because of both an internal (autochthonous) and external (allochthonus) infilling process. Decayed plant and animal material, along with the inorganic sediment transported by the Apple River, is deposited in a relatively flocculent manner on the lake beds. This results in a sediment that has a very high water content and low density. It was estimated that the infilling rates of the two basins are generally less than 1/4-inch per year (WDNR 1980).

3.5 Watershed Characteristics

The 21,000 acre watershed of White Ash Lake (South) (i.e., includes the direct watershed and the entire watershed of the Apple River) is dominated by woodland and wetland with agricultural land comprising only a small part. The Apple River is the main channelized input of surface water drainage to White Ash Lake. The river passes through the Rice Bed Creek Wildlife Area immediately before entering the lake. The 700-acre direct watershed of North White Ash Lake includes farm and wetland areas (WDNR 1980). The White Ash Lake (South) and North White Ash Lake watersheds primarily contain steep slopes and broad wetlands in the wooded portions and gentle slopes in the agricultural areas.

3.6 Hydrologic Budget

The WDNR estimated the hydrologic budget for White Ash Lake (South) and North White Ash Lake to be (WDNR 1980):

CALCULATED WATER BUDGET		
Source	**White Ash Lake (South)**	**North White Ash Lake**
Inputs:		
Precipitation	400 acre-ft,/yr.	300 acre-ft./yr.
Surface Water Runoff	14,300 acre-ft./yr.	1,500 acre-ft./yr.*
Groundwater Seepage	2,200 acre-ft./yr.	1,400 acre-ft./yr.
Total Inputs	16,900 acre-ft./yr.	3,200 acre-ft./yr.

* Includes an estimated 1,200 acre-ft/yr. contribution from the Apple River.

3.7 Phosphorus Loading

During 1980 the WDNR estimated annual phosphorus loads to White Ash Lake (South) and North White Ash Lake. Sources of phosphorus included surface water runoff, groundwater inputs, atmospheric loadings (i.e., both wet and dry deposition), and loadings from septic systems.

- Surface water loading was estimated from average phosphorus concentrations and average flow in the Apple River. An estimated average flow of 19 cubic feet per second (cfs) and an estimated average phosphorus concentration of 0.05 mg/L results in an estimated annual phosphorus load of 1,860 pounds per year for White Ash Lake (South). Inputs to North White Ash Lake were more difficult to quantify. As water levels change in White Ash Lake (South) in response to the flow inputs it receives, water levels in North White Ash Lake fluctuate. The north lake also receives runoff from its direct watershed. A loading of 250 pounds per year was estimated for North White Ash Lake.

- Atmospheric loading was estimated using a value of 0.3 pounds/surface acre of lake/year. Annual loading was estimated to be 50 pounds per year for the south lake and 40 pounds per year for the north lake.

- Groundwater inputs to the lakes were studied by the placement of observation wells around the lakes. The annual loads were estimated from an average phosphorus concentration of 0.03 mg/L and the annual groundwater flow from the water budget. The annual phosphorus loads were 180 pounds per year for the north lake and 120 pounds per year for the south lake.

- Septic system loading was estimated based upon the following assumptions. Approximately 50 cottages or homes were present around the south lake and 45 around the north lake. A 50 percent occupancy period was assumed. An average of 3 persons per cottage, each contributing 1.4 pounds of phosphorus per year was used. Effluent from all homes was assumed to enter the groundwater table and move toward the lakes. A value of 80 percent phosphorus attenuation capability was assumed based upon soils. The total annual phosphorus load from septic systems was assumed to be 40 pounds per year for both lakes.

The annual phosphorus budget estimated by the WDNR (1980) is:

Estimated Annual Phosphorus Budget				
Source	**North White Ash Lake**		**White Ash Lake (South)**	
	lbs./yr.	**Percent**	**lbs./yr.**	**Percent**
Inputs:				
Surface Runoff	250	55	1,860	87
Groundwater	120	27	180	9
Atmospheric	40	9	50	2
Septic Systems	40	9	40	2
Total Inputs	450	100	2,130	100

3.8 Macrophytes

Macrophyte surveys were completed in both basins during June and August of 1980. The macrophyte community in the north basin was comprised of a diverse population. Emergent species, particularly the large areas of wild rice and the floating-leafed species, were a desirable aspect of this basin's rooted plant community. Problem densities of primarily coontail and water stargrass were also present. Vegetation typically grew throughout the entire basin, with aquatic plant growth reaching the water's surface in areas with depths less than 6 ½ feet by June, and the entire basin (maximum depth of nine feet) by August.

In the south basin, macrophyte growth was limited to areas having water depths less than six feet. Vegetation in these areas reached the surface in June, but increased algal populations later in the summer limited surface aquatic plant growth to water depths of four feet or less (due to shading).

The diversity of the plant community in this basin was also quite good and growth of individual species was not exceptionally dense.

3.9 Shoreline Development

Shoreline development is essentially complete along the east and west shores of the two lakes (See Figure 2). The north and south shores are essentially undeveloped (See Figure 2). A plat map of the two lakes is found in Appendix A.

4.0 Methods

4.1 Membership Surveys

Members of the White Ash Lake Protection and Rehabilitation District were surveyed during 1997 to determine lake uses, lake use impairment, and opinions regarding macrophyte management options. The survey is presented in Appendix B.

4.2 Aquatic Plant Surveys

Aquatic plant (macrophyte) surveys of White Ash Lake (South) were completed during July 7 through 8 and during August 18 of 1997. Aquatic plant (macrophyte) surveys of North White Ash Lake were completed during July 9 through 10 and during August 2 through 3 of 1997. The July surveys were completed by Barr Engineering Co. with assistance from volunteers. The August surveys were completed by volunteers who were trained by Barr Engineering Co. staff during the July survey.

The methodology used was based upon Jessen and Lound (1962). The surveys were completed according to methods outlined in *Wisconsin's Department of Natural Resources Long-Term Trend Lake Monitoring Methods*, (Bureau of Water Resources Management, July 1987) as modified by Deppe and Lathrop (1992). This methodology enables the plant specialist an opportunity to determine the presence, frequency, and density of different plant species. The following outlines the methodology followed in the study.

- Transects were chosen at approximately 500-foot intervals of shoreline. The locations of the 23 transects selected for the study of White Ash Lake (South) are shown on Figure 3. The locations of the 20 transects selected for the study of North White Ash Lake are shown on Figure 4. Transects extended from shore to the maximum depth of plant growth. Transect locations were marked by a shoreline stake during the July survey to insure sampling from the same locations during the August survey.

- Compass readings were taken at each transect location for future reference.

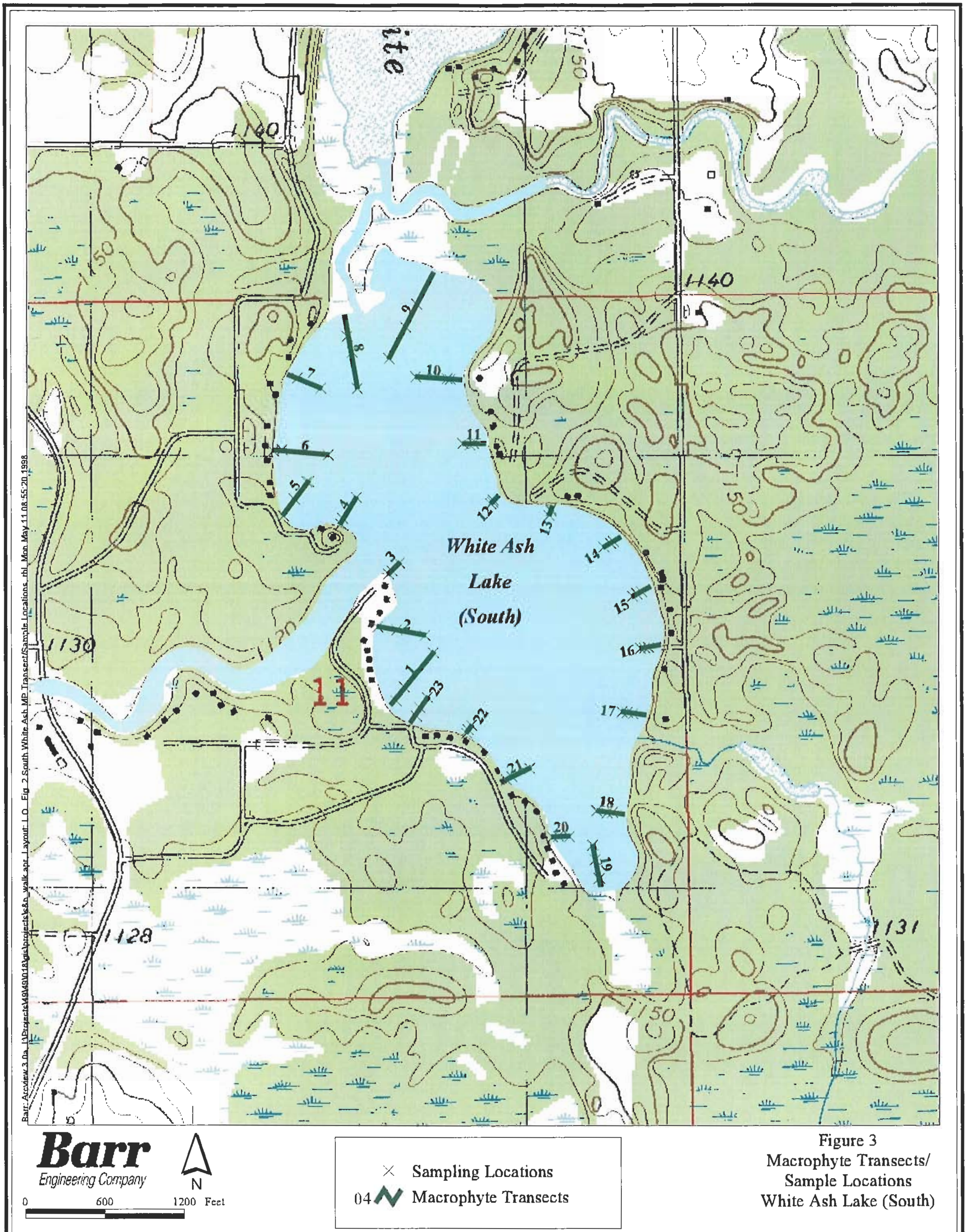
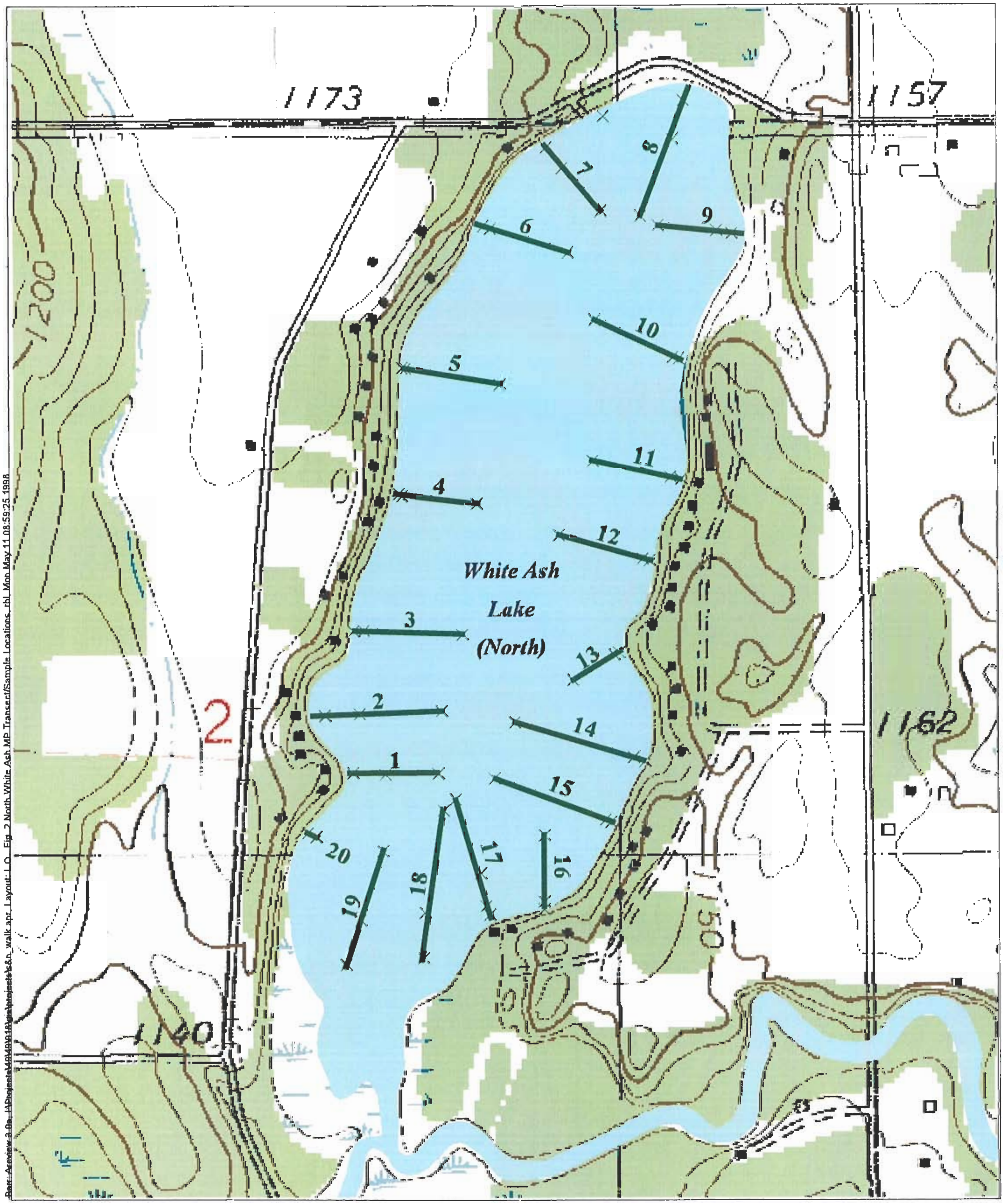


Figure 3
Macrophyte Transects/
Sample Locations
White Ash Lake (South)



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Engineering Company

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0 600 1200 Feet

× Sampling Locations

Macrophyte Transects

Figure 4
Macrophyte Transect/
Sample Locations
White Ash Lake (North)

- Transects were broken down into the following depth categories:
  0 to 1.5 feet
  1.5 to 5.0 feet
  5 to 10 feet (or to the maximum rooting depth)

- Four rake samples were taken at each depth zone to determine the presence and abundance of species. The sample point at each depth zone consisted of a 6-foot diameter circle divided into four quadrants. A tethered garden rake with an extended handle (16 feet) was used to collect a sample from each quadrant.

- Collection of samples, identification of species, and determination of density ratings for each species occurred at all sampling points. The rake coverage technique was used to assign density ratings (Deppe and Lathrop 1992) in accordance with the following criteria:

Rake Coverage (% of Rake Head) Covered by a Species	**Density Rating**
81-100	5
61-80	4
41-60	3
21-40	2
1-20	1
0	0

- A Global Positioning System (GPS) unit was used in the field to note latitude and longitude readings of each sampling point for future reference.

- Sediment type was determined at each sampling point.

- Maximum rooting depths were observed at all transects.

5.0 Results and Discussion

5.1 Membership Survey Results

Members of the White Ash Lake Protection and Rehabilitation District were surveyed to determine their:

- understanding of the functions and values of aquatic plants,
- uses of the lake,
- perceived impairment of lake uses by aquatic plants and
- aquatic plant management preferences.

A total of 173 surveys were mailed and 41 responses were received (i.e., 24% return rate). Survey results are presented in Figures 5 through 7 and are summarized in Appendix A. The survey results indicated:

- Most respondents (i.e., 83%) recognized that aquatic plants have value.
- Respondents indicated aquatic plants have a high to medium level of importance for fish shelter and spawning, fish food, and food and shelter for waterfowl.
- Respondents indicated aquatic plants have a low level of importance for aesthetics.
- Respondents indicated the primary use of White Ash Lake (South) and North White Ash Lake is fishing (80%). Other major uses include viewing (66%), swimming (63%), power boating (49%), and canoeing (34%).
- Respondents indicated the primary use impairment caused by aquatic plants is fishing (80%) and the second highest use impairment is swimming (76%). Other use impairments are viewing and power boating.
- A total of 73 percent of respondents indicated they have removed or attempted to remove aquatic plants around their dock or along their shoreline.
- A total of 51% of respondents indicated they are opposed to the use of chemicals to remove aquatic plants from the lake.
- Only 15% of respondents indicated they are opposed to mechanical harvesting of aquatic plants in the lake.
- A total of 68% of respondents indicated the lake district should own and operate a weed harvestor.

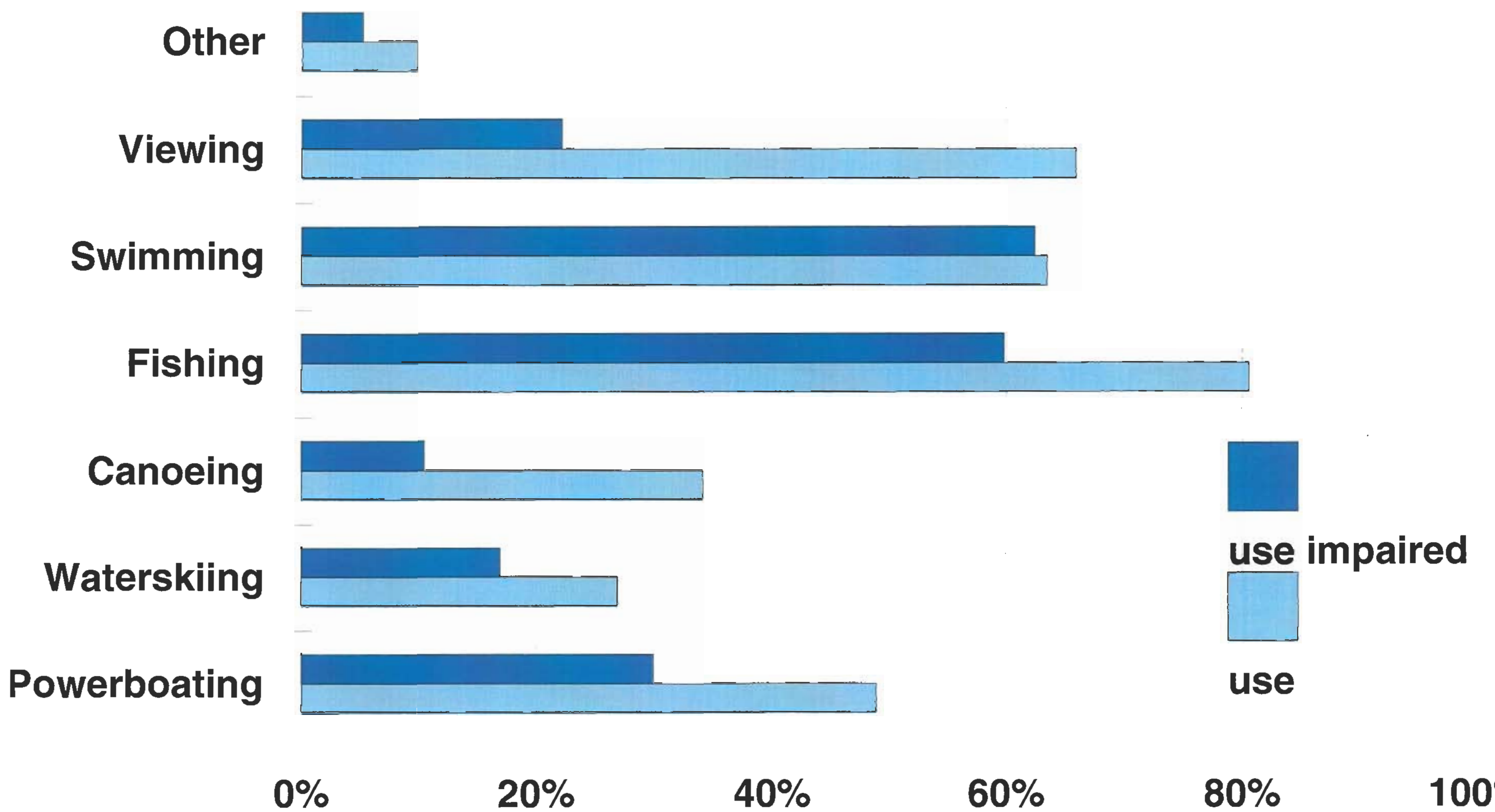


Figure 5. Recreation Use and Impairment Percent of Total Responses

Figure 6. Aquatic Plant Functions
Rated Level of Importance

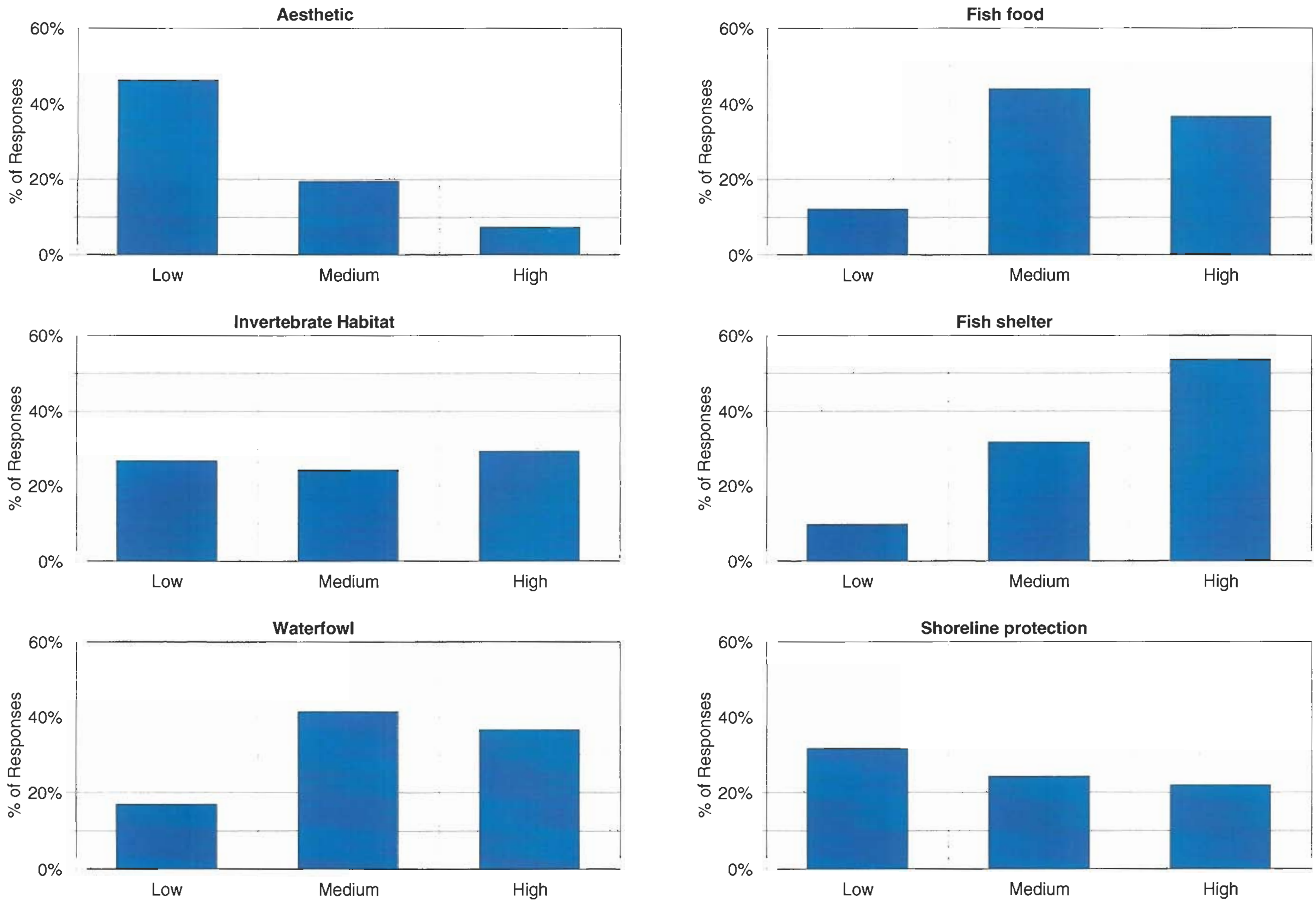
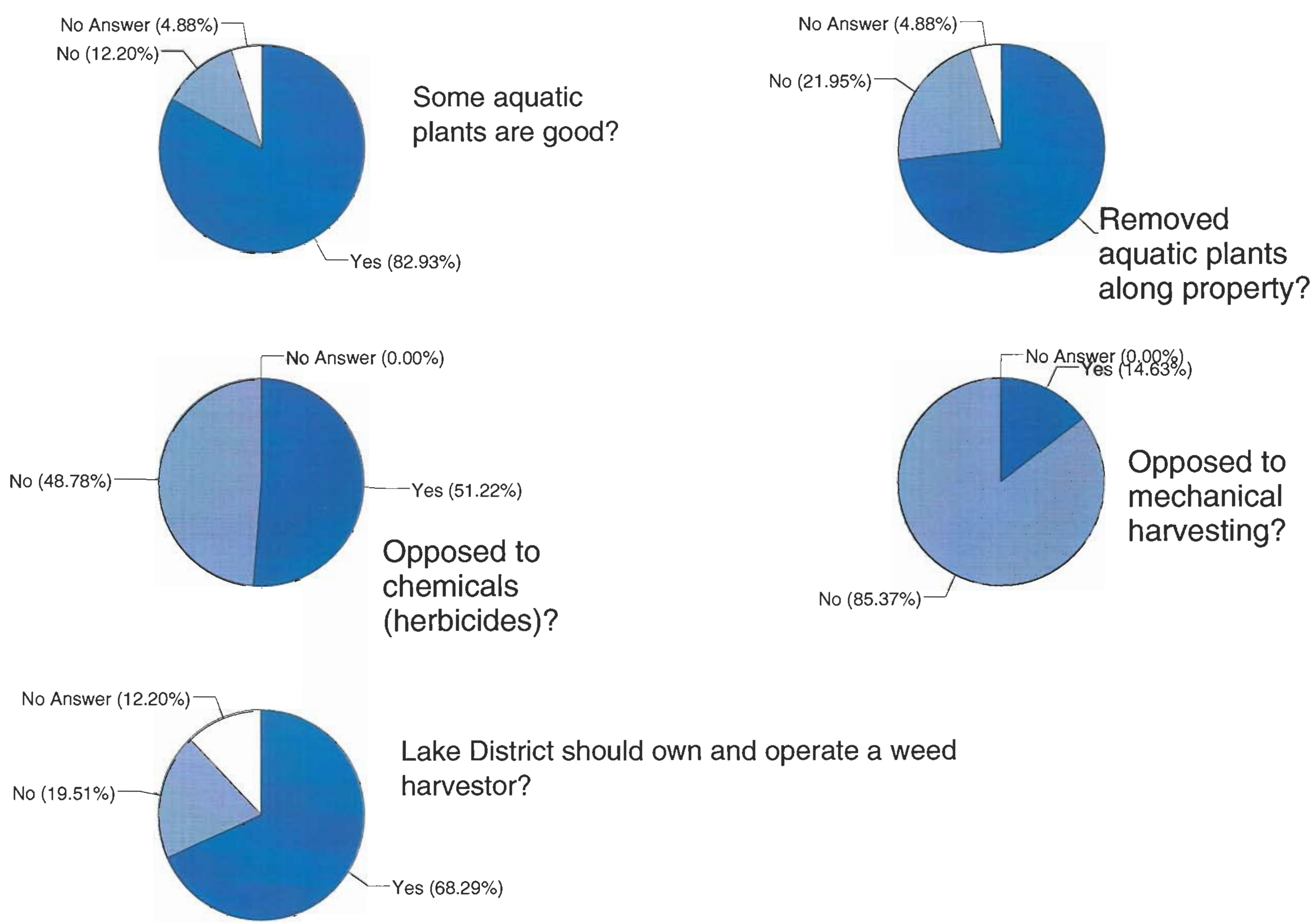


Figure 7
Responses for Managing Aquatic Plants



5.2 Macrophyte Survey Results

Results of the 1997 White Ash Lake (South) and North White Ash Lake surveys indicate the lakes contained a diverse assemblage of macrophyte (aquatic plant) species representing the four macrophyte types—submersed plants, floating-leaf plants, emergent plants and the alga *Chara*. Of the four types, submersed plants dominated the macrophyte community. Survey results indicated (See Figures 8 through 11 and Appendices C and D):

- Submersed plants were found in all sample transects during both surveys of White Ash Lake (South) and North White Ash Lake.

- Floating-leaf plants were found in most sample transects during the surveys of the two lakes. Specifically, floating-leaf plants were found in 100 percent and 87 percent of White Ash Lake (South) transects during the July and August surveys, respectively. Floating-leaf plants were found in 95 percent and 85 percent of North White Ash Lake transects during the July and August surveys, respectively.

- Emergent plants were found in some sample transects during the surveys of the two lakes. Specifically, emergent plants were found in 39 percent and 26 percent of White Ash Lake (South) transects during the July and August surveys, respectively. Emergent plants were found in 15 percent of the North White Ash Lake transects during July and were not sited during the August survey.

- The alga *Chara* was sited in 52 percent and 35 percent of the White Ash Lake (South) transects during the July and August surveys, respectively. The alga *Chara* was sited in 20 percent and 5 percent of the North White Ash Lake transects during the July and August surveys, respectively.

The large number of species noted in White Ash Lake (South) and North White Ash Lake during 1997 (i.e., 23 and 21 species from the south and north lakes, respectively) is indicative of a stable and healthy macrophyte community. Further evidence of a diverse plant community was indicated by the large number of species found in each transect. The average number of species occurring in each transect during July was 11 and during August was 7 (i.e., south lake) and 8 (i.e., north lake).

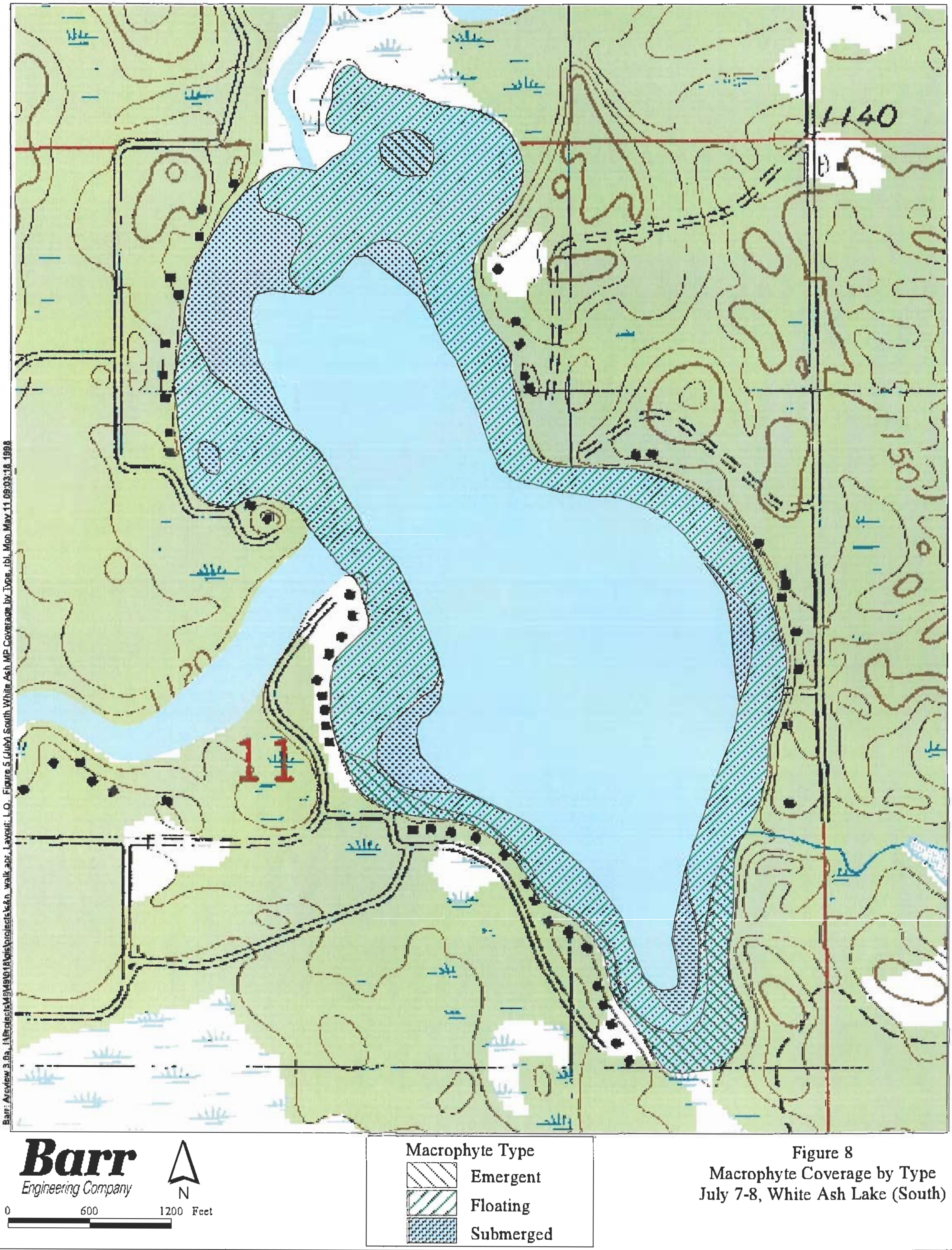
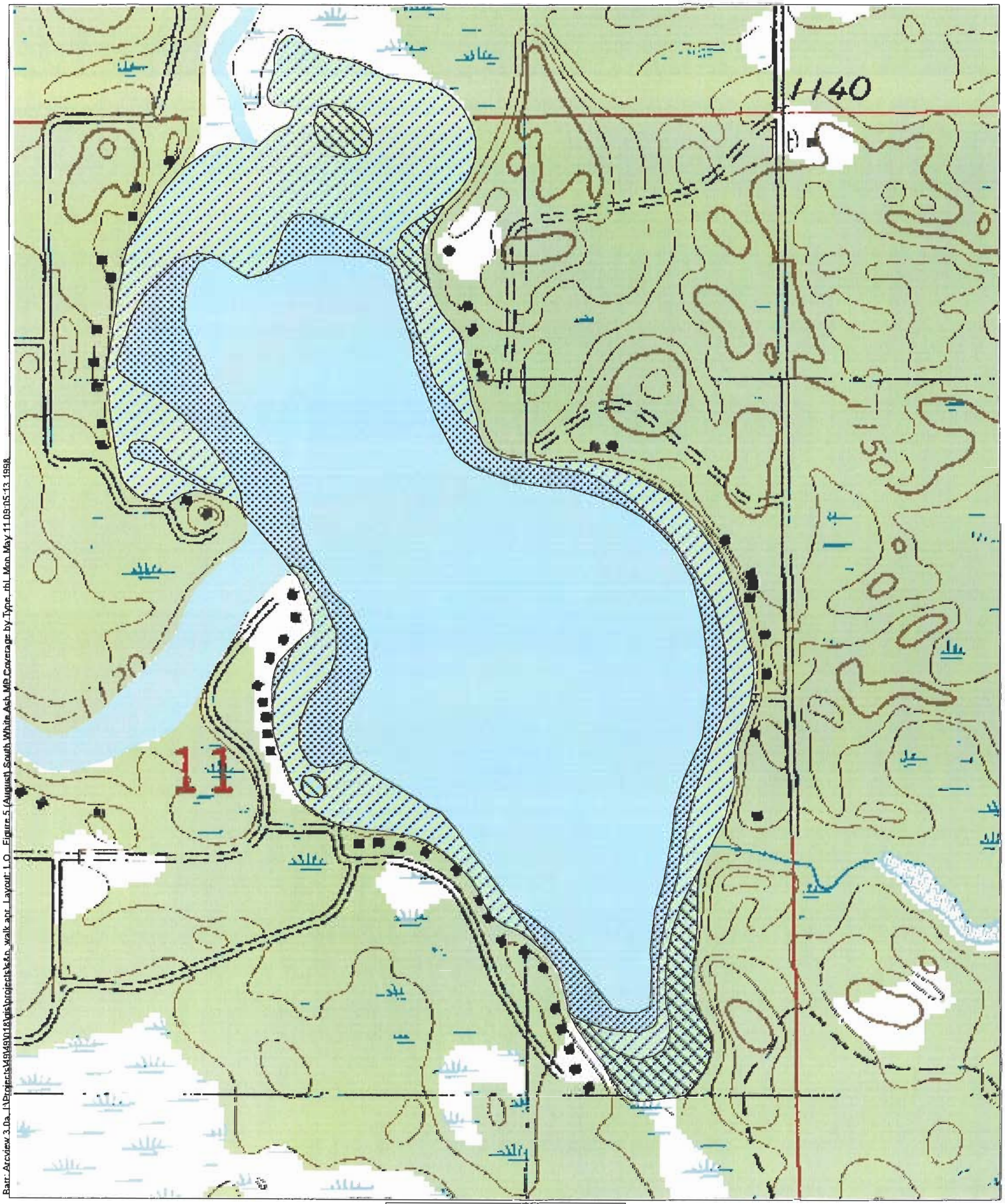


Figure 8
Macrophyte Coverage by Type
July 7-8, White Ash Lake (South)



Barr
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N

0 600 1200 Feet

Macrophyte Type
- Emergent
- Floating
- Submerged

Figure 9
Macrophyte Coverage by Type
August 18, White Ash Lake (South)

Barr
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N

0 600 1200 Feet

Macrophyte Type
Emergent
Floating
Submerged

Figure 10
Macrophyte Coverage by Type
July 9-10, White Ash Lake (North)

Barr Engineering Company

N

0 600 1200 Feet

Macrophyte Type

- Emergent
- Floating
- Submerged

Figure 11
Macrophyte Coverage by Type
August 2-3, White Ash Lake (North)

The large number of species in each transect:

- Provides a diverse habitat for fish and invertebrates (i.e., food for fish) and encourages a more diverse fish and invertebrate community;

- Protects fisheries' habitat from destruction by a disease as a species-specific disease would have little impact upon the diverse community;

- Affords protection from invasion by exotic species (i.e., exotic species generally invade areas lacking vegetation);

A few species were abundant in both lakes during 1997, but diversity characterized the macrophyte community. The two predominant species were *Ceratophyllum demersum* (Coontail/Hornwort) and *Elodea Canadensis* (Canada Waterweed), occurring in 71 percent to 97 percent of the White Ash Lake (South) sample locations and in 95 percent to 100 percent of the North White Ash Lake sample locations (See Figures 12 and 13). Other abundant species included:

- *Potamogeton crispus* (curly-leaf pondweed) in 73 percent of the White Ash Lake (South) and 57 percent of the North White Ash Lake locations sampled during July;

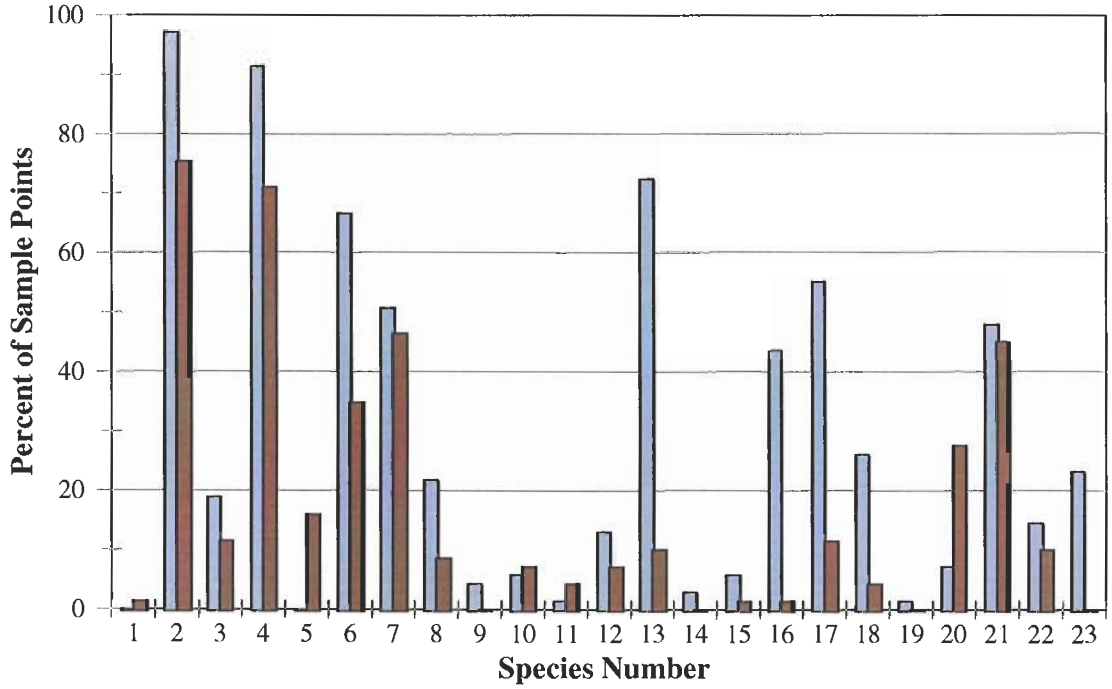
- *Potamogeton zosteriformis* (flat-stemmed pondweed) in 77 and 92 percent of the North White Ash Lake locations sampled during July and August, respectively; it was found in 55 percent of the White Ash Lake (South) locations sampled during July.

- *Lemna trisulca* (star duckweed) in 67 percent of the White Ash Lake (South) locations sampled during July.

- *Vallisneria americana* (Wild Celery) in 58 percent of the White Ash Lake (South) locations sampled during August.

Figure 12

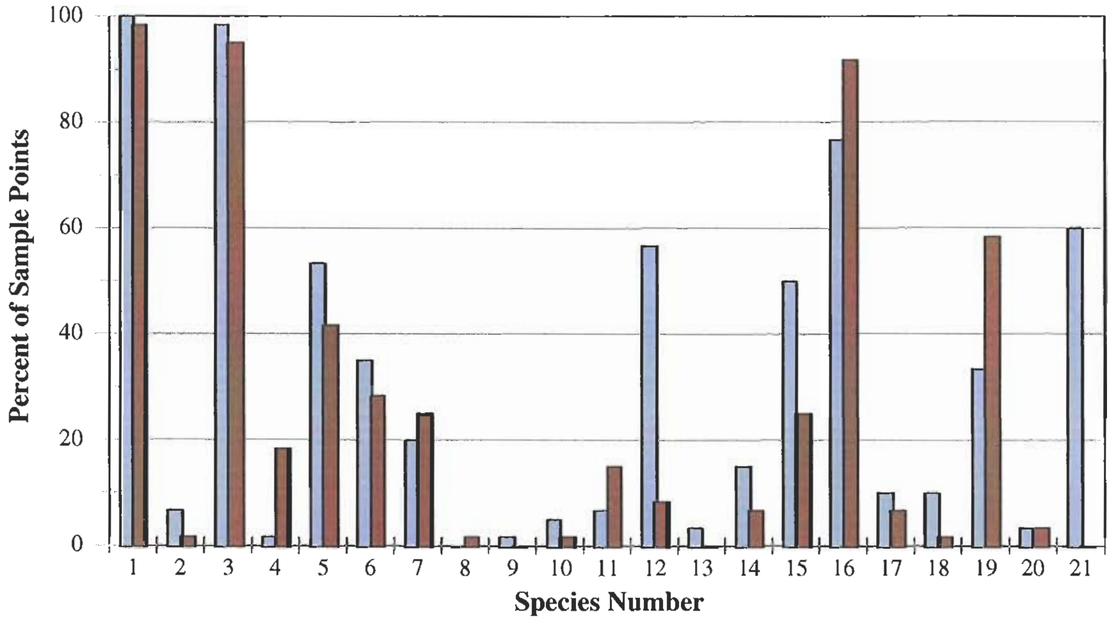
1997 White Ash Lake (South) Macrophyte Survey
Frequency of Occurrence (Percent of Sample Points)
July 7-8 and August 18



Species No.	Species	July 7-8	August 18
1	*Alisma triviala*	0.0	1.4
2	*Ceratophyllum demersum*	97.1	75.4
3	*Chara spp.*	18.8	11.6
4	*Elodea canadensis*	91.3	71.0
5	*Lemna spp.*	0.0	15.9
6	*Lemna triscula*	66.7	34.8
7	*Myriophyllum exalbescens*	50.7	46.4
8	*Najas spp.*	21.7	8.7
9	*Nuphar microphyllum*	4.3	0.0
10	*Nuphar variegatum*	5.8	7.2
11	*Nymphaea tuberosa*	1.4	4.3
12	*Potamogeton amplifolis*	13.0	7.2
13	*Potamogeton crispus*	72.5	10.1
14	*Potamogeton pectinatus*	2.9	0.0
15	*Potamogeton richardsonii*	5.8	1.4
16	*Potamogeton strictifolius*	43.5	1.4
17	*Potamogeton zosteriformis*	55.1	11.6
18	*Ranunculus spp.*	26.1	4.3
19	*Sagittaria spp.*	1.4	0.0
20	*Utricularia spp.*	7.2	27.5
21	*Vallisneria americana*	47.8	44.9
22	*Zizania aquatica*	14.5	10.1
23	*Zosterella dubia*	23.2	0.0

Figure 13

1997 White Ash Lake (North) Macrophyte Survey
Frequency of Occurrence (Percent of Sample Points)
July 9-10 and August 2-3



Species No.	Species	July 9-10	August 2-3
1	*Ceratophyllum demersum*	100.0	98.3
2	*Chara spp.*	6.7	1.7
3	*Elodea canadensis*	98.3	95.0
4	*Lemna spp.*	1.7	18.3
5	*Lemna triscula*	53.3	41.7
6	*Myriophyllum exalbescens*	35.0	28.3
7	*Najas flexilis*	20.0	25.0
8	*Najas spp.*	0.0	1.7
9	*Nuphar microphyllum*	1.7	0.0
10	*Nuphar variegatum*	5.0	1.7
11	*Nymphaea tuberosa*	6.7	15.0
12	*Potamogeton crispus*	56.7	8.3
13	*Potamogeton pectinatus*	3.3	0.0
14	*Potamogeton richardsonii*	15.0	6.7
15	*Potamogeton strictifolius*	50.0	25.0
16	*Potamogeton zosteriformis*	76.7	91.7
17	*Ranunculus spp.*	10.0	6.7
18	*Sagittaria spp.*	10.0	1.7
19	*Vallisneria americana*	33.3	58.3
20	*Zizania aquatica*	3.3	3.3
21	*Zosterella dubia*	6.0	0.0

Macrophyte diversity was calculated for White Ash Lake (South) and North White Ash Lake using a modification of Simpson's Index (1949):

$$1-\sum (rf/100)^2$$

Where:

rf = the relative frequency of each species. Frequencies were calculated as the number of sampling points where a species occurred divided by the total number of sampling points at depths less than or equal to the maximum depth of plant growth. Frequencies were relativized to 100% to describe community structure (i.e., rf). Frequencies are shown in Figure 12 and 13. Relative frequencies are presented in Appendix E.

The data indicate the lake's plant community was highly diverse. On a scale of 0 to 1, with 0 indicating no plant diversity and 1 indicating the highest plant diversity, White Ash Lake (South) noted a diversity of 0.91 during July and August of 1997. North White Ash Lake noted a diversity of 0.89 during July and 0.88 during August. The diversities measured in 1997 are near the high end of the range of diversities noted for 46 Wisconsin lakes sampled by the Wisconsin Department of Natural Resources, Office of Inland Lake Renewal (See Table 1).

The macrophyte community found in each lake was stable throughout the summer as evidenced by the similarity in species noted in the July and August surveys. In White Ash Lake (South), 21 of 23 species (i.e., 91 percent) observed during the summer were present during the July survey and 22 of its 23 species (i.e., 96 percent) were present during the August survey. In North White Ash Lake, 20 of the 21 species (i.e., 95 percent) observed during the summer were present during the July survey and 18 of its 21 species (i.e., 86 percent) were present during the August survey.

The cumulative effect of the large number of species in the lakes was assessed from the proportion of open area in the littoral zone (i.e., Percent Open Area). The percent open area was estimated from the number of sampling points containing no vegetation divided by the total number of sampling points at a depth less than or equal to the maximum depth of plant growth. Maximum depth of plant growth is the water depth at the deepest sampling point where plant growth was found. The maximum depth of plant growth in White Ash Lake (South) was, on average, 9 feet during July. The maximum depth of plant growth in North White Ash Lake was, on average, 8 feet during July. White Ash Lake (South) noted a 0 to 2 percent open area and North White Ash Lake noted a 0 percent open area during 1997. The cumulative effect of the large number of species in White Ash Lake (South) was little or no open area in areas containing plant growth. North White Ash Lake did not have any open areas in areas containing plant growth (i.e., nearly the entire lake).

Table 1 Diversities of some Wisconsin Plant Communities (from Nichols 1997)

Lake Name	Diversity (Late Summer)	Lake Name	Diversity (Late Summer)
Amnicon Lake	0.95	Leota Lake	0.78
Apple River Flowage	0.91	Little Arbor Vitae Lake	0.78
Ashippun Lake	0.91	Little Elkhart Lake	0.91
Balsam Lake	0.90	Long Lake T32N	0.81
Bear Lake	0.85	McCann Lake	0.80
Big Blake Lake (Blake)	0.89*	Mid Lake (Nawaii)	0.78
Big Butternut Lake	0.84	Morris Lake (Mt. Morris)	0.91
Big Hills Lake (Hills)	0.88	Mud Hen Lake	0.90
Big Round Lake	0.89	Muskellunge Lake	0.92
Cary Pond	0.79	Oconomowoc Lake, Upper	0.70
Cedar Lake	0.91	Okauchee Lake	0.86
Chain Lake	0.74	Pearl Lake	0.86
Church Pine Lake	0.93	Pigeon Lake	0.89
Chute Pond	0.86	Pike Lake	0.90
Clear Lake	0.74	Pine Lake	0.91
Como Lake	0.88	Post Lake	0.91
Decorah Lake	0.93	Rib Lake	0.71
Dowling Lake	0.87	Round (Wind) Lake	0.92
Enterprise Lake	0.86	Silver Lake (Anderson)	0.69
George Lake	0.58	Tichigan Lake	0.69
Half Moon Lake	0.93	Twin Lake, North	0.73
Half Moon Lake T47N	0.77	Twin Lake, South	0.81
Helen Lake	0.80	**White Ash Lake**	**0.91**
Island Lake	0.78	**White Ash Lake, North**	**0.88**

*Diversities during 1979 and during 1997 were the same, 0.89.

The cumulative effect of the large number of species in the lakes was further evaluated by estimating the total acreage covered by macrophytes during 1997. The total coverage by macrophytes of White Ash Lake (South) was 78 acres (i.e., 51 percent of the lake's surface area) during July and 70 acres (i.e., 46 percent of the lake's surface area) during August. North White Ash Lake noted a total macrophyte coverage of 117 acres (i.e., 98 percent of the lake's surface area during July and August.

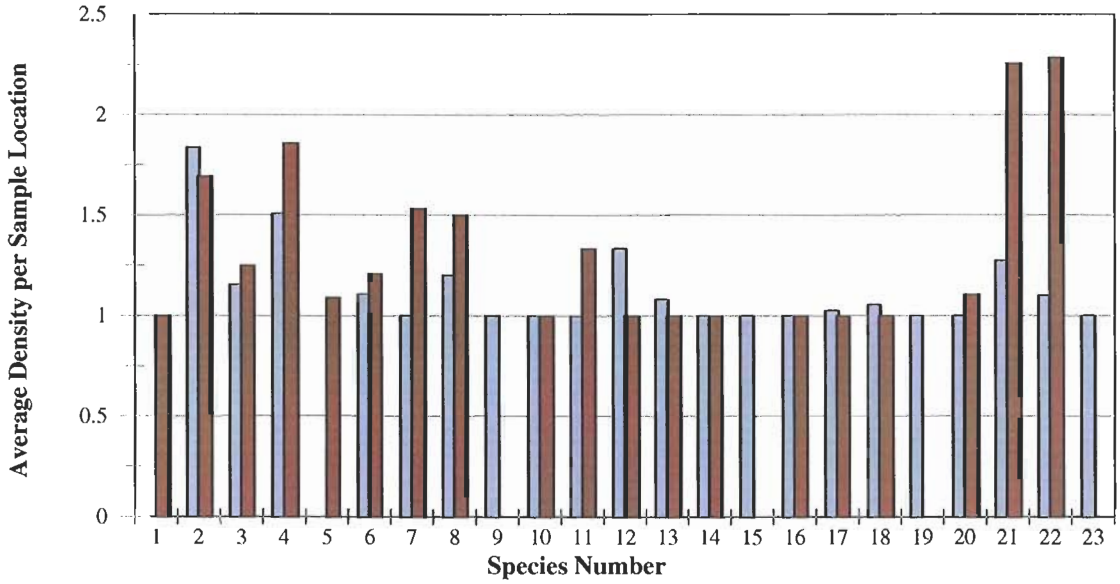
Although individual species in White Ash Lake (South) and North White Ash Lake generally occurred in a relatively low density during 1997, the concurrent growth of many species at each sample location resulted in an overall plant growth of high density. The density of individual species per sample location ranged from 1.0 to 5.0 (i.e., on a scale of 0 to 5, as discussed in the methods section, 0 indicated the lowest density and 5 indicated the highest density) during July and August in both lakes. However, the average density of individual species in White Ash Lake (South) ranged from 1.0 to 1.8 during July and from 1.0 to 2.3 during August (See Figure14). The average density of individual species in North White Ash Lake ranged from 1.0 to 5.0 during July and from 1.0 to 3.3 during August (See Figure 15). The concurrent occurrence of approximately 7 to 11 individual species per sample transect (i.e., average number of species per transect during July and August from the two lakes) resulted in an overall plant growth of high density (see Figures 16 through 19). In White Ash Lake (South), a dense macrophyte growth occurred from the lake's shoreline to a maximum depth that was, on average, 9 feet and ranged from 9 to 10 feet in individual sample transects. In North White Ash Lake, macrophyte coverage essentially occurred throughout the entire lake. The high macrophyte density posed navigation problems to lake users.

The White Ash Lake (South) and North White Ash Lake macrophyte communities perform a number of valuable functions. These include:

- Habitat for fish, insects, and small aquatic invertebrates
- Food for waterfowl, fish, and wildlife
- Oxygen producers
- Provide spawning areas for fish, in early spring
- Helps stabilize marshy borders of the lake; helps protect shorelines from wave erosion
- Provides nesting sites for waterfowl and marsh birds

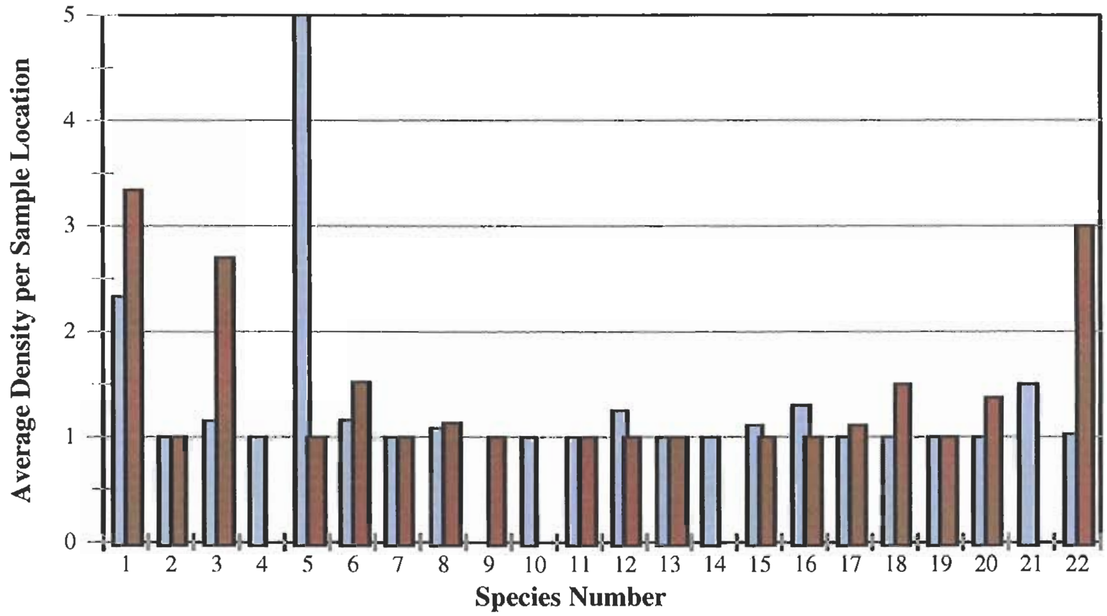
Table 2 summarizes the functions performed by several individual species noted in the lake.

Figure 14
1997 White Ash Lake (South)
Average Density (per Sample Point)
July 7-8 and August 18

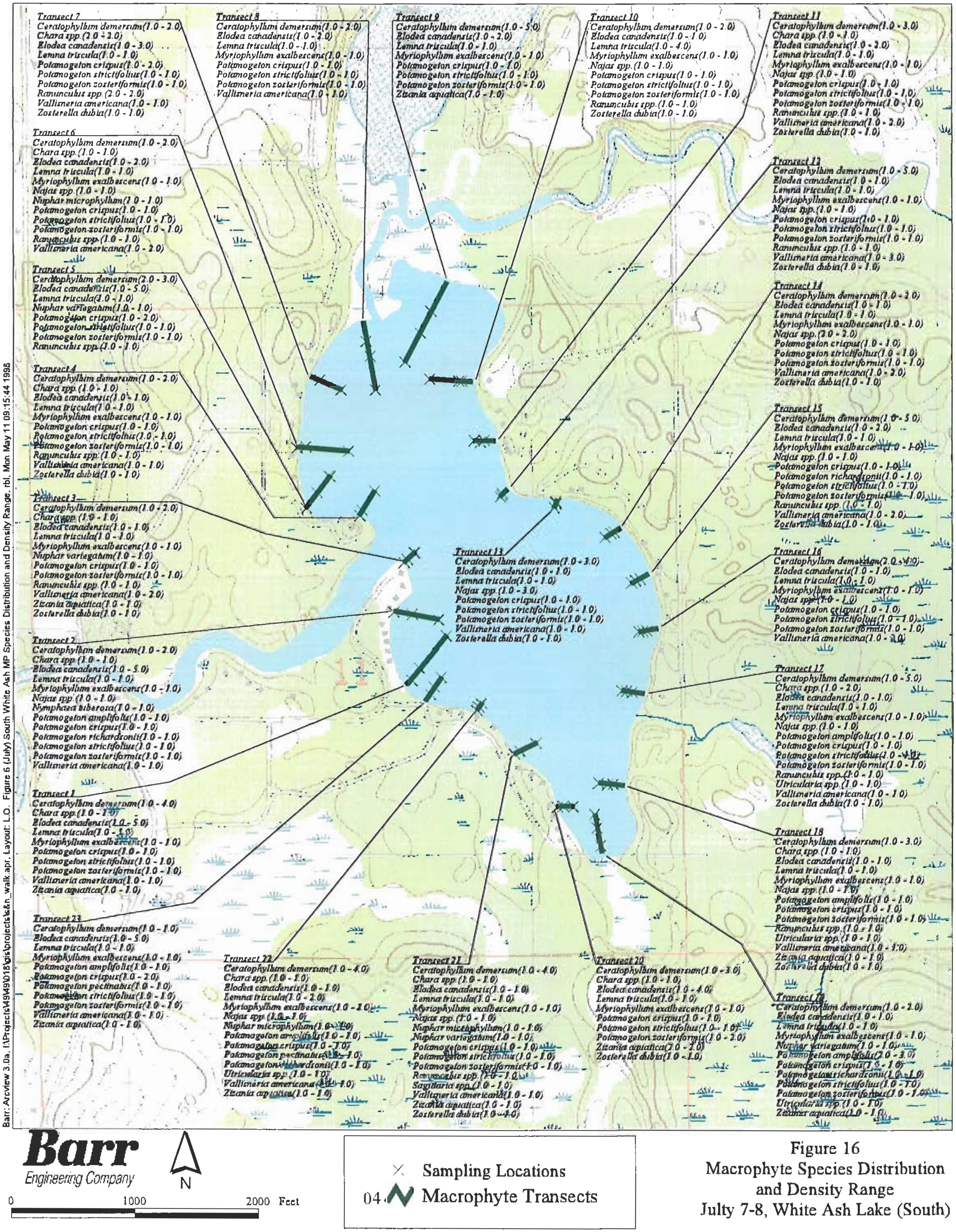


Species	Species Name	Common Name	Average Density July 7-8	Average Density August 18
1	*Alisma triviala*	Water Plantain	0.0	1.0
2	*Ceratophyllum demersum*	Coontail/Hornwort	1.8	1.7
3	*Chara spp.*	Muskgrass	1.2	1.3
4	*Elodea canadensis*	Canada Waterweed	1.5	1.9
5	*Lemna spp.*	Duckweed	0.0	1.1
6	*Lemna triscula*	Star Duckweed	1.1	1.2
7	*Myriophyllum exalbescens*	Northern Watermilfoil	1.0	1.5
8	*Najas spp.*	Bushy Pondweed	1.2	1.5
9	*Nuphar microphyllum*	Little Yellow Water Lily	1.0	0.0
10	*Nuphar variegatum*	Yellow Water Lily	1.0	1.0
11	*Nymphaea tuberosa*	White Water Lily	1.0	1.3
12	*Potamogeton amplifolis*	Large-leaf Pondweed	1.3	1.0
13	*Potamogeton crispus*	Curlyleaf Pondweed	1.1	1.0
14	*Potamogeton pectinatus*	Sago Pondweed	1.0	1.0
15	*Potamogeton richardsonii*	Claspingleaf Pondweed	1.0	0.0
16	*Potamogeton strictifolius*	Narrowleaf Pondweed	1.0	1.0
17	*Potamogeton zosteriformis*	Flat-stemmed Pondweed	1.0	1.0
18	*Ranunculus spp.*	Buttercup	1.1	1.0
19	*Sagittaria spp.*	Arrowhead	1.0	0.0
20	*Utricularia spp.*	Bladderwort	1.0	1.1
21	*Vallisneria americana*	Wild Celery	1.3	2.3
22	*Zizania aquatica*	Wild Rice	1.1	2.3
23	*Zosterella dubia*	Water Star Grass	1.0	0.0

Figure 15
1997 White Ash Lake (North)
Average Density (per Sample Point)
July 9-10 and August 2-3



Species Number	Species Name	Common Name	Average Density July 9-10	August 2-3
1	*Ceratophyllum demersum*	Coontail/Hornwort	2.3	3.3
2	*Chara spp.*	Muskgrass	1.0	1.0
3	*Elodea canadensis*	Canada Waterweed	1.2	2.7
4	*Eriocaulon spp.*	Pipewort	1.0	0.0
5	*Lemna spp.*	Duckweed	5.0	1.0
6	*Lemna triscula*	Star Duckweed	1.2	1.5
7	*Myriophyllum exalbescens*	Northern Watermilfoil	1.0	1.0
8	*Najas flexilis*	Bushy Pondweed	1.1	1.1
9	*Najas spp.*	Bushy Pondweed	0.0	1.0
10	*Nuphar microphyllum*	Little Yellow Water Lily	1.0	0.0
11	*Nuphar variegatum*	Yellow Water Lily	1.0	1.0
12	*Nymphaea tuberosa*	White Water Lily	1.3	1.0
13	*Potamogeton crispus*	Curlyleaf Pondweed	1.0	1.0
14	*Potamogeton pectinatus*	Sago Pondweed	1.0	0.0
15	*Potamogeton richardsonii*	Claspingleaf Pondweed	1.1	1.0
16	*Potamogeton strictifolius*	Narrowleaf Pondweed	1.3	1.0
17	*Potamogeton zosteriformis*	Flat-stemmed Pondweed	1.0	1.1
18	*Ranunculus spp.*	Buttercup	1.0	1.5
19	*Sagittaria spp.*	Arrowhead	1.0	1.0
20	*Vallisneria americana*	Wild Celery	1.0	1.4
21	*Zizania aquatica*	Wild Rice	1.5	0.0
22	*Zosterella dubia*	Water Star Grass	1.0	3.0



Barr: Arcview 3.0a, I:\Projects\49\49018\gis\projects\sn_walk.apr, Layout: L.O. Figure 6 (July) South White Ash MP Species Distribution and Density Range. tbl. Mon May 11 09:15:44 1998

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Figure 16
Macrophyte Species Distribution and Density Range
Julty 7-8, White Ash Lake (South)

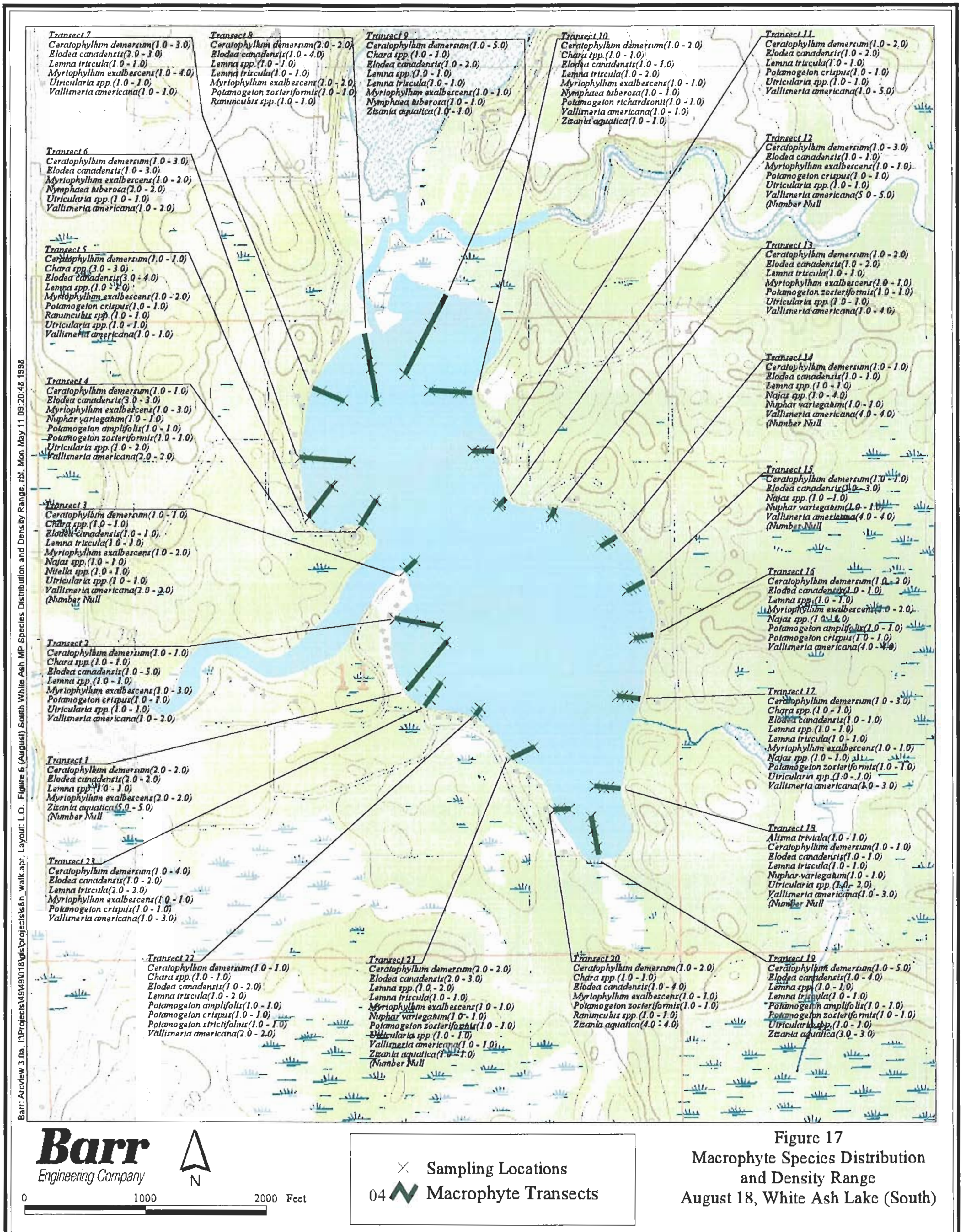


Figure 17
Macrophyte Species Distribution
and Density Range
August 18, White Ash Lake (South)

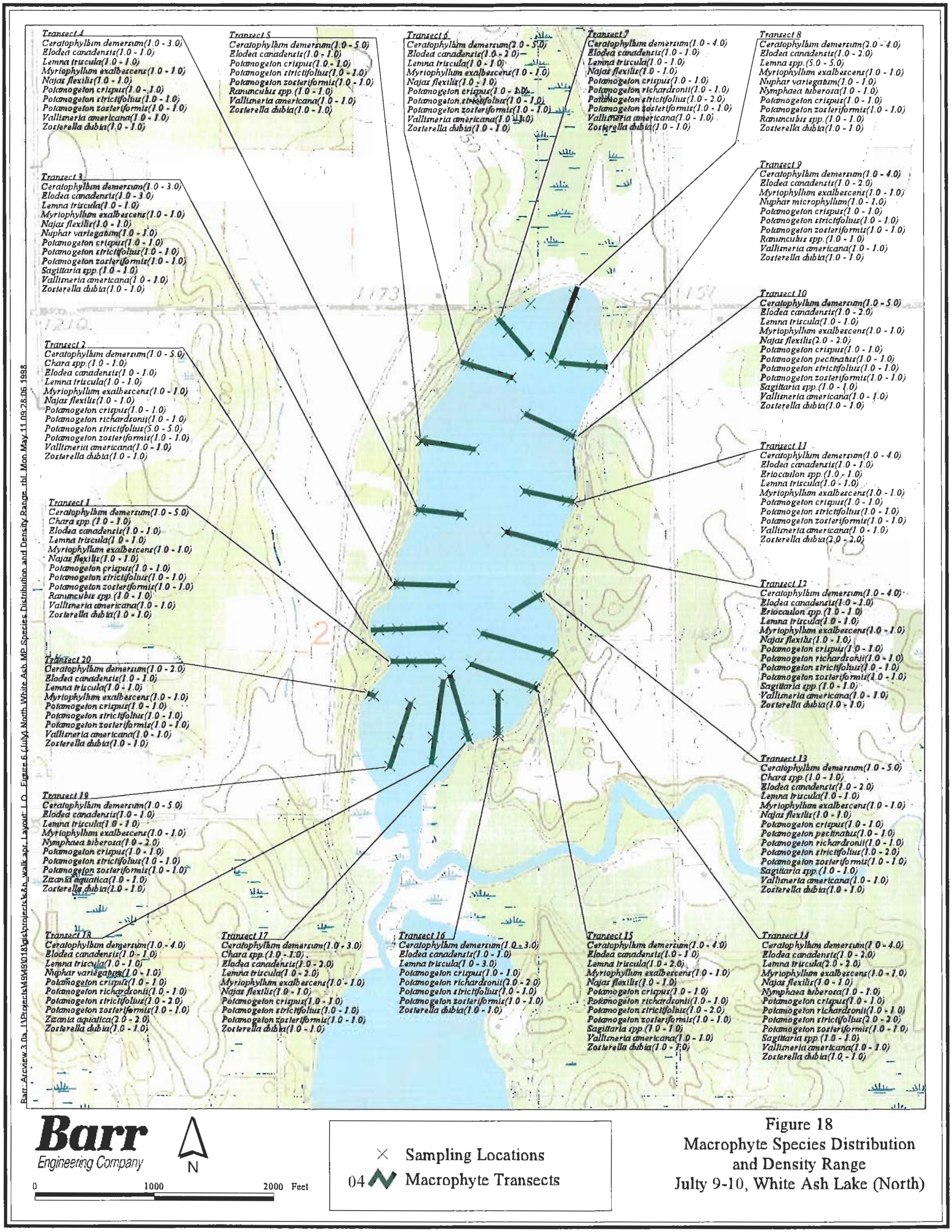
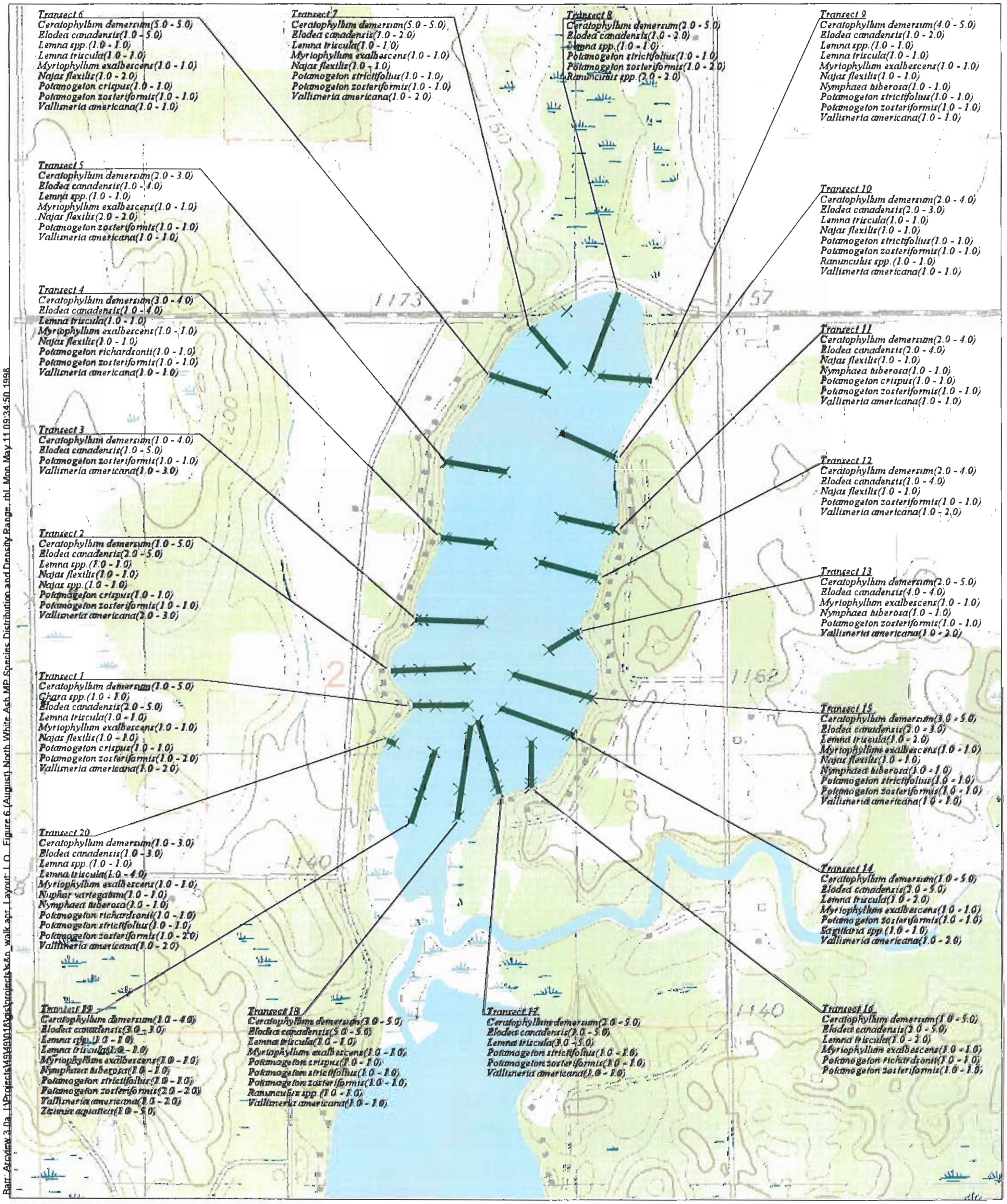


Figure 18
Macrophyte Species Distribution
and Density Range
Julty 9-10, White Ash Lake (North)



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N

0 1000 2000 Feet

× Sampling Locations
04 Macrophyte Transects

Figure 19
Macrophyte Species Distribution and Density Range
August 2-3, White Ash Lake (North)

Table 2 Functions of Aquatic Plant Species Found in White Ash Lake (South) and North White Ash Lake

Scientific Name (Common Name)	Plant Type	Plant Functions
Alisma triviale (Water Plantains)	Emergent	After the flowers go to seed, the sturdy stalk of water plantain becomes a favorite perch for song birds. Both the tubers and nutlets of water plantain are consumed by waterfowl including mallard, pintail, scaup, blue-winged and green-winged teal. The nutlets are also occasionally eaten by pheasants. The foliage offers shade and shelter for young fish. Muskrats and beavers feed on the leaves and roots.
Ceratophyllum demersum (Coontail)	Submersed	Many waterfowl species eat the shoots; it provides cover for young bluegills, perch, largemouth bass, and northern pike; supports insects that fish and ducklings eat.
Chara spp. (Muskgrass)	Submersed	Muskgrass is a favorite waterfowl food. Algae and invertebrates found on muskgrass provide additional grazing. It is also considered valuable fish habitat. Beds of muskgrass offer cover and are excellent producers of food, especially for largemouth bass and smallmouth bass.
Elodea canadensis (Canada Waterweed)	Submersed	Provides habitat for many small aquatic animals, which fish and wildlife eat.
Lemna trisulca (Star Duckweed)	Floating-leaf	Star duckweed is a good food source for waterfowl. Tangled masses of fronds also provide cover for fish and invertebrates.
Lemna sp. (Duckweed)	Floating-leaf	Small duckweed is a nutritious food source that can provide up to 90% of the dietary needs for a variety of ducks and geese. It is also consumed by muskrat, beaver and fish. Rafts of duckweed offer shade and cover for fish and invertebrates. Extensive mats of duckweed can also inhibit mosquito breeding.
Myriophyllum sibericum (formerly exalbescens) (Northern Milfoil)	Submersed	Provides cover for fish and invertebrates; supports insects and other small animals eaten by fish; waterfowl occasionally eat the fruit and foliage.
Najas flexilis. (Spiny Naiad, Bushy Pondweed)	Submerged	Bushy pondweed is one of the most important plants for waterfowl. Stems, leaves and seeds are all consumed by a wide variety of ducks including black duck, bufflehead, canvasback, gadwall, mallard, pintail, redhead, ringnecked duck, scaup, shoveler, blue-winged teal, green-winged teal,wigeon and wood duck. It is also important to a variety of marsh birds as well as muskrats. Slender naiad is a good producer of food and shelter for fish.

Table 2 Functions of Aquatic Plant Species Found in White Ash Lake (South) and North White Ash Lake

Scientific Name (Common Name)	Plant Type	Plant Functions
Nuphar variegatum (Yellow Water Lily)	Floating-leaf	Yellow water lily anchors the shallow water community and provides food for many residents. It provides seeds for waterfowl including mallard, pintail, ringneck and scaup. The leaves, stems and flowers are grazed by deer. Muskrat, beaver and even porcupine have been reported to eat the rhizomes. The leaves offer shade and shelter for fish as well as habitat for invertebrates.
Nymphaea tuberosa (White Water Lily)	Floating-leaf	White water lily provides seeds for waterfowl. Rhizomes are eaten by deer, muskrat, beaver, moose and porcupine. The leaves offer shade and shelter for fish.
Potamogeton amplifolius (Large-leaf Pondweed, Bass Weed, Musky Weed)	Submersed	The broad leaves of *Potamogeton amplifolius* offer shade, shelter and foraging opportunities for fish. Abundant production of large nutlets makes this a valuable waterfowl food.
Potamogeton crispus (Curly-leaf Pondweed)	Submersed	Provides some cover for fish, several waterfowl species feed on the seeds; diving ducks often eat the winter buds.
Potamogeton pectinatus (Sago Pondweed)	Submersed	Sago pondweed is considered one of the top food producers for waterfowl. Both the fruit and tubers are heavily grazed and are considered critical for a variety of migratory waterfowl. Sago also provides food and shelter for young trout and other juvenile fish.
Potamogeton Richardsonii (Clasping-leaf Pondweed)	Submerged	Broad-leaf pondweeds provide excellent habitat for panfish, largemouth bass, muskellunge, and northern pike; bluegills nest near these plants and eat insects and other small animals found on the leaves; walleyes use these pondweeds for cover.
Potamogeton zosteriformis (Flat-stem Pondweed), *Potamogeton pusillus* (Narrow-leaf Pondweed)	Submersed	Provides some cover for bluegills, perch, northern pike, and muskellunge, though these fish prefer broadleaf pondweeds; good cover for walleye; provide food for waterfowl; support aquatic insects and many small animals that fish and ducklings eat.
Ranunculus spp. (Water Crowfoot or Buttercup)	Submersed	As flowers give way to fruit, the water crowfoot bed becomes a choice spot for dabbling ducks. Both fruit and foliage of water crowfoot are consumed by a variety of waterfowl. When it is growing in shallow zones, it is sometimes consumed by upland game birds including ruffed grouse. Stems and leaves of water crowfoot provide valuable invertebrate habitat.

Table 2 Functions of Aquatic Plant Species Found in White Ash Lake (South) and North White Ash Lake

Scientific Name (Common Name)	Plant Type	Plant Functions
Sagittaria spp. (Arrowhead)	Emergent	Tubers, nutlets and other parts are eaten by waterfowl. Stems, roots and tubers are eaten by muskrats, porcupine and beaver. It also provides shade and shelter for young fish.
Vallisneria americana (Wild Celery)	Submersed	Provides shade and shelter for bluegills, young perch, and largemouth bass; choice food of waterfowl, particularly diving ducks; attracts muskrats, marsh birds, and shore birds.
Zizania aquatica (Wild Rice)	Emergent	Wild rice has a higher protein content than most cereal grains, making it a good food for wildlife and humans. Wild rice attracts many wild birds, especially waterfowl and red-winged blackbirds, and it also provides nesting cover for waterfowl.
Zosterella dubia (Water Star Grass)	Submersed	Water star grass can be a locally important source of food for geese and ducks including northern pintail, blue-winged teal and wood duck. It also offers good cover and foraging opportunities for fish.

Macrophytes in White Ash Lake (South) and North White Ash Lake consisted primarily of native species (i.e., species historically present in this region). Only one exotic (i.e., not native) species, *Potamogeton crispus* (curly-leaf pondweed), was noted. Curly-leaf pondweed is an exotic perennial, rooted, submersed aquatic vascular plant which was first noted in Minnesota about 1910 (Moyle and Hotchkiss 1945). Native to Eurasia, Africa, and Australia, this species has been found in most of the United States since 1950, and is currently found in most parts of the world (Catling and Dobson, 1985). Exotic or non-native species are undesirable because their natural control mechanisms are not introduced with the species. Consequently, exotic species frequently exhibit rapid unchecked growth patterns.

Curly-leaf pondweed is detrimental to lakes for three reasons:

1. It tends to crowd out native aquatic macrophyte (i.e., aquatic plant) species.

2. Dense colonies of the weed may interfere with recreational activities on the lake.

3. After curly-leaf pondweed dies out in early July, it may sink to the lake bottom and decay, causing oxygen depletion and exacerbating internal release of phosphorus.

Curly-leaf pondweed was found in 100 percent of the White Ash Lake (South) and North White Ash Lake sample transects during July (See Figures 20 and 21). Although it was found in all sample transects during July, it was not found in all sample locations. During July, estimated curly-leaf pondweed coverage in White Ash Lake (South) was 75 acres (i.e., 96 percent of macrophyte coverage contained curly-leaf pondweed). The estimated curly-leaf pondweed coverage in North White Ash Lake during July was 57 acres (i.e., 49% of macrophyte coverage contained curly-leaf pondweed). Curly-leaf pondweed was found in relatively few locations during the August survey. The estimated curly-leaf pondweed coverage during August was 2 acres (i.e., 3% of macrophyte coverage contained curly-leaf pondweed) in White Ash Lake (South) and 6 acres (i.e., 5% of macrophyte coverage contained curly-leaf pondweed) in North White Ash Lake (see Figures 20 and 21).

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N

0 600 1200 Feet

Curly Leaf Pondweed Extent

July 7-8

August 18

Figure 20
Curly Leaf Pondweed Coverage
White Ash Lake (South)

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N

0 600 1200 Feet

Curly Leaf Pondweed Extent
July 9-10
August 2-3

Figure 21
Curly Leaf Pondweed Coverage
White Ash Lake (North)

Curly-leaf pondweed generally occurred in low density (i.e., density of 1 on a scale of 0 to 5, with 0 being the lowest density and 5 being the highest density), but occasionally occurred in higher densities (i.e., ranging from 2 to 5). Curly-leaf pondweed occurred concurrently with several native species. Two native species (i.e., Coontail and Canada Waterweed) were more prolific in growth than curly-leaf pondweed from a coverage perspective and from a density perspective (See Figures 7 and 8). The data indicate that native species are relatively successful in competing with curly-leaf pondweed in White Ash Lake (South) and North White Ash Lake, thus minimizing its impact upon the native plant community.

5.3 Comparison of 1980 and 1997 Studies

Survey results from 1980 and 1997 were compared to assess long-term changes in the lakes' macrophyte communities. The following variables were assessed:

- ***Maximum depth of plant growth***—the water depth at the deepest sampling point where plant growth was found.
- ***Proportion of open area in the littoral zone (i.e., % Open Area)***—the number of sampling points containing no vegetation divided by the total number of sampling points at a depth less than or equal to the maximum depth of plant growth.
- ***Number of species***—the number of taxa (i.e., species) identified in the lake.
- ***Diversity***—a modification of Simpson's Index (1949) was used to calculate diversity:

$$1-\sum (rf/100)^2$$

Where:

rf = the relative frequency of each species. Frequencies were calculated as the number of sampling points where a species occurred divided by the total number of sampling points at depths less than or equal to the maximum depth of plant growth. Frequencies were relativized to 100% to describe community structure (i.e., rf). Frequencies are shown in Figure 12 and 13. Relative frequencies are presented in Appendix E.

- ***Floral and community similarities***—both were calculated using the formula:

$$(\sum 2W)/(A + B)$$

Where:

2W = twice the number of species that the two sampling efforts have in common for floral similarity and is twice the relative frequency that a species has in common between two sampling efforts for community similarity. The number of species and frequencies are shown in Figures 12 and 13. Relative frequencies are presented in Appendix E.

A and B = the sums of the values of the component communities (species number for floral similarity and 200% for community similarity when calculated using relative frequencies.

The assessment results are shown in Table 3.

The macrophyte communities in the two lakes appear to be relatively similar over time, although increases in coverage were noted in White Ash Lake (South). The proportion of open area in the White Ash Lake (South) littoral zone decreased from 49 (i.e., late summer) to 56 (i.e., early summer) percent during 1980 to 0 (i.e., early summer) to 2 (i.e., late summer) percent during 1997. Concurrently, the maximum depth of plant growth increased from 2.0 (i.e., late summer) to 2.4 (i.e., early summer) meters during 1980 to 2.7 (i.e., late summer) to 3.0 (i.e., early summer) meters during 1997. The lack of change in macrophyte converage in North White Ash Lake during this period is attributed to a lack of opportunity (i.e., shore to shore macrophyte coverage was observed during both sample years).

Comparable values of floral similarity (i.e., determined from the species present during both the early summer and late summer sample periods) were observed during 1980 and 1997. The data indicate few changes in species occurred during the summer period of each sample year (i.e., 1980 and 1997) and that changes occurring between the early and late summer period were similar during the two sample years (i.e., 1980 and 1997).

Comparable values of community similarity (i.e., determined from the relative frequency that species have in common during the early summer and late summer periods) were observed at White Ash Lake (South) during 1980 and 1997. The data indicate the macrophyte community has

Table 3 A comparison of 1980 and 1997 Macrophyte Survey Data from White Ash Lake (South) and North White Ash Lake

White Ash Lake (South)								
Parameter	1980		1997		Absolute Difference*		Absolute Similarity**	
	Early Summer	Late Summer	Early Summer	Late Summer	1980	1997	1980	1997
Max. Depth (m)	2.4	2.0	3.0	2.7	0.4	0.3	--	--
% Open Area	56	49	0	2	7	2	--	--
Species No.	21	17	21	19	4	2	--	--
Diversity	0.93	0.91	0.91	0.91	--	--	--	--
Floral Similarity	--	--	--	--	--	--	0.84	0.85
Community Similarity	--	--	--	--	--	--	0.70	0.73
North White Ash Lake								
Parameter	1980		1997		Absolute Difference*		Absolute Similarity**	
	Early Summer	Late Summer	Early Summer	Late Summer	1980	1997	1980	1997
Max. Depth (m)	2.7	2.7	2.7	2.7***	0	0	--	--
% Open Area	0	0	0	0	0	0	--	--
Species No.	14	17	20	18	3	2	--	--
Diversity	0.83	0.86	0.89	0.88	--	--	--	--
Floral Similarity	--	--	--	--	--	--	0.90	0.89
Community Similarity	--	--	--	--	--	--	0.72	0.90

* Absolute Difference means the difference between early summer and late summer during each sample year.

**Similarity means the similarity between early summer and late summer during each sample year.

***Estimated maximum rooting depth.

been relatively stable throughout the summer periods and that changes between the early and late summer periods have remained constant over time.

A higher community similarity was observed in North White Ash Lake during 1997 than 1980. The data indicate the lake's summer macrophyte community has become more stable since 1980. Consequently, fewer changes in the macrophyte community were observed during the 1997 summer period than during the 1980 summer period.

6.0 Developing a Macrophyte Management Plan

A macrophyte management plan is an orderly approach to plant management. It helps define the problem, set priorities, develop management strategies, and evaluate progress. As an educational tool, it can describe the what, how, why, and where of management techniques. As a team effort, a plan can focus community involvement. A successful macrophyte management plan is built on five principles:

- Define the problem
- Establish goals
- Understand plant ecology
- Consider all the techniques
- Monitor the results

These five principles were used to develop a macrophyte management plan for White Ash Lake (South) and North White Ash Lake.

6.1 Define the Problem

The combined effects of lake morphology and a relatively high nutrient input from the lakes' watersheds have resulted in a healthy and diverse macrophyte community in the lakes. Dense plant growths were observed throughout the littoral area of White Ash Lake (South) and throughout North White Ash Lake. The dense plant growths cause navigational problems for riparian owners and make it difficult for them to gain access to the lakes. Dense plant growths throughout the North White Ash Lake impair recreational use of the lake (i.e., primarily fishing and swimming). Therefore, navigation channels are needed in the dense plant growth areas to provide lake access to riparian residents and provide recreational use opportunities for lake users.

Submersed aquatic plants influence both fish distribution and abundance by creating structurally complex habitats (Crowder and Cooper, 1979) that affect predator-prey relationships (Barnett and Schneider, 1974; Moxley and Langford, 1982). Total fish abundance can be substantially higher in areas with aquatic plants than in areas without plants (Laughlin and Werner, 1980; Holland and Huston, 1984). However, foraging success of predators generally declines as plant density increases (Reynolds and Babb, 1978; Savino and Stein, 1982; Durocher, Provine, and Kraai, 1984; Wiley, et al., 1984). Extensive forage cover reduces hunting success of predator species, limiting growth rates and decreasing length/weight condition values. This can lead to an increase in numbers of forage species, which increases competition for food by the foraging species and ultimately leads to an over-crowded condition. Vegetation also serves as cover for macroinvertebrates, and forage species ability to find food may be decreased, intensifying intraspecific and interspecific competition for food. Abundant cover may also allow forage species to harass nesting predators, reducing spawning successes necessary to offset predator mortality rates (Madsen, et al., 1994). Additionally, water quality influenced by dense macrophyte or algae stands often affects fish growth and reproductive success, especially where photosynthesis causes pH shifts above 10. Largemouth bass, for example, become lethargic at high pH, and will not feed or spawn (Buck and Thoits, 1970). The data indicate a reduction in plant density within the lakes or the provision of fish cruising lanes through the dense vegetation would be beneficial to the lakes' fisheries.

The presence of curly-leaf pondweed in White Ash Lake (South) and North White Ash Lake is of concern because curly-leaf pondweed is an exotic species (i.e., not native to this region) and frequently causes problems by outcompeting native plants and developing objectionable dense growths. Although curly-leaf pondweed is not currently considered a problem in most areas of growth (i.e., low density and occurring concurrently with several native species), some areas of growth are very dense (i.e., densities of 3 to 5 on a scale of 0 to 5, with 0 representing no growth and 5 representing maximum density). Therefore, present curly-leaf pondweed growth areas may require management to reduce growth in areas of objectionable density and prevent the occurrence of additional objectionable curly-leaf pondweed growth areas.

6.2 Establish Goals

The White Ash Lake Protection and Rehabilitation District has established eight aquatic plant management goals for White Ash Lake (South) and North White Ash Lake:

- Improve navigation within the lakes through areas containing dense plant beds

- Improve recreational attributes of the lakes

- Remove or limit current exotic plants (i.e., curly-leaf pondweed)

- Preserve native species and prevent introduction of additional exotic species

- Preserve and/or improve fish and wildlife habitat

- Protect and/or improve quality of the resources for all to enjoy (i.e., people, fish, wildlife)

- Minimize disturbance of sensitive areas (i.e., fish and wildlife)

- Reduce long-term sedimentation from decaying macrophytes

The goals are consistent with Wisconsin Wetland Water Quality Standards stated in Chapter NR 103.03:

> *"To protect, preserve, restore and enhance the quality of waters in wetlands and other waters of the state influenced by wetlands, the following water quality related functional values or uses of wetlands, within the range of natural variation of the affected wetland, shall be protected: ...*
> *(e) Habitat for aquatic organisms in the food web including, but not limited to fish, crustaceans, mollusks, insects, annelids, planktonic organisms and the plants and animals upon which these organisms feed and depend upon for their needs in all life stages; (f) Habitat for resident and transient wildlife species, including mammals, birds, reptiles and amphibians for breeding, resting, nesting, escape cover, travel corridors and food: and (g) Recreational, cultural, educational, scientific and natural aesthetic values and uses."*

6.3 Understand Plant Ecology

Macrophyte management alternatives are based upon an understanding of plant ecology. Understanding the biology of aquatic plants and their habitat requirements is necessary to effectively manage plants. Effective management is necessary to maintain the delicate balance of preservation of fish and wildlife habitat and concurrently provide reasonable lake-use opportunities to area residents. The following discussion considers aquatic plant ecology and its relationship to macrophyte management alternatives.

The biology of aquatic plants and their habitat requirements are inseparably interrelated. The habitat requirements of plants are divided into two general groups, the living group (biotic) and the nonliving group (abiotic). The following discussion of plant habitat requirements is based upon Nichols (1988).

The biotic group contains the predators, parasites, and other organisms which depend upon or compete with an organism for their livelihood. These interrelationships form the basis for biological plant management methods.

The abiotic factors form the basis of plant control techniques involving habitat manipulation, and include those physical and chemical attributes which are necessary for plant growth and development: light, bottom type, water, temperature, wind, dissolved gases and nutrients. Light, water, temperature, dissolved gases and nutrients relate to the plant's ability to carry out the vital processes of photosynthesis and respiration. Bottom type and wind relate to specific physical locations where a plant can grow. The following discussion will show the relationship between critical habitat requirements and possibilities for management.

Both the quantity and quality of light influence plant growth. Light in the red and blue spectral bands is used for photosynthesis; low and high light intensities inhibit photosynthesis. Management activities that make use of shade and dyes, for example, are based on limiting light intensity or changing the spectral qualities of the light. Deepening the lake through dredging or damming is another method of altering the light available to a plant, as light is naturally attenuated in water and the spectral qualities changed.

In the aquatic environment, water is available in abundance and is, therefore, often overlooked as being critical for aquatic plants. Yet, aquatic plants are adapted to growing in an environment with an abundant water supply and are, therefore, sensitive to water stress. Macrophytes might be controlled by removing their water supply, resulting in the desiccation of the plant.

Plants are generally tolerant of a wide range of temperatures, and temperature fluctuations in the aquatic environment are smaller than in the surrounding aerial environment. Therefore, plant management schemes involving temperature effects depend on artificially exposing aquatic plants to the harsher aerial environment, where not only temperature but desiccation and other factors aid in controlling plant growth.

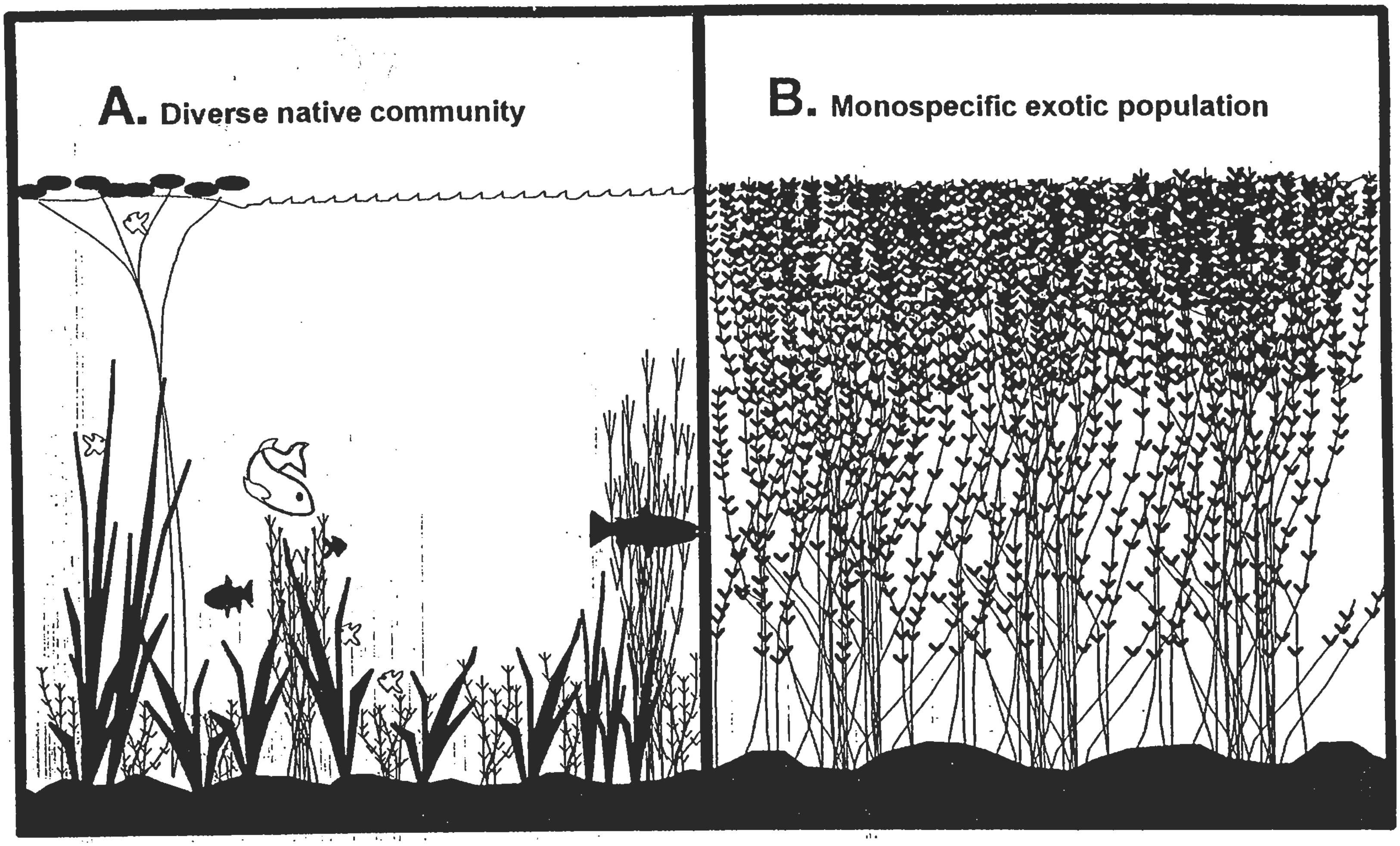
The two gases of primary importance in the aquatic system are carbon dioxide and oxygen, which are used for photosynthesis and respiration, respectively. The availability of carbon in the form of free CO_2 or bicarbonate appears to influence the distribution of some plant species (Hutchinson, 1970). Although oxygen is many times limiting in the aquatic system, most plants are adapted to living in low oxygen conditions. Because the carbon dioxide reaction is so well buffered by an equilibrium with CO_2 in the air and because the plants are tolerant to low oxygen supplies, the success of any scheme to manage plants by altering the dissolved gases in water seems doubtful.

Aquatic plant problems are caused by nutrient enrichment of the sediment. Nitrogen and phosphorus are the two nutrients of prime concern (Vollenweider, 1968; Sawyer, 1947; Stewart and Rohlich, 1967). Gerloff and Krombholz (1966) and Gerloff (1969) point out that the concentration of nutrients in the habitat may not be related to the concentration in the plant, depending on the availability of the nutrient. Plants remove nutrients in excess of their needs and store excess nutrients (i.e., luxury consumption, Gerloff 1969). These excess nutrient supplies could be used at times when the plant undergoes nutrient stress. These factors inherent in the biology of the plant will have to be overcome when developing practical, in-lake methods of nutrient limitation for macrophyte control.

Wind and bottom type are physical conditions that may limit plant growth. Heavy winds tear and uproot the plant, and soil types that are too coarse or are not consolidated enough make rooting very difficult. Some bottom types are rich in nutrients essential for plant growth. Substrates may be altered by removing, covering, or nutrient inactivation.

By manipulating the plant's environment, management tries to induce these limiting conditions and thus restrict the growth of the plants.

Differences in growth patterns between exotic plants (i.e., not native to this area) and native plants indicate a possible need for management of exotic species to protect native communities. Native plant communities are typically dominated by growth forms that concentrate biomass below the surface of the water (See Figure 22A), contain a high diversity of species, and have low to moderate levels of biomass. Exotic plants typically follow an extremely rapid growth pattern. Exotic species generally produce a dense canopy of vegetation at the air:water interface and develop high levels of biomass (See Figure 22B). Such a growth pattern interferes with use of the water resource by recreational-users and may eliminate the beneficial native plant community through shading (Smart, et al., 1996). Management to control the growth of exotic species is necessary to protect the native plant community and provide a reasonable use of the lake to recreational-users.



Source: Smart et al., 1996

FIGURE 22

SUBMERSED AQUATIC PLANT COMMUNITIES

The exotic species of concern in White Ash Lake (South) and North White Ash Lake is curly-leaf pondweed. Curly-leaf pondweed has unique life cycle adaptations which give it competitive advantages over many native aquatic plants. Unlike most native plants, curly-leaf pondweed may be in a photosynthetically active state even under thick ice and snow cover (Wehrmeister, 1978). Therefore, it is often the first plant to appear after ice-out. Extremely rapid growth results in the formation of dense mats by late spring which may crowd out native species and interfere with recreation. (Catling and Dobson, 1985). Curly-leaf usually senesces by early July, but it first forms small reproductive pods called turions (resembles a small pine cone) during late June. These turions disperse by water movement throughout a water body. Turions lay dormant during the summer when native plants are growing, and germinate in the fall when most native vegetation has senesced. Thus curly-leaf pondweed is able to use turions to invade new areas of a water body. The density of curly-leaf pondweed growth in a given year is influenced by winter conditions; winter months with heavy snow cover and thick ice conditions are often followed by less dense plant growth.

Large populations of curly-leaf pondweed can alter the nutrient dynamics of water bodies. As curly-leaf plants senesce in the summer, large amounts of vegetation fall to the lake bottom and decompose. This decomposition can increase internal nutrient loading in a water body, which in turn may cause an increase in algal growth.

Native species appear to compete well with curly-leaf pondweed, restricting its growth within White Ash Lake (South) and North White Ash Lake. Although control of curly-leaf may offer an opportunity for an improved native plant community, an overall reduction in plant coverage and density in the lakes is unlikely to result from curly-leaf pondweed control. Native species would likely occupy space vacated by curly-leaf resulting in a plant coverage and plant density similar to observations made during the 1997 plant surveys.

6.4 Consider All Techniques

Following a consideration of all possible management alternatives, feasible options may be identified for White Ash Lake (South) and North White Ash Lake. The following discussion focuses on four types of aquatic plant management techniques currently used for macrophyte control. They include:

1. Physical
2. Mechanical

3. Chemical
4. Biological

6.4.1 Physical

Physical tactics typically used to manage aquatic plants are light manipulation and habitat manipulation. Habitat manipulation includes such techniques as overwinter lake drawdown, dredging, sand blanketing, the use of dyes, and nutrient limitation and inactivation (Barr, 1997).

Although light manipulation has been used in lakes with some success, its greatest utility has been found in managing dense vegetation in streams through streamside shading. Shading by use of different densities of shading cloth has resulted in decreased plant biomass. Natural shade from streamside vegetation has also reduced plant biomass along the stream course (Barr, 1997).

Lake level drawdown, particularly over winter, is commonly used to control nuisance aquatic plants in northern North America. Biomass studies before and after drawdown have demonstrated that drawdown was effective in controlling plants down to the depth of drawdown, but had no effect at greater depths. While drawdown is an extremely effective technique for some species, it may actually stimulate the growth of other species. (Madsen and Bloomfield, 1992). A study of Trego Flowage (Washburn County, Wisconsin) indicated the benefits of drawdown were temporary, and the same species of plants returned in about their former abundance within a few years (Barr, 1994).

Another commonly-used group of physical control techniques uses benthic barriers, weed rollers, or sediment alteration to inhibit the growth of aquatic plants at the sediment surface. Benthic barriers are generally applied to small areas (Barr, 1997). These materials are anchored to or sink to the lake bottom and smother plants to prevent their growth. Negatively buoyant (i.e., sink in water) screens are available in rolls 7 feet wide and 100 feet long. The screens can be laid on the lake bottom in the spring and removed in the fall. These screens can be reused for about 10 years. Bottom barriers would be appropriate for controlling aquatic plant nuisances for small applications such as adjacent to a boat dock or from small swimming areas. The barriers are safe, effective, non-chemical control using a simple technology. The cost is reasonable (i.e., approximately $270 per bolt, 7' x 100') and the barriers are reusable for about 10 years (Osgood, 1997).

Weed rollers or 'Automated Unintended Aquatic Plant Control Devices' are motor-drive rollers (round bars) placed on the lake bottom and roll over and uproot plants. The rollers are 25-to-30 feet long and are centered on the end post of a dock. The rollers roll in a circular pattern, normally covering 270^0 or using a 25-foot roller over a full circular area. Weed rollers would be appropriate for controlling aquatic plant nuisances in small areas such as adjacent to a boat dock or for small swimming areas. The rollers are safe, effective non-chemical control using a simple technology. The cost is reasonable (approximately $2,000 to $2,500, and the device can be shared by several people) (Osgood, 1997).

Sediment inactivation has included the application of phosphorus binding substances to sediments (i.e., such as lime slurry). The growth of aquatic plants is inhibited by the reduced availability of phosphorus in sediments (Barr, 1997)

6.4.2 Mechanical

Mechanical control involves macrophyte removal via harvesting. Small scale harvesting may involve the use of the hand or hand-operated equipment such as rakes, cutting blades, or motorized trimmers. Individual residents frequently clear swimming areas via small scale harvesting. Large-scale mechanical control often uses floating, motorized harvesting machines that cut the plants and remove them from the water onto land, where they can be disposed. All harvested plants should be removed from the lake (Barr, 1997)

6.4.3 Chemical

Chemical aquatic vegetation management programs are widespread, being the preferred method of control in many areas. Chemical control involves the use of a herbicide (i.e., a plant-killing chemical) that is applied in liquid, granular, or pellet form. The aquatic plants (sometimes only stems and leaves) die and decompose in the lake. To reduce human exposure to the chemicals, temporary water-use restrictions are imposed in treatment areas whenever herbicides are used. Only herbicides for aquatic use are allowed, and any use of an herbicide requires a WDNR permit (Barr, 1997).

6.4.4 Biological

Biological control involves the use of a biological control agent to control macrophyte growth. Biological controls include predation by herbivorous fish, mammals, waterfowl, insects and other invertebrates, diseases caused by microorganisms and competition from other aquatic plants (Little, 1968). The most widely used biological control agent is herbivorous fish, particularly grass carp. Weevils have been used experimentally to control Eurasian Watermilfoil (Creed, et al., 1995; Newman, et al., 1995).

A summary of aquatic macrophyte control techniques available in Wisconsin are summarized in Table 4.

Table 4 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Mechanical and Physical Removal			+Immediate plant removal and creation of open water +No interference with water supplies or water-use	– Creates plant fragments – Usually disturbs sediments, affecting biota and causing short-term turbidity – Plant disposal necessary
Harvesting	Plant stems and leaves cut up to 8 ft below water surface, collected and removed from lake	Cut from 1 to 2 ac/day @ $1,200/day New machine: $80,000-100,000+	+Relatively low operational cost	– Can get regrowth within 4 weeks – Removes small fish, turtles, etc.
Hydro-raking	Mechanical rake removes plants up to 14 ft below water surface and deposits them on shore	Rake up to 1 ac/day @ $1,500–$2,000/ac	+Longer lasting control than harvesting because of root removal	– Regrowth by end of growing season
Rotovating	Sediment is "tilled" to a depth of 4"-6" to dislodge plant roots and stems Can work in depths up to 17 ft	Can do up to 2-3 ac/day @$700–$1,200/ac Cost of new machine is $100,000+	+Immediate 85% – 95% decrease in stem density +Up to 2 years control +Frequently done in fall when plant fragments not viable	

Table 4 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Hydraulic Dredging	Steel cutter blade dislodges sediment and plants; removed by a suction pump	$2,500/ac and up Cost of new machine is $100,000+	+90% effective at root removal, with plant regrowth probable within 1 year	– Expensive
Control Technique	**Procedure**	**Cost**	**Advantages**	**Disadvantages**
Diver-operated Suction Harvesting	Scuba divers use 4" suction hose to selectively remove plants from lake bottom Plants disposed of on shore	Cost is $800–$10,000/ac depending on cost of divers, type of sediments, travel time, etc. Cost of new machine $20,000+	+Up to 97% effective at removing plant roots and stems +1–2 years of control +Can work in areas with underwater obstruction	– Effectiveness varies greatly with type of sediment – Slow and labor intensive – Expensive – Potentially hazardous because of scuba
Handpulling	Plants and roots are removed by hand using snorkeling and wading Plants disposed of on shore	Variable, depending on volunteers; divers cost $15-$60/hr	+Most effective on newly established populations that are scattered in density +Volunteers can keep cost down +Long term control if roots removed	– Too slow and labor intensive to use on large scale – Short-term turbidity makes it difficult to see remaining plants

Table 4 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Chemical Treatment			+ Doesn't interfere with underwater obstructions	– Affects water-use; can be toxic to biota – Plants remain in lake and decompose, which can cause oxygen depletion late in the season
2,4-D (Aquakleen, Aquacide)	Systemic herbicide available in liquid and pellet form that kills plants by interfering with cell growth and division Can be applied at surface or subsurface in early spring as soon as plants start to grow, or later in the season	$350–$700/ac depending on plant density and water depth; cost does not include collection or analysis of water samples, which may be required	+Under favorable conditions can see up to 100% decrease +Kills roots and root crowns +Fairly selective for EWM +Control for up to 2 years possible	– Toxic to fish – Potential risk to human health remains controversial – Plants decompose over 2-3 weeks
Tripclopyr (Garlon 3A)	Liquid systemic herbicide that kills plants by interfering with hormones that regulate normal plant growth	$75/gal or $1200-$1700/ac, depending on water depth, concentration of chemical, etc. Sample collection cost not included	+Effectively removes up to 99% of EWM biomass 4 weeks after treatment +Control may last up to 2 years +Fast-acting herbicide +Kills roots and root crowns +Fairly selective for EWM	– No domestic-use of water within 1 mile of treated area for 21 days after treatment – No fishing in treated area for 30 days after treatment – Expensive – Experimental

Table 4 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Control Technique	Procedure	Cost	Advantages	Disadvantages
Fluridone (Sonar)	Systemic herbicide available in liquid and pellet form that inhibits a susceptible plant's ability to make food Can be applied to surface or subsurface in early spring as soon as plants start to grow	$500-$1500/ac depending on water depth and formulation Sample collection cost not included	+Can be applied near water intakes if concentration is less than 20 ppb +Under favorable conditions susceptible species may decrease 100% after 6-10 weeks +Control lasts 1-2 years depending supplemental hand removal +Because slow-acting, low oxygen generally not a problem	– Long contact time required; may take up to 3 months to work – Potential risk to human health remains controversial – Not selective for milfoil – Spot treatments generally not effective
Endothall (Aquathol and Aquathol K)	Granular (Aquathol) and liquid (Aquathol K) kills plants on contact by interfering with protein synthesis Can be applied to surface or subsurface when water temperature is at least 65˚F	$300-$700/ac depending on treatment area and use of adjuvants Sample collection cost not included	+Under favorable conditions can see up to 100% decrease +Fast-acting herbicide	– Regrowth within 30 days – Not selective for milfoil – Does not kill roots; only leaves and stems that it contacts – No swimming for 24 h, no fishing for 3 days

Table 4 Control Techniques for Aquatic Plants: Procedure, Cost, Advantages and Disadvantages (Modified from a Summary Prepared by the Vermont DNR)

Control Technique	Procedure	Cost	Advantages	Disadvantages
Control Technique	Procedure	Cost	Advantages	Disadvantages
Diquat (Reward)	Liquid kills plants on contact by interfering with photosynthesis Can be applied to surface or subsurface when water temperature is at least 65°F	\$200-\$500/ac Sample collection cost not included	+Fast-acting herbicide +Relatively cheap per acre	– Retreatment within same season may be necessary – Not selective for milfoil – Does not kill roots; only leaves and stems that it contacts – No swimming for 24 h, no drinking for 14 days – Toxic to wildlife

6.5 Monitor the Results

A monitoring program to evaluate results will provide information to determine whether the management program results in goal achievement. Monitoring will determine changes, both desirable and undesirable, and detect problems before they become unmanageable.

7.0 Macrophyte Management Plan for White Ash Lake (South) and North White Ash Lake

The management plan for White Ash Lake (South) and North White Ash Lake is based upon the need to:
(1) provide a reasonable access to the lake by users living adjacent to very dense plant growths, (2) provide recreational use opportunities within North White Ash Lake, (3) improve fisheries by providing cruising lanes for fish through areas of dense vegetation and increasing the numbers of invertebrates by increasing the edge area, (4) preserve native plant species, and (5) prevent the introduction of additional exotic species to the lake. Details of the management plan follow.

7.1 Harvesting Plan

A harvesting plan is recommended for White Ash Lake (South) and North White Ash Lake to provide navigation channels to lake-users living adjacent to very dense plant growths. Additional navigation channels are recommended for North White Ash Lake to provide recreational use opportunities for lake users. The harvested navigation channels will concurrently provide benefits to the lakes' fisheries. Benefits include cruising lanes for fish (e.g., bass) and increased invertebrate populations. The increased numbers of invertebrates will result from an increase in the edge area within the dense plant beds. Studies have shown that larger quantities of invertebrates live at the edge of dense plant beds than in the middle. Consequently, cutting channels through dense plant beds will increase the edge area, thus increasing invertebrate numbers. Increased invertebrate numbers result in increased quantities of food for the fish (Pellet 1998). Cutting channels through plant beds also makes it easier for fish to move through the plant bed and capture their prey (Marshall 1990).

The harvesting plans for White Ash Lake (South) and North White Ash Lake are presented in Figures 23 and 24. In general, harvested navigation channels will be approximately 20 feet wide. The harvested channel width of 20 feet complies with WDNR restrictions in areas designated as fish or wildlife sensitive areas by the area fisheries manager or wildlife manager (See Figures 25 and 26). The restriction is established to minimize disturbance to the fishery and wildlife areas, while allowing navigation channels for riparian residents. Chemical treatment is not allowed in fish sensitive areas.

The harvesting plan for White Ash Lake (South) includes harvesting a navigation channel through areas of dense plant growth to allow access to the lake by riparian residents (See Figure 23). The harvested area totals approximately 5.3 acres.

The harvesting plan for North White Ash Lake (See Figure 24) includes:

- Harvesting a navigation channel around the periphery of the lake to provide access to the lake for riparian residents;

- Harvesting navigation channels throughout the lake to facilitate fishing and boating lake uses;

- Harvesting a swimming area to provide a swimming opportunity for interested lake users.

The total harvested area of North White Ash Lake totals approximately 8.7 acres.

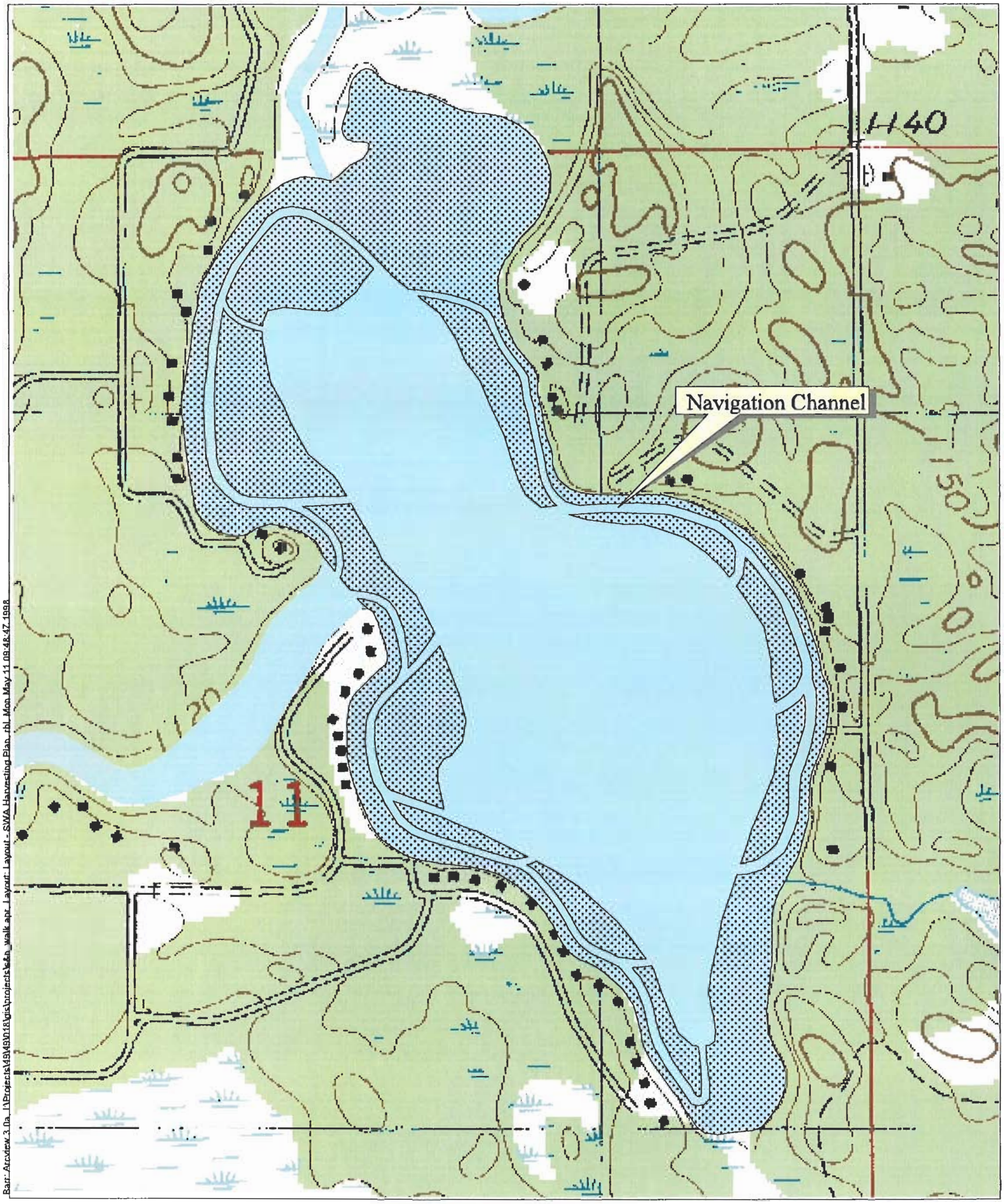
7.2 Education of Lake Homeowners

An education program will be completed to help area residents achieve an understanding of:

- The functions and roles of native species/native communities within White Ash Lake (South) and North White Ash Lake.

- The exotic species, curly-leaf pondweed, and its threat to the native plant community within White Ash Lake (South) and North White Ash Lake.

The education program will be completed by the White Ash Lake Protection and Rehabilitation District with assistance from the WDNR.



Barr
Engineering Company

N

0 600 1200 Feet

Macrophyte Cover

Figure 23
Macrophyte Harvesting Plan
White Ash Lake (South)

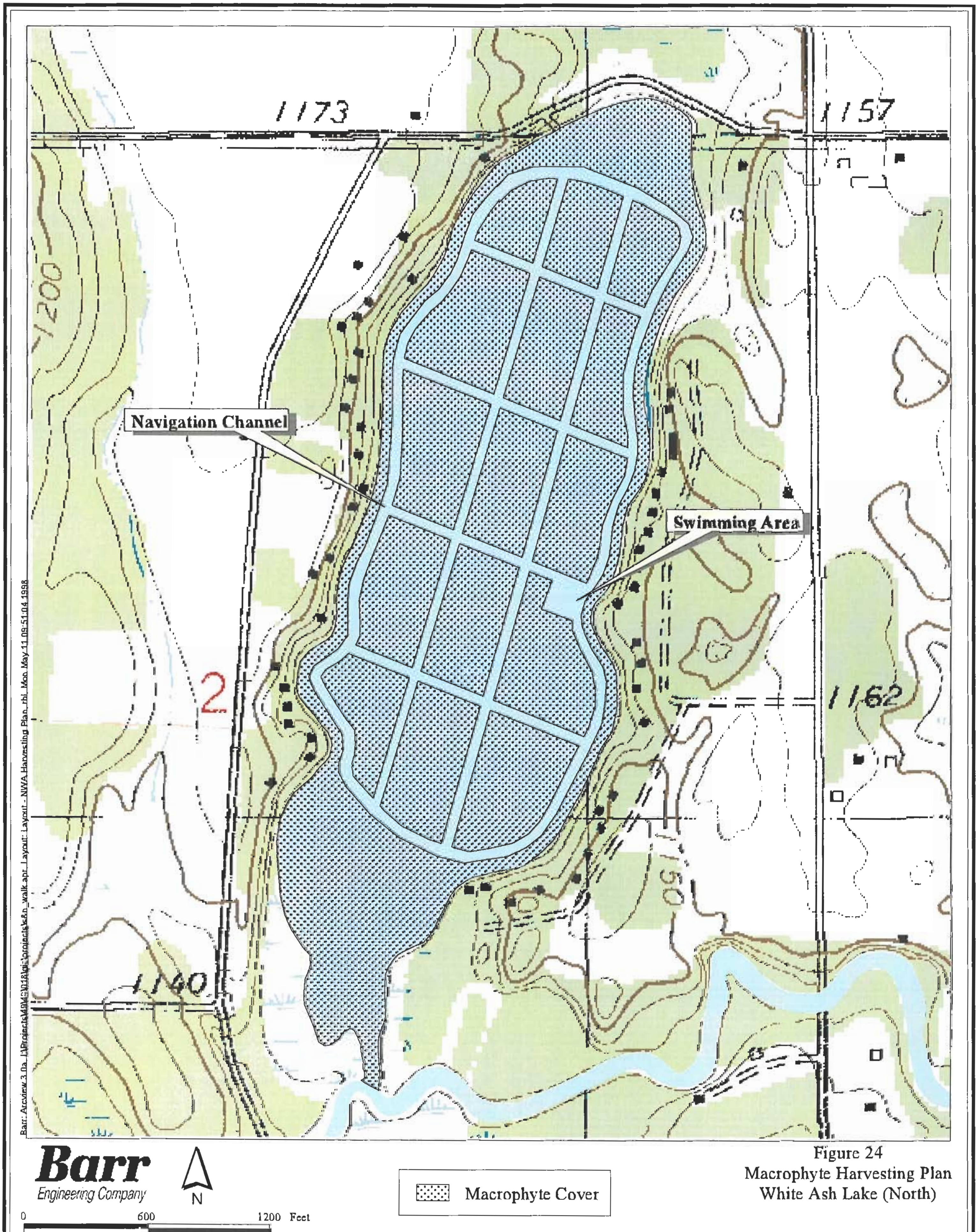


Figure 24
Macrophyte Harvesting Plan
White Ash Lake (North)

Barr
Engineering Company

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0 600 1200 Feet

Sensitive Areas
Fish
Wildlife

Figure 25
Sensitive Areas
White Ash Lake (South)

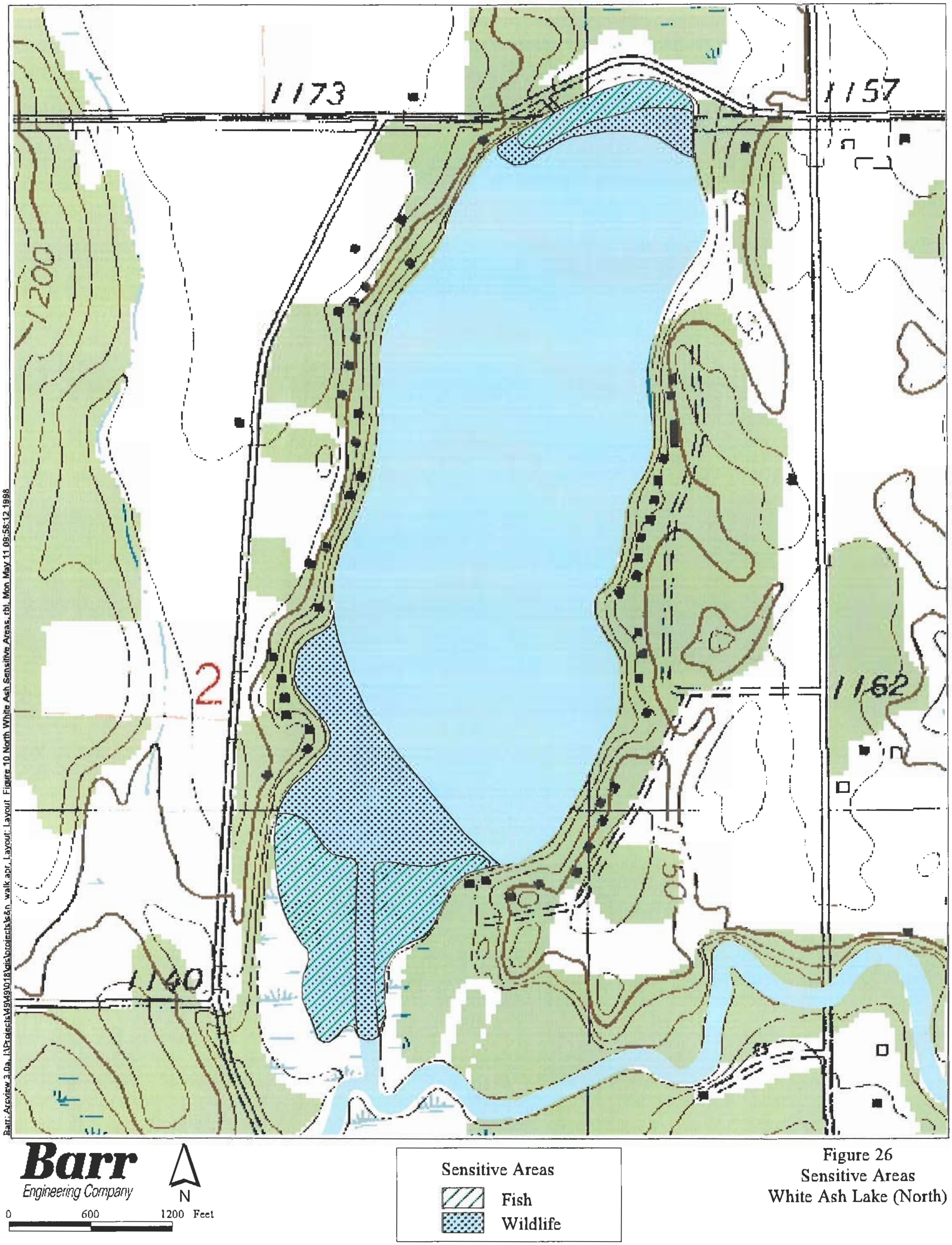

Figure 26
Sensitive Areas
White Ash Lake (North)

7.3 Control Introduction of Exotic Species to the Lake

A plan to control the introduction of exotic species was developed to protect the native species communities within the lakes. The plan involves education of lake-users and constant vigilance by lake residents. The education component involves:

- Posting signs at boat launches reminding lake-users to remove aquatic plants from boat trailers before entering and before leaving the lakes to prevent the introduction of unwanted species.

- Volunteers from the White Ash Lake Protection and Rehabilitation District could be present at the boat launches during busy weekends in June through August to inspect boats and trailers, distribute educational flyers, and advise boat owners to always remove vegetation from boats and trailers before entering or leaving the lakes.

- Information concerning exotic species and a reminder to remove plants from boat trailers could be displayed on bulletin boards at the boat launches. The bulletin board could be used to encourage boaters to pick up a free brochure describing exotic species, the potential dangers of exotic species, and the importance of vegetation removal to prevent exotic species introduction. The brochure could be placed in a dispenser located near the boat launch.

- Professionals such as WDNR staff, Polk County staff, or a consultant could hold informational meetings. The meetings could provide information about exotic species, methods of exotic species introduction, problems caused by introduction of exotic species, and prevention of exotic species introduction. Training to identify exotic species such as curly-leaf pondweed and Eurasian watermilfoil could be provided by a professional.

Creation of a Shoreline Weed Attack Team (SWAT) to inspect the littoral or plant growth areas of the lakes for possible invasion by exotic species is recommended. A combination of planning and teamwork by lake residents will protect the lakes from invasion by additional exotic species. The two most likely points for exotic species introduction are the public boat launch and the water inlet to the lake (Apple River). The lake inlet and boat launch area should be inspected regularly throughout the summer for possible pioneer Eurasian Watermilfoil or other exotic vegetation establishing in that area. An inspection schedule could be established for SWAT volunteers to insure that regular inspection occurs.

Lastly, constant vigilance by lake residents and/or SWAT volunteers will be needed to identify changes in curly-leaf pondweed growth within the lake and/or the establishment of Eurasian watermilfoil or other exotic species in the lake. The White Ash Lake Protection and Rehabilitation District could form SWAT teams to conduct annual surveys of the entire littoral area of White Ash Lake (South) and selected portions of North White Ash Lake (e.g., the transect locations used for the 1997 survey). The team could establish an inspection schedule and plan a cookout/social gathering to follow completion of the inspection. Individual exotic plants identified by the survey should be removed by covering with a fine mesh bag[1] and the root crown of the plant should be removed whenever possible. This is likely to require snorkeling equipment. The plants that are dug up should be removed from the lake and disposed of where they have no chance of being washed into the lake. The areas with beds of exotic plants (e.g. curly-leaf pondweed, Eurasian watermilfoil) should be marked clearly on a map and could also be supplemented with markers along the shoreline. A treatment approach for the beds should be identified and a WDNR permit for treatment obtained.

7.4 Evaluation Program

An evaluation program is recommended to monitor the effectiveness of the lake management plan. A macrophyte survey of each lake should be completed once every five years. The methodology used for the 1997 surveys of the lakes should be used for each survey. Survey results should be compared with results of previous surveys to determine changes in the macrophyte community. The survey results will indicate the effectiveness of macrophyte management plan implementation and will identify any needed modifications of the plan.

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[1]Nitex - a nylon mesh used for plankton nets can be purchased from aquatic suppliers, such as WILDCO and mesh bags could be sewn from the material. A 300 micron mesh would be adequate for capturing plants, including plant fragments.

8.0 Equipment Purchase and Estimated Cost

The White Ash Lake Protection and Rehabilitation District considers the purchase of an new harvester essential to the implementation of the recommended harvesting plan for White Ash Lake (South) and North White Ash Lake. The aging harvester currently owned by the District needs to be replaced because of escalating maintenance costs and declining reliability. An evaluation was completed to determine a recommended harvester purchase and the estimated equivalent annual cost of the recommended harvester purchase. The first step in the evaluation was the estimation of annual labor costs for harvesters ranging in size from a 4 foot cutter width (i.e., present machine) to a 10 foot cutter width. The harvest area recommended in the plan (i.e., 14 acres) comprised the harvested area for the evaluation. The evaluation assumed a frequency of once per month during the May through September period for the estimated harvesting frequency. The harvest rate in hours of time per acre included both the cutting time and the time required to transport plants to shore for disposal. Labor costs were estimated at $11.53 per hour. Using these assumptions, the total harvest time per season ranged from 168 hours (i.e., 10 foot cutter width) to 546 hours (i.e., 4 foot cutter width) and estimated annual labor costs ranged from $1,937 (i.e., 10 foot cutter width to $6,295 (i.e., 4 foot cutter width) (See Table 5).

Estimated equivalent annual costs were then determined for harvesters ranging in size from a 6 foot cutter width to a 10 foot cutter width. The evaluation included a summation of the capital cost of each machine (i.e., 1998 cost), ten years of labor costs, and ten years of operation and maintenance costs (i.e., excluding labor costs). The sum was then divided by 10 to estimate the equivalent annual cost for each harvester. The equivalent annual costs ranged from $13, 253 to $16,479 (See Table 6).

An evaluation of the equivalent annual costs indicates a demonstration harvester with a 10 foot cutter width is the recommended harvester for purchase by the White Ash Lake Protection and Rehabilitation District. The discounted purchase price of the demonstration harvester results in an equivalent annual cost for a harvester with a 10 foot cutter width that is only slightly larger than the comparable cost for a harvester with a 6 foot cutter width. Use of the larger machine would complete the harvesting in approximately 40 percent of the time required by the smaller machine. The time savings results in less wear and tear on the harvester and is expected to result in a longer machine life and lower annual maintenance costs on a long-term basis (i.e., the Operation and Maintenance Costs used in the calculation did not estimate differences in repair costs because of differences in machine usage). The time savings for the harvesting operation is also expected to result in less management time and effort by the District. Therefore, it is recommended that the District purchase a demonstration unit with a 10 foot cutter width (i.e., currently available from Inland Lake Harvesters, Inc.). Details of the recommended harvester purchase are presented in Appendix I (i.e., equipment and cost details).

Table 5. Estimated Annual Labor Costs for White Ash Lake (South) and North White Ash Lake Harvesting

Machine Size	Harvest Rate (Hours/acre)	Harvest Area (acres)	Harvest Time per Event (Hours)	Weather Delays (20%) (Hours)	# of Events per Season*	Total Harvest Time per Season	Estimated Cost of Labor per Season
4 foot cutter (Current Machine)	6.5	14	91	18.2	5	546	$6,295
6 foot cutter	5.0	14	70	14.0	5	420	$4,843
8 foot cutter	3.5	14	49	9.8	5	294	$3,390
10 foot cutter	2.0	14	28	5.6	5	168	$1,937

*Assume one pass per month during May through September period.

Table 6. Cost estimates of alternative aquatic plant harvesting systems for White Ash Lake (South)and North White Ash Lake

Alternatives	Capital Costs	Labor Costs	Operation & Maintenance Costs, Excluding Labor	Present Worth: 1998-2008			Equivalent Annual Cost: 1998-2008		
				Capital	O&M	Total	Capital	O&M	Total
6 foot cutter w/conveyor trailer	$74,100	$4,843	$1,000	$74,100	$58,430	$132,530	$7,410	$5,843	$13,253
7 foot cutter w/conveyor trailer	$90,500	$4,117	$900	$90,500	$50,170	$140,670	$9,050	$5,017	$14,067
8 foot cutter w/conveyor trailer	$113,000	$3,390	$800	$113,000	$41,900	$154,900	$11,300	$4,190	$15,490
9 foot cutter w/conveyor trailer	$113,000	$2,661	$700	$113,000	$33,610	$146,610	$11,300	$3,361	$14,661
10 foot cutter (Demo) w/conveyor trailer	$111,900	$1,937	$600	$111,900	$25,370	$137,270	$11,190	$2,537	$13,727
10 foot cutter (New) w/conveyor trailer	$139,420	$1,937	$600	$139,420	$25,370	$164,790	$13,942	$2,537	$16,479

9.0 Field Operation and Maintenance

Successful implementation of the harvesting plan will involve a successful field operation and equipment maintenance program. The field operation program includes staffing, harvesting operation, and program administration. The maintenance program includes proper and systematic maintenance of the harvesting equipment. The following discussion of a recommended field operation and maintenance program assumes the purchase of the recommended harvester (i.e., 10 foot cutter width).

A staff of two people (i.e., one harvester operator and one person to haul harvested plants to the disposal site) is recommended for the implementation of the harvesting plan for White Ash Lake (South) and North White Ash Lake. A time commitment of about 40 hours per month during the May through September period is estimated. To assure that staff understand the management operation and what is expected of them, written policies and procedures are recommended. A manual that contains this type of information is recommended. Examples of employee work rules include:

- Employees are expected to read and observe the District policies and procedures.
- Employees are expected to abide by the District safety rules.
- Employees should attend to maintenance and cleaning tasks when not actually occupied with aquatic plant harvesting activities during agreed upon work days.
- Employees are the public contacts of the Lake District and are expected to be polite and respectful when talking or dealing with the public.
- Employees shall not accept money from any member of the District. The agreed upon compensation from the District shall comprise the total compensation received by employees.
- Diving and swimming off of harvesting equipment is not allowed. If a swim break is taken, it will be taken from shore.
- No employee shall operate motor vehicles on public highways unless over the age of eighteen (18) years.
- In the event an employee is unable to report to work, the supervisor must be called prior to the scheduled work time.
- All employees are responsible for the security of the equipment. Make sure that the equipment is secured at the end of each day.
- Fill the barge completely before coming across the lake to unload.
- Large fish captured by the harvester will be thrown back into the lake by the harvester operator. The harvester operator should watch to see large fish coming up the harvester with

the plants, reach over and grab the fish as they are carried past the operator on the conveyer, and toss the fish back into the lake.

- When picking up harvested plants on the shoreline, start where picking left off, with the goal of getting the entire lake picked up each day.
- Pick up only piled plants and rake excess plants, leaving the shoreline neat and clean.
- New employees must be trained by an experienced employee or the harvester manager until familiar with the equipment and comfortable with its operation.
- The harvester operator will follow the District harvesting plan and harvest only the areas indicated by the plan.
- Plants will be disposed in the agreed upon disposal site and in the agreed upon manner of disposal.

The harvesting program will be administered by the District Administrator (i.e., currently Pat Mahoney) and the Harvesting Manager (i.e., currently Glen Holacek). Duties of each will be determined by the District Board of Directors. Duties may include hiring and supervising employees, maintaining payroll and tax records for the harvesting operation, maintaining adequate insurance coverage for the program such as workers compensation insurance, a policy to cover the equipment, liability, and accident insurance (i.e., similar to auto policies), and a liability policy for the harvesing program. Both will work closely with The District Board of Directors to insure a successful harvesting program.

The harvester maintenance program will be administered by the Harvesting Manager and will consist of:

- Fuel the machine daily
- Check hydraulic oil daily
- Check screen for tightness daily
- Check cutting head daily
- Grease all fittings once daily
- Check engine oil twice daily
- Check conveyer belting weekly
- Check oil chain couplings once per month
- Change engine oil once every 100 hours of use
- Change hydraulic oil and filter every 500 hours of use
- Check and replace air filters as needed
- Annually (i.e., in the fall), check the cycle sections and change as needed

- Annuallly (i.e., in the fall), check the bearings of the harvester and the conveyer trailer for tightness, grease them, and change as needed.
- Annuallly (i.e., in the fall), check the belting and change as needed.
- Annuallly (i.e., in the fall), check the radiator fluid and change every other year.
- Annuallly (i.e., in the fall), check the seal tight tanks for moisture (i.e., take out the plugs).
- Annuallly (i.e., in the fall), pressure wash the harvester.
- Store the harvester in a shed overwinter.

10.0 Record Keeping and Evaluation

Harvesting records will be kept by District staff and reviewed by the District Board periodically. Records will include:

- Daily and annual harvest record (loads and hours of harvesting)
- Equipment maintenance record including costs
- Deviations from the harvesting plan and the reasons for the changes
- Reassessment of the harvesting program (suggest approximately once every 3 or 4 years).

The harvesting program manager will be responsible for the harvesting records (i.e., instruct District staff to keep records, peiodically check to be certain records are kept, obtain records from District staff and provide to Board for periodic review).

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Appendix A
White Ash Lake Plat Map