AN AQUATIC PLANT MANAGEMENT PLAN FOR CRYSTAL LAKE SHEBOYGAN COUNTY, WISCONSIN

Prepared By:

Environmental Horizons, Incorporated

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Chapter I

INTRODUCTION

Crystal Lake is located in the northwestern part of Sheboygan County, Wisconsin, in the Town of Plymouth. The Lake is located to the northwest of the community of Plymouth, as shown on Map 1. Crystal Lake is a valuable natural resource offering a unique setting and variety of recreational and related-use opportunities to a small residential community and its visitors, using the Lake and surrounding lands. The Lake offers a range of water-based recreational opportunities in the summer, including fishing, boating, water-skiing, and swimming, and in the winter, including ice-fishing. Public access to the Lake is provided through a County-operated public recreational boating access site located on the southwestern shoreline of the western embayment of this Lake.

The Crystal Lake community is served by a public sanitary sewerage system operated by the Sanitary District #1 of the Towns of Rhine and Plymouth, a special purpose governmental unit. The Sanitary District has assumed public inland lake protection and rehabilitation powers pursuant to Section 60.782, Subchapter IX of Chapter 60 of the *Wisconsin Statutes*, and has the authority to conduct studies and undertake other lake management activities with respect to Crystal Lake. The Lake Sanitary District has subsequently undertaken a program of study that has included the conduct of watershed, water quality, and lake management planning investigations, funded, in part, under the Chapter NR 190 Lake Management Planning Grant Program.

The Sanitary District is supported in their lake-related endeavors by two voluntary citizen-based organizations, the Crystal Lake Management District and the Crystal Lake Advancement Association

This report sets forth an inventory of the aquatic plant communities present within Crystal Lake, and related information on the drainage area tributary to the Lake relevant to the delivery of sediments and nutrients to the Lake that sustain and support the production of aquatic plants in the Lake. The inventory data presented herein were collected by Environmental Horizons, Incorporated, during 2008.

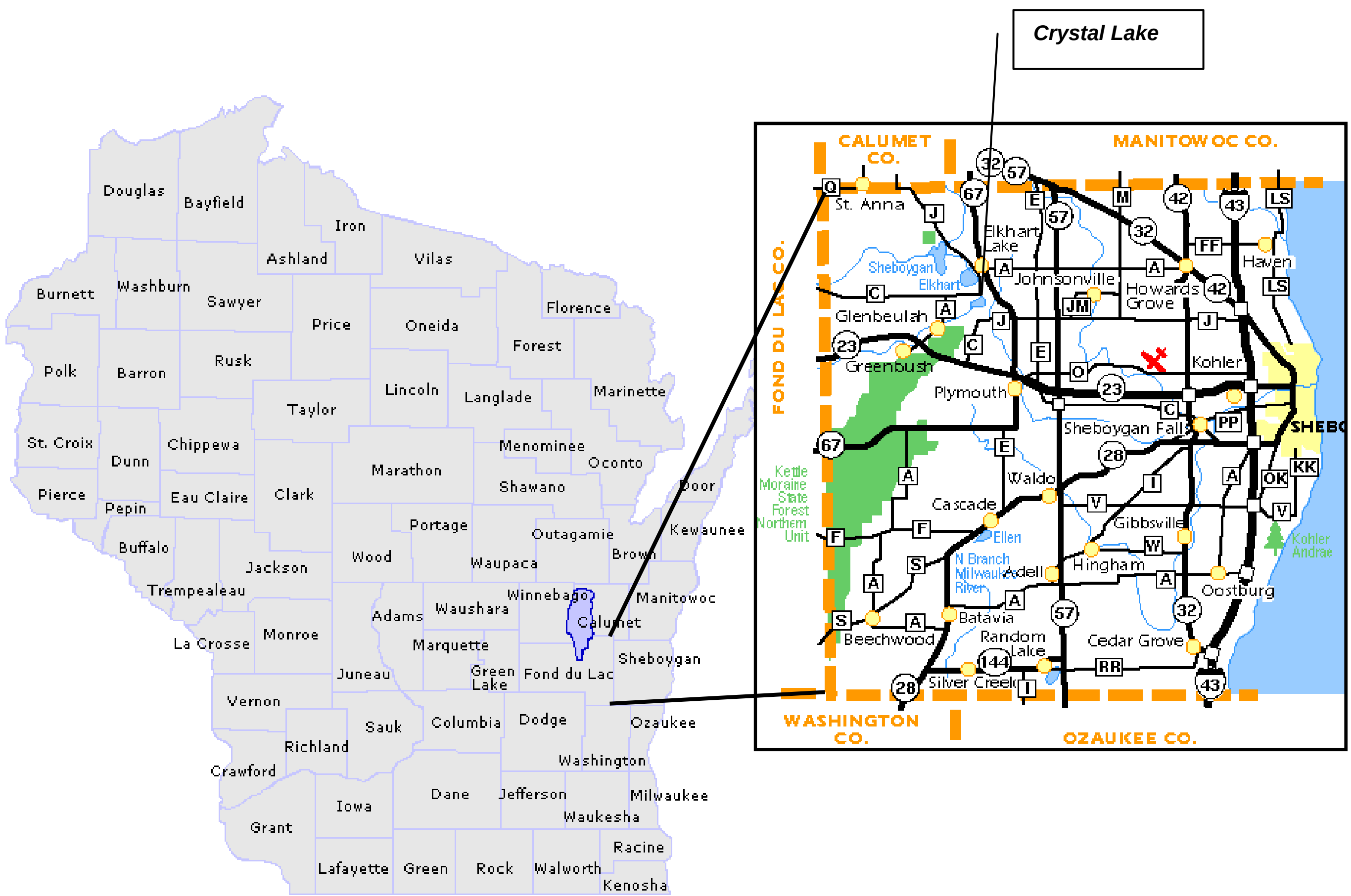
The aquatic plant survey of Crystal Lake was conducted during late-June 2008 by Environmental Horizons staff. The survey was completed using the modified Jesson and Lound transect-based aquatic plant survey method developed for use in the State of Minnesota and adapted for use elsewhere in the upper Midwest.[1] Field inventory data were gathered by Environmental Horizons staff during the aquatic plant survey.

The scope of this report is limited primarily to consideration of the factors affecting aquatic plant growth and community composition in Crystal Lake, including the effects of

[1] Jesson, R. and R. Lound, Minnesota Department of Conservation Game Investigational Report No. 6, *An Evaluation of a Survey Technique for Submerged Aquatic Plants*, 1962.

Map 1

LOCATION OF CRYSTAL LAKE



Source: Environmental Horizons, Inc, Wisconsin Department of Natural Resources and Wisconsin Online.

water quality and aquatic plant growths on recreational uses of the Lake. However, this plan will form an integral part of any future comprehensive lake management plan for Crystal Lake. The preparation of a comprehensive lake management plan for Crystal Lake would require additional water quality and biological data acquisition and analysis.

This plan is intended to address the recreational lake use goals and objectives of the Crystal Lake community. These goals can be summarized as:

- The protection and maintenance of the public health, and promotion of public comfort, convenience, necessity and welfare, through the environmentally sound management of the vegetation in Crystal Lake;

- The provision of high-quality, water-oriented recreational and aesthetic use opportunities for resident and visitors to Crystal Lake; and,

- The effective management of the water quality of Crystal Lake so as to maintain healthy aquatic and riparian plant communities and, thereby, facilitate the conduct of water-based recreation, improve the aesthetic value of the resource to the community, and enhance the resource value of the waterbody.

This inventory and plan conforms to the requirements and standards set forth in the relevant chapters of the *Wisconsin Administrative Code* applicable to aquatic plant management—notably Chapter NR 107 and Chapter NR 109—and serves as an initial step in achieving the objectives set forth in these rules over time.[2]

[2] This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the *Wisconsin Administrative Code*: Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 103, "Water Quality Standards for Wetlands;" Chapter NR 107, "Aquatic Plant Management;" and, Chapter NR 109, "Aquatic Plants Introduction, Manual removal and Mechanical Control Regulations."

Chapter II

INVENTORY FINDINGS

INTRODUCTION

Crystal Lake is a seepage lake and is comprised of comprised of two main basins oriented in an east-west direction. Crystal Lake is the central feature in a lake-oriented community, which includes both year-round residences and seasonal accommodations, and is actively utilized for recreational and aesthetic purposes by both the riparian community and visitors from the surrounding area.

WATERSHED CHARACTERISTICS

Crystal Lake is located within a fairly narrowly defined drainage area formed by the steeply sloping hillsides of the Northern Unit of the Kettle Moraine. These topographic features are illustrated on Map 2. There is no defined surface inflow to or outflow from the Lake which derives the majority of its water from groundwater inflows and direct precipitation onto the Lake surface.

The watershed is approximately 360 acres in areal extent, also shown on Map 2; an aerial photograph of the Lake and watershed is presented in Appendix D. The drainage basin is characterized by steeply sloping lands focused on the Lake, although the lands to the southwest of the lake basin occupied by the Crystal Lake Golf Course, in the vicinity of the public recreational boating access site are less steeply sloped. The lands forming the drainage area to Crystal Lake are occupied largely by the residential dwellings forming the lake-oriented residential community of Crystal Lake.

WATERBODY CHARACTERISTICS

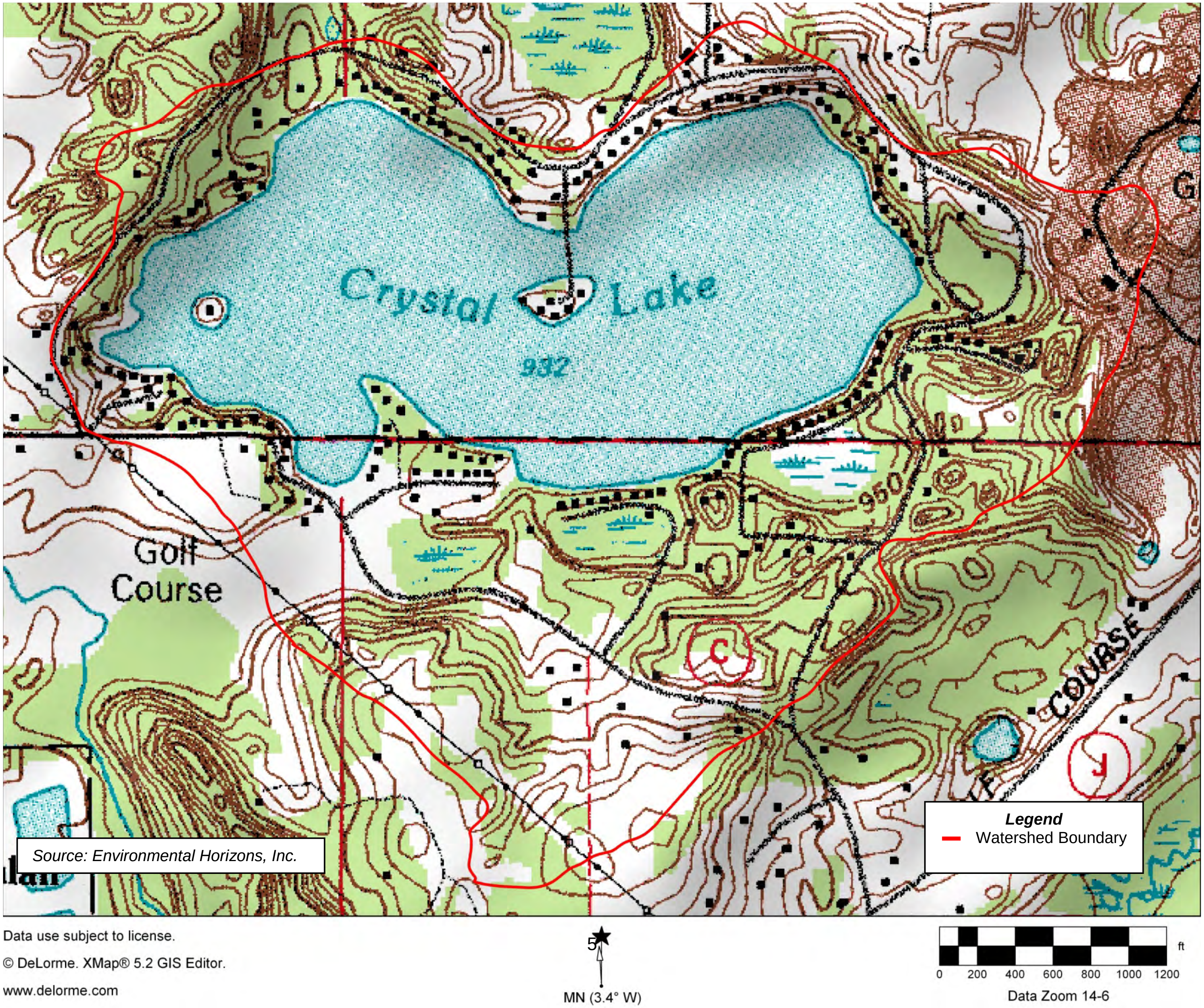
Crystal Lake is about 113.7 acres in surface area that formed in the glacially derived gravel and sand outwash. It is dependent upon groundwater and precipitation to maintain its water level. The Lake has a maximum depth of 61 feet, a mean depth of 20 feet, and approximately 2.4 miles of shoreline. The hydrographic characteristics of Crystal Lake are summarized in Table 1.

The Lake has two main basins, oriented in a generally east-west direction, with the eastern basin being the deeper of the two basins. The bathymetric features of the lake are illustrated on Map 3. There are two islands located within the Basin, one being located toward the westward extreme of the Lake and the other forming the point of division between the eastern and western lake basins. Both islands are occupied by residential dwellings, with the central island being connected to the northern shoreline by a short causeway to the northern shoreline of the Lake.

The substrate of the Lake is comprised primarily of cobble, although portions of the western basin of the Lake can be described as being of a more silty-gravelly nature, with abundant marl depositions and some organic sediments. The majority of the shoreline is protected by a variety of shoreline protection structures, including concrete and timber

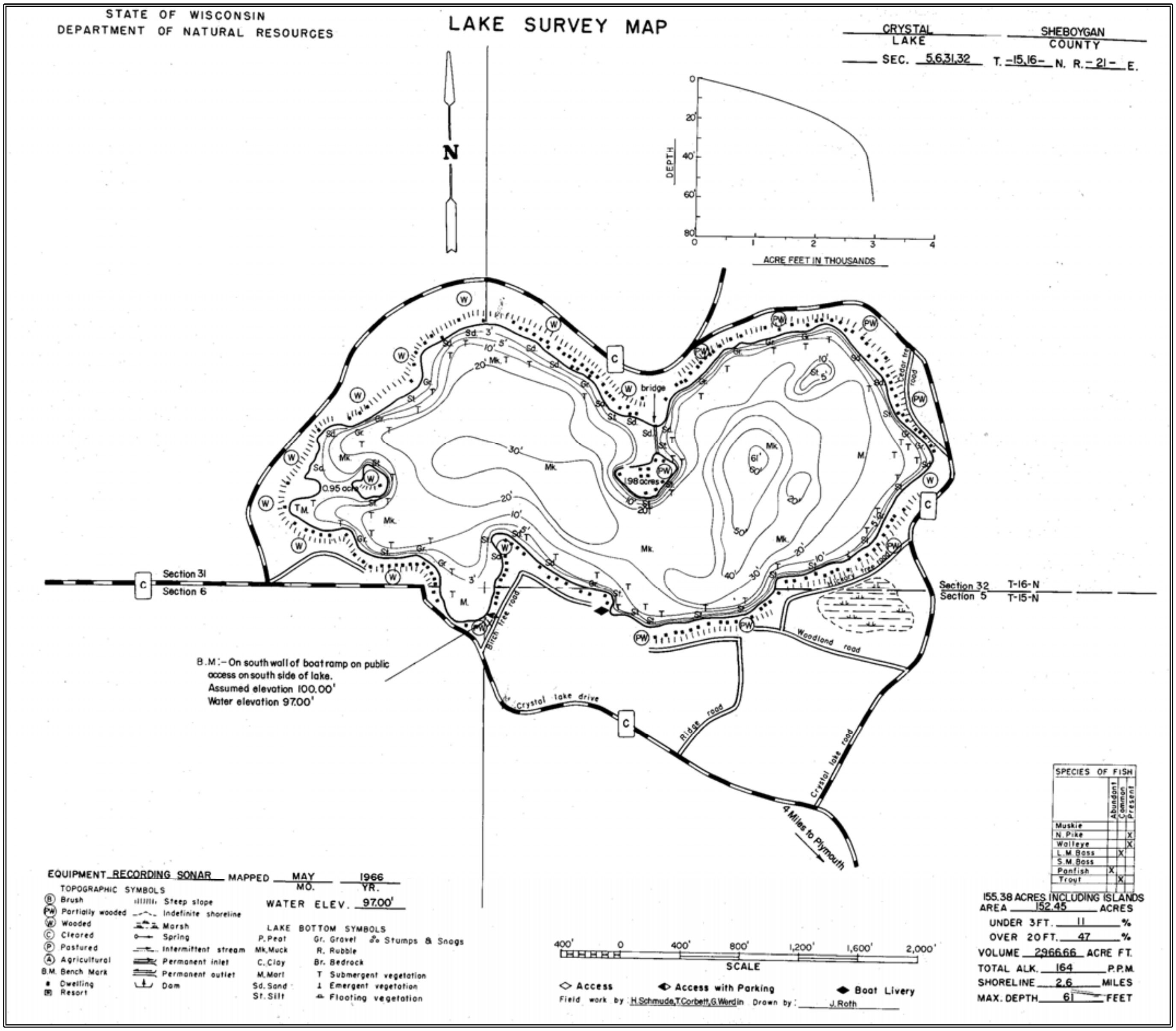
Map 2

CRYSTAL LAKE WATERSHED BOUNDARY



Map 3

CRYSTAL LAKE BATHYMETRIC DATA[a]



[a]*Surface area of the Lake is actually 113.7 acres and not the 152.4 acres shown on this map.*

Source: Wisconsin Department of Natural Resources.

bulkheads and rock rip-rap. Two small beaches have been created by adjacent residential landowners upslope of the ordinary high water mark (OHWM), and a few pockets of natural shoreline remain unprotected by shoreland protection structures. All of the protection structures observed by Environmental Horizons staff, shown on Map 4, appeared to be functional, and no areas of significant shoreline erosion were observed.

Table 1

HYDROGRAPHIC CHARACTERISTICS OF CRYSTAL LAKE

Parameter	Measurement
Surface Area…………………………	113.7 acres
Volume………………………………	2,274 acre-feet
Shoreline Length……………………..	2.4 miles
Maximum Depth………………………	61 feet
Mean Depth…………………………..	20 feet
Direct Drainage Area[a]…………………	362.4 acres

[a]*Direct drainage area is inclusive of Crystal Lake.*

Source: Environmental Horizons, Inc. and the Wisconsin Department of Natural Resources.

RECREATIONAL USES AND FACILITIES

Crystal Lake is a multi-purpose waterbody serving a variety of recreational uses. Recreational uses of Crystal Lake included boating, swimming and fishing during the summer months. Signage provided by Sheboygan County at the public recreational boating access site serving Crystal Lake notes that the Lake is a year round recreational resource of the County. The Lake is deemed to have adequate public recreational boating access by the Wisconsin Department of Natural Resources, pursuant to Chapter NR 1 of the *Wisconsin Administrative Code*.

Crystal Lake is used for both active and passive recreational uses. Passive uses include the use of the Lake as a visual amenity serving as the focus of the lake-oriented hamlet of Crystal Lake. Walking, sun-bathing, and picnicking/barbecuing were popular passive recreational activities, while boating, angling, swimming, water-skiing and high-speed boating were popular active recreational pastimes observed by Environmental Horizons staff.

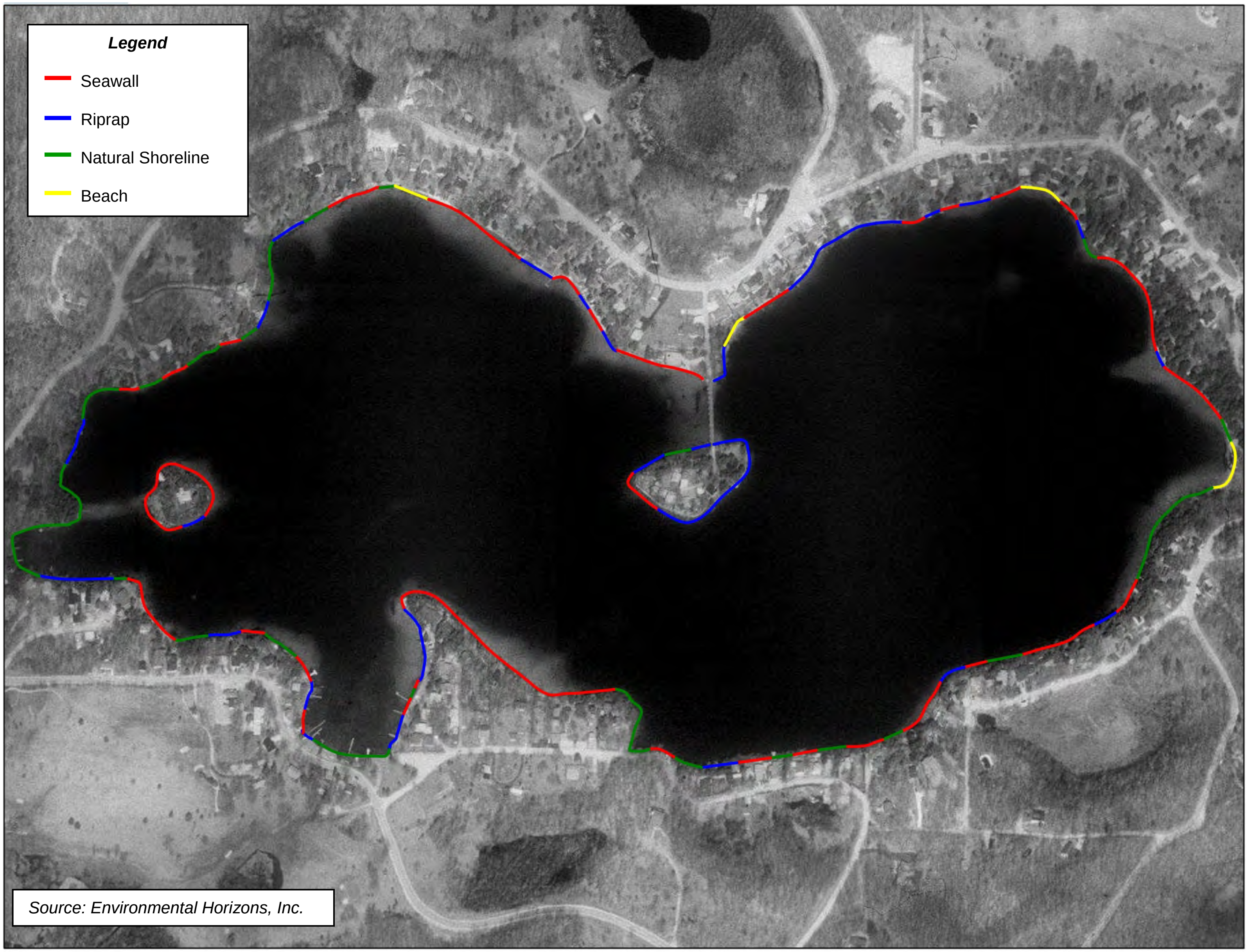
Observations of water-based recreational activities were undertaken by Environmental Horizons staff during late-June 2008. These activities are summarized in Table 2 for morning and afternoon observations periods over two weekdays. Recreational anglers, fishing from boats, were the most common recreational users in the morning hours, while boaters, including water-skiers and operators of personal watercraft (PWCs) were the most common types of recreational users during the afternoon observation periods.

Crystal Lake supports a high density of recreational watercraft. The types of watercraft observed by Environmental Horizons staff on Crystal Lake included high speed watercraft, pontoon boats, fishing boats, and PWCs. Non-powered watercraft included kayaks and canoes, rowboats, and sail boats. A large number of paddle boats were observed on the Lake. The numbers and types of watercraft observed are summarized in Table 3.

It should be noted that both zebra mussel (*Dreissena polymorphia*) and Eurasian water milfoil (*Myriophyllum spicatum*), Wisconsin designated exotic or nonnative invasive species, are present in Crystal Lake. These species can be easily transported from lake to lake by recreational boating traffic, in live wells or wet wells, and the Wisconsin Department of Natural Resources strongly recommends that lake users ensure that

Map 4

CRYSTAL LAKE SHORELINE SURVEY: JUNE 2008



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MN (3.4° W)

0 160 320 480 640 800 ft

Data Zoom 15-2

Table 2

RECREATIONAL USE SURVEY ON CRYSTAL LAKE: JUNE 2008

Date and Time	Participants						
	Fishing	Pleasure Boating[a]	Skiing	Personal Watercraft Use	Swimming	Other	Total
June 24, 2008							
11:00 a.m. to 11:15 a.m.	2	1	1	1	0	0	5
2:00 p.m. to 2:15 p. m.	0	1	0	1	3[b]	0	5
June 25, 2008							
10:00 a.m. to 10:15 a.m.	3	0	0	0	0	2[c]	2
12:50 p.m. to 1:05 p.m	2	2	1	3	5	1[d]	14
Total	7	4	2	5	8	3	29
Percent	24	14	7	17	28	10	100

[a] *Pleasure boating consists of pontoon boating and other types of boating that do not involve fishing, waterskiing, or tubing.*
[b] *Two swimmers and one sunbather were observed at 2:00 p.m.*
[c] *Two kayakers were observed at 10:00 a.m.*
[d] *One kayaker was observed at 12:50 p.m.*
Source: Environmental Horizons, Inc.

Table 3

WATERCRAFT ON CRYSTAL LAKE: JUNE 2008

WATERCRAFT TYPE	NO. OF WATERCRAFT	PERCENTAGE OF TOTAL WATERCRAFT
Pontoon Boats	24	5.31
Speed/Ski Boats	65	14.35
Fishing Boats	11	2.43
Canoes	86	18.98
Paddleboats	76	16.78
Sailboats	32	7.06
Personal Watercraft	18	3.97
Water Toys	26	5.74
Kayaks	44	9.71
Swim Rafts	44	9.71
Row Boats	27	5.96
Total	453	100

[a] *- - Watertoys consist of water trampolines, swim rafts and water tubes.*
Source: Environmental Horizons, Inc.

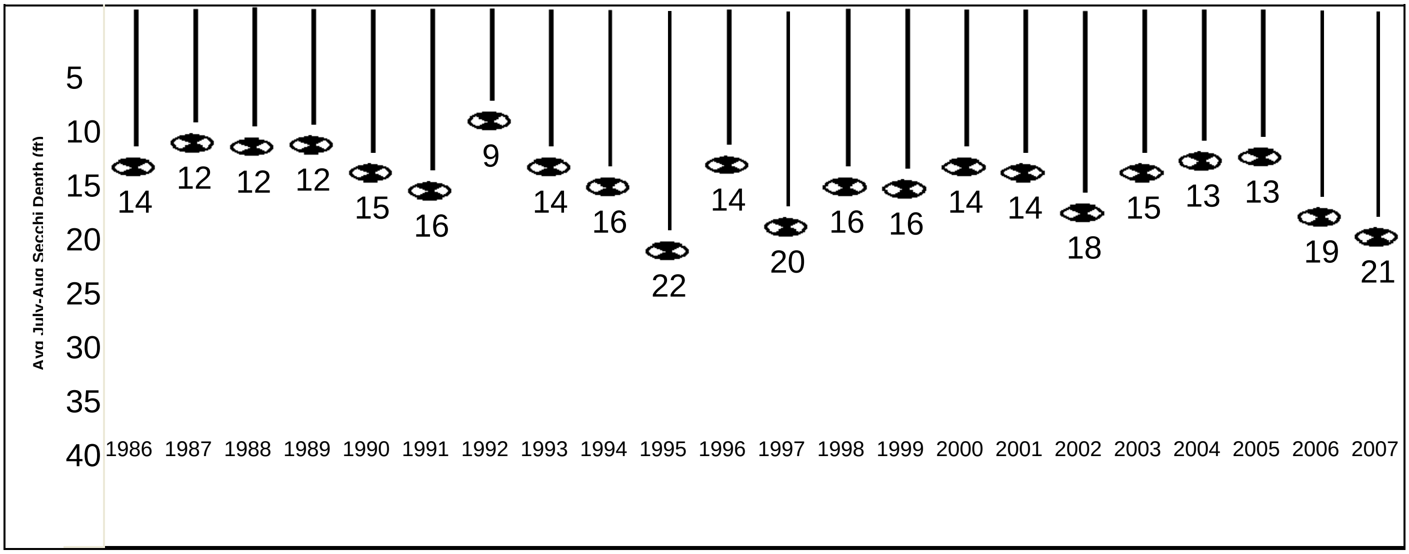
boats and equipment are (i) free of visible plants and debris upon removal from the Lake, and (ii) dried for up to three or four days in direct sunlight to avoid the introduction of these species into lakes not currently infested. It is an offense under Chapter NR 107 of the *Wisconsin Administrative Code* to transport designated nonnative species of aquatic plants between lakes.

WATER QUALITY

Water quality measurements of Crystal Lake have been reported by a citizen lake monitor over the period between 1986 and 2007, under the auspices of the WDNR Self-Help Monitoring Program, now the Citizen Lake Monitoring Network, as shown in Figure 1. Secchi disc transparency values during this 22-year period averaged about 15 feet (4.7 meters), within a range from 9.5 feet (2.9 meters) in 1992 to 22.5 feet (6.9 meters)

Figure 1

HISTORIC WATER CLARITY DATA FOR CRYSTAL LAKE: 1986 to 2007



Source: Wisconsin Department of Natural Resources.

in 1995. During the present study, Secchi disc transparency values, a measure of water clarity, ranged from 10 feet (3.0 meters) to 12 feet (3.75 meters), which were slightly below the long term average value. This result is likely to be a function of the record-setting winter and summer precipitation that occurred throughout southeastern Wisconsin during 2008, which led to high levels of runoff and greater than normal nutrient loadings to area lakes.

Based upon the observed 2008 Secchi disc transparency values, Crystal Lake has a Wisconsin Trophic State Index (WTSI) value of about 41 to 44.[1] Based upon the long term Secchi disc transparency, the average WTSI value for Crystal Lake would be expected to be approximately 37.5. These values are typical of a moderately-enriched mesotrophic lake capable of supporting abundant aquatic plant growths and productive fisheries. Mesotrophic lakes typically do not exhibit nuisance growths of algae and plants, although some algal growth does occur in the open water areas of the Lake. Many of the cleaner lakes in southeastern Wisconsin are classified as mesotrophic, primarily due to the shared glacial heritage of these waterbodies.[2]

In Crystal Lake, both Environmental Horizons staff and of the Wisconsin Department of Natural Resources staff noted significant growths of filamentous algae, the former during

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[1] Lillie, R.A., S. Graham and P. Rasmussen, Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes, *Research and Management Findings*, Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.

[2] Lillie, R.A. and J.W. Mason, *Limnological Characteristics of Wisconsin Lakes*, Wisconsin Department of Natural Resources Technical Bulletin No. 138, 1983.

the current year 2008 survey and the latter during a previous year 2006 aquatic plant reconnaissance.

Aquatic plant growth in lakes is sustained by the input of plant nutrients to a waterbody from the surrounding landscape. Under undisturbed conditions, this loading rate is typically low, leading to a low level of productivity in undisturbed waterbodies. As human activities increase in scope within a watershed, nutrient loads typically increase with the level of human disturbance. In a seepage lake, such as Crystal Lake, nutrients entering the system tend to remain within the system unless removed in the form of fish or plant biomass or encapsulated into the Lake sediments as a result of senescence, death and decomposition of aquatic organisms.

Different types of human activities result in varying degrees of disturbances within the watershed, and differing amounts of specific contaminants being mobilized and delivered to a lake. In most inland lakes, the plant nutrient phosphorus tends to be present in least supply and generally limits the ability of aquatic plant growth. These so-called limiting nutrients, if added in greater quantity to the waterbody, usually result in enhanced plant and more abundant aquatic plant growth, whether they be algae (free-floating, generally microscopic, plants) or macrophytes (larger, rooted plants).

An estimate of the mass of phosphorus delivered to Crystal Lake can be obtained using the Wisconsin Lake Model Spreadsheet (WiLMS).[3] Based upon the land uses observed within the drainage area tributary to Crystal Lake, the estimated phosphorus load to the Lake is approximately 25 pounds of phosphorus per year, as shown in Table 4. Table 4 also shows the relative percentage of the total load contributed by various types of land usage within the drainage area. These data indicate that about 9 percent of the phosphorus load to Crystal Lake was generated by urban density residential lands surrounding the Lake. The balance of the load was generated from other land uses within the drainage basin.

Table 4

ESTIMATED PHOSPHORUS LOADS TO CRYSTAL LAKE[a]

Land Use	Acres	Percent	Phosphorus - lbs	Percent
Residential	50.0	13.8	2.2	8.7
Recreational[b]	9.6	2.6	1.0	4.0
Woodlands and Wetlands	180.9	49.9	8.8	34.9
Water[c]	113.7	31.4	11.0	43.7
Commercial[d]	8.2	2.3	2.2	8.7
Total	362.4	100.0	25.2	100.0

[a]*The Wisconsin Lake Model Spreadsheet (WiLMS) was used to estimate the phosphorus loads.*

[b]*Recreational land use includes the acres of the golf course which lie in the drainage area to Crystal Lake.*

[c]*When the lake is the largest land use in the watershed, deposition of phosphorus from the atmosphere onto the water surface can exceed phosphorus loading from other land uses*

.[d]*Commercial land use includes the gravel pit to the east of Crystal Lake.*
Source: Environmental Horizons, Inc. and the Wisconsin Department of Natural Resources.

[3] Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-96 REV, *Wisconsin Lake Model Spreadsheet, Version 2.00, Users Manual*, June 1994.

In the case of Crystal Lake, the contribution of phosphorus from the surrounding landscape is minimal compared with the contribution of phosphorus from the atmosphere onto the lake surface. This phosphorus is introduced from the atmosphere as dry fall out—dust—and as phosphorus contained within rainfall. Such a circumstance is not unusual in the case of seepage or groundwater-fed lakes that have relatively small drainage areas, compared with the lake surface area. Also, in the case of Crystal Lake, the shorelands are relatively well vegetated, further limiting the input of phosphorus from the watershed, relative to the atmospheric sources. Phosphorus enters the atmosphere as particulates from automobile exhausts, dust from agricultural activities such as ploughing, and related human activities in the surrounding area.

To validate the estimated phosphorus load to the Lake, Environmental Horizons staff applied the estimated phosphorus load in the Vollenweider-type OECD phosphorus budget model to estimate an in-lake phosphorus concentration and water transparency.[4] This calculation resulted in an estimated in-lake total phosphorus concentration of about 5 milligrams per liter (mg/l) and an estimated Secchi disc transparency value of about 3.5 meters (11.5 feet). The latter value corresponds favorably with the observed Secchi disc transparency of approximately 3.0 meters (about 10 feet) measured during June 2008, but is somewhat lower than the long term transparency value of about 4.7 meters (15 feet). This agreement would suggest that the estimated nutrient loading to Crystal Lake is an overestimate of the actual nutrient load entering the Lake. It also suggests that other nutrient sources, such as groundwater inflows, are relatively small when compared with nutrient loads from external sources. It should be noted that the equations used in these calculations are presented in Appendix C.

The residential community surrounding Crystal Lake is served by a public sanitary sewerage system operated by the Sanitary District #1 of the Towns of Rhine and Plymouth. This system removes between approximately 10 pounds and 20 pounds of phosphorus per year that otherwise would have been discharged to the Lake through conventional onsite sewage disposal system. Of the remaining sources, the urban residential loads form the most significant inputs of phosphorus to the Lake, and represent potentially controllable sources that can be moderated through various control measures as elaborated in Chapter III.

FISHERIES

The Wisconsin Department of Natural Resources reports that Crystal Lake supports populations of northern pike and largemouth bass.[5] Walleye and panfish are reported to be present. The Lake is an actively used waterbody from the point of view of anglers, with a significant proportion of the Lake users observed by Environmental Horizons staff being comprised of anglers, especially during the morning hours, as noted above.

AQUATIC PLANTS

The Wisconsin Department of Natural Resources conducted an aquatic plant survey of Crystal Lake during 2006 using a grid-based survey technique, known as the point-

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[4] Ryding, S.-O. and W. Rast, *The Control of Eutrophication in Lakes and Reservoirs*, Unesco Man and the Biosphere Programme Series Vol. 1, 1989.

[5] Wisconsin Department of Natural Resources Publication No. PUB-FH-800 2005, *Wisconsin Lakes*, 2005.

intercept methodology. This method assumes that aquatic plants are randomly distributed across the entire lake, without regard to depth or substrate type. Because this methodology ignores the environmental requirements of the aquatic plants, which are highly dependent upon substrate for rooting and overlying water depth for access to sunlight necessary for plant growth, it does not permit as rigorous a statistical analysis of the data nor the formulation of as robust a suite of aquatic plant management measures. However, the methodology can allow the compilation of a representative list of species in a lake. This species list is shown in Table 5.

During 2008, Environmental Horizons conducted an aquatic plant survey of Crystal Lake using the transect methodology developed for Wisconsin lakes.[6] This methodology takes into account the rooting substrate preferences and rooting depths of the aquatic plants in the determination of aquatic plant communities. By focusing the survey into areas where aquatic plants may be expected to grow, this methodology permits a more rigorous assessment of the abundance, frequency of occurrence, and community composition of those plants which are most likely to interfere with or affect human recreational use of a waterbody. Consequently, the transect methodology is better suited to the development of an aquatic plant management plan. The species of aquatic plants observed by Environmental Horizons staff also are tabulated in Table 5. The distribution of aquatic plant communities during 2008 is shown on Map 5, and photographs of the plant species observed are shown in Appendix A.

Table 5

PLANT SPECIES PRESENT IN CRYSTAL LAKE: 2006 AND 2008

2006 - Aquatic Plant Species Present	2008 - Aquatic Plant Species Present
Ceratophyllum demersum – Coontail	*Ceratophyllum demersum* – Coontail
Chara sp. – Muskgrass	*Chara sp.* – Muskgrass
Elodea canadensis – Common waterweed	*Elodea canadensis* – Common Waterweed
Myriophyllum spicatum – Eurasian water milfoil	*Myriophyllum spicatum* – Eurasian water milfoil
Myriophyllum sibiricum –Northern water milfoil	- -
Najas flexilis – Slender naiad, Bushy pondweed	*Najas flexilis* – Slender naiad, Bushy pondweed
Nitella spp. – Stonewort	- -
Potamogeton amplifolius – Large leaf pondweed	*Potamogeton amplifolius* – Large leaf pondweed
Potamogeton friesii – Fries' pondweed	- -
Potamogeton illinoensis – Illinois pondweed	*Potamogeton illinoensis* – Illinois pondweed
Potamogeton pectinatus – Sago pondweed	*Potamogeton pectinatus* – Sago pondweed
Potamogeton pusillus – Small pondweed	*Potamogeton pusillus* – Small pondweed
Potamogeton zosterformis – Flatstem pondweed	*Potamogeton zosterformis* – Flatstem pondweed
Ranunculus longirostris – Stiff water crowfoot	- -
Zannichellia palustris – Horned pondweed	- -
Zosterella dubia – Water star grass	- -
Filamentous algae	Filamentous algae

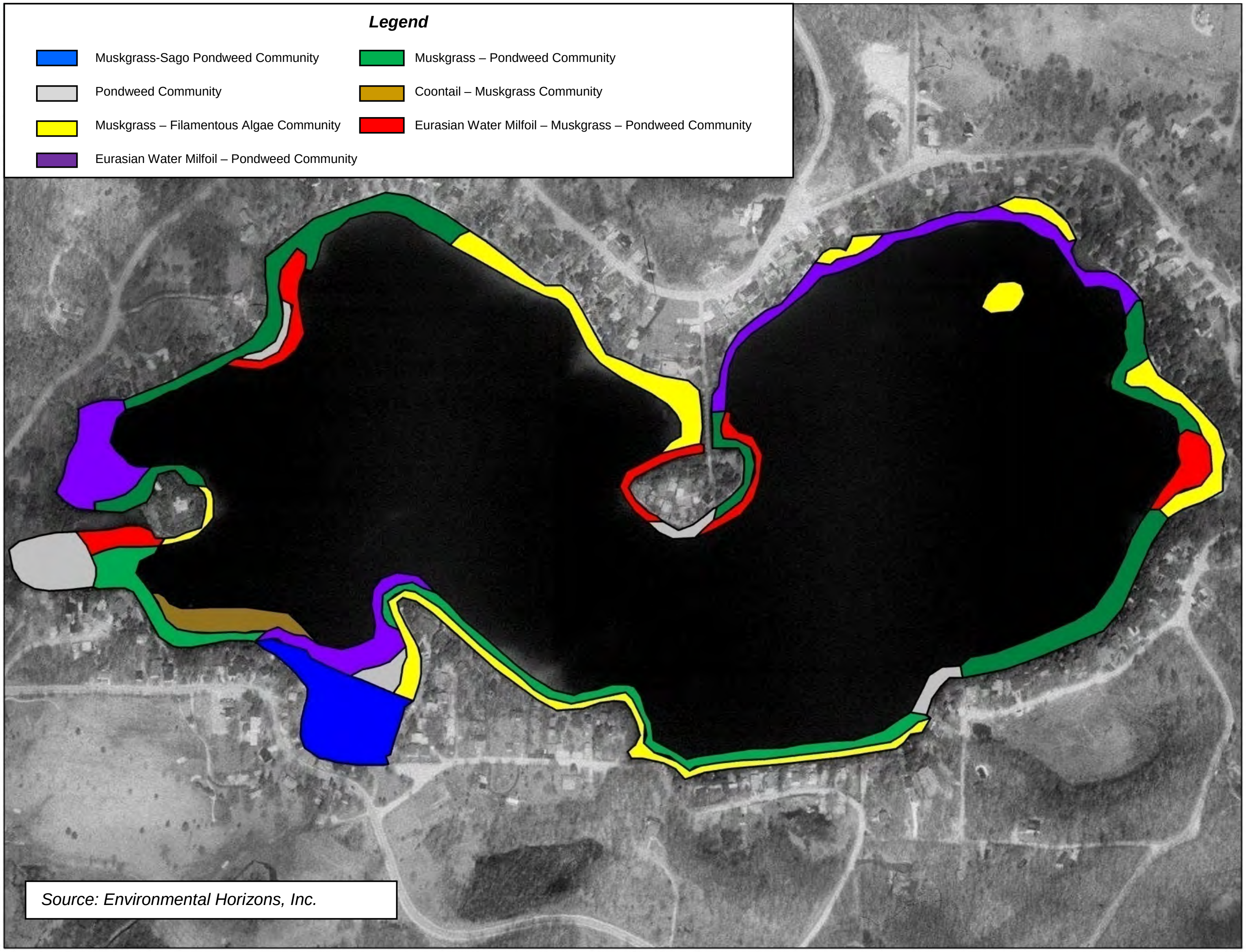
Source: Environmental Horizons, Inc. and the Wisconsin Department of Natural Resources.

The Jesson and Lound methodology, when utilized in successive aquatic plant surveys, will allow the statistical evaluation of changes in the aquatic plant community within a

[6] Memorandum from Prof. Stan Nichols to J. Bode, J. Leverence, S. Borman, S. Engel, and D. Helsel, entitled "Analysis of macrophyte data for ambient lakes—Dutch Hollow and Redstone Lakes example," Wisconsin Geological and Natural History Survey and University of Wisconsin-Extension, February 4, 1994.

Map 5

CRYSTAL LAKE PLANT COMMUNITIES



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0 160 320 480 640 800 ft

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lake. The methodology, described in Appendix B, supports the calculation of specific indicies, the values of which are given in Table 6. These indices include:

1. The frequency of occurrence (FREQ) is the number of occurrences of a species divided by the number of samples with vegetation, expressed as a percentage. It is the percentage of times a particular species occurred when there was aquatic vegetation present, and is analogous to the Jesson and Lound point system.

2. The relative frequency of occurrence (RFREQ) is the frequency of a species divided by the total frequency of all species. The sum of the relative frequencies should equal 100 percent. The statistic presents an indication of how the plants occur throughout the lake in relation to each other. It is used to calculate the Importance Value and Simpson Diversity Index, described below.

3. The relative or average density (RDEN) is the sum of the density ratings for a species divided by the number of sampling points with vegetation. The maximum density rating of 4.0 is assigned to plants that occur at all points sampled at a given depth as the modified Jesson and Lound methodology uses four sampling points per depth sampled. The average density presents an indication of how abundant the growth of a particular plant is throughout the lake. This measure, along with the percent occurrence, gives a good indication of the distribution of aquatic plant communities in the lake.

4. The Importance Value (IV) is defined as the product of the relative frequency of occurrence and the average density, expressed as a percentage:

   $$IV = (RFREQ)\ (RDEN)\ (100)$$

   Where IV is the importance value, RFREQ is the relative frequency, and RDEN is the relative density. This number provides an indication of the dominance of a species within a community based upon both the frequency and density of a specific aquatic plant. It also somewhat addresses the problem of difference in stature between different plant species.

The differences between the two surveys could reflect differences due to time of year, specific differences caused by inter-annual variations in lake quality and condition, and/or the presence of species that are sufficiently rare as to present little management concern. This latter also may reflect the methodological differences between the two surveys. Despite these potential variables, however, the two aquatic plant community assessments differ only in degree and not in overall quality.

The two surveys reveal an aquatic plant community that is largely comprised of native species of aquatic plants, although the nonnative Eurasian water milfoil was found to be present in the littoral areas of the Lake, especially along the northern shorelines of the eastern basin of the Lake. Based upon the morphological characterization of the specimens obtained from Crystal Lake, it could be suggested that the nonnative varietal has hybridized with the native Northern milfoil, previously reported from the Lake by the WDNR. This hybridization is becoming more common in Wisconsin lakes. Eurasian water milfoil is a designated nonnative invasive aquatic plant species under Chapter NR 109 of the *Wisconsin Administrative Code*. Photograph 1 shows a characteristic presentation of Eurasian water milfoil in the Lake.

Table 6

AQUATIC PLANT SPECIES PRESENT IN CRYSTAL LAKE AND THEIR ECOLOGICAL SIGNIFICANCE: JUNE 2008

Aquatic Plant Species Present	Sites Found	Absolute Frequency of Occurrence (percent)[a]	Relative Frequency of Occurrence (percent)[b]	Relative Density at Sites Found[c]	Importance Value[d]	Ecological Significance[e]
Ceratophyllum demersum – Coontail	10	11.2	4.1	1.30	5	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara sp. – Muskgrass	63	70.7	26.4	2.65	70	Provides a preferred food source to waterfowl; provides food and shelter for a a variety of fish species
Elodea canadensis – Common waterweed	5	5.6	2.1	1.40	3	Provides shelter and support for insects which are valuable as fish food
Myriophyllum spicatum. – Eurasian water milfoil	21	23.6	8.8	2.09	18	Eurasian and hybrid milfoils are considered a nuisance species, but Northern milfoil provides valuable food and shelter for fish; fruits eaten by many waterfowl
Najas flexilis – Slender naiad, Bushy pondweed	21	23.6	8.8	1.86	16	Considered one of the most important plants for waterfowl; provides food and shelter for fish
Potamogeton amplifolius – Large leaf pondweed	6	6.7	2.5	2.00	5	Provides shade, shelter and forage for fish; valuable food source for waterfowl
Potamogeton illinoensis – Illinois pondweed	45	65.2	18.9	2.42	46	Provides an important food source for waterfowl as well as muskrat, beaver, deer, and moose; provides excellent shelter for fish; provides habitat for invertebrates
Potamogeton pectinatus – Sago pondweed	29	32.6	12.1	2.24	27	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish

Aquatic Plant Species Present	Sites Found	Absolute Frequency of Occurrence (percent)[a]	Relative Frequency of Occurrence (percent)[b]	Relative Density at Sites Found[c]	Importance Value[d]	Ecological Significance[e]
Potamogeton pusillus – Small pondweed	3	3.4	1.2	1.00	1	Provides food for waterfowl; provides food for muskrat, beaver, deer, and moose; also provides cover and a food source for fish
Potamogeton zosterformis – Flatstem pondweed	15	16.9	6.3	1.53	10	Provides some food for ducks
Sagittaria sp. – Arum-eaved arrowhead, Common arrowhead	- - *f*	- -	- -	- -	- -	A high value food source for waterfowl; also a food source for muskrats, beavers, and porcupines; provides shade and shelter for young fish
Typha latifolia – Broad-leaved cattail	- - *f*	- -	- -	- -	- -	Nesting habitat for marsh birds, shoots and rhizomes are food sources for waterfowl and water mammals, and submerged stalks provide shelter and spawning habitat for fish
Filamentous algae	21	23.6	8.8	1.95	17	- -

NOTE: There were 89 sites sampled during the June 2008 survey.

[a]*Sums to 100 percent.*

[b]*Maximum equals 100 percent*

[c]*Maximum equals 4.0.*

[d]*The product of the absolute frequency of occurrence and the relative density at sites found.*

[e]*Information obtained from* A Manual of Aquatic Plants by *Norman C. Fassett,* An Aquatic Plant Identification Manual for Washington's Freshwater Plants by *Washington State Department of Ecology, and* Through the Looking Glass…A Field Guide to Aquatic Plants *by Wisconsin Lakes Partnership.*

[f]*Emergent and floating-leaved aquatic plants are not included in the analysis of density and frequency of occurrence of submerged macrophytes.*

Source: Environmental Horizons, Inc.

Eurasian water milfoil—including the hybridized varietals—reproduces by the rooting of plant fragments. Consequently, some recreational uses of lakes can result in the expansion of Eurasian water milfoil communities, especially when boat propellers artificially fragment the Eurasian water milfoil plants.[7] These fragments, as well as

[7] Wisconsin Department of Natural Resources, *Eurasian Water Milfoil in Wisconsin: A Report to the Legislature*, 1993.

Photo 1

EURASIN WATER MILFOIL IN CRYSTAL LAKE

Source: Environmental Horizons, Inc.

fragments that occur naturally for reasons such as wind-induced turbulence or fragmentation by fishes, are able to generate new root systems, allowing the plant to colonize new sites. The fragments can also cling to boats, trailers, motors, and/or bait buckets, and can stay alive for weeks, contributing to the transfer of the plant to other lakes. For this reason, it is very important to remove all vegetation from boats, trailers, and other equipment after removing them from the water and prior to launching in other waterbodies. Such precautions also are effective measures to limit the spread of other nonnative organisms, such as the zebra mussel.

In addition to water milfoil, nine species of native submergent aquatic plants were observed during the 2008 survey. These included five species of pondweed, including large-leaf pondweed (*Potamogenton amplifolius*), Illinois pondweed (*Potamogeton illinoensis*), Sago pondweed (*Potamogeton pectinatus*), small pondweed (*Potamogeton pusillus*), and flatstem pondweed (*Potamogeton zosterformis*). Other submergent aquatic plant species included coontail (*Ceratophyllum demersum*), muskgrass (*Chara* spp.), elodea (*Elodea canadensis*), and bushy pondweed (*Najas flexilis*), all of which provide excellent aquatic habitat for aquatic organisms such as fishes and amphibians, as summarized in Table 6.

Of these submergent aquatic plants, muskgrass and Illinois pondweed were the dominant species present in the Lake at the time of the 2008 survey. Sago pondweed also appeared to be of importance to the aquatic plant community, followed by bushy pondweed and Eurasian water milfoil, which were found to be of similar but lesser importance. Notwithstanding, each of these five species was present at approximately similar densities at the sites where they were found, as shown in Table 6. All five aquatic plants had relative density ratings of between 1.86 and 2.65 on a scale of one through four, where four is the highest relative density possible, suggesting that, on average, aquatic plant growth in Crystal Lake during the 2008 aquatic plant survey was relatively sparse. This finding is consistent with the steeply sloping littoral zone of the Lake that limits available aquatic plant habitat in the Lake.

Several emergent aquatic plants were observed, including the arum-leaved and common arrowhead (*Sagittaria* spp.), common rush (*Juncus* spp.), and cattail (*Typha latifolia*), which were relatively abundant in the vicinity of the public recreational boating access site. Curiously, lily pads were not observed in the Lake, a fact that may reflect the gravel and cobble nature of the substrate in much of the Lake. These emergent plant are not included in the statistical analysis, but are noted as forming beneficial habitat in the shoreland zone.

Chapter III

ALTERNATIVE AND RECOMMENDED AQUATIC PLANT MANAGEMENT MEASURES

INTRODUCTION

The abundance of aquatic plants, including muskgrass, coontail, and Eurasian water milfoil, continues to be perceived as a nuisance by the Crystal Lake community. Ongoing aquatic plant management measures, in part, have maintained the abundance and distribution of these plants in such a condition as to minimize user-related concerns. Notwithstanding, localized recreational use problems have been experienced in various parts of the Lake. While these problems depend on the uses to which those portions of the Lake are utilized by recreational users, the concerns generally involve the moderate growths of Eurasian water milfoil. These plants often grow to the surface of the Lake, making certain recreational uses in those areas of the Lake less enjoyable in addition to impairing the aesthetic quality of the Lake. Eurasian water milfoil, in particular, interferes with recreational boating activities by entangling propellers, clogging cooling water intakes, and generally impeding navigation.

Shallow areas of Crystal Lake are especially limited by abundant growths of aquatic plant. However, the steeply sloping nature of much of the shoreland and littoral area of the Lake limits the extent of such interferences to a relatively narrow band around the perimeter of the waterbody. Notwithstanding, without control measures, some areas of the Lake could become impassable to navigation and be subjected to limitation of other recreational activities such as angling and swimming. While native aquatic plant communities provide a range of breeding, feeding, and other habitat values for fish and aquatic life, such benefits can be limited if the aquatic plant community becomes dominated by nonnative species such as Eurasian water milfoil.

Following a brief summary of the ongoing lake management program, alternative and recommended aquatic plant management measures are described. The alternatives and recommendations set forth herein focus on those measures which are applicable to Crystal Lake. The scope and nature of these measures conforms to the requirements of applicable Chapters of the *Wisconsin Administrative Code*, specifically Chapters NR 107 and NR 109 governing herbicide-based and other aquatic plant management measures, respectively.

PAST AND PRESENT LAKE MANAGEMENT ACTIONS

The residents of the Crystal Lake community have long recognized the value and importance of informed and timely action in the management of Crystal Lake. Consequently, the community, primarily through the Sanitary District #1 of the Towns of Rhine and Plymouth, has participated in the volunteer Citizen Lake Monitoring Network—previously the Self-Help Monitoring Program—currently coordinated by the University of Wisconsin-Extension (UWEX). The District also has coordinated a series of groundwater investigations, being executed by RSV Engineering, Inc., and Hey and

Associates, Inc. These latter studies have provided insights into the water budget of the Lake.

With respect to aquatic plant management in particular, the Sanitary District has coordinated a program of aquatic plant management based upon the control of nonnative species using aquatic herbicides. While this program has effectively addressed user concerns, periodic refinement of the control program is required to ensure that the ongoing aquatic plant management program continues to meet community aspiration and current State permitting requirements. This plan is designed to update and refine the current aquatic plant management program being implemented at Crystal Lake.

AQUATIC PLANT MANAGEMENT MEASURES

Aquatic plant management refers to a group of management and restoration measures aimed at both the removal of nuisance vegetation and the manipulation of species composition in order to enhance and facilitate recreational water use and encourage the development of a natural plant community that will provide the basis of a healthy lake ecosystem.[1] Generally, aquatic plant management measures are categorized into four groups; namely, 1) physical measures, which include water level management; 2) mechanical measures, which include harvesting and removal; 3) chemical measures, which include the use of aquatic herbicides; and, 4) biological measures, which include the use of various organisms, including insects. All of these measures are regulated by the State of Wisconsin and require permits issued by the Wisconsin Department of Natural Resources (WDNR) pursuant to Chapters NR 107 and NR 109 of the Wisconsin Administrative Code.

The costs of aquatic plant management measures range from minimal for the manual removal of aquatic plants using rakes and hand-pulling to upwards of $120,000 for the purchase of a mechanical aquatic plant harvester, with operational costs of about $40,000 per year, depending on staffing and operating policies. Harvesting is frequently the measure most applicable to large areas, whereas chemical controls are often best suited to confined areas and initial control of invasive plants. Planting of native plant species and control of Eurasian water milfoil by the weevil, *Eurhychiopsis lecontei*, are largely experimental in Wisconsin lakes, but potentially could be considered in specialized shoreland areas.

Aquatic Herbicides

Chemical treatment with aquatic herbicides is a short-term means of controlling heavy growths of aquatic macrophytes and algae. The use of herbicides can contribute to the ongoing aquatic plant problem by releasing plant nutrients back into the environment and increasing the natural rates of accumulation of decaying organic matter in the lake sediments, in turn contributing to an increased oxygen demand which may cause anoxia. The use of aquatic herbicides also can potentially damage or destroy nontarget plant species that provide needed habitat for fish and other aquatic life. As a result, use of aquatic herbicides is poorly suited for use on a large-scale; however, chemical control is often a viable technique for the control of relatively small-scale infestations of Eurasian water milfoil and certain other plants such as curly-leaf pondweed and purple

[1] U.S. Environmental Protection Agency Report No. EPA-440/4-90-006, *The Lake and Reservoir Restoration Guidance Manual*, August 1990.

loosestrife.[2] Chemicals are applied to the growing plants in either a liquid or granular form. Chemical treatments can be administered at relatively low cost, and, therefore, are considered to be a viable lake management option. This measure is considered to be viable for Crystal Lake.

Chemical applications should be conducted in accordance with the current Wisconsin Administrative Code requirements, under the authority of a WDNR permit, and by a licensed applicator working under the supervision of the WDNR staff. Records accurately delineating the treated areas, and documenting the type and amount of herbicide used in each area, should be maintained and used as a reference when applying for permits in subsequent years. A recommended checklist is provided as Figure 2.

Figure 2

DISTRICT CHECKLIST FOR HERBICIDE APPLICATION

- ☐ Nuisance report completed defining areas of potential treatment
- ☐ Permit filed with the Wisconsin Department of Natural Resources
- ☐ Certified applicator hired[a]
- ☐ Required public notice in the newspaper
- ☐ Public informational meeting (required if five or more parties request a meeting)
- ☐ Posting of areas to be treated in accordance with regulations (discussed previously in report)
- ☐ Weather conditions cooperating
    - Wind direction and velocity
    - Temperature

[a]*A licensed applicator will determine the amount of herbicide to be used, based upon discussions with appropriate staff from the Wisconsin Department of Natural Resources, and will keep records of the amount applied.*

Source: Environmental Horizons, Inc.

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[2] A few "whole-lake" aquatic herbicide applications have been undertaken in Wisconsin, principally utilizing the herbicide fluoridone for Eurasian water milfoil control. These applications remain experimental.

Aquatic Plant Harvesting

Aquatic plant harvesting may be undertaken using manual techniques or mechanical equipment. Manual harvesting is best suited for shallow areas around piers and docks, and often involves the removal of aquatic plants using rakes or other devices effective in these limited water depths. Specially-designed rakes are available to manually remove aquatic plants from the shoreline area. The District may consider purchasing a number of these rakes which could be made available to riparian owners for use on a trial basis before purchasing them individually. The advantage of the rakes is that they are easy and quick to use, immediately removing the cut plants from the shoreline area.

Mechanical harvesting is generally undertaken with specialized equipment, consisting of a cutter apparatus which cuts up to about five feet below the water surface and a conveyor system that picks up the cut plants for transport to the shore. Mechanical harvesting typically leaves enough plant material in the lake to provide shelter for fish and other aquatic organisms and to stabilize the lake sediments. Mechanical harvesting may have some negative consequences on fish and aquatic organisms which may be caught up in the harvesting process, may cause fragmentation and spread of some plants, and could disturb loosely consolidated lake bottom sediments. However, if carried out in a responsible manner, harvesting has been shown to reduce the regrowth of nuisance aquatic plants, such as Eurasian water milfoil, by altering the competitive advantage of the plant as shown in Figure 3.

Harvesting removes the plants from the lake, avoiding the accumulation of organic matter on the lake bottom and limiting the release of nutrients back into the water where they would be available to spur further aquatic plant growth. Cut plants must be removed from the lake, and can be used for compost and mulch if desired. Aquatic plants generally have a high water content, and so add moisture to the soils when used as compost; their low level of organic matter generally means that they plant material upon decomposition has little volume and decomposes rapidly.

Manual control is considered to be a viable alternative for the control of aquatic plants in Crystal Lake. Given the limited extent of the aquatic plant community in Crystal Lake, use of mechanical harvesting is not indicated at this time.

Biological Controls

Another approach to controlling nuisance aquatic plant growths, particularly in the case of Eurasian water milfoil, is biological control. Classical biological control has been successfully used to control a variety of aquatic plants.[3] Recent studies have shown that the aquatic weevil, *Eurhychiopsis lecontei*, has potential as a biological control agent effective against Eurasian water milfoil.[4] This weevil is frequently found to be naturally occurring within Eurasian water milfoil beds. While the artificial inoculation of lakes with Eurasian water milfoil weevils remains largely experimental in Wisconsin, anecdotal evidence from many southeastern Wisconsin lakes would suggest that the weevils are

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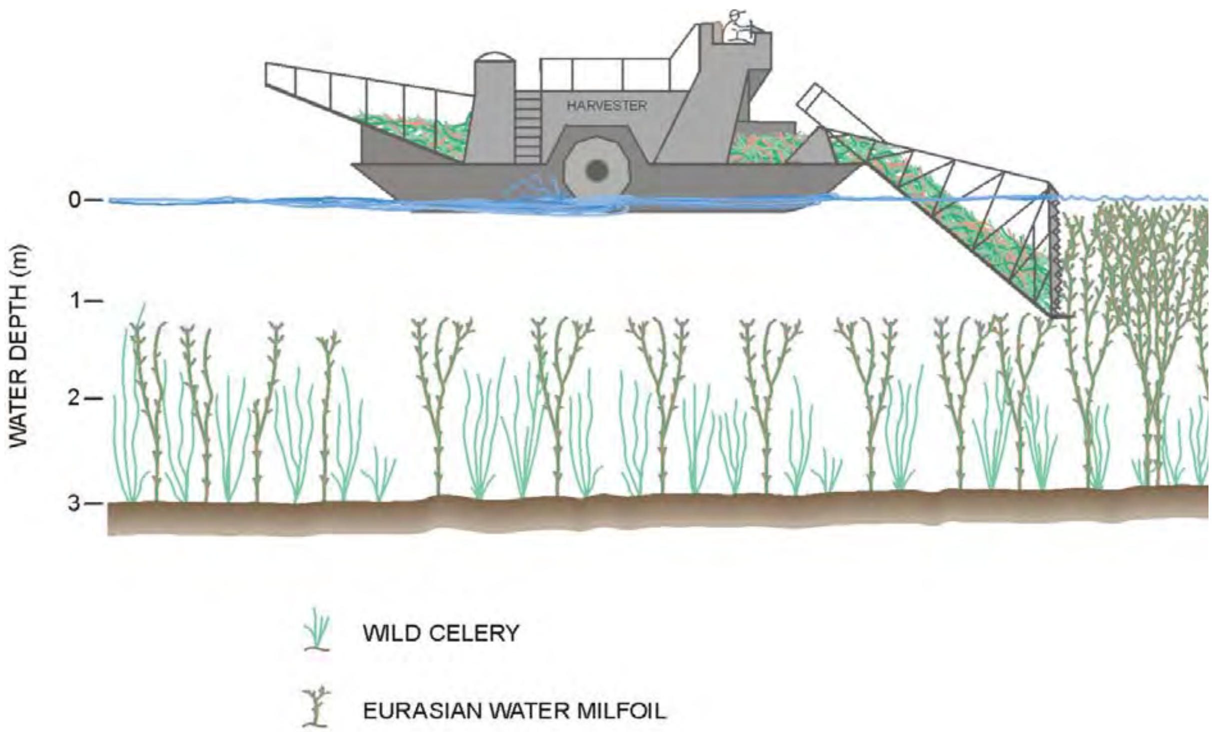
[3] C.B. Huffacker, D.L. Dahlsen, D.H. Janzen, and G.G. Kennedy, "Insect Influences in the Regulation of Plant Populations and Communities." In: C.B. Huffacker and R.L. Rabb, editors, *Ecological Entomology*, John Wiley, New York. 1984.

[4] S.P. Sheldon, "The Potential for Biological Control of Eurasian Water Milfoil (*Myriophyllum spicatum*) 1995-1995 Final Report," Department of Biology, Middlebury College, February 1995.

Figure 3

PLANT CANOPY REMOVAL WITH AN AQUATIC PLANT HARVESTER



NOTE: Selective cutting or seasonal harvesting can be done by aquatic plant harvesters. Removing the canopy of Eurasian water milfoil may allow native species to reemerge.

Source: Wisconsin Department of Natural Resources and Environmental Horizons, Inc.

widespread and naturally present within the lakes where their presence may be responsible for the periodic"crashes" in Eurasian water milfoil populations. Such rapid declines in populations of aquatic plants follow a classical predator-prey relationship, that requires the predator to reach sufficient levels of population that they cause a catastrophic decline in the prey population. At this time, the predator population declines until such future time as the prey populations recover and initiate another growth cycle. Experimental inoculations of the weevils in Wisconsin lakes have yielded variable results, with limited control being evidenced in those lakes that experienced heavy recreational boating traffic.[5] Under such conditions, the insects were easily disturbed and washed off the plants by boat-generated wakes. Given these variable results, the artificial inoculation of Eurasian water milfoil weevils into Crystal lake is not indicated at this time.

The use of grass carp, *Ctenopharyngodon idella*, is not permitted in Wisconsin.

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[5] L.L. Jester, M.A. Bozek, and D.R. Helsel, "Wisconsin Milfoil Weevil Project: Lower Spring Lake—Final Report," Wisconsin Cooperative Fisheries Unit, University of Wisconsin-Stevens Point, March 1999.

A variation on biological controls is the planting of aquatic vegetation and the stocking of fishes to manipulate the natural populations within the Lake, thereby enhancing natural populations in order to achieve a specific purpose, such as an improved recreational fishery or more stable land-water interface. Shoreland plantings, in particular, have proven beneficial for stabilizing shorelines, holding shoreline sediments in place, and providing treatment for overland runoff that would otherwise convey sediment and nutrients into the nearshore waters of a lake. These plantings also provide habitat for amphibians utilizing the land and water interface, and, when comprised of native plants that include taller-growing species, provide natural barriers limiting the intrusion of resident goose populations onto the shorelands while adding to the shoreland aesthetics of the properties. This is in contrast to lawned areas that provide ideal resting and grazing habitat for nonmigratory waterfowl. Installation of shoreline buffer strips is considered to be viable for Crystal Lake.[6]

Physical Measures

Lake bottom covers and light screens provide limited control of rooted aquatic plants by creating a physical barrier which reduces or eliminates the sunlight available to the plants. Such barriers have been used to create swimming beaches on muddy shores, to improve the appearance of lakefront property, and to open channels for motorboating. Sand and gravel are usually readily available and relatively inexpensive to use as cover materials, but aquatic plants can usually recolonize these areas in about a year. Synthetic materials, such as polypropylene, fiberglass, and nylon, can provide relief from rooted aquatic plants for several years; however, these structures must be placed and removed annually. Given the steeply sloping shorelands of Crystal Lake, use of such structures is not indicated at this time.

In addition to the placement of materials on the lakebed, manipulation of the water surface forms an alternative physical management measure. Periodic drawdowns, for example, can allow shoreline restoration work to proceed, and potentially allow flocculent lake sediments to consolidate. Overwinter drawdowns also have been known to freeze out certain aquatic plant species, including Eurasian water milfoil, but also potentially including desirable species such as elodea and coontail. Because Crystal Lake is a seepage lake, there is no ability to readily effect such a drawdown. Hence, this alternative is not a feasible option for Crystal Lake.

Other Management Measures

Boating Ordinances

In addition to the traditional aquatic plant management measures summarized above, other measures such as watercraft regulation to minimize recreational boating traffic through aquatic plant beds or sensitive areas of a lake can be employed. Such measures include establishing traffic patterns for recreational watercraft that avoid sensitive shorelands or specific areas where there are known beds of Eurasian water milfoil, for example. Any ordinances enacted pursuant to Section 30.77(4) of the *Wisconsin Statutes* must conform to State boating regulations, be subject to advisory review by the WDNR, and be clearly posted at public landings; regulatory markers considered for use in such a regulatory program must be consistent with the

[6] It should be noted that much of the shoreland of Crystal Lake is maintained in a natural condition; use of natural vegetation within the shoreland zone maintains this aesthetic tradition.

requirements set forth in Section NR 5.09 of the *Wisconsin Administrative Code*. Notwithstanding, given the current level of regulation of public recreational boating traffic on Crystal Lake, further regulation of boat traffic is not indicated at this time.

Public Informational Programming

Aquatic plant management usually centers on the eradication of nuisance aquatic plants for the improvement of the recreational use of a lake. The majority of the public often views all aquatic plants as “weeds” and residents often spend considerable time and financial resources on removing desirable aquatic plants without considering the environmental impact of these actions. For this reason, informational programming is an important component of the aquatic plant management plan for Crystal Lake. Inclusion of public informational programming at meetings of the Crystal Lake organizations, both governmental and nongovernmental, is considered to be a viable option for Crystal Lake. Posters and pamphlets on a variety of lake-oriented topics are readily available from the UWEX and WDNR. Many of these provide information and illustrations of aquatic plants, their importance as habitat and a food base, and of nonnative and invasive species recognition and control. Use of these materials during public meetings of the Crystal Lake organizations is considered to be a viable option.

RECOMMENDED AQUATIC PLANT MANAGEMENT MEASURES

The goal of the management program is to accommodate a range of recreational uses of Crystal Lake, to the extent practicable, and to enhance the public perception of the Lake, without damaging the underlying natural resource base of the Lake or impairing its natural structure and functioning. To accomplish this goal, specific control measures are recommended to be applied to various areas of the Lake. The recommended Crystal Lake aquatic plant management measures are summarized in Table 7 and the recommended measures are graphically summarized on Map 6. It is recommended that the Sanitary District #1 of the Towns of Rhine and Plymouth, a Wisconsin lake sanitary district, take the lead in implementing the plan.

In order to implement the recommended aquatic plant management program, the following management measures are recommended:

1. The District and the Association should continue the periodic applications of chemical herbicides to control the growths of Eurasian water milfoil (*Myriophyllum spicatum*) and its hybrids in the Lake Basin, especially those growths along the northern shorelines of the Lake. Herbicides such as 2,4-D, which target Eurasian water milfoil are recommended for use, with the granular formulation being recommended for reasons of its ability to provide a more long-lasting effect.

2. Early spring treatment of Eurasian water milfoil populations is recommended. Such treatments minimize the use of chemical herbicides and limit the potential for the chemical damaging non-target species in the Lake, as many of the native species sensitive to this herbicide will still be in a dormant state following the winter. Special care should be taken, however, to avoid disturbance of fish spawning which occurs in late spring and early summer.

Table 7

RECOMMENDED AQUATIC PLANT MANAGEMENT PLAN ELEMENTS FOR CRYSTAL LAKE

Plan Element	Subelement	Location	Management Measures	Initial Estimated Cost	Management Responsibility
Recreational Use Management	Lakewide nonnative species management program	Eurasian water milfoil control zone, and zebra mussel control	Prevent the spread of nonnative plants and animals through cleaning of boats, trailers and related facilities throughout the Lake; limited use of herbicides in spring, manual removal during summer and fall, is recommended	- -	Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association
	Public informational programming	Direct drainage area tributary to Crystal Lake	Continue public awareness and information programming	- -	Sanitary District #1 of the Towns of Rhine and Plymouth, Crystal Lake Advancement Association
Aquatic Plant Management	Manual harvesting	Localized areas of shoreline	Harvest nuisance plants, including Eurasian water milfoil, as required around docks and piers; collect plant fragments arising from boating and harvesting activities	- -a	Individual property owners
	Chemical controls	Lakewide along the shorefringe as needed	Control aquatic plants through limited use of herbicides in spring; consider use of copper sulphate-based products for control of filamentous algae as required [approximately 13.5 acres]	$ 15,000	Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association
	Eurasian water milfoil control	Localized areas of the Lake, especially along the northern and western nearshore areas.	Control nonnative, invasive species as required to prevent the spread of nuisance species within the Lake; use of herbicides in spring to limit the volume of decomposing biomass and quantity of herbicides required is recommended [approximately 8.75 acres]	$10,000	Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association
	Boating ordinances	Public Recreational Boating Access	Maintain adequate public recreational boating access as defined in Chapter NR 1 of the Wisconsin Administrative Code; post advisory notices at public access site	- -	Sanitary District #1 of the Towns of Rhine and Plymouth, Towns of Plymouth and Rhine, WDNR

Plan Element	Subelement	Location	Management Measures	Initial Estimated Cost	Management Responsibility
Aquatic Plant Management	Public informational programming	Drainage area tributary to Crystal Lake	Continue public awareness and information programming with respect to nonnative and invasive species; continue monitoring of aquatic plant communities	$ 500[b,c]	Sanitary District #1 of the Towns of Rhine and Plymouth, Crystal Lake Advancement Association
Informational Programming	Water quality monitoring	Drainage area tributary to Crystal Lake	Continue participation in the Citizen Lake Monitoring Network	- -	Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association
	Watercraft inspections	Public recreational boating access site	Consider participation in the "Clean Boats, Clean Waters" inspection program	- -	Sanitary District #1 of the Towns of Rhine and Plymouth, Crystal Lake Advancement Association
	Community awareness	Informational programming	Continue to disseminate relevant information on lake-friendly living; maintain websites and other public informational programs	$ 500	Sanitary District #1 of the Towns of Rhine and Plymouth, Crystal Lake Advancement Association

[a]*Measures recommended generally involve low or no cost and would be borne by private property owners. Cost is included under public informational and educational component.*

[b]*Partial funding available through the Wisconsin Department of Natural Resources grant programs.*

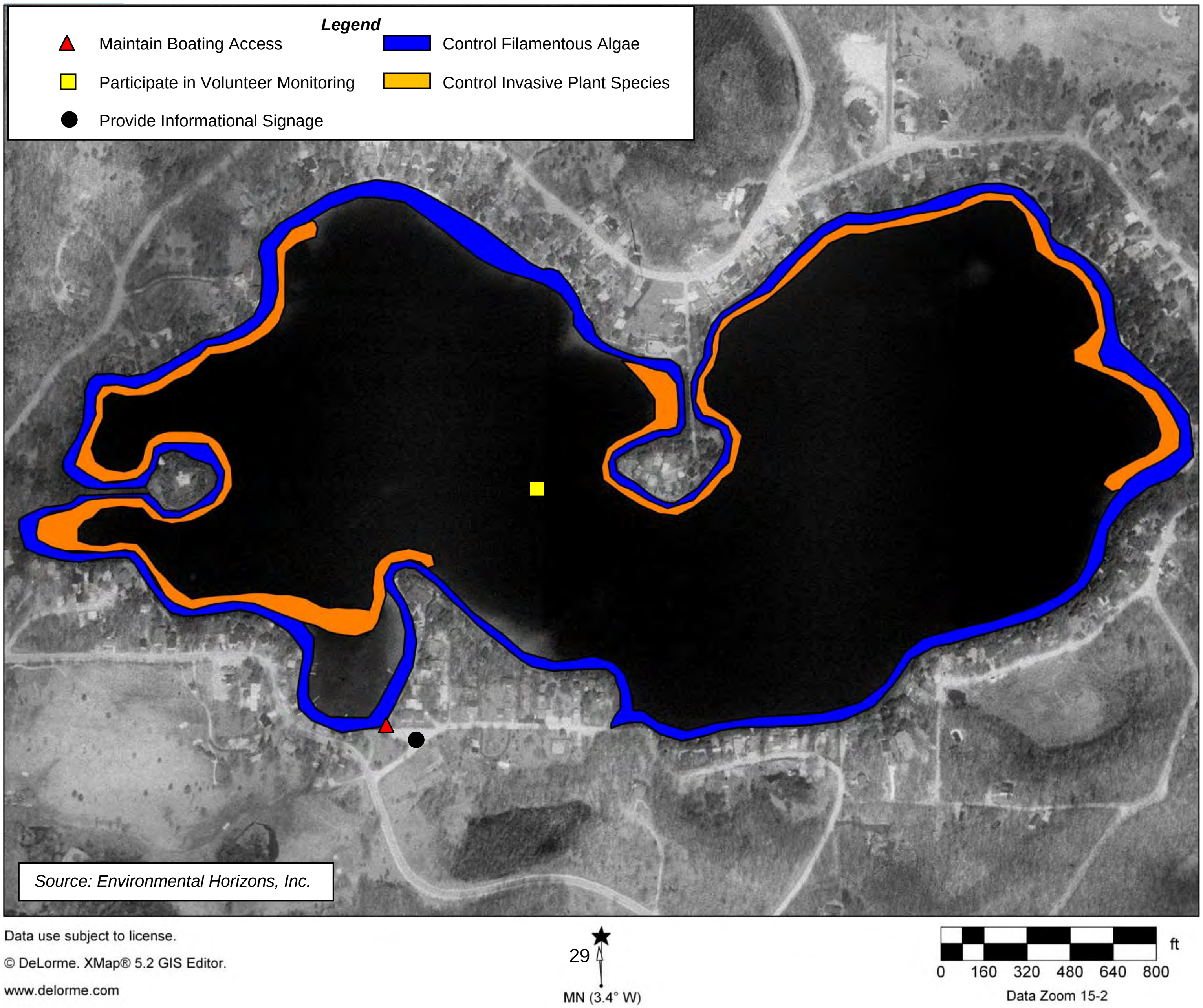
[c]*Periodic additional surveys are recommended at three- to five-year intervals.*
Source: Environmental Horizons, Inc.

3. The control of aquatic vegetation around piers and docks is recommended to be undertaken by the homeowners concerned. Riparian owners may manually harvest aquatic plants around piers and docks along a 30 feet per 100 feet length of shoreline pursuant to a general permit included within Chapter NR 109 of the *Wisconsin Administrative Code*; greater lengths of shoreline subject to management measures would require an individual permit to be issued by the WDNR pursuant to this Chapter.

4. The District and the Association should target designated nonnative invasive species for specific control, regardless of their location within the Lake. Currently, control measures should focus on the control of Eurasian water milfoil, a state designated invasive species pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*. Given the current population abundances and morphometry of the Lake, chemical controls are indicated as an appropriate control measure.

Map 6

RECOMMENDED AQUATIC PLANT MANAGEMENT PLAN FOR CRYSTAL LAKE



5. The District and the Association should continue to monitor the Lake periodically for other nonnative species, especially purple loosestrife (*Lythrum salicaria*) in the shoreland areas of the Lake.

6. Consideration should be given to the application of chemical algicides to control the growths of filamentous algae in the Lake. These growths are widespread in the Lake and diminish the aesthetic appeal of the Lake waters for recreational water users. Use of the algicide, copper sulphate, is recommended for this control.

7. It is recommended that the District and the Association consider participation in the State "Clean Boats, Clean Waters" program, operated by the University of Wisconsin-Extension (UWEX) and place advisory placards at the public recreational boating access site to encourage awareness and response by recreational water users to limit the spread of nonnative species.

8. The conduct of shoreline clean-up activities, such as the collection of plant fragments generated by wind waves, autofragmentation of the Eurasian water milfoil plants, and recreational boating activity, should be undertaken to limit the spread of nonnative aquatic plants within the Lake basin. It is recommended that shoreland homeowners and residents take the lead in conducting such actions.

9. Continued participation of the District in the Citizen Lake Monitoring Network (CLMN), formerly the Self-Help Monitoring Program, is recommended.

10. The implementation of community informational and educational programming is recommended. Sources of information to support such an effort include the UWEX and WDNR, who have numbers of publications, brochures, and pamphlets covering issues such as lakeshore living, water quality, and related topics of interest to homeowners and recreational lake users.

CHEMICAL TREATMENT

Chemical herbicides are recommended to control State-designated nonnative invasive species, currently including Eurasian water milfoil, that are present in the Lake basin. Targeted aquatic herbicides, approved for use in the State of Wisconsin, are recommended to be used as necessary to manage occurrences of designated nonnative species. Elsewhere, aquatic herbicides should be limited to controlling growths of exotic species in shallow water around piers and docks. Only registered herbicides that are selective in their control, such as 2,4-D, should be used. Algicides, such as Cutrine Plus, are recommended to treat periodic and recurring blooms of filamentous algae in the Lake.

In addition, the Sanitary District #1, Towns of Rhine and Plymouth, the Crystal Lake Advancement Association, in cooperation with the Wisconsin Department of Natural Resources, should work together to develop a herbicide usage policy for application to Crystal Lake, focused on the control of existing populations of Eurasian water milfoil and filamentous algae in the Lake. Consideration should be given to a policy that would allow rapid response to new infestations of State-designated nonnative species, including purple loosestrife which may occur in the shoreland areas and curly-leaf pondweed which could enter the flora of the Lake. To this end, early spring treatment of Eurasian water milfoil in the Lake has proven effective in other lakes in southern Wisconsin, and is recommended. Early spring applications maximize the effectiveness of the chemical herbicide and limit impacts of the herbicide on nontarget species. This treatment generally should be carried out in May for best results.

PRECAUTIONS TO PROTECT WILDLIFE, FISH AND ECOLOGICALLY VALUABLE AREAS

Chemical applicators should be provided with a copy of the approved aquatic plant management plan, which is illustrated on Map 6. Areas considered to be important for fish spawning and areas of less than three feet of water depth, should be excluded from aquatic plant management actions during the fish breeding season to avoid disturbance of nests and breeding behaviors.

EVALUATION AND MONITORING

It is the intention of the Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association to undertake a periodic, formal review of the aquatic plant management program for Crystal Lake. A copy of this plan will be lodged with the WDNR South East Region office. The District further intends to publish periodic refinements of the aquatic plant management plan for Crystal Lake, based upon future inventory data to be acquired at three- to five-yearly intervals, in order to ensure that the recommended aquatic plant management measures remain applicable; such periodic review and inventory acquisition also will permit the District, Association, and lake community to respond to changing conditions within the aquatic plant community, including both interannual variability and longer term variability in the community.

RECREATIONAL USE MANAGEMENT

In the control of potentially invasive nonnative species of plants and other organisms, prevention is generally preferable to extensive post-introduction control programs. Consequently, participation of the Crystal Lake community in programs such as the "Clean Boats, Clean Waters" programs sponsored by the UWEX and WDNR form an important element in the prevention of infestations and containment of currently-present nonnative species within those lakes in which they currently exist. The Clean Boats, Clean Waters program trains citizen volunteers to identify species of concern and provides informational materials for use at public recreational boating access sites. Training in this program is offered by UWEX staff upon request.

In addition to inspection programs, it is recommended that notices regarding invasive and other nonnative species be included with the informational postings at the public recreational boating access site. Such notices can encourage recreational boaters and lake users to remove aquatic plant fragments from their watercraft both prior to launching and after retrieving their watercraft. Disposal canisters for such plant fragments should be provided. Disposal canisters could also be used for the disposal of unused bait organisms, during both open water and ice fishing seasons, to limit the spread of other organisms, such as the virus that causes viral hemorrhagic septicemia (VHS) in fishes.

PUBLIC INFORMATIONAL PROGRAMMING

It is the policy of the Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association to maintain an active dialog with the Crystal Lake community. This is done through the medium of District public meetings and other scheduled hearings, as well as through the District website—http://www.sanitarydistrict.com—and the related website of the Crystal Lake Advancement Association—http://crystallakewi.org. These media provide opportunities to share information throughout the community, and mechanisms to enhance awareness amongst community members and visitors. This information should promote lake-friendly practices both within the watershed and on the Lake. Protection of environmentally valuable areas, control of nonnative species introductions, and related topics could be considered. As noted above, posting of appropriate signage and participation in State programs, such as the Clean Boats, Clean Waters and Citizen Lake Monitoring Network programs, are recommended. Support for such participation is available from the UWEX and WDNR. Where necessary, personal contacts with landowners should be made, most likely by the Crystal Lake Advancement Association.

SUMMARY

This plan, which documents the findings and recommendations of a study requested by the Sanitary District #1 of the Towns of Rhine and Plymouth and the Crystal Lake Advancement Association, presents an aquatic plant management plan for Crystal Lake, Sheboygan County. The recommended aquatic plant management plan is summarized in Table 7 and shown graphically on Map 6. The management plan recommends actions to be taken to limit the introduction and spread of nonnative species of aquatic plants and promote a quality human recreational and residential experience within the vicinity of Crystal Lake.

The plan recommends the limited use of aquatic herbicides to specifically target Eurasian water milfoil, a State-designated nonnative invasive species, as well as the limited use of algicides to control growths of filamentous algae in the Lake. These measures are designed to enhance the ecological integrity of the aquatic ecosystem and promote human recreational uses, including fishing, recreational boating and scenic viewing. In addition, the plan recommends manual control of aquatic plants, as necessary, around piers and docks. It is noted that such controls are subject to State permitting requirements, which limit such management actions to an area of not more than 30 feet in width within a shoreline of 100 feet in width. It is recommended that the Sanitary District #1 of the Towns of Rhine and Plymouth together with the Crystal Lake Advancement Association take the lead in implementing the recommended aquatic plant management program for Crystal Lake.

In addition, the plan recommends an active program of public informational and educational programming, including continued participation in the Citizen Lake Monitoring Network (formerly the Self-Help Monitoring Program), and consideration of participation in related programs such as the Clean Boats, Clean Waters Program sponsored by the UWEX and WDNR.

Beyond these formal participatory mechanisms, it is recommended that the Sanitary District #1 of the Towns of Rhine and Plymouth, in collaboration with the Towns and the Crystal Lake Advancement Association, also make use of informational materials available from the UWEX and WDNR to encourage lake-friendly practices within the Crystal Lake community. Information on household chemical usage, lawn and garden care, shoreland protection and maintenance, and recreational usage of the Lake should be made available to riparian householders, thereby providing riparian residents with information on alternatives to traditional practices and activities. Informational programming on the control of nonnative species such as Eurasian water milfoil, zebra mussel, VHS and other undesirable organisms is strongly recommended.

The recommended plan seeks to balance the demand for a high-quality water-based residential and recreational experience at Crystal Lake with requirements for environmental and ecosystem protection and maintenance.

APPENDIX A

PHOTOS OF COMMON AQUATIC PLANTS IN CRYSTAL LAKE

Photo A-1

Coontail – *Ceratophyllum demersum*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-2

Muskgrass - *Chara sp.*

Beneficial Algae
Source: Environmental Horizons, Inc.

Photo A-3

Common waterweed – *Elodea canadensis*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-4

Arum-leaved arrowhead – *Sagittaria cuneata*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-5

Common and Arum leaved arrowhead – *Sagittaria sp.*

Beneficial Plant
Source: Environmental Horizons, Inc.

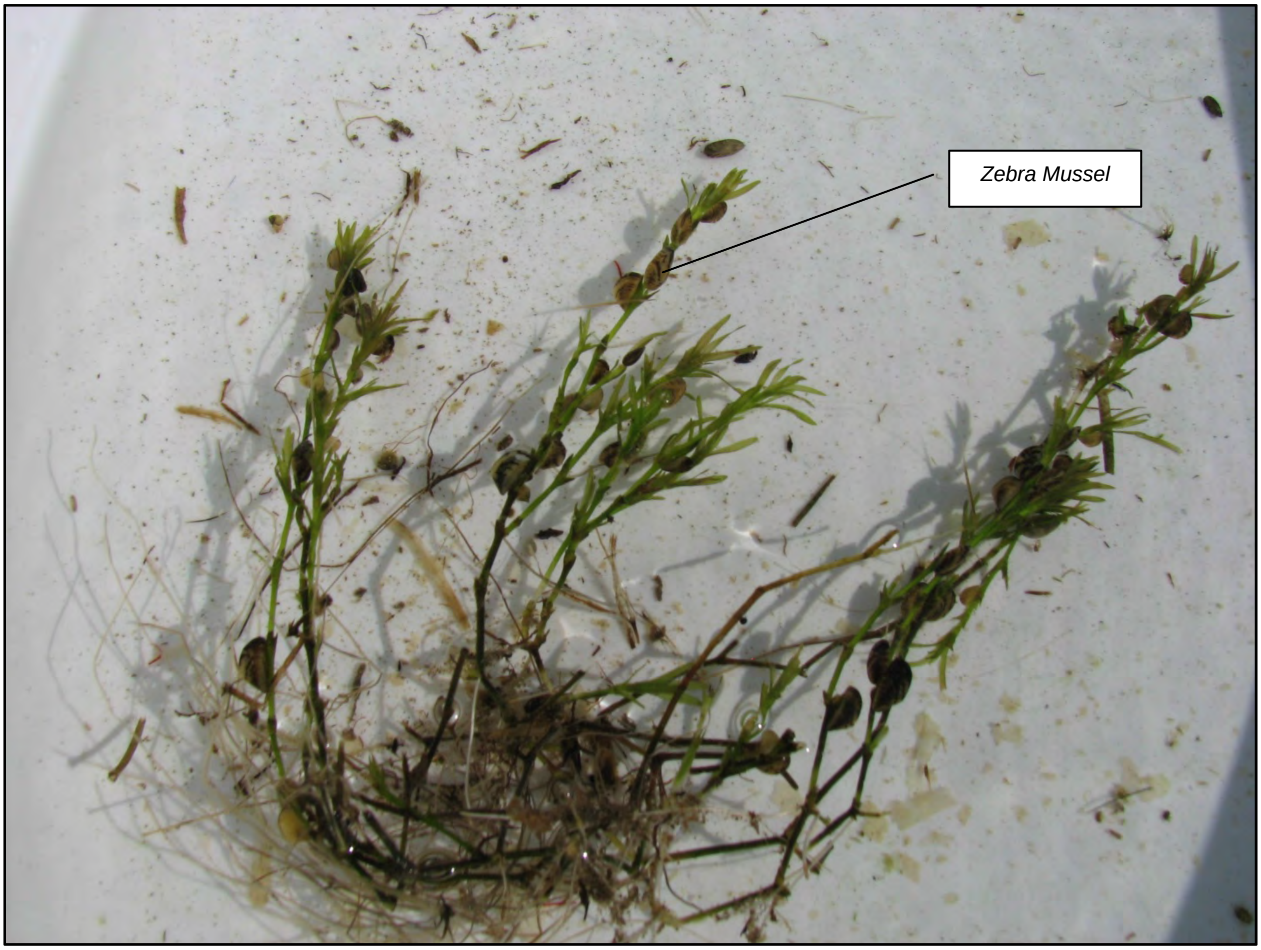
Photo A-6

Eurasian water milfoil – *Myriophyllum spicatum*

Non-native, Invasive Plant
Source: Environmental Horizons, Inc.

Photo A-7

Slender naiad, Bushy pondweed – *Najas flexilis*



Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-8

Large leaf pondweed – *Potamogeton amplifolius*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-9

Illinois pondweed – *Potamogeton illinoensis*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-10

Sago pondweed – *Potamogeton pectinatus*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-11

Small pondweed – *Potamogeton pusillus*

Beneficial Plant
Source: Environmental Horizons, Inc.

Photo A-12

Broad-leaved cattail – *Typha latifolia*

Source: Environmental Horizons, Inc.

Photo A-13

Flatstem pondweed – *Potamogeton zosterformis*

Beneficial Plant
Source: Environmental Horizons, Inc.

APPENDIX B

JESSON AND LOUND TRANSECT METHOD

The inventory data used in developing the refined aquatic plant management plan for Crystal Lake were gathered using standard aquatic plant survey techniques and protocols. The aquatic plant survey of Crystal Lake was conducted by Environmental Horizons staff using the modified Jesson and Lound[1] transect method employed by various natural resource management agencies throughout the upper Midwest.

Prior to the initiation of the field survey, Environmental Horizons staff identified a series of transects or sampling lines running perpendicular to the shoreline which typically extended from shallow to deeper water at intervals around the Lake. These transects were located at easily identifiable points, typically adjacent to structures or other landmarks that are likely to be permanent landscape features. These transects allow subsequent sampling of the same sites at future dates, and comparison of the data gathered during the 2007 survey with data gathered at that future date. The current transects, shown on Map B-1, and the sampling sites, shown on Map B-2 are described in Table B-1. Water depth, surface water temperature and substrate data are also shown in the Table B-1. Sampling sites were tabulated using a Garmin global positioning system (GPS). Samples were proposed to be obtained from depth intervals of approximately 1.5 feet, 3 feet, 6 feet, 9 feet, and 12 feet where plant growth and such depths were present.

Aquatic plants at each location were sampled using a modified garden rake. At depths of three feet or less, aquatic plants were sampled using a standard rake; at depths in excess of three feet, aquatic plants were sampled by a modified rake equipped with a throwing line that facilitated sampling at depths that were beyond the reach of the rake handle. Plants obtained during each rake “haul” were identified and recorded. Type specimens of most species of aquatic plants were photographed and are documented in Appendix A. Four samples were obtained at each station, with one sample being obtained from each quarter of the boat. The presence or absence of each species was noted. These data allow for statistical analysis of the data set as described in Chapter II of this report. Species that were present in abundance were recorded as being present in a greater number of rake hauls than species that were less common in the aquatic plant population. These data were recorded in the field.

Analysis of these data was conducted using a spreadsheet. The data are summarized in Table B-2. Based upon the presence of specific species, a number of aquatic plant communities were identified. These communities share similar assemblages of aquatic plants, and, therefore, are amenable to being managed in a similar manner. As noted in Chapter I, the aquatic plant management objectives are based upon managing the Lake so as to:

---

[1]R. Jesson and R. Lound, Minnesota Department of Conservation Game Investigational Report No. 6, *An Evaluation of a Survey Technique for Submerged Aquatic Plants*, 1962.

1. Protect and maintain public health, and promote public comfort, convenience, necessity and welfare, through the environmentally sound management of native vegetation, in and Crystal Lake;

2. Effectively control the quantity and density of aquatic plant growths in portions of the Crystal Lake basin to better facilitate the conduct of water-related recreation, improve the aesthetic value of the resource to the community, and enhance the resource value of the waterbody;

3. Promote a quality, water-based experience for residents and visitors to Crystal Lake consistent with the policies and objectives of the Wisconsin Department of Natural Resources as set forth in the relevant *Wisconsin Administrative Codes.*[2]

Consequently, while the aquatic plant management program set forth in Chapter III targets nonnative aquatic plant species, especially those designated as nonnative invasive species, it should be noted that these plants occur in assemblages that include the more desirable native plants which may also be affected by specific management measures. Hence, in developing the recommended aquatic plant management plan, it is important to recognize these assemblages so as to avoid damaging the underlying native aquatic plant species and negatively impacting the lake ecosystem by interfering with the essential function of the aquatic plants. Such functions include provision of habitat and foodstocks for fish and wildlife, as summarized in tabular form in Chapter II. These various assemblages were transferred from Table B-2 to the aquatic plant community distribution map included in Chapter II as Map 5, although the totality of the aquatic plant species that contribute to each community were abbreviated on Map 5 to only those species that were most frequently occurring at each location for purposes of clarity of presentation. By examining these assemblages, it was possible to develop the aquatic plant management program for Crystal Lake as set forth in Chapter III.

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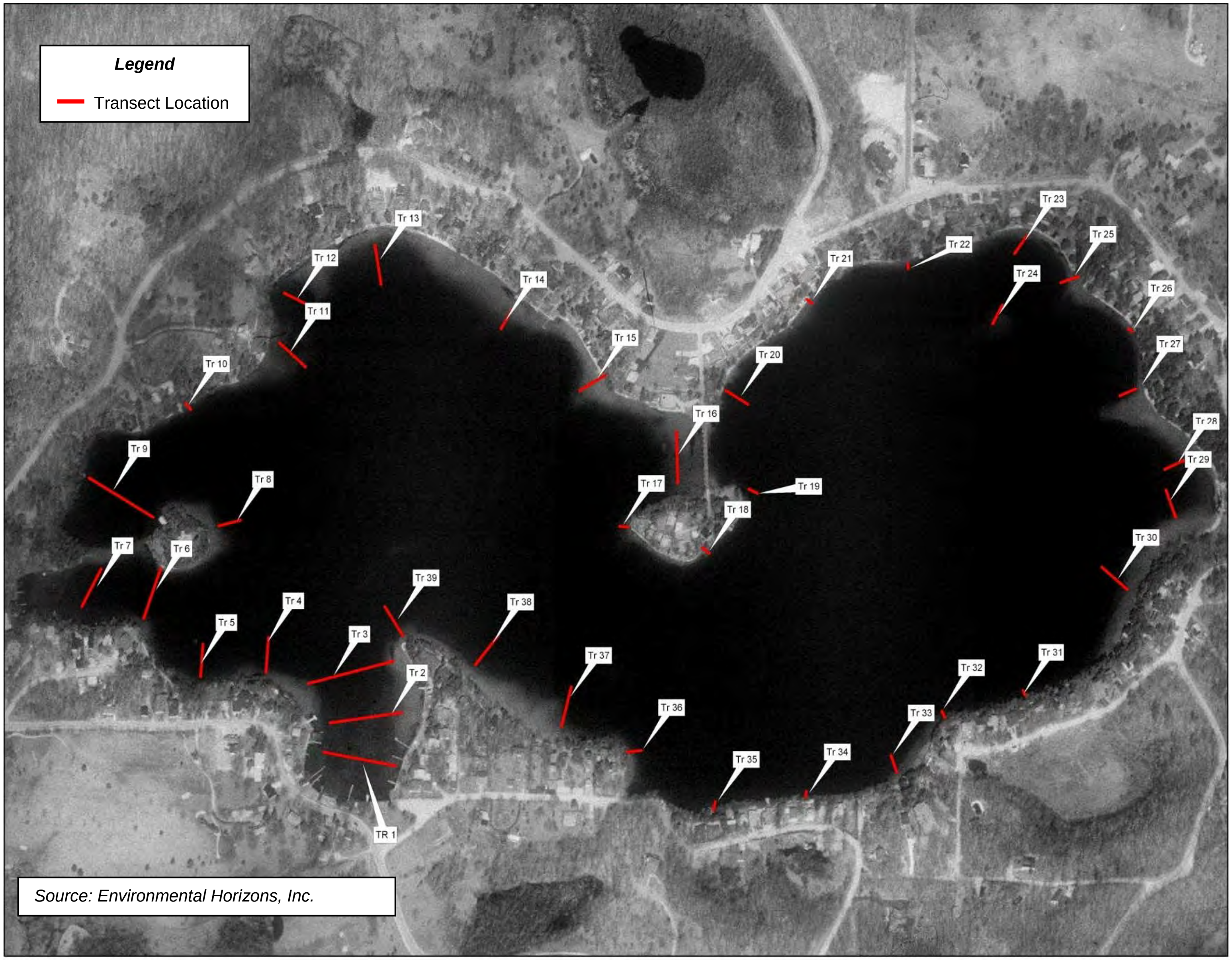
[2]This plan has been prepared pursuant to the standards and requirements set forth in the following chapters of the Wisconsin Administrative Code*: Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 103, "Water Quality Standards for Wetlands; " Chapter NR 107, "Aquatic Plant Management;" and Chapter NR 109, "Aquatic Plants Introduction, Manual Removal and Mechanical Control Regulations.*

Map B1

CRYSTAL LAKE TRANSECTS



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MN (5.4° W)

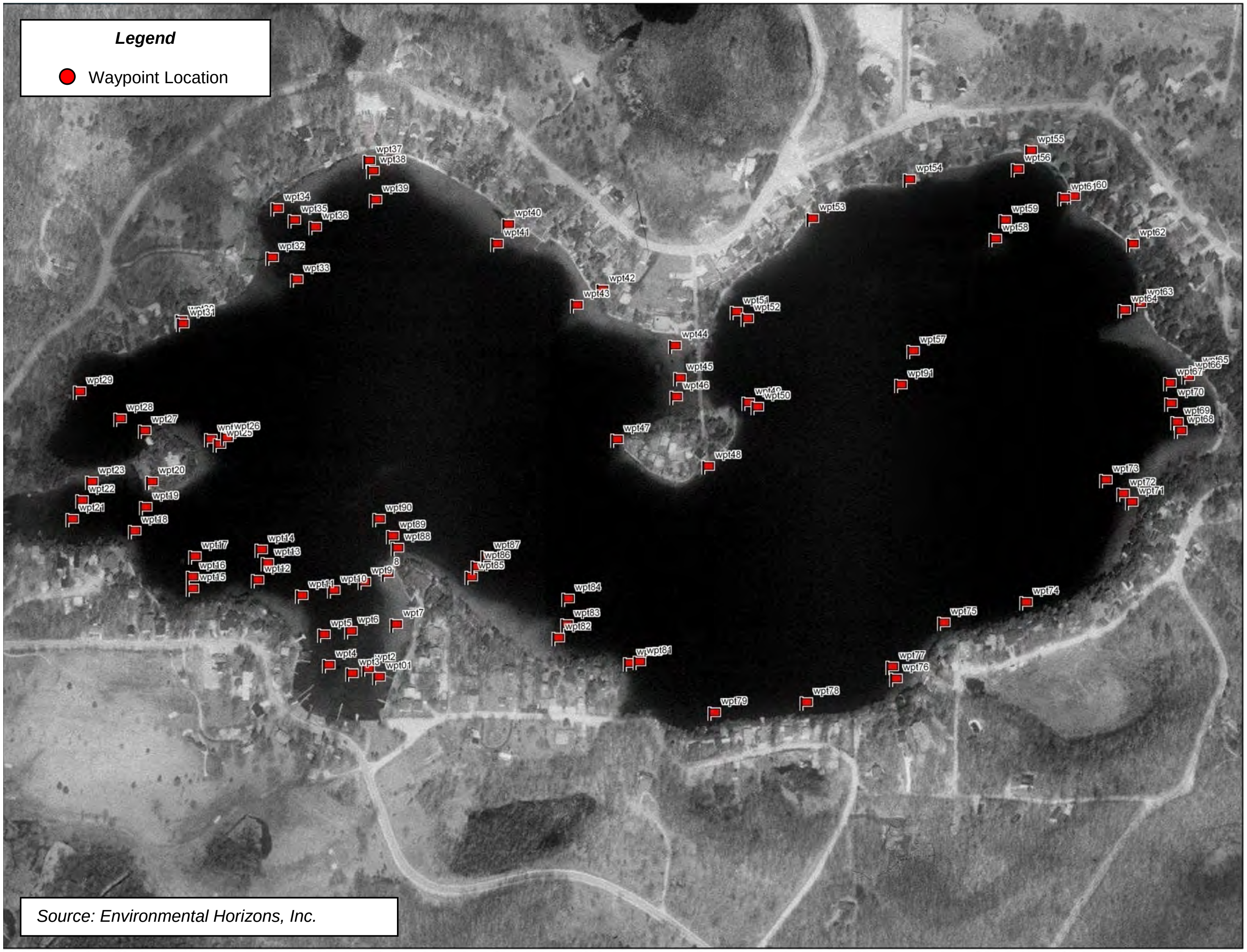
0 160 320 480 640 800 ft

Data Zoom 15-2

50

Map B2

CRYSTAL LAKE WAYPOINTS



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MN (3.4° W)

0 160 320 480 640 800 ft

Data Zoom 15-2

TABLE B1

CRYSTAL LAKE TRANSECT AND WAYPOINT DATA

TRANSECT NO.	WAYPOINT NO.	LATITUDE AND LONGITUDE	WATER DEPTH – FT.	SUBSTRATE	WATER TEMPERATURE	DATE SAMPLED
1	1	N43 48.236 W88 01.265	1.0	MARL	70.1 °F	6/24/2008
	2	N43 48.241 W88 01.274	2.9	MARL	70.4 °F	6/24/2008
	3	N43 48.238 W88 01.287	2.2	MARL	70.6 °F	6/24/2008
	4	N43 48.243 W88 01.306	2.2	- -	70.7 °F	6/24/2008
2	5	N43 48.261 W88 01.310	2.2	MARL	71.1 °F	6/24/2008
	6	N43 48.263 W88 01.288	4.3	- -	71.1 °F	6/24/2008
	7	N43 48.267 W88 01.251	2.3	- -	71.1 °F	6/24/2008
3	8	N43 48.297 W88 01.258	3.3	COBBLE/GRAVEL	71.1 °F	6/24/2008
	9	N43 48.292 W88 01.277	6.4	MARL	71.2 °F	6/24/2008
	10	N43 48.287 W88 01.302	5.5	- -	71.2 °F	6/24/2008
	11	N43 48.284 W88 01.328	3.0	COBBLE/GRAVEL	71.4 °F	6/24/2008
4	12	N43 48.293 W88 01.364	3.2	COBBLE	71.7 °F	6/24/2008
	13	N43 48.303 W88 01.356	8.9	- -	71.6 °F	6/24/2008
	14	N43 48.311 W88 01.361	14.8	- -	71.5 °F	6/24/2008
5	15	N43 48.288 W88 01.417	1.8	COBBLE/GRAVEL	71.8 °F	6/24/2008
	16	N43 48.295 W88 01.417	6.7	- -	72.0 °F	6/24/2008
	17	N43 48.307 W88 01.415	8.4	- -	72.1 °F	6/24/2008
6	18	N43 48.322 W88 01.464	3.0	COBBLE/GRAVEL	72.1 °F	6/24/2008
	19	N43 48.336 W88 01.455	9.1	- -	72.1 °F	6/24/2008
	20	N43 48.351 W88 01.450	2.2	COBBLE/GRAVEL	72.1 °F	6/24/2008
7	21	N43 48.329 W88 01.515	4.2	SILT/SAND	72.3 °F	6/24/2008
	22	N43 48.340 W88 01.507	5.3	- -	72.7 °F	6/24/2008
	23	N43 48.351 W88 01.499	3.3	- -	72.3 °F	6/24/2008
8	24	N43 48.376 W88 01.402	4.2	COBBLE/GRAVEL	72.2 °F	6/24/2008
	25	N43 48.373 W88 01.395	6.4	COBBLE/GRAVEL	72.0 °F	6/24/2008
	26	N43 48.377 W88 01.389	10.2	- -	71.9 °F	6/24/2008
9	27	N43 48.381 W88 01.456	3.8	MARL	71.9 °F	6/24/2008
	28	N43 48.388 W88 01.476	6.8	- -	71.7 °F	6/24/2008
	29	N43 48.404 W88 01.509	6.1	- -	72.4 °F	6/24/2008
10	30	N43 48.446 W88 01.426	5.1	COBBLE/GRAVEL	72.8 °F	6/24/2008
	31	N43 48.444 W88 01.425	6.8	- -	72.7 °F	6/24/2008
11	32	N43 48.483 W88 01.352	2.3	SILT/SAND	72.4 °F	6/24/2008
	33	N43 48.470 W88 01.332	7.2	- -	72.3 °F	6/24/2008
12	34	N43 48.512 W88 01.348	2.5	SAND	72.2 °F	6/24/2008
	35	N43 48.505 W88 01.334	4.6	- -	73.3 °F	6/24/2008
	36	N43 48.501 W88 01.317	11.6	- -	72.4 °F	6/24/2008
13	37	N43 48.540 W88 01.273	4.3	SAND	72.9 °F	6/24/2008
	38	N43 48.534 W88 01.270	6.3	SAND	73.4 °F	6/24/2008
	39	N43 48.517 W88 01.268	10.6	- -	73.1 °F	6/24/2008
14	40	N43 48.503 W88 01.160	3.0	SAND	- -	6/24/2008
	41	N43 48.491 W88 01.169	13.9	- -	73.0 °F	6/24/2008
15	42	N43 48.464 W88 01.083	2.5	COBBLE	- -	6/24/2008
	43	N43 48.455 W88 01.104	9.0	COBBLE	- -	6/24/2008
16	44	N43 48.431 W88 01.024	3.0	SAND	- -	6/24/2008
	45	N43 48.412 W88 01.020	3.9	SAND	72.7 °F	6/24/2008
	46	N43 48.401 W88 01.023	3.1	SAND	72.4 °F	6/24/2008
17	47	N43 48.376 W88 01.071	4.5	COBBLE	- -	6/24/2008
18	48	N43 48.360 W88 00.997	10.4	- -	72.2 °F	6/24/2008
19	49	N43 48.398 W88 00.964	4.0	COBBLE	- -	6/24/2008
	50	N43 48.395 W88 00.957	9.6	- -	72.1 °F	6/24/2008
20	51	N43 48.451 W88 00.974	3.9	COBBLE	- -	6/24/2008
	52	N43 48.447 W88 00.965	9.0	- -	- -	6/24/2008
21	53	N43 48.506 W88 00.912	6.0	COBBLE/GRAVE;	- -	6/24/2008
22	54	N43 48.529 W88 00.833	7.0	- -	72.2 °F	6/24/2008
23	55	N43 48.546 W88 00.734	3.5	COBBLE	- -	6/24/2008
	56	N43 48.535 W88 00.745	7.0	- -	- -	6/24/2008

TRANSECT NO.	WAYPOINT NO.	LATITUDE AND LONGITUDE	WATER DEPTH – FT.	SUBSTRATE	WATER TEMPERATURE	DATE SAMPLED
SECCHI DISC SAMPLING POINT	57	N43 48.428 W88 00.830	61.0	- -	- -	6/24/2008
24	58	N43 48.494 W88 00.763	6.1	SAND/GRAVEL	71.3 °F	6/25/2008
	59	N43 48.505 W88 00.755	8.7	- -	71.3 °F	6/25/2008
25	60	N43 48.519 W88 00.699	2.6	COBBLE	71.3 °F	6/25/2008
	61	N43 48.518 W88 00.707	7.6	- -	71.2 °F	6/25/2008
26	62	N43 48.491 W88 00.651	7.1	COBBLE/GRAVEL	71.1 °F	6/25/2008
27	63	N43 48.456 W88 00.645	4.5	SAND/GRAVEL	71.1 °F	6/25/2008
	64	N43 48.452 W88 00.658	7.4	- -	71.1 °F	6/25/2008
28	65	N43 48.416 W88 00.600	2.6	COBBLE	71.2 °F	6/25/2008
	66	N43 48.413 W88 00.606	4.5	- -	71.2 °F	6/25/2008
	67	N43 48.409 W88 00.621	7.9	- -	71.3 °F	6/25/2008
29	68	N43 48.381 W88 00.612	2.9	COBBLE	71.3 °F	6/25/2008
	69	N43 48.386 W88 00.615	5.0	COBBLE	71.4 °F	6/25/2008
	70	N43 48.397 W88 00.620	9.8	- -	71.4 °F	6/25/2008
30	71	N43 48.339 W88 00.652	3.6	COBBLE	71.3 °F	6/25/2008
	72	N43 48.344 W88 00.659	4.5	COBBLE	71.3 °F	6/25/2008
	73	N43 48.352 W88 00.673	9.2	- -	71.4 °F	6/25/2008
31	74	N43 48.280 W88 00.738	3.8	COBBLE	71.5 °F	6/25/2008
32	75	N43 48.268 W88 00.805	2.5	COBBLE	71.6 °F	6/25/2008
33	76	N43 48.235 W88 00.844	4.3	COBBLE	71.6 °F	6/25/2008
	77	N43 48.242 W88 00.847	12.2	- -	71.6 °F	6/25/2008
34	78	N43 48.221 W88 00.917	4.5	COBBLE	71.7 °F	6/25/2008
35	79	N43 48.215 W88 00.992	5.7	SAND/GRAVEL	71.7 °F	6/25/2008
36	80	N43 48.244 W88 01.061	3.1	COBBLE	71.8 °F	6/25/2008
	81	N43 48.245 W88 01.053	7.6	- -	71.8 °F	6/25/2008
37	82	N43 48.259 W88 01.119	2.5	SAND	72.0 °F	6/25/2008
	83	N43 48.267 W88 01.112	5.3	- -	72.0 °F	6/25/2008
	84	N43 48.282 W88 01.111	9.2	- -	71.9 °F	6/25/2008
38	85	N43 48.295 W88 01.190	3.2	SAND	72.1 °F	6/25/2008
	86	N43 48.301 W88 01.185	6.3	- -	72.2 °F	6/25/2008
	87	N43 48.307 W88 01.177	15.8	- -	72.2 °F	6/25/2008
39	88	N43 48.312 W88 01.250	2.0	SAND/GRAVEL	72.1 °F	6/25/2008
	89	N43 48.319 W88 01.254	4.3	COBBLE	72.1 °F	6/25/2008
	90	N43 48.329 W88 01.265	9.6	- -	72.1 °F	6/25/2008
SECCHI DISC SAMPLING POINT	91	N43 48.408 W88 00.840	60.8	- -	72.5 °F	6/25/2008

[a] *Non applicable.*

Source: Environmental Horizons, Inc.

Table B-2

CRYSTAL LAKE PLANT DATA

Transect No.	Waypoint No.	Coontail	Muskgrass	Common Waterweed	Milfoil	Bushy PW	Large Leaf PW	Illinois PW	Sago PW	Small PW	Flat Stem PW	Filamentous Algae
1	1	1	4						2		1	
	2		1									
	3		4						3			
	4		4						3			
2	5		4						4		1	
	6							1	1		1	
	7		1									
3	8		3									
	9				2	4			2			
	10			2	3	1		2				
	11		4									4
4	12		4					2				
	13	1			2	2		3				
	14	1	4									
5	15		1		1	1		1				2
	16		3	1				3	2		1	
	17	2	3						1		1	
6	18											
	19		3					1				
	20		2	1	4	3	1	2		1	1	
7	21							2	4		3	
	22					2	3	1	4		2	
	23		2			1	2	1	3		2	
8	24		3									3
	25		4									3
	26											
9	27		1			1	3	2	2		1	
	28		1		3			3	2		2	
	29				1			1	1		1	1
10	30		1			1						1
	31	1										1
11	32		4					1				1
	33		4					2				
12	34	1	2		1				4		1	
	35					2		3	3		1	
	36		2		1							
13	37		3			3		4	1			
	38		3			2		4	2			
	39		1									
14	40											1
	41		1									
15	42		1									
	43		3									
16	44											1
	45		4									
	46		4		1							3
17	47		1		2			3				
18	48							1	1			
19	49	1	2			1		1	1			
	50		1		3	2		1	3	1		
20	51	1			3			3	3			
	52				3			4			4	
21	53		4									1
22	54				1			3				
23	55		3									
	56				4	1	1	1		1		
Secchi Disc Sampling Point	57	- - *a*	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
24	58											1
	59		4									1
25	60		2					1				
	61				1	2		2				
26	62		3			1						
27	63		2									
	64		3					2				
28	65		2									
	66		1		1	4	2	2	2			
	67			1	1	3		4	1			
29	68	2	2									
	69		4					1				
	70		1		2	1		1				

Transect No.	Waypoint No.	Coontail	Muskgrass	Common Waterweed	Milfoil	Bushy PW	Large Leaf PW	Illinois PW	Sago PW	Small PW	Flat Stem PW	Filamentous Algae
30	71											
	72		2					1				
	73		4			1			2			
31	74		2					2				1
32	75							2				3
33	76		3									4
	77											
34	78		3					1				1
35	79		1					1	1			3
36	80		3									3
	81		2					2				
37	82		4									1
	83		4					4	3			
	84		3					1				1
38	85		3									
	86		4					4				
	87		4									
39	88											
	89		1					1	3			
	90	2		2	4			3	1			
Secchi Disc Sampling Point	91	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Frequency Totals		13	167	7	44	39	12	109	65	3	23	41

[a]*Non applicable*
Source: Environmental Horizons, Inc.

Legend

- Muskgrass-Sago Pondweed Community
- Muskgrass – Pondweed Community
- Pondweed Community
- Coontail – Muskgrass Community
- Muskgrass – Filamentous Algae Community
- Eurasian Water Milfoil – Muskgrass – Pondweed Community
- Eurasian Water Milfoil – Pondweed Community

APPENDIX C

EMPIRICAL MODELS USED FOR CALCULATIONS

WISCONSIN TROPHIC STATE INDEX (WTSI)

Source: Lillie, R.A., S. Graham and P. Rasmussen, Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes, *Research and Management Findings*, Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.

Source: Carlson, R.E., A Trophic State Index for Lakes, *Limnology and Oceanography*, volume 22, no. 2, 1977.

$$WTSI_{SD} = 60 - (33.2 \log_{10} SD)$$

Where: $WTSI_{SD}$ = Secchi disc-based Wisconsin Trophic State Index Number

SD = Secch disc transparency in meters.

WISCONSIN LAKE MODEL SPREADSHEET

Source: Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-96 REV, Wisconsin Lake Model Spreadsheet, Version 2.00, Users Manual, June 1994.

VOLLENWEIDER MODEL

Source: Ryding, S.-O. and W. Rast, *The Control of Eutrophication in Lakes and Reservoirs*, Unesco Man and the Biosphere Programme Series Vol. 1, 1989.

Source: Organisation for Economic Cooperation and Development (OECD), *Eutrophication of Waters: Monitoring, Assessment and Control*. Organisation for Economic Cooperation and Development, Paris. 1982.

$$[P] = L / q_s (1 + T_w^{1/2})$$

Where: [P] = Forecast in-lake total phosphorus concentration in micrograms per liter

L = Phosphorus loading rate in milligrams per square meter of lake surface

q_s = Water loading rate in meters per year

T_w = Water residence time in years

Source: Hoyer, M.V., T.K. Frazer, S.K. Notestein, and D.E. Canfield, Jr., Nutrient, Chlorophyll, and Water Clarity Relationships in Florida's Nearshore Coastal Waters with Comparisons to Freshwater Lakes, *Can. J. Fish. Aquat. Sci.*, volume 59: 1024–1031, 2002.

$$\log_{10}SDT = 0.88 - 0.48 \log_{10}TP$$

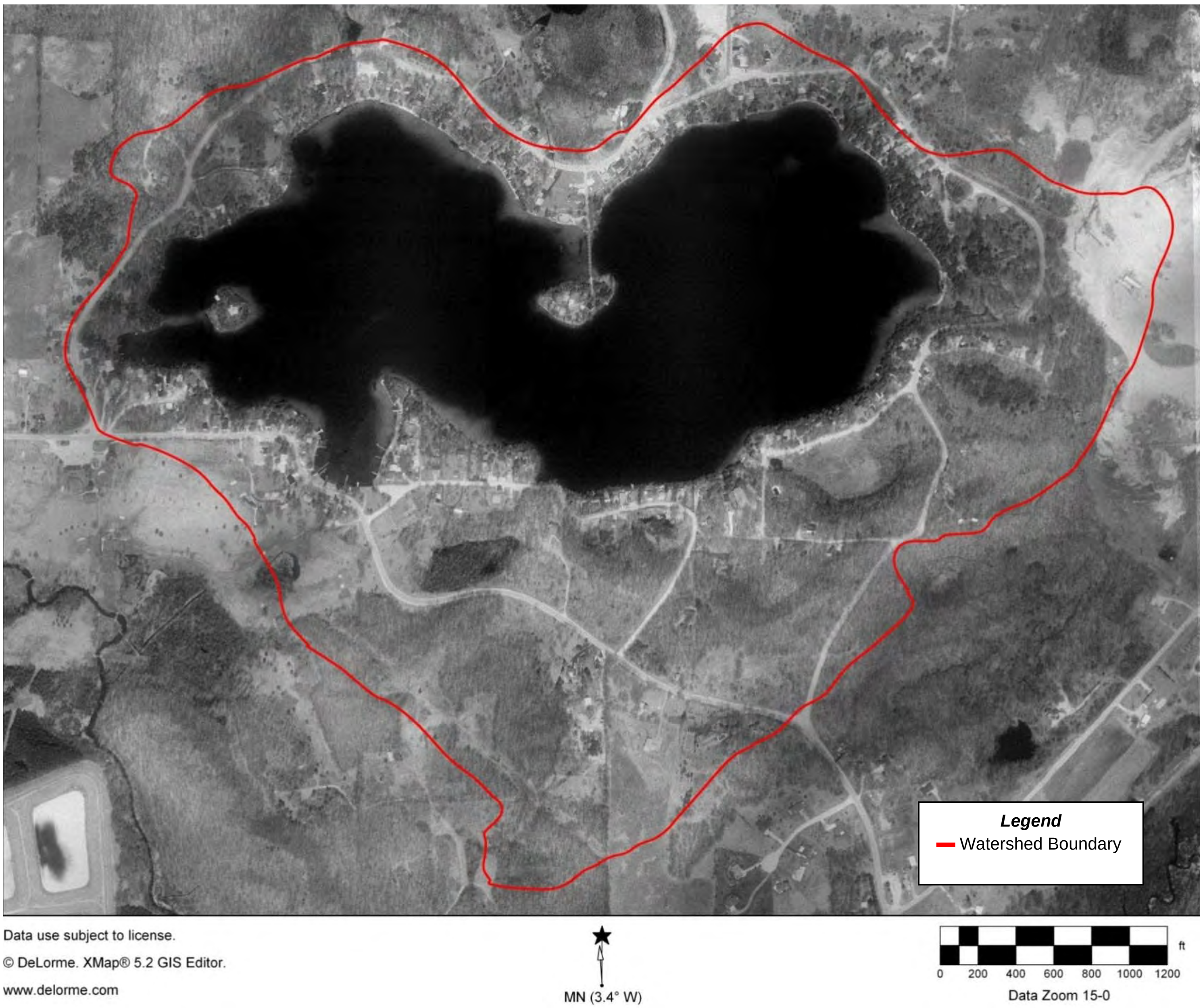
where: SDT = Secchi disc transparency in meters

TP = Total phosphorus concentration in milligrams per cubic meter [= micrograms per liter]

APPENDIX D

Map D-1

AERIAL VIEW OF CRYSTAL LAKE WATERSHED BOUNDARY



Source: Environmental Horizons, Inc.