Big Lake Macrophyte Survey and Management Plan

Prepared for
Church Pine, Round, and Big Lake Protection and Rehabilitation District

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Table of Contents

Table of Contents (Continued)

List of Tables

List of Figures

List of Appendices

Executive Summary

Following a long history of nuisance macrophyte (aquatic plant) growth, macrophyte surveys were completed in Big Lake during 1996. The surveys evaluated plant coverage, density, and species composition during June and August. The results indicate macrophyte density in the lake's littoral region is bothersome throughout the summer period. The dense coverage results from the concurrent growth of a large number of species. The results further indicate the exotic species (i.e., not native to this region) *Potamogeton crispus* (curlyleaf pondweed) was the dominant species during the June sample period. 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 survey results were used to develop a macrophyte management plan. The goals of the Big Lake Macrophyte Management Plan are:

- Reduce plant density throughout the littoral region from the existing high density to a moderate plant density. A moderate density is defined as approximately 111 stems per square meter and corresponds to the optimum plant density for fisheries growth as determined by Crowder and Cooper (1979).

- Reduce the exotic, curlyleaf pondweed to the greatest extent possible from Big Lake, while maintaining a healthy native aquatic plant community.

The macrophyte management plan includes five parts:

- Education of Lake Homeowners
- Pilot Treatment Program
- Large Scale Treatment Program
- Control Introduction of Exotic Species to the Lake Evaluation Program
- Evaluation Program

The pilot treatment program will evaluate three treatment options to achieve the lake's goals. The treatment option to reduce plant density involves the application of a lime slurry mixture during the spring. Prepas et al. (1992) found that application of lime to immature plants caused a 30 to 46 percent decrease in biomasses (i.e., decreased plant density). The management strategy to control curlyleaf pondweed involves spring treatment to reduce its coverage prior to the growth of the lake's native species. Herbicide treatment and mechanical harvesting will be tested to determine which method is most effective.

A rigorous evaluation program will determine the effectiveness of the pilot program in achieving the lake's goals. The evaluation program results will be used to design a large scale treatment program for Big Lake. The large scale program will also include an evaluation program to determine its effectiveness. Although the large scale evaluation program will be designed following completion of the pilot program, its focus will be plant density and curlyleaf pondweed coverage.

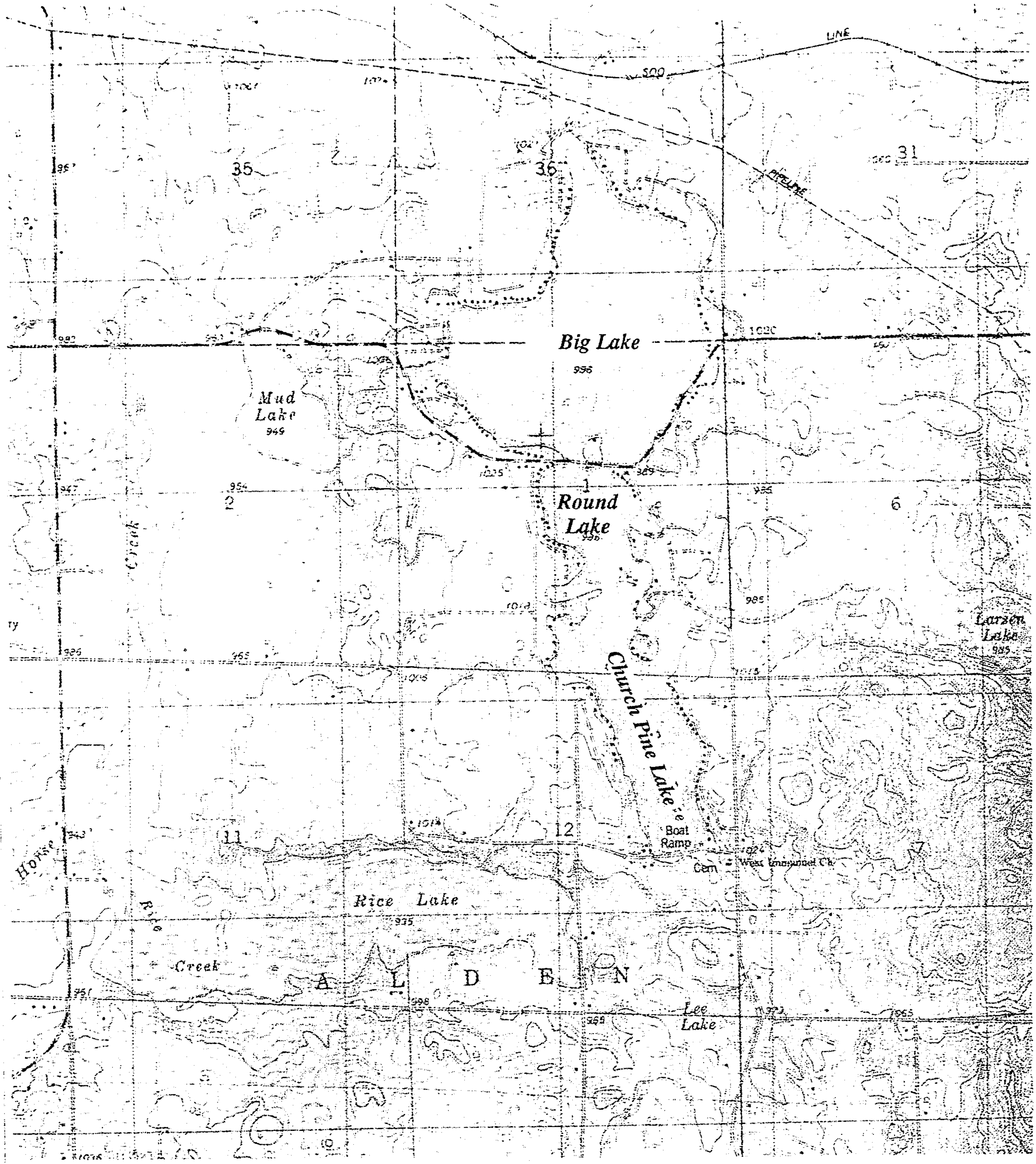
Introduction

Big Lake is located in the Church Pine, Round, and Big Lakes chain in Polk County, Wisconsin. The chain is valued by riparian owners, area residents, Polk County, and the WDNR for its fisheries and for recreational use (see Figure 1). However, all three lakes have experienced problems with weed beds and Big Lake has experienced problems with algal blooms for more than 30 years. Concern for the lakes resulted in the formation of a lake association during the 1960s, and the Church Pine, Round and Big Lake Protection and Rehabilitation District in the 1970s.

The District, with assistance from a consultant, completed a lake and watershed analysis of the chain during 1987. The study concluded that all three lakes exhibited weed growth throughout their littoral areas. Species identified in the lakes included *Potamogeton crispus*, a nuisance exotic species. The study further concluded that Church Pine and Round lakes exhibited good water quality, while Big Lake exhibited irritating summer algal blooms. Excessive phosphorus loading from North Creek, a tributary to Big Lake, was considered the primary cause of Big Lake's summer algal blooms (Lim Tech Consultants 1987).

From 1986 through the present, volunteers have collected water transparency data through the WDNR "Self-Help" program. The data corroborate the 1987 study results. Each year, Big Lake has noted declining water transparency throughout the summer months because of algal blooms. Church Pine Lake exhibited good water transparency throughout the period of record, while Round Lake exhibited a water transparency midway between that of Church Pine and Big lakes.

During 1995, representatives from the Church Pine, Round, and Big Lake Protection and Rehabilitation District approached the WDNR to discuss management of the lakes' problematic macrophyte (aquatic plant) growth. The WDNR recommended that the District complete macrophyte surveys and a macrophyte management plan for the three lakes. Consequently, macrophyte surveys of Big Lake were completed during 1996 and the report, which follows, was prepared.



Source: USGS Quadrangle Nye, Wis.

0 2000
Scale in Feet

Figure 1

BIG, ROUND, AND
CHURCH PINE LAKES

This report discusses:

- Overview of macrophyte growth in lakes
- The methodology of the 1996 Big Lake macrophyte surveys
- Results of the 1996 Big Lake macrophyte surveys
- The process of macrophyte management plan development
- A Macrophyte Management Plan for Big Lake

Overview of Macrophyte Growth in Lakes

The basis of the following text on macrophyte growth in lakes is MDNR's "A Guide to Aquatic Plants" (1994).

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.

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.

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 in addition to 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.

Methods

Aquatic plant (macrophyte) surveys of Big Lake were completed during June 13–14 and July 30–31 periods of 1996. The methodology used was based upon Jessen and Lound (1962). The survey was 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 25 transects selected for the study are shown on Figure 2.

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

- 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 quadrats. A tethered garden rake with an extended handle (16 feet) was used to collect a sample from each quadrat.

- 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:

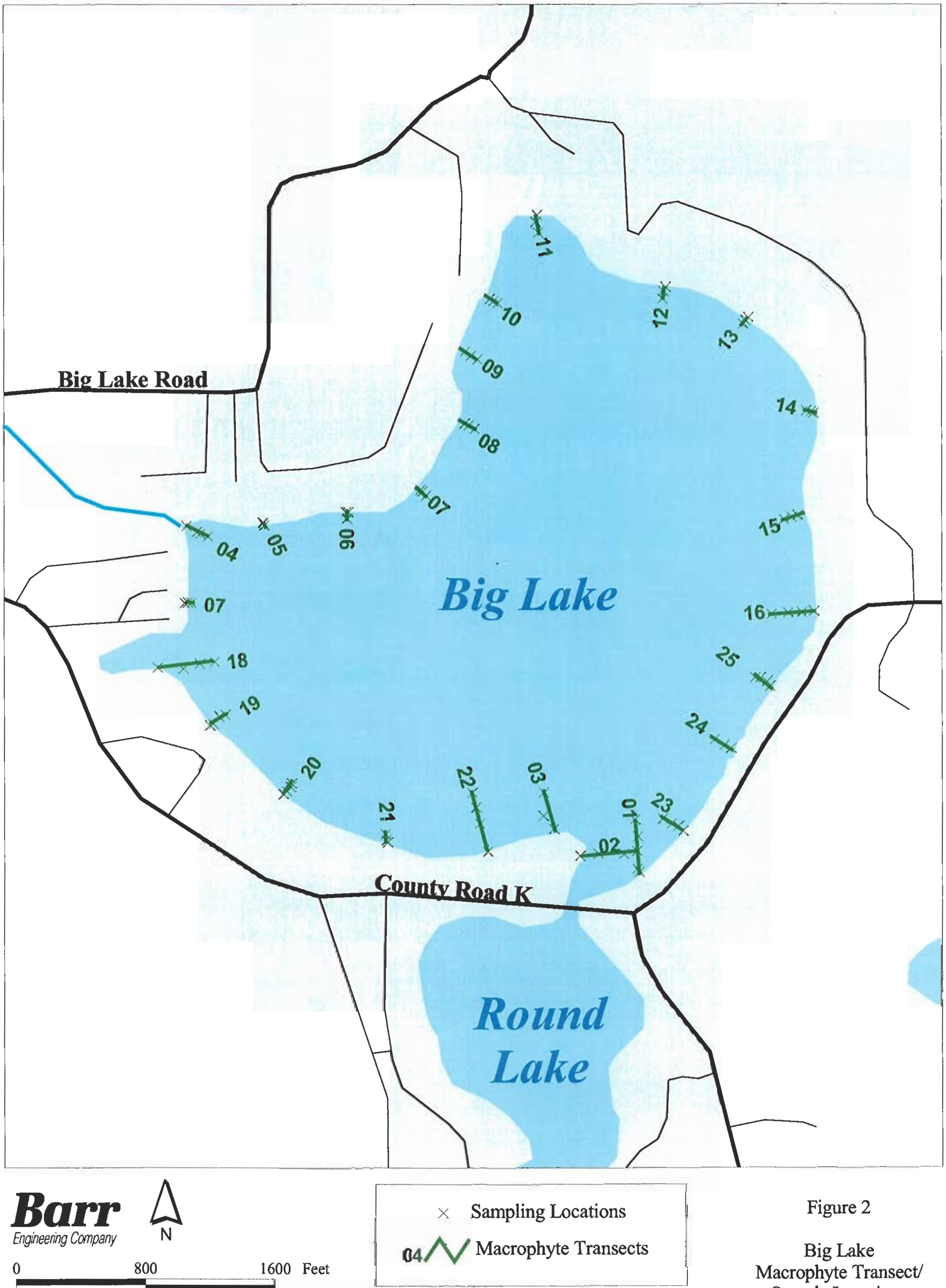


Figure 2

Big Lake
Macrophyte Transect/
Sample Locations

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.

Results and Discussion

Results of the Big Lake 1996 macrophyte surveys indicate bothersome macrophyte (aquatic plant) growth occurred in Big Lake. However, despite problematic conditions, several positive attributes of the macrophyte community were noted. A discussion of the positive and negative attributes of the macrophyte community follow.

Big Lake contains 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 throughout the growing season. June and July survey results indicated:

- Submersed plants were found in all sample locations during both surveys.

- Floating-leaf plants were found in one third of sample locations during the June survey and less than ten percent of sample locations during the July survey.

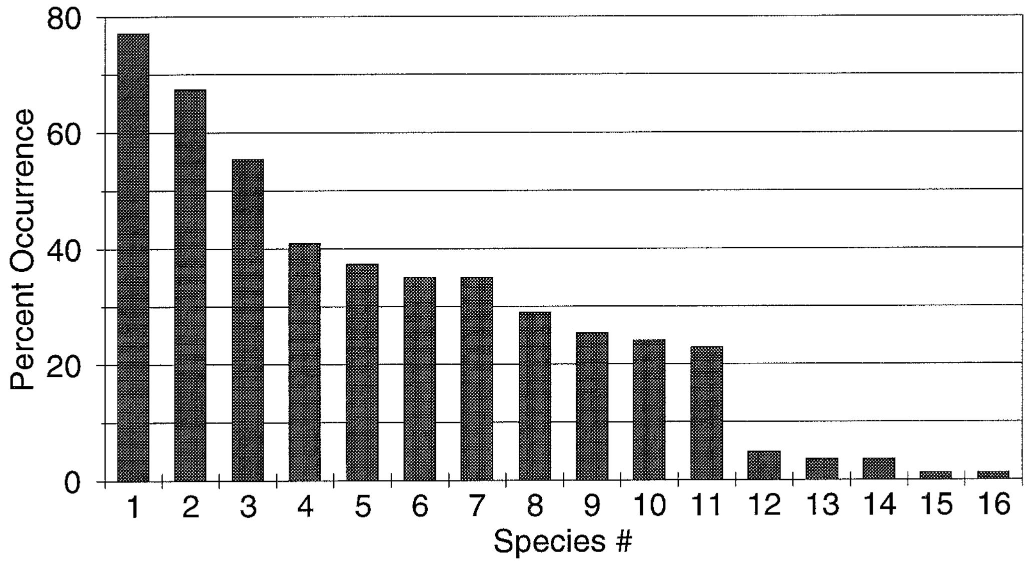
- Emergent plants were not sited during the June survey and were sited in less than ten percent of sample locations during the July survey.

The large number of species noted in Big Lake during 1996 (i.e., 22 species) is indicative of a stable and healthy macrophyte community. Community health and stability are determined by the number of species found in a community and by the changes in species occurring over time.

Dominance by a few species occurred during both 1996 surveys, but diversity characterized the macrophyte community. During June, three species were noted in more than 50 percent of the locations sampled (See Figure 3). They included:

- *Potamogeton crispus* (curlyleaf pondweed) in 77 percent of the locations sampled,
- *Ceratophyllum demersum* (coontail) in 67 percent of the locations sampled, and
- *Potamogeton zosteriformis* (flat-stemmed pondweed) in 55 percent of the locations sampled.

Figure 3
1996 Big Lake Macrophyte Survey
Frequency of Occurrence (Percent of Sample Points)
June 13, 1996



Species #	Scientific Name	% Occurrences
1	Potamogeton crispus	77
2	Ceratophyllum demersum	67
3	Potamogeton zosteriformis	55
4	Myriophyllum exalbescens	41
5	Potamogeton pectinatus	37
6	Vallisneria americana	35
7	Lemna triscula	35
8	Elodea canadensis	29
9	Potamogeton amplifolis	25
10	Potamogeton richardsonii	24
11	Zosterella dubia	23
12	Potamogeton robbinsii	5
13	Ranunculus spp.	4
14	Eriocaulon spp.	4
15	Nymphaea tuberosa	1
16	Chara sp.	1

C:\BAM_JOBS\BIGLAKE\BL13JUN3.WB2

During July, five species were noted in more than 50 percent of the locations sampled (See Figure 4). They included:

- *Valisneria americana* (Wild Celery) in 73 percent of the locations sampled
- *Ceratophyllum demersum* (Coontail) in 70 percent of the locations sampled
- *Potamogeton zosteriformis* (Flat-stemmed Pondweed) in 62 percent of the locations sampled
- *Potamogeton richardsonii* (Claspingleaf Pondweed) in 60 percent of the locations sampled
- *Najas spp.* (Bushy Pondweed) in 55 percent of the locations sampled

The similarity in species noted in Big Lake during its two surveys is indicative of community stability. Fourteen of its 23 species (i.e., 61 percent) were found during both the June and July surveys. Two species were only found during the June survey and seven species were found only during the July survey.

The Big Lake macrophyte community performs a number of valuable functions. These include:

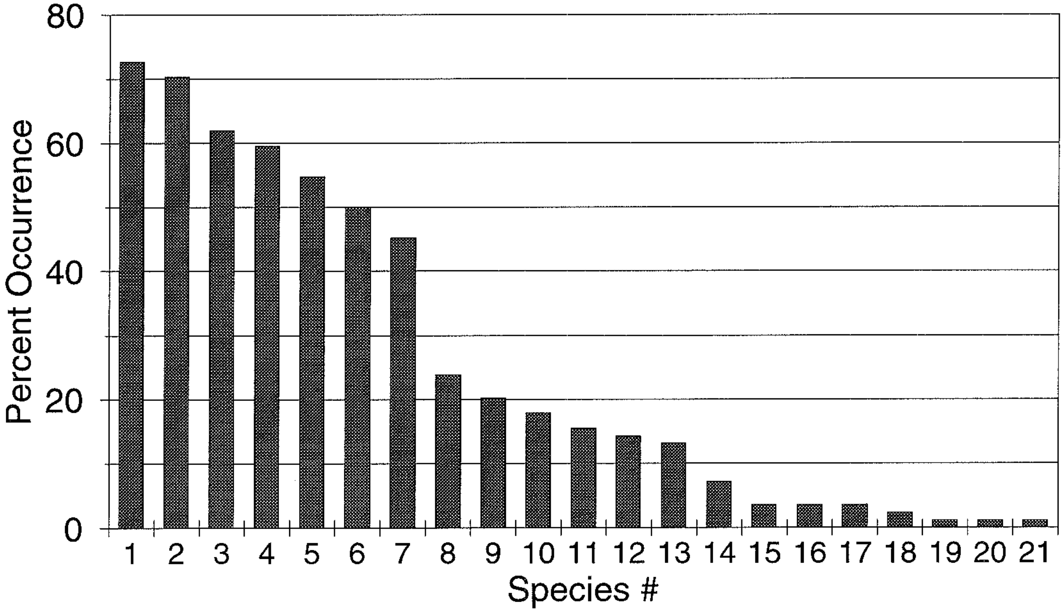
- Habitat for fish, insects, and small aquatic invertebrates
- Food for waterfowl, fish, and wildlife
- Oxygen producers
- Provide spawning areas for fish, in early spring
- Helps stabilize marshy borders of lakes and ponds; helps protect shorelines from wave erosion
- Provides nesting sites for waterfowl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

Table 1 summarizes the functions performed by several individual species noted in the lake.

Nuisance macrophyte coverage and density, which impact the lake's fishery and reasonable use of the lake by recreational users, were noted during both surveys. The surveys indicated a dense macrophyte growth occurred from the lake's shoreline to a maximum depth that was, on average, 9 feet and ranged from 8 to 18 feet (See Figure 5). The dense coverage, considered annoying by recreational users, resulted from the concurrent growth of a large number of species (See Figures 6 and 7). The results suggest it may be necessary to reduce overall macrophyte density to achieve user satisfaction and an optimum density for the lake's fishery.

Macrophytes in Big Lake consisted primarily of native species (i.e., species historically present in this region). Only one exotic (i.e., not native) species, *Potamogeton crispus* (curlyleaf pondweed),

Figure 4
1996 Big Lake Macrophyte Survey
Frequency of Occurrence (Percent of Sample Points)
July 30, 1996



Species #	Scientific Name	% Occurrences
1	Vallisneria americana	73
2	Ceratophyllum demersum	70
3	Potamogeton zosteriformis	62
4	Potamogeton richardsonii	60
5	Najas spp.	55
6	Myriophyllum exalbescens	50
7	Elodea canadensis	45
8	Zosterella dubia	24
9	Potamogeton pectinatus	20
10	Potamogeton crispus	18
11	Potamogeton amplifolis	15
12	Potamogeton strictifolius	14
13	Potamogeton pusillus	13
14	Lemna triscula	7
15	Ranunculus aquatilus	4
16	Eleocharis spp.	4
17	Potamogeton robbinsii	4
18	Nymphaea tuberosa	2
19	Eriocaulon spp.	1
20	Nuphar variegatum	1
21	Sagittaria spp.	1

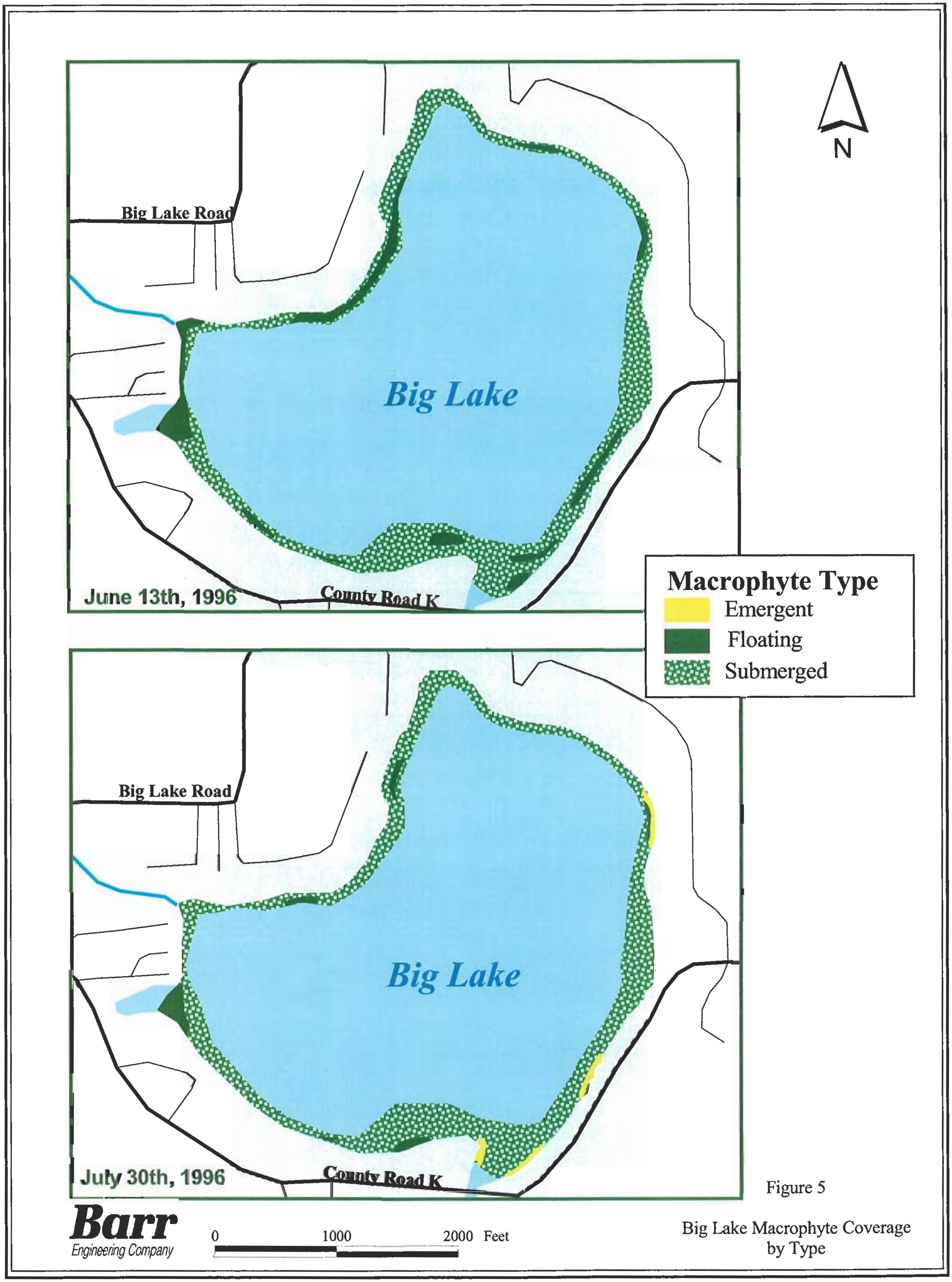


Figure 5

Big Lake Macrophyte Coverage by Type

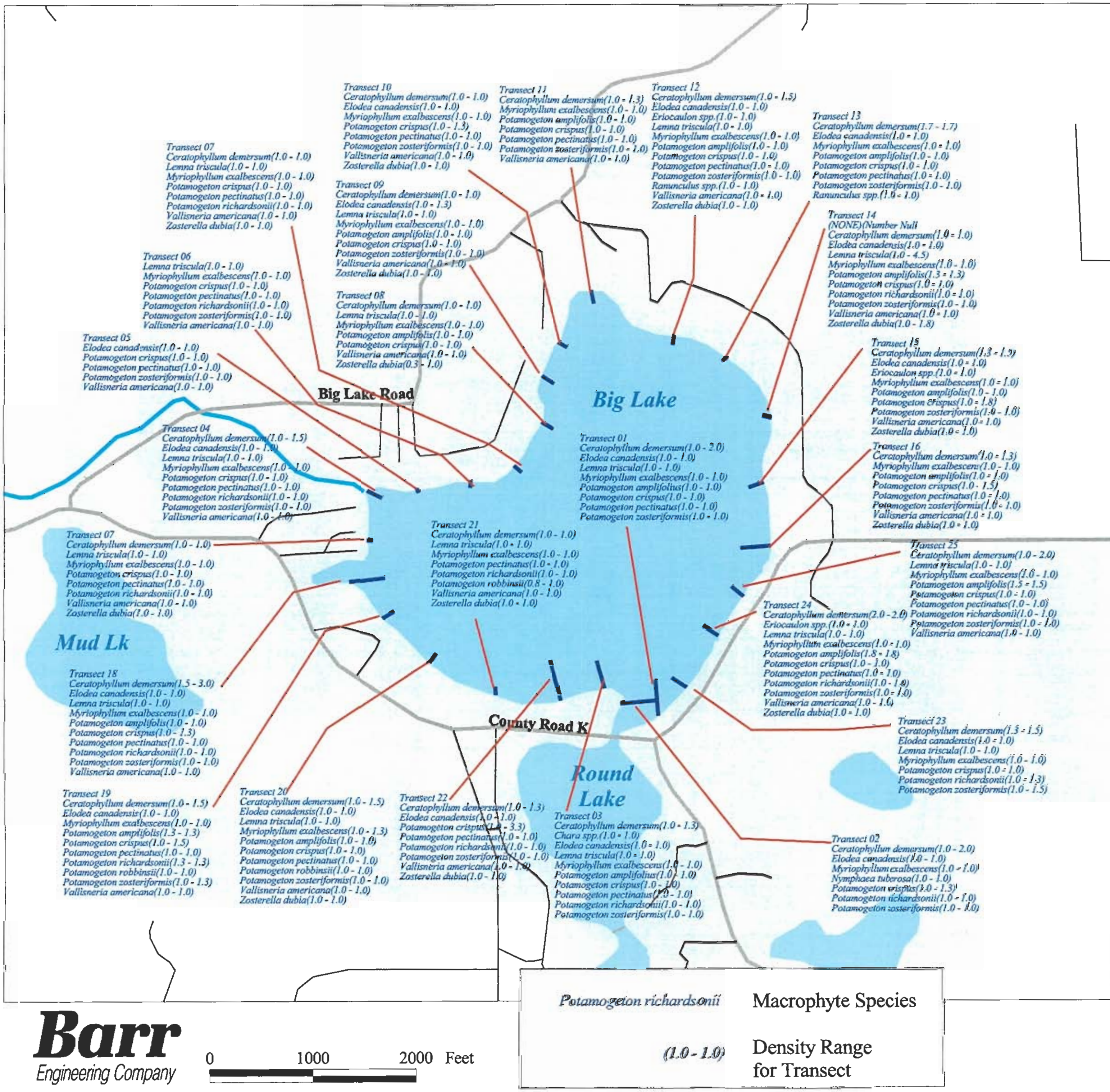


Figure 6

Big Lake
June 13-14 Macrophyte Species
Distribution and Density Range

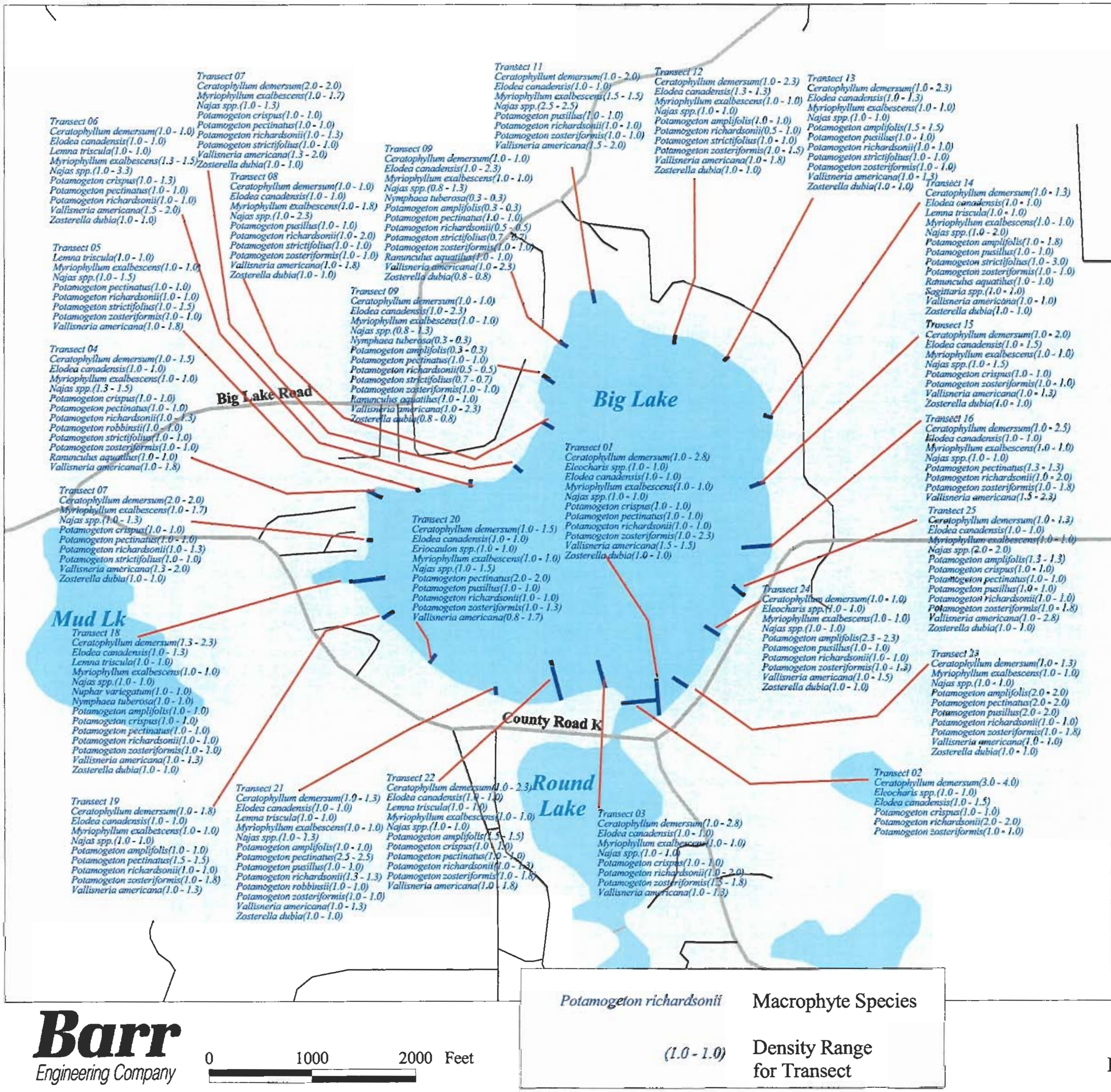


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Figure 7

Big Lake
July 30th Macrophyte Species
Distribution and Density Range

Figure 8

Big Lake
Curly Leaf Pondweed
Coverage

was noted. Curlyleaf 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.

Curlyleaf pondweed is detrimental to Big Lake for three reasons:

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

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

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

Curlyleaf pondweed is considered the most problematic species in Big Lake. Consequently, its control offers an opportunity for improved conditions. As discussed previously, curlyleaf pondweed was the dominant species during the June survey and was found in 77 percent of the sample locations (See Figure 8). Reduction of curlyleaf pondweed density would reduce macrophyte density on a lakewide basis during the early summer. Its control would improve user satisfaction of the lake. Curlyleaf pondweed was also the predominant species in Big Lake during 1987. However, local residents believe the coverage and density of curlyleaf pondweed has increased during the 1987 through 1996 period. Elimination of native species has occurred concurrently with the increased curlyleaf pondweed coverage. Failure to control its spread will result in additional losses of native vegetation.

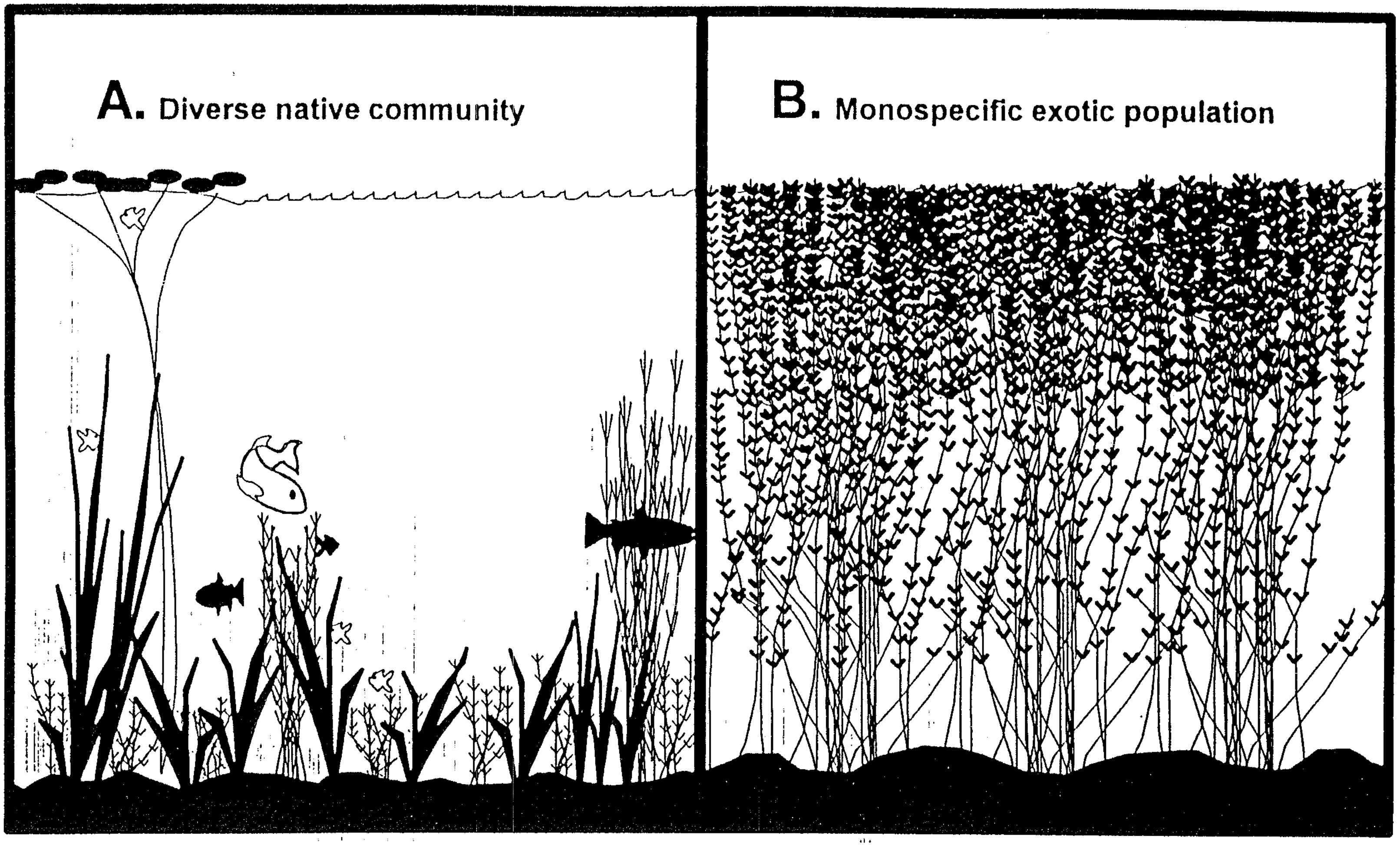

Figure 9

SUBMERSED AQUATIC PLANT
COMMUNITIES
Big Lake

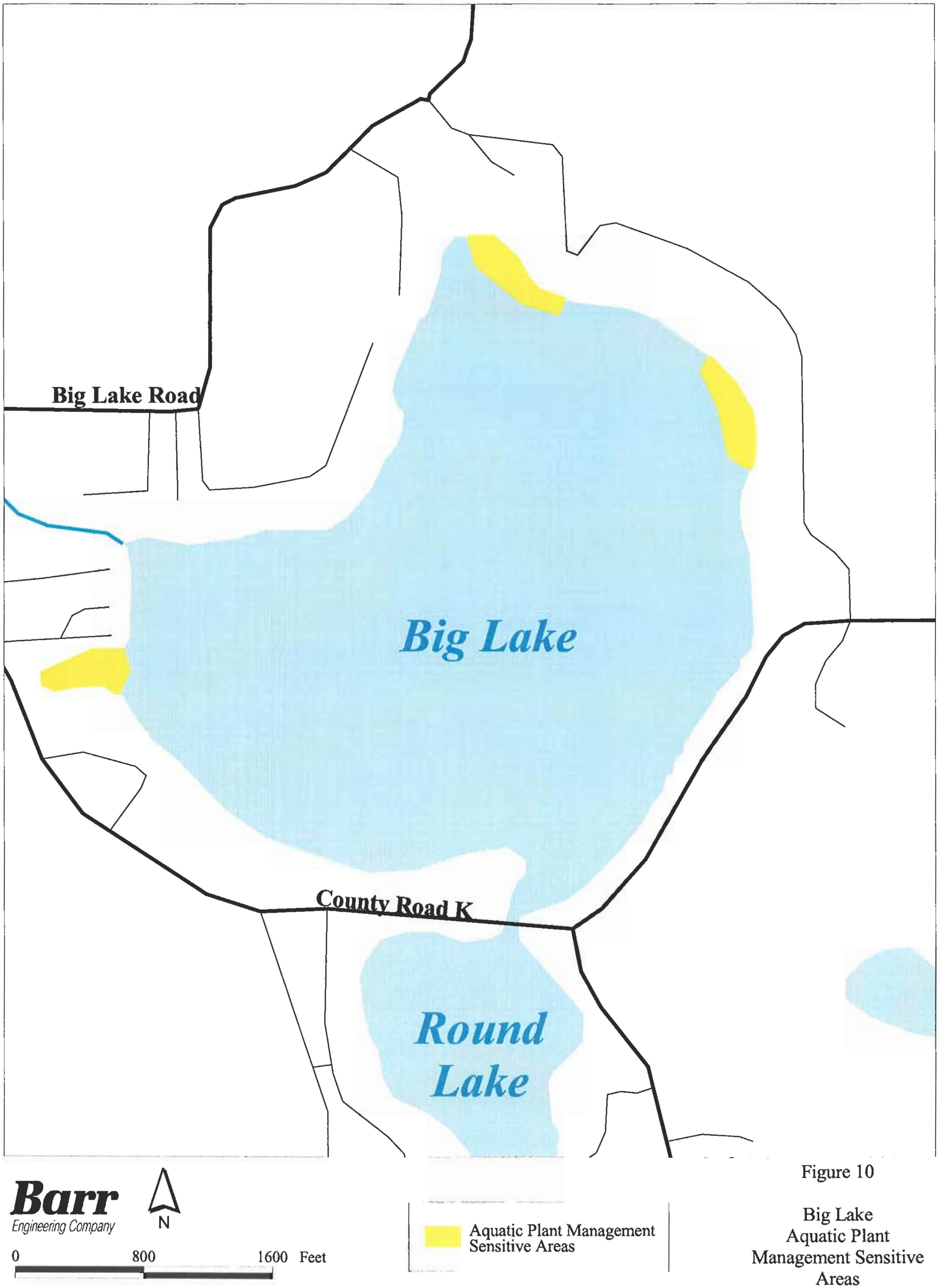

Figure 10

Big Lake
Aquatic Plant
Management Sensitive
Areas

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).

Macrophyte management plan development is the process of defining a reasonable balance between competing interests relative to plant growth and determining a feasible means of achieving the balance. Competing interests within Big Lake include:

- The interests of fisheries managers in providing requisite vegetation cover for optimum sustainable yield of the lake's fisheries versus the interests of recreational users to have minimal vegetation cover.

- The interests of some lake residents to have adequate vegetation cover to prevent shoreline erosion versus the interests of other lake residents to have a weed free lake.

Definition of and successful achievement of the balance requires a careful consideration of principles for aquatic vegetation management. The vegetation management principles upon which the macrophyte management plan development process is based were derived from suggestions by Nichols, et al. (1988). They include:

- Define the problem
- Understand plant ecology
- Consider all techniques
- Develop a management strategy
- Monitor the results

The following paragraphs discuss the use of these vegetation principals in the process of developing a macrophyte management plan of Big Lake.

Define the Problem

The first question that must be answered in the development of an aquatic macrophyte management plan is "Is there really a problem?" A dandelion is a pretty yellow flower, unless a few thousand are dotting your prize Kentucky bluegrass lawn. Each user that shares the lake shoreline and surface will have a different view of the extent of nuisance conditions caused by aquatic plants. Some people consider the presence of a few water lilies or cattails to be objectionable. People who fish often seek out the edge of large beds of submerged plants, as a location for catching the "big lunker." The experience of scattered Eurasian watermilfoil plants in a clear, deep, unproductive mountain lake is often enough to create widespread ecological hysteria. A small shallow pond that has always been weedy may not cause any concern to its owner, unless it shows signs of filling in. However, most lake users will agree that widespread use impairment exists when aquatic vegetation grows at great densities within 0.5 meters of surface, along much of the usable lake shore and surface. (Madsen, 1992). User's also generally agree that a problem exists when an exotic (i.e., non-native) species is present in the lake because exotic species frequently exhibit voracious growth and crowd out beneficial native species.

The answer to the question "Is there really a problem in Big Lake?" is yes. Big Lake notes widespread use impairment throughout its littoral region and the presence of the exotic species, *Potamogeton crispus* (i.e., curlyleaf pondweed).

Understand Plant Ecology

The second step in the development of a macrophyte management plan is attaining an understanding of plant ecology and an understanding of the plant community within the lake of concern. The understanding must encompass beneficial native species and any exotic species found in the lake of concern. The following paragraphs discuss general plant ecology and its relationship to management plan development. A discussion of native versus exotic plant growth and the ecology of the exotic species of concern in Big Lake (i.e., curlyleaf pondweed) follow the discussion of general plant ecology.

In order to design, assess and utilize management techniques, a basic understanding of the biology of aquatic plants and the habitat in which they grow is necessary. 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 (1974).

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 blamed on nutrient enrichment (eutrophication) of the water and 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.

The Big Lake macrophyte management problem is caused by aquatic plants growing densely throughout its littoral (shallow area near shore) area. The residents perceive all aquatic plants as weeds and desire implementation of control measures to reduce plant density. In general, aquatic plants are a desirable and necessary part of the aquatic ecosystem. The excessive growth of many species in given locations can have undesirable aesthetic or economic consequences for man and can become a problem. In summarizing this problem, Sculthorpe (1967) states, "One of the major consequences of the luxuriant vegetative growth and adventive spread of hydrophytes is that numerous species attain prime importance as insidious weeds. Indeed, since about 1850 almost the only interest in these hydrophytes has been the desire to extirpate them." The term "weed" has no precise biological definition. A weed is usually considered to be a plant without utility or beauty, growing wild and rank, and cumbering the ground or hindering superior vegetation (Harlan and de Wet, 1965). Curtis (1959) points out that weeds have many biological properties in common. They generally have a rapid growth rate, can surmount high interspecific competition, show great tolerance to regressive influence, can spread and invade in large numbers and have seeds that are tolerant of extreme fluctuations in conditions.

The aquatic plant (i.e., "weed) within Big Lake of greatest concern is the exotic (non-native species) curlyleaf pondweed. An understanding of growth differences between native species and exotic species provides an understanding of the basis of the concerns regarding curlyleaf pondweed. An understanding of the ecology of curlyleaf pondweed provides insight into feasible macrophyte control options and underscores the need to manage this nuisance species.

Differences in growth patterns between exotic plants and native plants indicate a need for management of exotic species to protect native communities. As noted previously, native plant communities are typically dominated by growth forms that concentrate biomass below the surface of the water (See Figure 9A), contain a high diversity of species, and have low to moderate levels of biomass. Exotic plants typically follow a voracious growth pattern. Exotic species generally produce a dense canopy of vegetation at the air:water interface and develop high levels of biomass. Such a growth pattern interferes with use of the water resource by recreational users and eliminates 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.

The exotic species of concern in Big Lake, curlyleaf pondweed, has exhibited the invasive growth pattern typical of exotic species. Curlyleaf pondweed has unique life cycle adaptations which give it competitive advantages over many native aquatic plants. Unlike most native plants, curlyleaf 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. Tenacious 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). Curlyleaf 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 curlyleaf pondweed is able to use turions to invade new areas of a water body. The density of curlyleaf 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 curlyleaf pondweed can alter the nutrient dynamics of water bodies. As curlyleaf plants senesce in the summer, large amounts of vegetation falls 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.

Consider all Techniques

The third step in the development of a macrophyte management plan is the consideration of all macrophyte control techniques. Following a consideration of all possible techniques, feasible control options may be identified for the lake of concern. 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

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.

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.

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 or sediment alteration to inhibit the growth of aquatic plants at the sediment surface. Benthic barriers are generally applied to small areas.

Sediment inactivation has included the application of phosphorus binding substances to sediments. The growth of aquatic plants is inhibited by the reduced availability of phosphorus in sediments.

Mechanical Control

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 plants that are mechanically controlled should be removed from the lake.

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.

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 2 .

Table 2

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 up to 3 ac/day @ $300–600/ac 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	
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

Table 2 (continued)

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
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
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

Table 2 (continued)

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
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
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 2 (continued)

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
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

Develop a Management Strategy

The fourth step in the development of a macrophyte management plan is the development of a management strategy. The strategy is based upon the lake's problem, an understanding of its plant ecology, and a consideration of available aquatic plant control techniques. The management strategy frequently involves a phased approach. The first phase consists of a small scale pilot study to test the effectiveness of potential treatment options. The second phase consists of a large scale treatment program, which is based upon the results of the pilot study.

The management strategy for Big Lake is based upon the need to reduce plant density in the lake's littoral (shallow) region and to control the exotic species, curlyleaf pondweed. The strategy to reduce plant density is based upon a plant's dependance upon light and porewater nutrients for growth. Consequently, reduced plant growth occurs when available light and porewater nutrients are limited. The strategy to control curlyleaf pondweed growth is based upon growth characteristics unique to curlyleaf pondweed.

The management strategy to reduce plant density in Big Lake involves a treatment which inactivates porewater nutrients, primarily phosphorus, and blocks light required by plants. Spring application of a lime mixture offers the potential of inactivating porewater phosphorus. Adherence of the lime mixture to plant leaves also blocks the light required for photosynthesis (Prepas, et al., 1992). Consequently, application of a lime mixture offers the potential to reduce plant density within Big Lake. Prepas, et al. (1992) found that application of lime to immature plants caused a 30 to 46 percent decrease in biomass (i.e., decreased plant density).

The management strategy to control curlyleaf pondweed growth in Big Lake involves a spring treatment to eliminate curlyleaf pondweed prior to the growth of the lake's native species. Herbicide treatment and mechanical harvesting will be tested to determine which method is the most effective. Spring treatment of curlyleaf pondweed offers the potential of facilitating the spread of native species within the lake. Native species are expected to colonize vacant areas, formerly occupied by curlyleaf pondweed. The strategy uses direct treatment of curlyleaf pondweed and increased coverage by native species as dual control mechanisms to reduce the coverage of curlyleaf pondweed.

Implementation of the macrophyte management strategy will occur in two phases. Phase 1 will include completion of a pilot study during 1997 through 1999 to evaluate the three treatment options. Following the completion of the pilot study, a large scale treatment program will be designed and implemented.

Regardless of the management strategy chosen for Big Lake, a WDNR permit is needed before management procedures are initiated. Under Wisconsin law, aquatic plants growing in public waters are the property of the state. Because of their value to the lake ecosystem, they may not be destroyed or transplanted unless authorized by the WDNR. Procedures for the management of aquatic plants have been established by the WDNR pursuant to s.227.11, Stats., and s. 144.025 (2)(i), Stats. The permit application process has been outlined in Chapter NR 107, Aquatic Plant Management, in the Wisconsin Administrative Code, Department of Natural Resources. The WDNR should be contacted regarding a permit prior to beginning any type of aquatic plant management program.

Study the Results

The fifth step in the development of a macrophyte management plan is the design of a sampling program to evaluate changes in the macrophyte community and/or individual species following implementation of the previously discussed management strategy. The study results will indicate the effectiveness of the macrophyte management plan. The Big Lake evaluation program will encompass two phases. Phase 1 sampling will evaluate the effectiveness of the pilot treatment program proposed for Big Lake (i.e., spring application of a lime mixture, spring harvesting of curlyleaf pondweed, and spring herbicide treatment of curlyleaf pondweed). Macrophytes within the small test plots will be sampled before and after treatment to determine changes in species and in species density. Phase 2 sampling will evaluate the effectiveness of a large scale implementation program to control macrophyte growth within Big Lake. It will focus upon stem density of the macrophyte community and curlyleaf pondweed coverage.

Macrophyte Management Plan

The goals of the Big Lake Macrophyte Management Plan are:

- Reduce plant density throughout the littoral region from the existing high density to a moderate density. A moderate density is defined as approximately 111 stems per square meter and corresponds to the optimum plant density for fisheries growth as determined by Crowder and Cooper (1979).

- Reduce the coverage of the exotic, curlyleaf pondweed to the greatest extent possible from Big Lake, while maintaining a healthy native aquatic plant community.

The proposed management strategy for Big Lake can be considered:

- A fisheries management strategy—Manipulation of plant density to optimize fisheries growth manages macrophytes from a fisheries perspective.

- An integrated pest management approach—Removal of the exotic, curlyleaf pondweed approaches macrophyte management from a pest removal perspective. The integrated pest management approach may be defined as an economical and ecologically sound manner to reduce pest aquatic plant populations and maintain them at levels that do not adversely impact the native plant population and enable a reasonable use of the lake by recreational users.

The preliminary Big Lake Macrophyte Management Plan includes five parts:

- Education of Lake Homeowners
- Pilot Treatment Program
- Large Scale Treatment Program
- Control Introduction of Exotic Species to the Lake
- Evaluation Program

Details of the Macrophyte Management Plan are discussed in the following paragraphs.

Education of Lake Homeowners

The first step in the management plan is to educate the people using the lake. The education program will embody two parts:

- An understanding of the functions and roles of native species/native communities within Big Lake.

- An understanding of the exotic species, curlyleaf pondweed, and its threat to the native plant community within Big Lake.

The education program will be completed by the Church Pine, Round, and Big Lake Protection and Rehabilitation District with assistance from the WDNR and the Polk County Land Conservation Department.

Pilot Treatment Program

A pilot treatment program will be completed to identify the most effective means of reducing plant density and controlling curlyleaf pondweed growth within Big Lake. The program includes:

- Lime slurry treatment to reduce plant density
- Spring application of herbicide to control curlyleaf pondweed growth
- Spring harvesting to control curlyleaf pondweed growth

Following is a detailed description of the pilot program.

Lime Slurry Treatment

During 1997 through 1999 a pilot program will be completed to investigate the feasibility of reducing aquatic plant density in Big Lake via a mid-June application of lime slurry. Two test plots and two control plots, approximately one acre in size, will be selected within the 3- to 6-foot depth range during mid-June of 1997. Calcium hydroxide will be applied as a slurry at a dose of 150 grams/square meter to each test plot. A study will be completed to determine the effectiveness of the pilot treatment program (i.e., described under evaluation program).

Spring Herbicide Treatment of Curlyleaf Pondweed

Control of curlyleaf pondweed is typically done by herbicide treatments applied from a barge or boat or by mechanical harvesting, or by a combination of these methods. Herbicide treatments are more effective at eradicating the plant but DNR regulations limit the extent of the lake that can be treated in any year. Aquatic herbicides are among the most closely scrutinized compounds known, and must be registered for use by both the U.S. EPA and the State of Wisconsin. Registration of an aquatic herbicide requires extensive testing. Consequently, all of the aquatic herbicides currently registered for use are characterized by excellent toxicology packages, are only bio-active for short periods of time, have relatively short-lived residuals, and are not bioconcentrated (Pullman, 1992). Examples of two aquatic herbicides appropriate for use in controlling the curlyleaf pondweed growth in Big Lake are Reward (active ingredient = Diquat) and Aquathol-K (active ingredient = Endothall).

Until recently, the most common management strategy for controlling curlyleaf pondweed growth has been for individual lakeshore owners to manually rake and remove the weeds immediately adjacent to their property, or to contract a professional weed management company to remove the weeds by either mechanical harvesting or herbicide application. This type of management strategy is usually carried out during the period of peak curlyleaf pondweed growth (approximately mid-June) when the weeds are most noticeable. By the time the curlyleaf pondweed growth has reached nuisance levels each summer, formation of the reproductive turion has already occurred. Therefore, the strategy of treating the weeds with herbicide at the time of peak growth does not offer long-term benefits, and the weed growth will reoccur each year.

Recently, several agencies and lake managers have begun implementing lake-wide management plans to reduce densities of curlyleaf pondweed. The strategies used involve eliminating the plants prior to formation of the turion and prior to peak plant growth. Therefore, the negative effects created by large masses of decaying plant matter (such as phosphorus release and oxygen depletion) are eliminated, and the following year's plant crop is reduced. Spring application of herbicides (i.e., endothall and diquat) have been shown to be effective against curlyleaf pondweed. In order to effectively reduce the plant growth and reproduction, entire plant beds should be treated simultaneously. Several projects involving the early-spring application of herbicide to reduce curlyleaf pondweed growth have been carried out in Minnesota and Wisconsin, including Big Butternut Lake (Polk County, Wisconsin; Barr Engineering, 1996), Forest Lake (Washington County, Minnesota; K. Kretsch, personal communication); Schmidt Lake (Hennepin County, Minnesota; K. Kretsch, personal communication). The results of these studies have generally been observed to be positive, but have not yet been scientifically quantified.

Elimination of curlyleaf pondweed prior to establishment of the native vegetation community offers the added advantage of facilitating the growth of native species. Most native species grow from seed and, therefore, do not become established until late spring. Application of herbicide during early spring would, therefore, eradicate curlyleaf pondweed prior to the growth of native species. Native species would have the opportunity to replace the curlyleaf pondweed, thus ensuring requisite habitat for fish and other aquatic animals.

During 1997 through 1999, a pilot program will be completed to investigate the feasibility of controlling Big Lake's curlyleaf pondweed via spring application of herbicide. The herbicide Reward will be used in the pilot program. Two test plots and two control plots, approximately one acre in size, will be selected within the 3- to 6-foot depth range during May of 1997. Each plot will be similar in fetch, slope, vegetation (i.e., contain curlyleaf pondweed) and exposure. The test plots will be treated with Reward during May of 1997 and 1998. A study will be completed to determine the effectiveness of the pilot treatment program.

Spring Harvesting of Curlyleaf Pondweed

Mechanical harvesting during spring offers a second alternative to control of curlyleaf pondweed. The strategy for spring harvesting is the same as spring application of herbicide. Spring harvesting eliminates the plants prior to formation of the turion and prior to peak growth. Elimination of curlyleaf pondweed prior to establishment of the native vegetation community offers the added advantage of facilitating the growth of native species. Native species would have the opportunity to replace the curlyleaf pondweed, thus ensuring requisite habitat for fish and other aquatic animals. Harvesting during successive years is expected to cause a continued reduction in the growth of curlyleaf pondweed and a continued increase in the density of beneficial native species (S. Engel, Personal Communication, 1996).

During 1997 through 1999, a pilot program will be completed to investigate the feasibility of controlling Big Lake's curlyleaf pondweed via spring harvesting. Two test plots and two control plots, approximately one acre in size, will be selected within the 3- to 6-foot depth range during May of 1997. Each plot will be similar in fetch, slope, vegetation (i.e., contain curlyleaf pondweed) and exposure. Harvesting of test plots will occur during May of 1997 and 1998. A study will be completed to determine the effectiveness of the pilot treatment program.

Large Scale Treatment Program

A large scale treatment program will be designed and implemented following an evaluation of the results of the pilot treatment program. The results will determine the most effective curlyleaf pondweed control option. In addition, the results will indicate the feasibility of using lime slurry on a large scale to reduce plant density to a moderate level.

Control Introduction of Exotic Species to the Lake

In addition to attempting eradication of existing curlyleaf pondweed within the lake, the Big Lake Management Plan addresses the introduction of additional curlyleaf pondweed and other exotic species, such as Eurasian Watermilfoil. Control of exotic species introduction involves education of lake users and constant vigilance by lake residents. The two most likely control points are the public boat launch and the water inlets to the lake. The latter would include Horse Creek and the channel between Big Lake and Round Lake.

The education component could involve posting signs at the boat launch reminding lake users to remove aquatic plants from boat trailers before entering and before leaving the lake to prevent the introduction of unwanted species. Volunteers from the Church Pine, Round, and Big Lake Protection and Rehabilitation District could be present at the boat launch 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 Big Lake.

The lake inlets should be inspected regularly throughout the summer for possible pioneer Eurasian Watermilfoil or curlyleaf pondweed establishing in that area. An inspection schedule could be established for volunteers to insure that regular inspection occurs.

Lastly, constant vigilance by lake residents will be needed to identify changes in curlyleaf pondweed growth within the lake and/or the establishment of Eurasian Watermilfoil in the lake. The Church Pine, Round Big Lake Protection and Rehabilitation District could form inspection teams to conduct surveys during June of each year. The team could make the inspection an annual weekend event followed by a cookout/social gathering. The team would establish a schedule to completely survey the shoreline of the lake to identify Eurasian Watermilfoil introductions or changes in curlyleaf pondweed growth. Individual plants identified by the survey should be removed by covering with a fine mesh bag[1] and attempting to remove the root crown of the plant. 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 Eurasian Watermilfoil beds or curlyleaf pondweed beds 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. Curlyleaf pondweed beds should be treated as determined from the pilot program. Eurasian Watermilfoil should be treated with a herbicide treatment of 2,4-D at a concentration found to be effective. Treatment should occur shortly after florescence because it is a vulnerable period for the plants and occurs prior to peak autofragmentation.

Evaluation Program

An evaluation program will completed to determine the effectiveness of the pilot treatment program and the large scale treatment program in accomplishing the lake's goals. A discussion of the pilot treatment program evaluation follows. The evaluation of the large scale treatment program will be designed concurrently with the large scale treatment program. Design will be based upon the evaluation of the pilot treatment program.

Evaluation of Lime Slurry Treatment

Two test plots and two control plots, approximately one acre in size, will be selected within the 3- to 6-foot depth range during mid-June of 1997. Each plot will be similar in fetch, slope, vegetation and exposure. GPS coordinates from the 1996 macrophyte surveys will be used to tentatively select plot locations. Final selection will occur in the field, however. The selection process will consider fish spawning areas (see Figure 10) to insure that spawning areas are not treated. However, control plots may include fish spawning areas. The WDNR area fisheries manager will assist with plot selection. Plots will be delineated by using Global Positioning System (GPS) coordinates and a laser range-finder will be used to measure the length of each plot side. Each plot will be marked at the four corners with yellow buoys. Plots will be at least 100 yards apart.

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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.

Using a stratified random pattern, 10 sample locations will be selected within each plot. A Global Positioning System unit will be used in the field to note latitude and longitude of each sample location. Each sample location will be sampled before treatment during 1997 (i.e., in mid-June), after treatment but before senescence during 1997 (i.e., in late June), after treatment but before senescence during 1998 (i.e., in late June) and in late June of 1999. Lime slurry treatments will occur during mid-June of 1997 and 1998.

Sample collection will involve the collection of all stem/shoot material found within a 0.1 square meter quadrat at each sample location. Samplers may include a PVC frame, a square, open-sided square, or a bucket with the bottom cut out. All stem/shoot material within the sampler will be placed in a bag and labeled as to plot, sample location, and sample date. Samples within the three and four foot depths will be collected by volunteers and samples within the five and six foot depths will be collected by a scuba diver. Samples will be sent to Barr Engineering Co. for species identification. Plant material from each sample location will be sorted by species and placed in paper bags (i.e., each species in a separate paper bag). The number of stems representing each species will be counted and recorded. Each bag will be labeled as to treatment plot, sample location, species, and collection date. Samples will be oven dried at 105 degrees Celsius until a constant weight is noted. The weight (i.e., biovolume) of each species at each sample location will be recorded for each sample date. Therefore, data obtained on a species basis will include stem density and biovolume.

During the late-June sample event during 1997, 1998, and 1999, samples will be collected to evaluate curlyleaf pondweed turion densities at each sample location. A turion is the reproductive structure of curlyleaf pondweed, a problematic exotic (i.e., non native) species found in Big Lake. An Eckman dredge will be used to collect sediment samples at each sample location. Once collected, each sediment sample will be washed through a sieve to remove the turions. The number of turions will then be counted and recorded. Turion density will be determined by converting the numbers to an areal density (# per square meter) based on the area sampled by the dredge (150 mm by 150 mm). The data will be evaluated to determine whether the lime slurry treatment results in reduced reproduction by curlyleaf pondweed via reduction in plant density.

During mid-August of 1997, 1998, and 1999, volunteers/scuba diver will perform an additional survey to determine stem density. Samples will be collected from the same locations and using the same methods described above. The total number of stems found in each sample will be counted and recorded. Temporal (i.e., same station over time) and spatial (i.e., control versus test plots) comparisons will evaluate changes in overall stem density during the late summer period.

Evaluation of Spring Herbicide Treatment of Curlyleaf Pondweed

Two test plots and two control plots, approximately one acre in size, will be selected within the 3- to 6-foot depth range during May of 1997. Each plot will be similar in fetch, slope, vegetation (i.e., contain curlyleaf pondweed) and exposure. GPS coordinates from the 1996 macrophyte surveys will be used to tentatively select plot locations. Final selection will occur in the field, however. The selection process will consider fish spawning areas (see Figure 10) to ensure spawning areas are not treated. However, control plots may include fish spawning areas. The WDNR area fisheries manager will assist with plot selection. Plots will be delineated by using GPS coordinates and a laser range-finder will be used to measure the length of each plot side. Each plot will be marked at the four corners with yellow buoys. Plots will be at least 100 yards apart.

Using a stratified random pattern, 10 sample locations will be selected within each plot. A GPS unit will be used in the field to note latitude and longitude of each sample location. Each sample location will be sampled before treatment during 1997 (i.e., in early May), after treatment but before senescence during 1997 (i.e., in late June), after treatment but before senescence during 1998 (i.e., in late June) and in late June of 1999. Reward treatments will occur during early May of 1997 and 1998.

Sample collection will involve the collection of all stem/shoot material found within a 0.1 square meter quadrat at each sample location. Samplers may include a PVC frame, a square, open-sided square, or a bucket with the bottom cut out. All stem/shoot material within the sampler will be placed in a bag and labeled as to plot, sample location, and sample date. Samples within the three and four foot depths will be collected by volunteers and samples within the five and six foot depths will be collected by a scuba diver. Samples will be sent to Barr Engineering Co. for species identification. Plant material from each sample location will be sorted by species and placed in paper bags (i.e., each species in a separate paper bag). The number of stems representing each species will be counted and recorded. Each bag will be labeled as to treatment plot, sample location, species, and collection date. Samples will be oven dried at 105 degrees Celsius until a constant weight is noted. The weight (i.e., biovolume) of each species at each sample location will be recorded for each sample date. Therefore, data obtained on a species basis will include stem density and biovolume.

During the late-June sample event during 1997, 1998, and 1999, samples will be collected to evaluate turion densities at each sample location. An Eckman dredge will be used to collect sediment samples at each sample location. Once collected, each sediment sample will be washed through a sieve to remove the turions. The number of turions will then be counted and recorded. Turion density will be determined by converting the numbers to an areal density (# per square meter) based on the area sampled by the dredge (150mm by 150mm).

During mid-August of 1997, 1998, and 1999, volunteers/scuba diver will perform an additional survey to determine stem density. Samples will be collected from the same locations and using the same methods described above. The total number of stems found in each sample will be counted and recorded. Temporal (i.e., same station over time) and spatial (i.e., control versus test plots) comparisons will evaluate changes in overall stem density during the late summer period.

Evaluation of Spring Harvesting of Curlyleaf Pondweed

Two test plots and two control plots, approximately one acre in size, will be selected within the 3- to 6-foot depth range during May of 1997. Each plot will be similar in fetch, slope, vegetation (i.e., contain curlyleaf pondweed) and exposure. GPS coordinates from the 1996 macrophyte surveys will be used to tentatively select plot locations. Final selection will occur in the field, however. The selection process will consider fish spawning areas (see Figure 10) to insure spawning areas are not treated. However, control plots may include fish spawning areas. The WDNR area fisheries manager will assist with plot selection. Plots will be delineated by using GPS coordinates and a laser range-finder will be used to measure the length of each plot side. Each plot will be marked at the four corners with yellow buoys.

Using a stratified random pattern, 10 sample locations will be selected within each plot. A GPS unit will be used in the field to note latitude and longitude of each sample location. Each sample location will be sampled before treatment during 1997 (i.e., in early May), after treatment but before senescence during 1997 (i.e., in late June), after treatment but before senescence during 1998 (i.e., in late June) and in late June of 1999. Spring harvesting will occur during 1997 and 1998.

Sample collection will involve the collection of all stem/shoot material found within a 0.1 square meter quadrat at each sample location. Samplers may include a PVC frame, a square, open-sided square, or a bucket with the bottom cut out. All stem/shoot material within the sampler will be placed in a bag and labeled as to plot, sample location, and sample date. Samples within the three and four foot depths will be collected by volunteers and samples within the five and six foot depths will be collected by a scuba diver. Samples will be sent to Barr Engineering Co. for species identification. Plant material from each sample location will be sorted by species and placed in paper bags (i.e., each species in a separate paper bag). The number of stems representing each species will be counted and recorded. Each bag will be labeled as to treatment plot, sample location, species, and collection date. Samples will be oven dried at 105 degrees Celsius until a constant weight is noted The weight (i.e., biovolume) of each species at each sample location will be recorded for each sample date. Therefore, data obtained on a species basis will include stem density and biovolume.

To evaluate the effect of the treatments on turion density, annual surveys will be completed to evaluate turion density. During the late-June sample event during 1997, 1998, and 1999, samples will be collected to evaluate turion densities at each sample location. An Eckman dredge will be used to collect sediment samples at each sample location. Once collected, each sediment sample will be washed through a sieve to remove the turions. The number of turions will then be counted and recorded. Turion density will be determined by converting the numbers to an areal density (# per square meter) based on the area sampled by the dredge (150mm by 150mm).

Late summer surveys will be completed to determine the impact of treatment upon late summer macrophyte density. During mid-August of 1997, 1998, and 1999 volunteers/scuba diver will perform an additional survey to determine stem density. Samples will be collected from the same locations and using the same methods described above. The total number of stems found in each sample will be counted and recorded. Temporal (i.e., same station over time) and spatial (i.e., control versus test plots) comparisons will evaluate changes in overall stem density during the late summer period.

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