MEMORANDUM REPORT NO. 122

A LAKE PROTECTION PLAN FOR PRETTY LAKE

WAUKESHA COUNTY WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgment is due to Mr. Thomas Casper, former Commission Chairman, for his contribution to the conduct of this study and preparation of this report.

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WAUKESHA COUNTY, WISCONSIN

Prepared by the

Southeastern Wisconsin Regional Planning Commission
for
the Pretty Lake Protection and Rehabilitation District
with Grant Assistance Provided by the
Wisconsin Department of Natural Resources

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Chapter I

INTRODUCTION

Pretty Lake, located within the Town of Ottawa, Waukesha County, Wisconsin, is a valuable resource offering a variety of recreational and related opportunities to the resident community and its visitors. The Lake is an integral part of the community. However, the recreational and visual value of the Lake is perceived to be adversely affected by changing conditions. Seeking to improve the usability of Pretty Lake and to prevent deterioration of the natural assets and recreational potential of the Lake, the residents of the watershed formed the Pretty Lake Protection and Rehabilitation District which has undertaken a lake-orientated program of community involvement, education, and management. The lake residents have enrolled in the Wisconsin Department of Natural Resources Self-Help Monitoring Program, and sought assistance from the Department of Natural Resources and the U.S. Geological Survey. The District has recently supported the formation of, and works closely with, the Kettle Moraine Conservation Foundation, Inc., a nonprofit organization created to acquire and manage environmentally sensitive lands in the Pretty Lake area. These actions help provide the residents of Pretty Lake with a better understanding of their Lake and its watershed.

This report sets forth a lake protection and recreational use plan for Pretty Lake and represents part of the ongoing commitment of the Pretty Lake Protection and Rehabilitation District to a sound lake management planning program. This plan was prepared during 1995 and 1996 by the Southeastern Wisconsin Regional Planning Commission in cooperation with the Pretty Lake Protection and Rehabilitation District and the U.S. Geological Survey. The planning program was funded, in part, by the Wisconsin Department of Natural Resources Lake Management Planning Grant awarded to the Pretty Lake Protection and Rehabilitation District under Chapter NR 190 Lake Management Planning Grant Program.

The plan is intended to form an integral part of any future comprehensive lake management plan for Pretty Lake. The scope of this report is limited to a consideration of those management measures which can be determined to be effective in the protection of lake water quality and lake use based upon the available data. The preparation of a comprehensive lake management plan for Pretty Lake will require additional water quality and biological data collection and analysis.

The lake protection and recreational use plan goals and objectives for Pretty Lake were developed in consultation with the Pretty Lake Protection and Rehabilitation District. The goals and objectives are:

1. To protect and maintain public health, and to promote public comfort, convenience, necessity, and welfare, through the environmentally sound management of the vegetation, fishery, and wildlife populations in and around Pretty Lake;

2. To provide for high-quality, water-based recreational experiences by residents and visitors to Pretty Lake, and manage the waterbody in an environmentally sound manner; and,

3. To effectively maintain the water quality of Pretty Lake so as 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.

This plan, which conforms to the requirements and standards set forth in the relevant Wisconsin Administrative Codes,[1] should serve as an initial guide to achieving these objectives over time.

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[1] *This plan has been prepared pursuant to the standards and requirements set forth in Administrative Codes NR 1, Public Access Policy for Waterways; NR 103, Water Quality Standards for Wetlands; and NR 107, Aquatic Plant Management.*

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Chapter II

INVENTORY FINDINGS

INTRODUCTION

Pretty Lake is located southwest of the Village of Dousman, and northwest of the Kettle Moraine State Forest–Southern Unit and Ottawa Lake Recreational Center, in the Town of Ottawa, Waukesha County. The Pretty Lake study area, defined for purposes of this study as the drainage area directly tributary to Pretty Lake, plus the total drainage area tributary to School Section Lake located to the north and in the same drainage subbasin as Pretty Lake, is approximately 6.2 square miles in areal extent as shown on Map 1. The riparian shorelines of both Pretty and School Section Lakes are partially developed for residential use. The surrounding land uses in the study area are primarily agricultural in nature, the balance being wetland or woodland areas, and scattered single-family residential development.

WATERBODY CHARACTERISTICS

Pretty Lake is a 64-acre waterbody, the hydrographical characteristics of which are set forth in Table 1. The Lake is considered to be a groundwater flow-through, or seepage, lake. As such, the Lake's water level is dependent upon the regional groundwater table as shown in Figure 1. Pretty Lake has little surface inflow and no defined surface outflow. The Lake is roughly oval in aspect, having one small bay in the southeastern quadrant of the basin. This waterbody has a maximum depth of about 35 feet, a mean depth of 12 feet, and a volume of 752 acre-feet. The bathymetry of the Lake is shown on Map 2.

LAND USE AND SHORELINE DEVELOPMENT

Population

As of 1990, there were approximately 510 persons residing within the study area of Pretty Lake. Of these persons, about 440, or 86 percent, were resident within the study area year around. About 70, or 14 percent, were resident for only part of the year. There were about 210 housing units located within the study area of Pretty Lake. Of those units, about 180, or 86 percent, were occupied year around.

Land Use

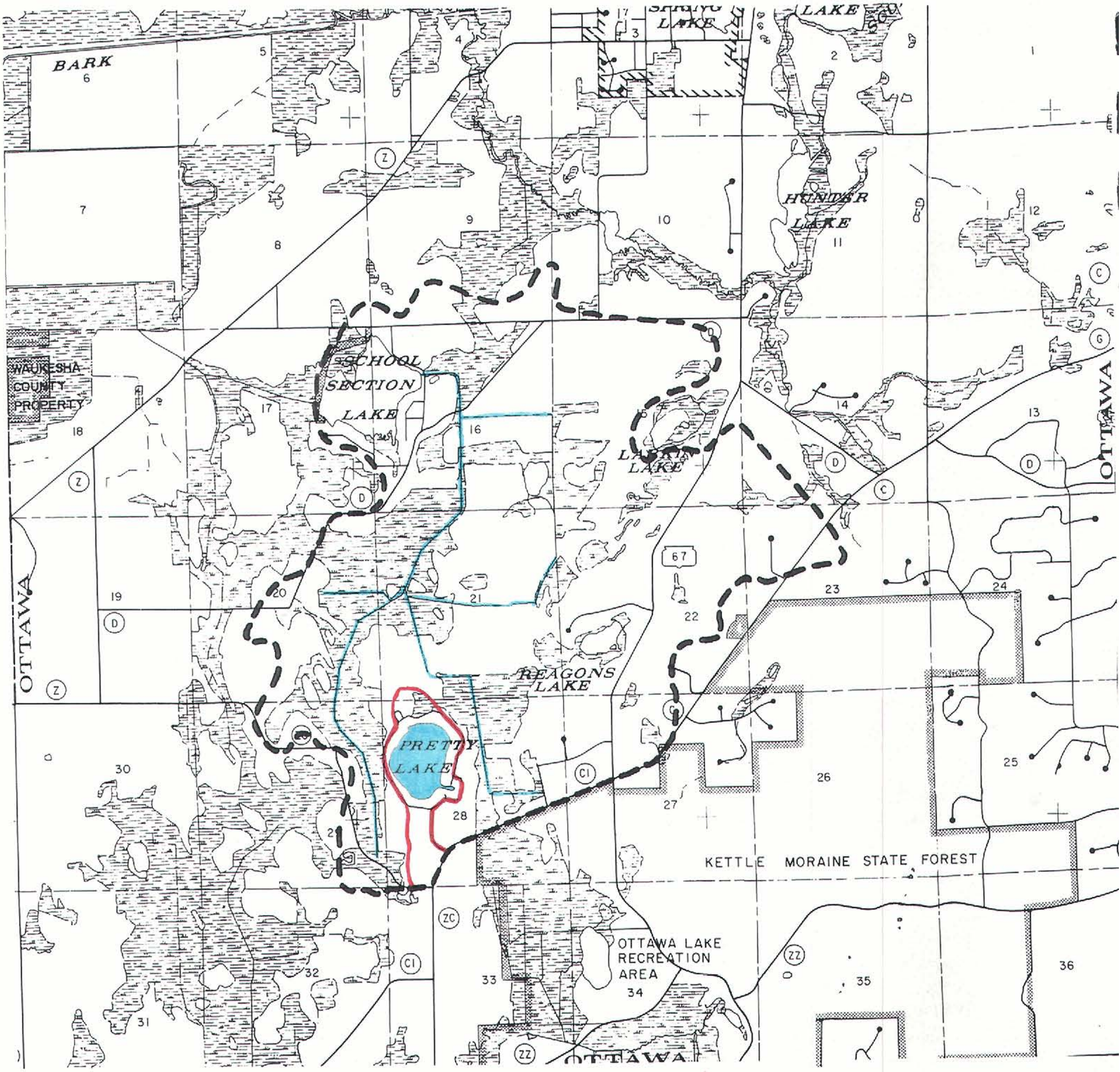
The riparian areas of Pretty Lake are used primarily for urban residential development. As shown on Map 2, the Lake has a total of four public access sites, including three boat launches, and one walk-in access site, and is considered as having adequate public access in terms of the criteria set forth in Chapter NR 1 of the *Wisconsin Administrative Code*.

The existing (1990) land use pattern in the direct drainage area and the study area of Pretty Lake is shown on Map 3 and is quantified in Table 2. About 60 acres, or 36 percent, of the drainage area directly tributary to Pretty Lake, were devoted to urban uses. The dominant urban land use was residential, encompassing about 50 acres, or 85 percent of the area in urban use. About 110 acres, or 64 percent of the Pretty Lake direct drainage area, remain devoted to rural land uses. About 40 acres, or 33 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface water, including the surface area of Pretty Lake, accounted for approximately 70 acres, or 77 percent of the rural land uses (see Map 4).

In the Pretty Lake study area, as of 1990, about 3,410 acres, or 87 percent of the study area, were still devoted to rural land uses, with the dominant rural land use being agricultural, encompassing about 1,570 acres, or 40 percent of the study area. Other rural land uses-woodlands, wetlands, surface water and landfill, comprised about 1,830 acres, or 46 percent, of the study area. Urban lands, consisting of residential, commercial, transportation and communication, and recreational land uses comprised about 500 acres, or 13 percent of the Pretty Lake study area.

Map 1

LOCATION MAP OF PRETTY LAKE



LEGEND

STUDY AREA BOUNDARY

DIRECT DRAINAGE AREA BOUNDARY

GRAPHIC SCALE
0 2000 4000 FEET

Source: SEWRPC.

Under year 2010 conditions, only limited additional conversion of rural land to urban land uses within the study area of Pretty Lake is envisioned in the regional land use plan.[1] The riparian residential areas and access sites may be considered to be largely developed with minimal potential for infilling on a limited number of platted lots. However, infilling of existing platted lots and additional low-density, single-family residential development within the study area and in the vicinity of the Lake was expected to occur.

Table 1

HYDROGRAPHIC CHARACTERISTICS OF PRETTY LAKE

Parameter	Measurement
Surface Area	64 acres
Volume	752 acre-feet
Maximum Depth	35 feet
Mean Depth	12 feet
Direct Drainage Area	173 acres
Study Area	3,906 acres

Source: SEWRPC.

In 1996, the Commission refined and extended the regional land use plan within Waukesha County under a county development plan.[2] Forecast development within the Pretty Lake study area under the recommended plan buildout conditions set forth in the Waukesha County development plan is similar to the recommended land use plan set forth in the regional land use plan (see Map 5).

WATER QUALITY

Based upon water quality investigations completed by the U.S. Geological Survey with Phase I Chapter NR 190 Lake Management Planning Grant funding from 1993 through 1995, Pretty Lake has good to excellent water quality, as shown in Figure 2. The Lake has a Wisconsin Trophic State Index of 46, based upon total phosphorus, indicating the Lake to be a mesotrophic waterbody, which status is supported by data shown in Table 3 and Figure 3.[3] Total phosphorus concentrations in the surface waters of Pretty Lake are equal to or less than the 20 micrograms per liter (μg/l) recommended by the Regional Planning Commission as the level below which nuisance algal and macrophyte growths are unlikely to occur. Wisconsin Trophic State Indices determined on the basis of chlorophyll-a and Secchi-disk transparency values, also shown in Figure 2 and Table 3, are indicative of a clear water lake with little algal growth. These data suggest that Pretty Lake is an oligotrophic to mesotrophic waterbody, or oligo-mesotrophic lake. Oligo-mesotrophic lakes have relatively low fertility and typically support a balanced, but not abundant, aquatic plant community and fishery. Nuisance growths of algae and plants are generally not exhibited by oligo-mesotrophic lakes. Many of the cleanest lakes in Southeastern Wisconsin are classified as oligo-mesotrophic.[4]

Pollutant loads to a lake are generated by various natural processes and human activities that take place in the drainage area tributary to a lake. These loads are transported to the lake through the atmosphere, by stormwater runoff across the land surface and via groundwater, and by way of inflowing streams entering the waterbody. Pollutants transported by the atmosphere are deposited onto the surface of the land as dry fallout and direct precipitation. Pollutants transported across the land surface enter the lake as direct runoff and, indirectly, as groundwater inflows, including drainage from onsite wastewater treatment systems. Pollutants transported by streams enter a lake as surface water

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[1]*SEWRPC Planning Report No. 40,* A Regional Land Use Plan for Southeastern Wisconsin—2010, *January 1992.*

[2]*SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996.*

[3]*R.A. Lillie, 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.*

[4]*See R.A. Lillie and J.W. Mason,* Limnological Characteristics of Wisconsin Lakes, *Wisconsin Department of Natural Resources Technical Bulletin No. 138, 1983; also see SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

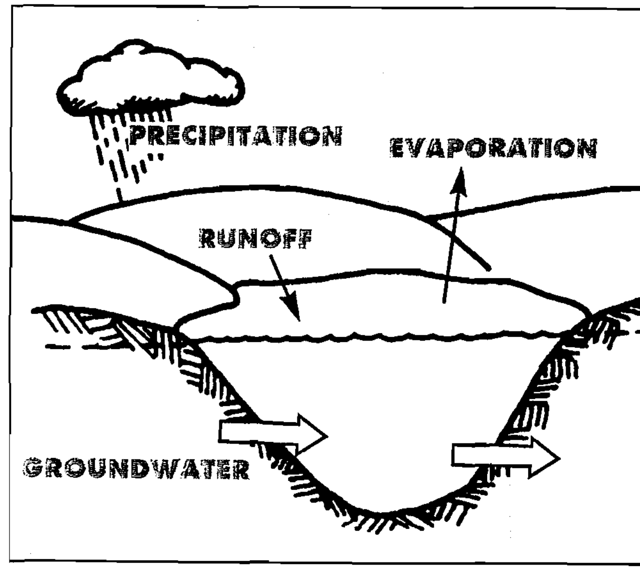
inflows. In groundwater flow-through, or seepage lakes, local septic systems and other groundwater contamination and pollutant loadings transported across the land surface directly tributary to the lake, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities, comprise the principal routes by which contaminants enter a water body.[5] For this reason, the discussion that follows is based upon nonpoint source pollutant loadings to Pretty Lake.

The nonpoint source pollutant loads to Pretty Lake were estimated on the basis of land use inventory data and unit areas loads coefficients determined for Southeastern Wisconsin.[6] Annual contaminant loads entering Pretty Lake were calculated to be approximately 18 tons of sediment, 56 pounds of phosphorus, and one pound and eight pounds of copper and zinc, respectively (see Table 4). Copper and zinc are used in these analyses as surrogate values for metals and other pollutants that are contributed primarily from urban sources.

Table 4 shows the relative percentage contributions of the various land uses to the pollutant loads to Pretty Lake. The data indicate that, based on 1990 land use conditions in the Pretty Lake study area, 57 percent of the phosphorus load to Pretty Lake is contributed from agricultural and open lands within the study area; about 15 percent from woodlands, wetlands, and surface waters; and, about 30 percent from residential areas. In addition, based upon the 1990 population in the drainage area directly tributary to Pretty Lake, a further five pounds of phosphorus, or about 9 percent of the nonpoint source phosphorus load set forth in Table 4, was contributed to the Lake from onsite sewage disposal systems.[7] Approximately 20 percent of the sediment load is generated from urban sources, 45 percent from agricultural and open lands, and about 35 percent from woodlands, wetlands, and surface water sources, as set forth in Table 4.

Figure 1

SEEPAGE LAKE DEFINITION



SEEPAGE LAKE—a natural lake fed by precipitation, limited runoff and groundwater. It does not have a stream outlet.

Source: University of Wisconsin-Extension and SEWRPC.

To validate the estimated contaminant loads to Pretty Lake, Commission staff applied the estimated phosphorus load of 61 pounds, using a Vollenweider-type OECD phosphorus budget model, to the estimation of the annual average in-lake total phosphorus concentration. This calculation resulted in an estimated annual average phosphorus concentration of 14 μg/l, which value is within the range of total phosphorus concentrations measured in Pretty Lake, of 0.007 to 0.017 mg/l. This agreement would suggest that the estimated contaminant loads are a reasonable estimate of the loads entering Pretty Lake, and that other pollutant sources to Pretty Lake, including internal loading as indicated by the higher total phosphorus concentrations and reduced dissolved oxygen concentrations observed in the

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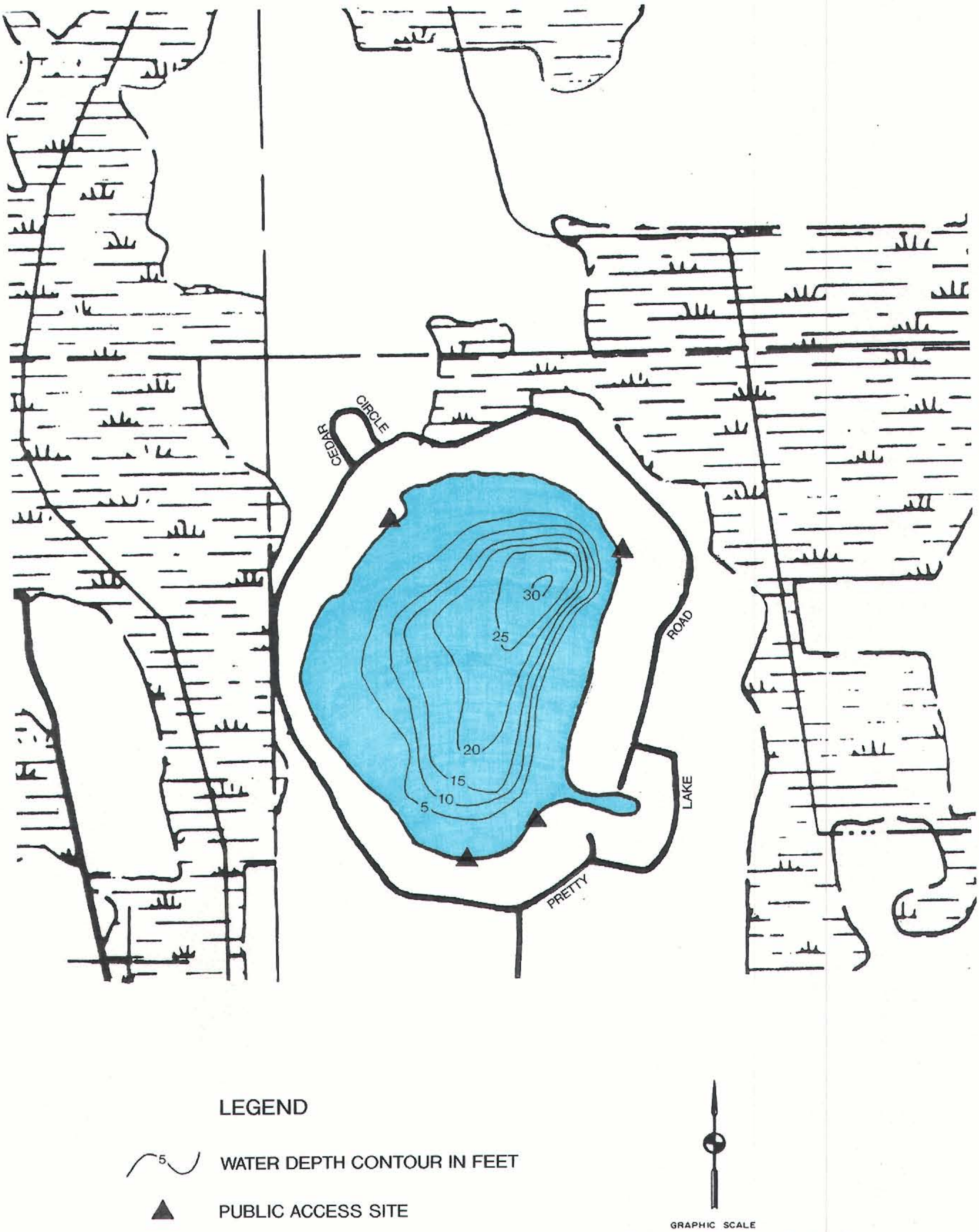
[5]*Sven-Olof Ryding and Walter Rast,* The Control of Eutrophication of Lakes and Reservoirs, *Unesco Man and the Biosphere Series, Volume 1, Parthenon Press, Carnforth, 1989.*

[6]*See SEWRPC Memorandum Report No. 101,* Upper Nemahbin Lake Watershed Inventory Findings, Waukesha County, Wisconsin, *May 1995, for a description of the methodology employed.*

[7]*Onsite sewage disposal system loadings were calculated using the Wisconsin Lake Model Spreadsheet (WILMS) as described in Wisconsin Department of Natural Resources Publication PUBL-WR-363-96 REV,* Wisconsin Lake Model Spreadsheet Version 2.00: User's Manual, *June 1994.*

Map 2

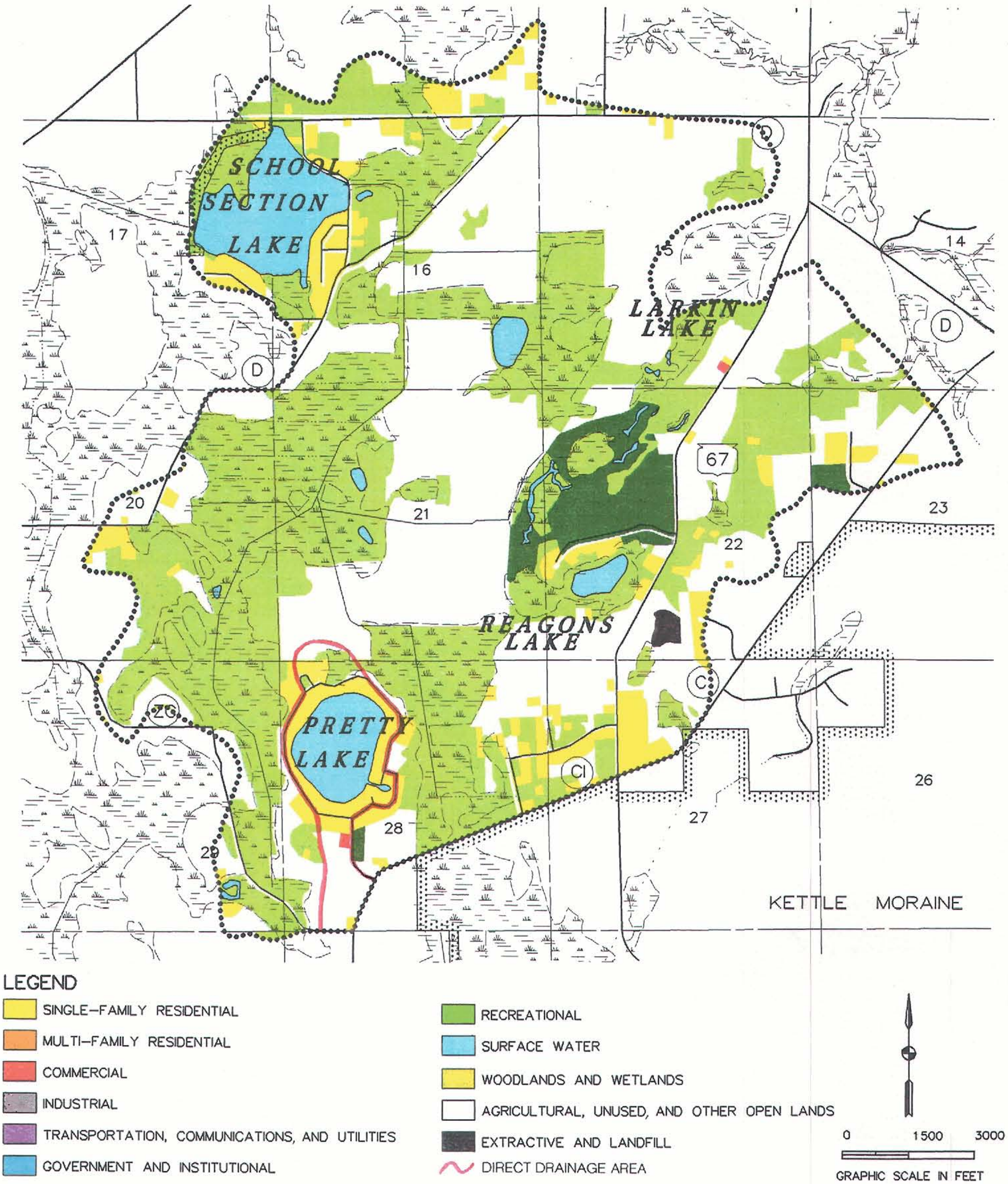
BATHYMETRIC MAP OF PRETTY LAKE



Source: SEWRPC.

Map 3

EXISTING LAND USES WITHIN THE PRETTY LAKE STUDY AREA: 1990



Source: SEWRPC.

Table 2

LAND USE IN THE STUDY AREA TRIBUTARY TO PRETTY LAKE: 1990

Land Use Category	Direct Drainage Area			Study Area		
	Acres	Percent of Category	Percent of Total	Acres	Percent of Category	Percent of Total
Urban						
Residential	53	85	31	285	57	7
Commercial	1	2	<1	2	<1	<1
Transportation Communication and Utilities	8	13	5	84	17	2
Recreational	0	0	0	126	25	3
Subtotal	62	100	36	497	100	13
Rural						
Agricultural	37	33	21	1,574	46	40
Woodlands	3	3	2	580	17	15
Wetlands	7	6	4	1,032	30	26
Water	64	58	37	215	6	5
Extractive and Landfill	0	0	0	8	<1	<1
Subtotal	111	100	64	3,409	100	87
Total	173	- -	100	3,906	- -	100

Source: SEWRPC.

bottom waters of Pretty Lake during summer and winter, shown in Table 3, are relatively small compared to the loading from external sources. Also, the fact that the forecast mean annual phosphorus concentration somewhat exceeds the observed mean annual surface water phosphorus concentration of about 10 μg/l is consistent with the fact that groundwater flows are not an explicit variable within the Vollenweider-OECD-type models. Groundwater flows into groundwater-fed lakes would increase the water load to the Lake and reduce the water residence time, both of which would reduce the in-lake phosphorus concentration predicted by the relationships. Thus, groundwater inflows to the Lake may be moderating the contaminant load to the Lake from surface sources by dilution of the high nutrient content runoff with low nutrient content groundwater.

Of the controllable pollutant sources, the most significant sources under existing land use condition vary with the particular pollutants of concern. Agricultural lands are the principal sources of sediment and phosphorus loads to Pretty Lake, while urban lands generate the largest percentage of metals loadings. Control of contaminants from these various sources can be effected through a variety of measures as set forth in Chapter IV.

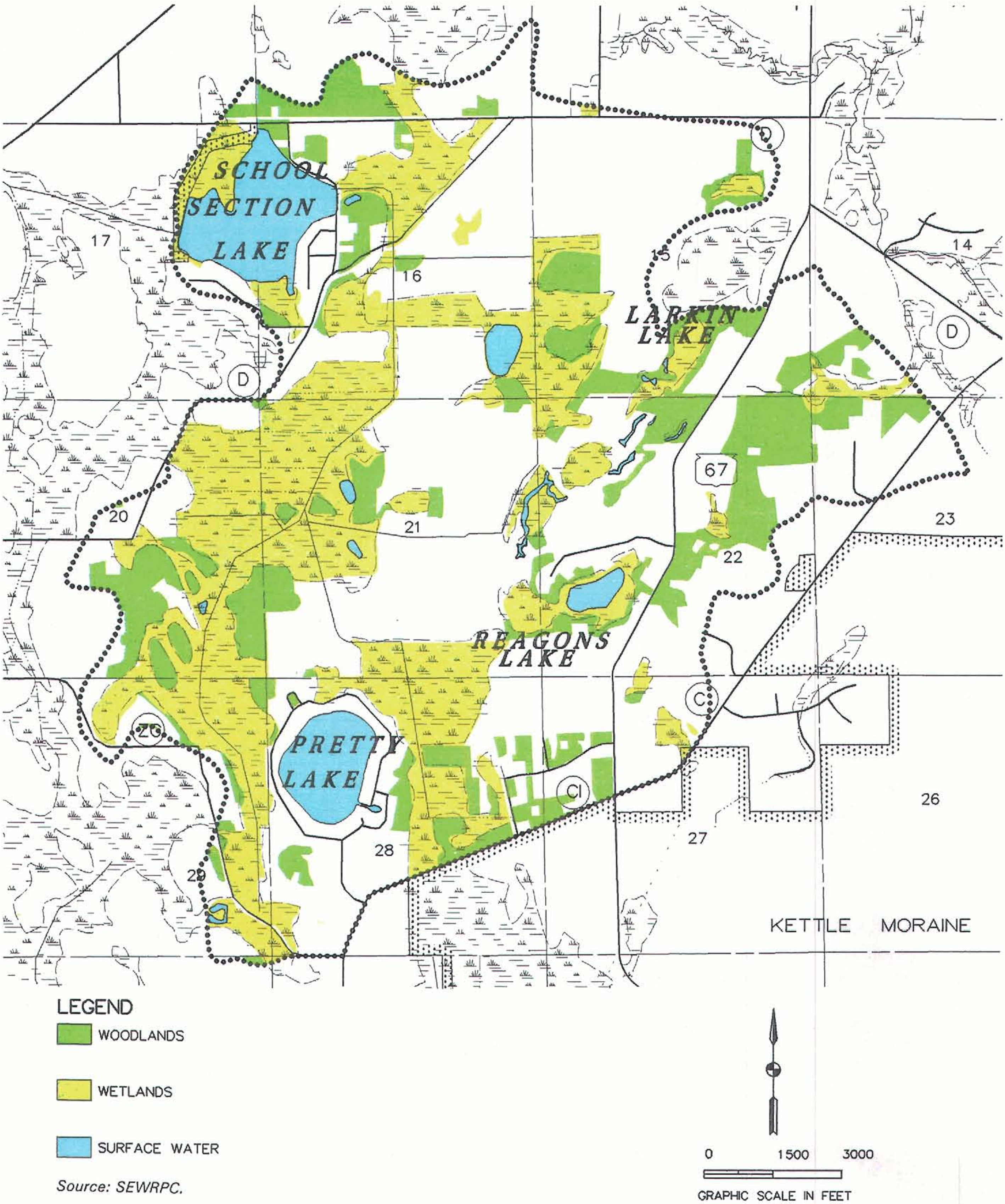
GROUNDWATER RESOURCES

Groundwater resources constitute an extremely valuable element of the natural resource base related to Pretty Lake, both as a source of water supply and as a component of the surface water system. Groundwater in the vicinity of Pretty Lake moves within two distinct systems: a shallow water table system,[8] and a deep sandstone system. The shallow water table system consists of glacial deposits and bedrock near the surface. In some areas, the deep artesian well system is separated from the surface and the water table by a relatively impermeable layer of Maquoketa shale, and includes all bedrock, mostly sandstone, below the Maquoketa shale and above the crystalline Precambrian basement

[8]*The water table is the upper limit of the portion of the ground which is fully saturated with water.*

Map 4

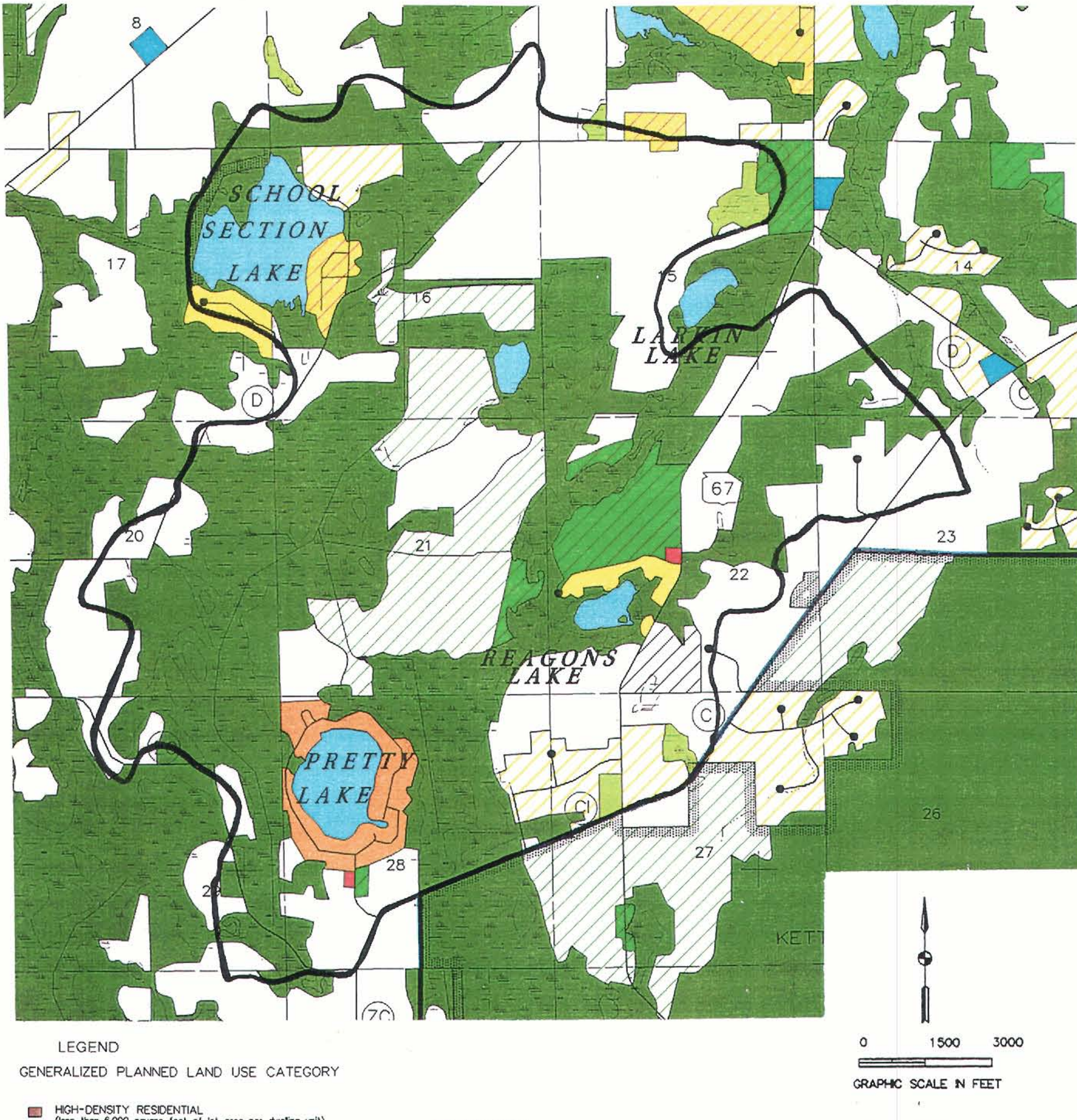
EXISTING WETLANDS WITHIN THE PRETTY LAKE STUDY AREA



Source: SEWRPC.

Map 5

PLANNED LAND USES WITHIN THE PRETTY LAKE STUDY AREA: WAUKESHA COUNTY DEVELOPMENT PLAN



LEGEND

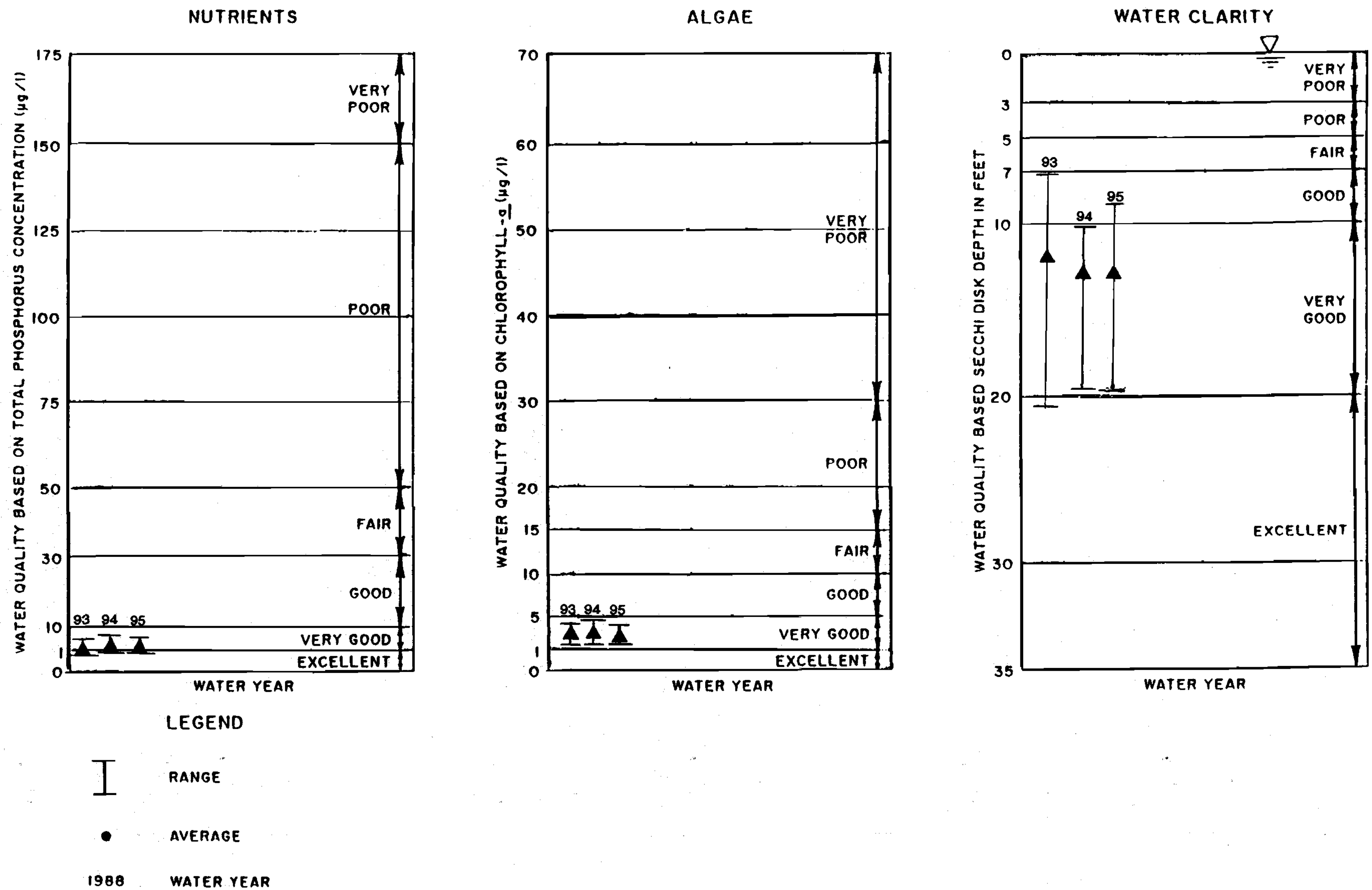
GENERALIZED PLANNED LAND USE CATEGORY

- HIGH-DENSITY RESIDENTIAL (less than 6,000 square feet of lot area per dwelling unit)
- MEDIUM-DENSITY RESIDENTIAL (6,000–19,999 square feet of lot area per dwelling unit)
- LOW-DENSITY RESIDENTIAL (20,000 square feet to 1.4 acres of lot area per dwelling unit)
- SUBURBAN I DENSITY RESIDENTIAL (1.5 to 2.9 acres of lot area per dwelling unit)
- SUBURBAN II DENSITY RESIDENTIAL (3.0 to 4.9 acres of lot area per dwelling unit)
- RURAL-DENSITY RESIDENTIAL AND OTHER AGRICULTURAL LANDS
- COMMERCIAL
- INDUSTRIAL
- GOVERNMENTAL AND INSTITUTIONAL
- RECREATIONAL
- TRANSPORTATION, COMMUNICATION, AND UTILITIES
- EXTRACTIVE
- LANDFILL
- PRIMARY ENVIRONMENTAL CORRIDOR
- SECONDARY ENVIRONMENTAL CORRIDOR
- ISOLATED NATURAL RESOURCE AREA
- OTHER OPEN LANDS TO BE PRESERVED
- PRIME AGRICULTURAL
- WATER
- ADOPTED WISCONSIN DEPARTMENT OF NATURAL RESOURCES PROJECT BOUNDARY

Source: SEWRPC.

Figure 2

PRETTY LAKE PRIMARY WATER QUALITY INDICATORS: 1993-1995



Source: U.S. Geological Survey and SEWRPC.

Table 3

SEASONAL WATER QUALITY DATA FOR PRETTY LAKE: 1993-1995

Water Quality Parameter	Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
Water Temperature (°F)						
Range	35.5-40.3	41.0-42.0	44.5-47.0	47.0	71.6-81.5	53.0-62.0
Mean	38.0 (3)	41.1 (3)	46.5 (3)	47.0 (3)	76.0 (9)	58.0 (9)
Dissolved Oxygen (mg/l)						
Range	12.2-16.2	0.5-1.5	10.9-12.1	10.4-12.0	6.8-10.2	0-0.5
Mean	14.1 (3)	1.1 (3)	11.6 (3)	11.3 (3)	9.0 (9)	0.1 (9)
Specific Conductivity (μS/cm at 25°C)						
Range	365-393	425-444	355-384	356-381	322-365	382-456
Mean	379 (3)	433 (3)	366 (3)	365 (3)	339 (9)	419 (9)
Alkalinity (mg/l)						
Range	- -	- -	150-170	150-170	- -	- -
Mean	- -	- -	160 (3)	160 (3)	- -	- -
pH (standard units)						
Range	8.3-8.6	7.5-7.7	7.0-8.4	8.4	8.2-8.7	7.1-7.4
Mean	8.4 (3)	7.6 (3)	7.9 (3)	8.4 (3)	8.5 (9)	7.3 (9)
Secchi-Disk (feet)						
Range	- -	- -	16.4-20.6	- -	7.2-18.4	- -
Mean	- -	- -	18.9 (3)	- -	10.7 (9)	- -
Turbidity (Nephelometric turbidity units)						
Range	- -	- -	0.5-15.0	0.5-10.0	- -	- -
Mean	- -	- -	5.3 (3)	3.7 (3)	- -	- -
Nitrate Nitrogen (mg/l)						
Range	- -	- -	0.04-0.07	0.03-0.08	- -	- -
Mean	- -	- -	0.06 (3)	0.06 (3)	- -	- -
Total Ammonia (mg/l)						
Range	- -	- -	0.07-0.28	0.07-0.28	- -	- -
Mean	- -	- -	0.15 (3)	0.16 (3)	- -	- -
Organic Nitrogen (mg/l)						
Range	- -	- -	0.12-0.63	0.12-0.43	- -	- -
Mean	- -	- -	0.34 (3)	0.28 (3)	- -	- -
Total Nitrogen, as N (mg/l)						
Range	- -	- -	0.57-0.94	0.57-1.00	- -	- -
Mean	- -	- -	0.76 (3)	0.71 (3)	- -	- -
Total Phosphorus, as P (mg/l)						
Range	- -	- -	0.007-0.011	0.008-0.015	0.009-0.017	0.020-0.093
Mean	- -	- -	0.009 (3)	0.012 (3)	0.012 (9)	0.044 (9)
Ortho-Phosphorus, as PO_4P (mg/l)						
Range	- -	- -	<0.002-0.002	<0.002-0.002	- -	- -
Mean	- -	- -	<0.002 (3)	<0.002 (3)	- -	- -
Calcium, as Ca (mg/l)						
Range	- -	- -	28-32	28-32	- -	- -
Mean	- -	- -	30 (3)	30 (3)	- -	- -
Magnesium, as Mg (mg/l)						
Range	- -	- -	24-32	24-32	- -	- -
Mean	- -	- -	25 (3)	25 (3)	- -	- -
Sodium, as Na (mg/l)						
Range	- -	- -	8.0-8.6	8.0-8.7	- -	- -
Mean	- -	- -	8.3 (3)	8.3 (3)	- -	- -

Table 3 (continued)

Water Quality Parameter	Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
Potassium, as K (mg/l)						
Range	- -	- -	1.0-2.0	1.0-2.0	- -	- -
Mean	- -	- -	1.6 (3)	1.6 (3)	- -	- -
Sulfate, as SO_4 (mg/l)						
Range	- -	- -	16-17	16-17	- -	- -
Mean	- -	- -	16 (3)	16 (3)	- -	- -
Chloride (mg/l)						
Range	- -	- -	14-15	14-15	- -	- -
Mean	- -	- -	15 (3)	14 (3)	- -	- -
Chlorophyll-a						
Range	- -	- -	1.3-2.1	- -	1.2-4.0	- -
Mean	- -	- -	1.6 (3)	- -	2.9 (9)	- -
Iron, as Fe (µg/l)						
Range	- -	- -	<50[a]	<50[a]	- -	- -
Mean	- -	- -			- -	- -

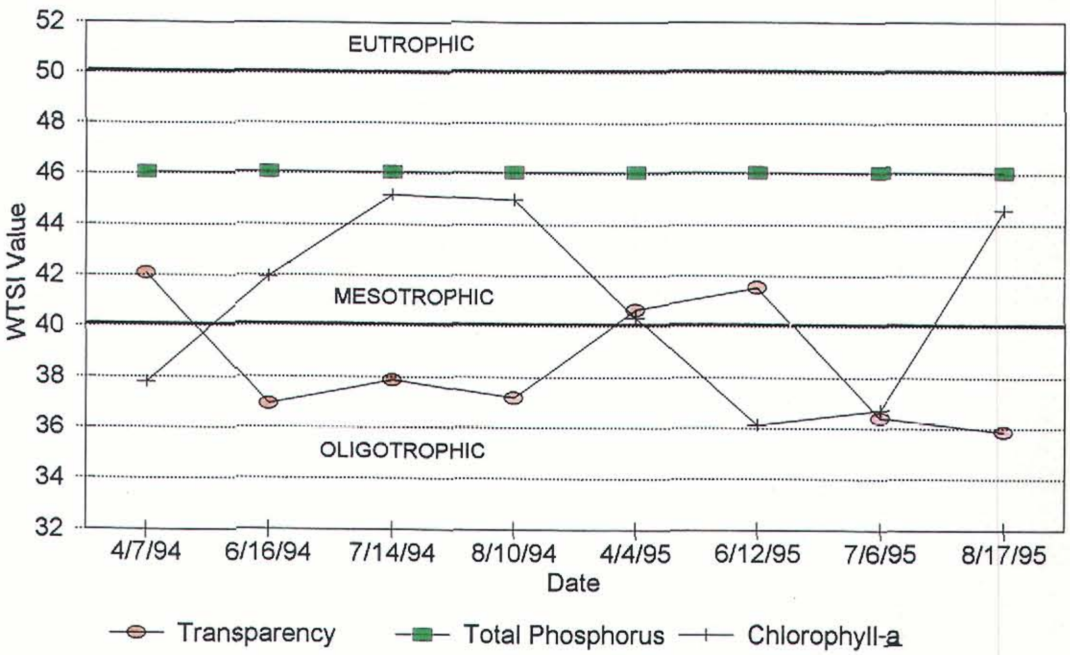
NOTE: Number in parentheses represents number of samples.

[a]*Less than 50 (µg/l) falls below detection limits*

Source: U.S. Geological Survey and SEWRPC.

Figure 3

WISCONSIN TROPHIC STATUS INDICES FOR PRETTY LAKE: 1994-1995



Source: U.S. Geological Survey and SEWRPC.

Table 4

FORECAST ANNUAL POLLUTANT LOADINGS TO PRETTY LAKE BY LAND USE CATEGORY: 1990

Land Use Category	Pollutant Loads							
	Sediment (tons)	Percent	Phosphorus (pounds)	Percent	Copper (pounds)	Percent	Zinc (pounds)	Percent
Urban								
Residential	3	17	14	25	1	82	7	87
Commercial	<1	3	1	2	<1	18	1	13
Communications and Utilities	<1	2	1	2	0	0	0	0
Governmental and Institutional	0	0	0	0	0	0	0	0
Recreational	0	0	0	0	0	0	0	0
Subtotal	4	22	16	29	1	100	8	100
Rural								
Agricultural	8	44	32	57	0	0	0	0
Open Lands	0	0	0	0	0	0	0	0
Surface Water	6	33	8	14	0	0	0	0
Wetlands	<1	<1	<1	<1	0	0	0	0
Woodlands	<1	<1	<1	<1	0	0	0	0
Subtotal	14	78	40	71	0	0	0	0
Total	18	100	56	100	1	100	8	100

Source: SEWRPC.

rocks. In the area north and west of Pretty Lake, the sandstone is overlain directly by glacial deposits with no complete, confining layer of shale or dolomite, as shown on Map 6 and in Figure 4.

Groundwater is available from three aquifers.[9] From the land surface downward, they are the sand and gravel glacial drift aquifer, part of the shallow system; the Niagara aquifer, also part of the shallow system; and, the sandstone aquifer, comprising the deep artesian system. The glacial drift aquifer, consisting of water-bearing sand and gravel, is relatively thin, less than 200 feet in thickness, in the vicinity of Pretty Lake. The Niagra aquifer thickness is also less than 100 feet of thickness and is absent in some areas in the vicinity of Pretty Lake. The deep sandstone aquifer ranges from 800 to 1,200 feet in thickness in the vicinity of Pretty Lake. The shallow sand and gravel aquifer is the most significant in terms of its relationship with Pretty Lake and its tributary surface waters and adjacent wetlands.

Groundwater movements into and out of Pretty Lake were simulated by the U.S. Geological Survey using the GFLOW groundwater flow model,[10] a more detailed description of which is set forth in Appendix A. This analytic element model uses an hierarchy of arithmetic operations to represent the influence of aquifer features, such as horizontal hydraulic conductivity, recharge rate, and head dependent fluxes, on the movement and behavior of groundwater within a coupled groundwater-lake system. The analytic elements assume a single-layer aquifer of infinite extent, while the model boundaries consist of readily identifiable topographic features, as shown on Figure 5. Model output is a two-dimensional representation of the movement of groundwater under steady state conditions. Steady state conditions may

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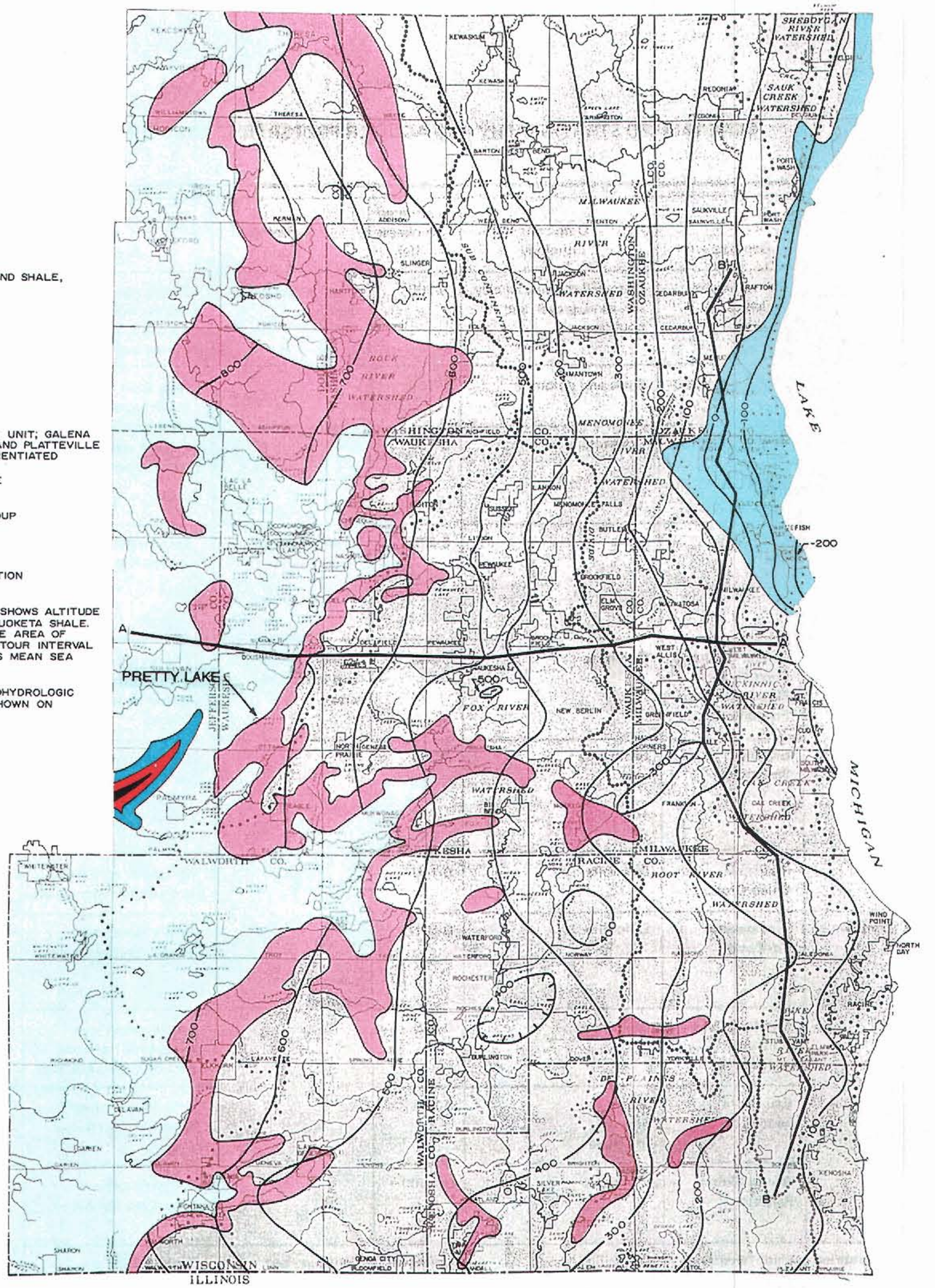
[9]*An aquifer is a water-bearing stratum of rock, sand, or gravel.*

[10]*Haitjema Software, LLC,* GFLOW Analytical Element Groundwater Flow Modeling User's Manual Version 1.0, *July 1994.*

Map 6

BEDROCK GEOLOGY AND STRUCTURE CONTOURS ON THE BASE OF THE MAQUOKETA SHALE



LEGEND

DEVONIAN

DEVONIAN DOLOMITE AND SHALE, UNDIFFERENTIATED

SILURIAN

SILURIAN DOLOMITE, UNDIFFERENTIATED

ORDOVICIAN

MAQUOKETA SHALE

GALENA-PLATTEVILLE UNIT; GALENA DOLOMITE, DECORAH AND PLATTEVILLE FORMATIONS, UNDIFFERENTIATED

ST. PETER SANDSTONE

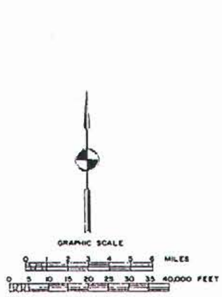
PRAIRIE DU CHIEN GROUP

CAMBRIAN

TREMPEALEAU FORMATION

—400— STRUCTURE CONTOUR SHOWS ALTITUDE OF BASE OF THE MAQUOKETA SHALE. HACHURED TO INDICATE AREA OF LOWER ALTITUDE. CONTOUR INTERVAL IS 100 FEET. DATUM IS MEAN SEA LEVEL.

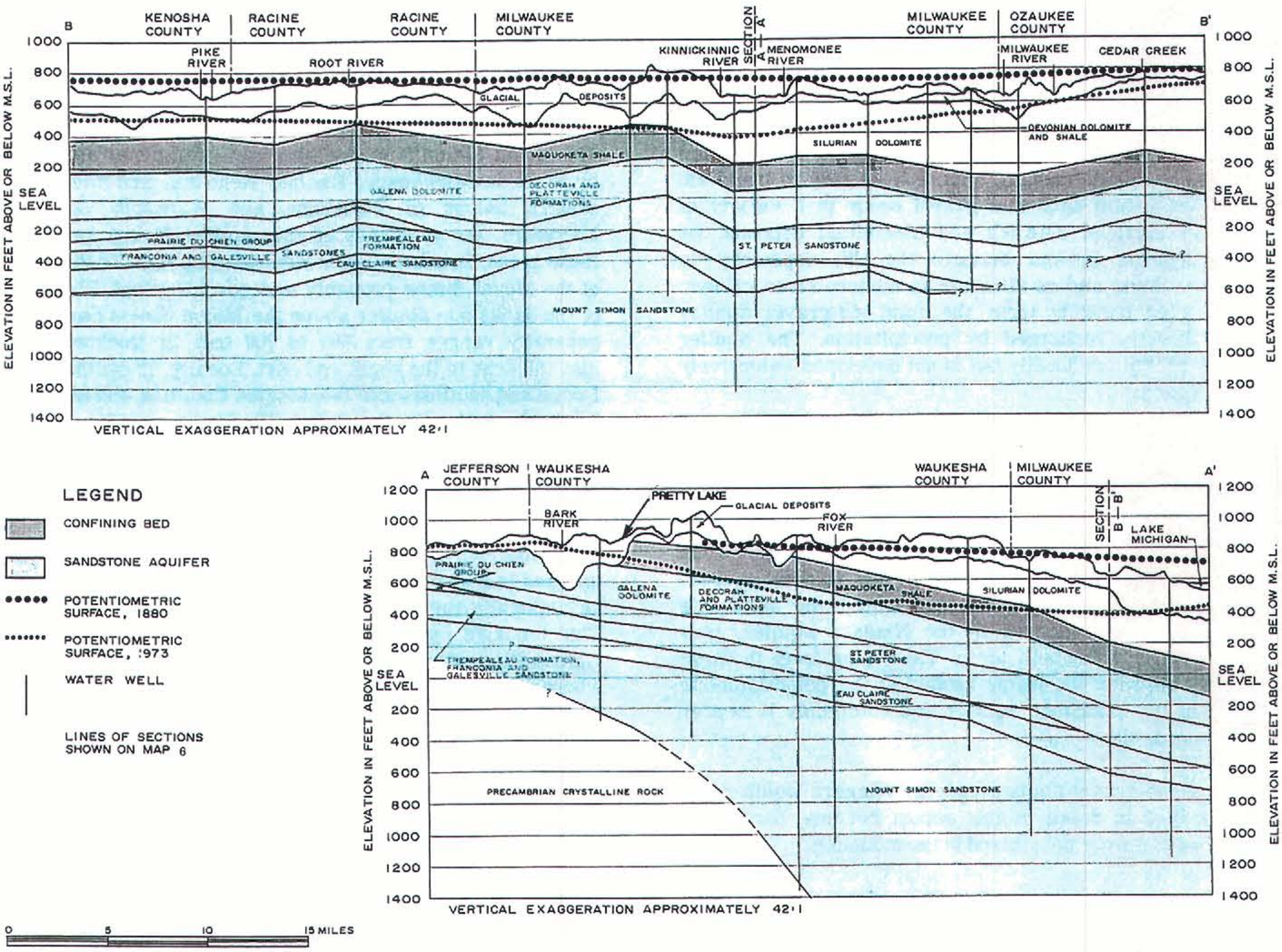
A——A' DENOTES LINE OF GEOHYDROLOGIC SECTION. SECTIONS SHOWN ON FIGURE 4



Source: U.S. Geological Survey.

Figure 4

GEOHYDROLOGIC SECTION THROUGH SOUTHEASTERN WISCONSIN



Source: U.S. Geological Survey.

be viewed as representing the long-term average condition of the aquifer-lake system. In addition, GFLOW incorporates a particle tracking submodel that provides for the simulation of the movement of groundwater, and groundwater-borne contaminants, through the coupled aquifer-lake system. This submodel has specific application in the delineation of the groundwatershed of Pretty Lake.

Based on the groundwater modeling and particle track analysis, summarized in Figure 5, the groundwater flow from the area to the south and the west of Pretty Lake has the most direct impact on lake water quality and quantity.[11] In particular, the removal of about 18 inches of accumulated sediment from the drainage ditch located to the west of Pretty Lake could result in a decrease in lake level of up to one foot. This is in contrast to the ditches located to the

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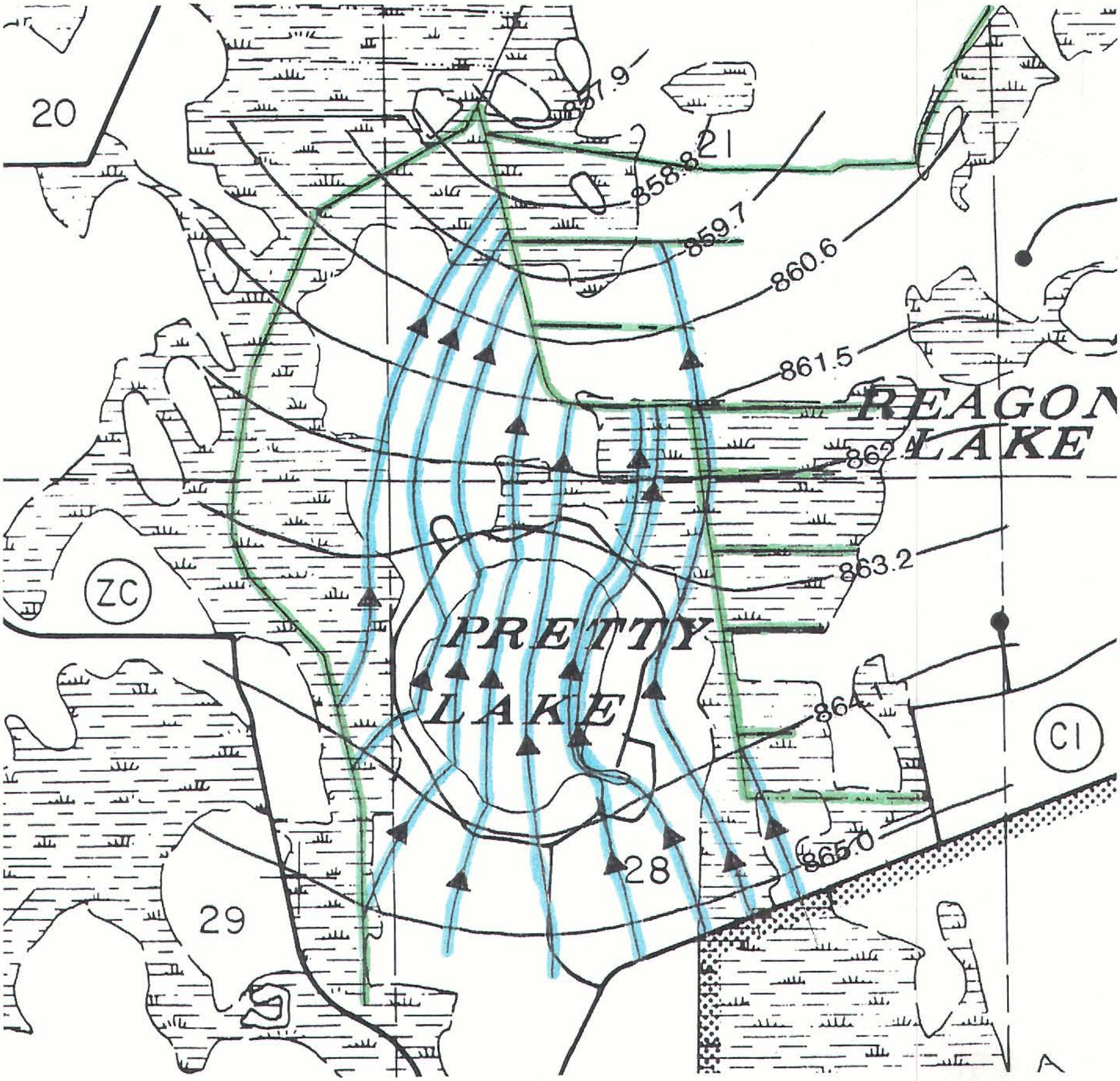
[11] *Randy J. Hunt and James T. Krohelski, "The Application of an Analytic Element Model to Investigate Groundwater-Lake Interactions at Pretty Lake, Wisconsin,"* Journal of Lake and Reservoir Management, *Volume 12 (4), pages 487-495, 1996.*

Figure 5

DIRECTION OF GROUNDWATER FLOW IN THE PRETTY LAKE AREA
AS REPRESENTED IN THE GFLOW MODELING PROGRAM

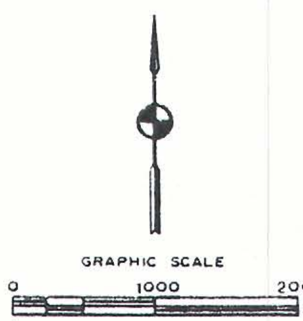


LEGEND

DRAINAGE DITCH

GROUNDWATER FLOW DIRECTION

—860.6— CONTOUR IN FEET



Source: U.S. Geological Survey and SEWRPC.

east of Pretty Lake, which were determined to have little sustained impact on the water level of Pretty Lake. Thus, protection of the lands to the south and west of the Lake should be viewed as a priority action for the protection of water quantity and quality in Pretty Lake.

SOIL TYPES AND CONDITIONS

Soil type, land slope, and land use management practices are among the more important factors determining lake water quality conditions. Soil type, land slope, and vegetative cover are also important factors affecting the rate, amount, and quality of stormwater runoff. The soil texture and soil particle structure influence the permeability, infiltration rate, and erodibility of soils. Land slopes are also important determinants of stormwater runoff rates and of susceptibility of erosion.

The U.S. Natural Resources Conservation Service, under contract to the Southeastern Wisconsin Regional Planning Commission, completed a detailed soil survey of the Pretty Lake area in 1966.[12] Using the regional soil survey, an assessment was made of the hydrologic characteristics of the soils in the Pretty Lake study area. Soils within the study area of Pretty Lake were categorized into four main hydrologic soil groups, as well as an "other" category, as indicated on Map 7. Approximately one-half of the study area is covered by moderately drained soils, and about 40 percent of the study area by very poorly drained soils, with the remaining areas being mainly surface water.

The regional soil survey also contained interpretations of planning and engineering applications. The suitability of the soils for urban residential development was assessed using three common development scenarios: development with conventional onsite sewage disposal systems; development with alternative onsite sewage disposal systems; and development with public sanitary sewers. At present all residential lands in the study area of Pretty Lake are served by private onsite sewage disposal systems. The soil suitability interpretations for the use of such systems were updated by the Regional Planning Commission based upon the soil characteristics provided by the detailed soil surveys and the field experience of County and State technicians responsible for overseeing the location and design of such systems. The classifications reflect the current soil site specification set forth in Chapter Comm 83 (formerly ILHR 83) of the *Wisconsin Administrative Code*, as shown on Map 8, about 30 percent of the Pretty Lake study area is covered by soils considered suitable for onsite sewage disposal using conventional onsite sewage disposal systems. About 50 percent of the study area is covered by soils unsuitable for such systems. The remainder of the study area has been classified as having undetermined suitability for conventional onsite sewage disposal systems—about 16 percent of the area—or consisting of surface waters—about 5 percent. Considering the use of alternative onsite wastewater treatment methods, as shown on Map 9, such as mound systems, does not appreciable change these determinations. About one-half of the study area has soils unsuited to residential development even with public sanitary sewer service (see Map 10).

AQUATIC PLANTS, DISTRIBUTION, AND MANAGEMENT AREAS

A survey of aquatic plant species within the lake basin was conducted by Wisconsin Department of Natural Resources (DNR) staff in 1982 as part of the DNR feasibility study.[13] That study was updated by a field reconnaissance conducted by the Commission staff in September of 1997. The results of these surveys, in addition to a tabulation of the ecological significance of the plants determined to be present in the Lake, are presented in Table 5, and graphically depicted on Map 11.

The flora of the main lake basin was found to be relatively impoverished compared with that of the surrounding wetlands and shoreland edges of the Lake. The flora of the lake basin was dominated by muskgrass, *Chara vulgaris*, which posed little problem for most recreational uses of the waterbody. Other plant species present were bushy pondweed, Sago pondweed, whitestem pondweed, and eel grass. In addition to those species, Elodea was reported

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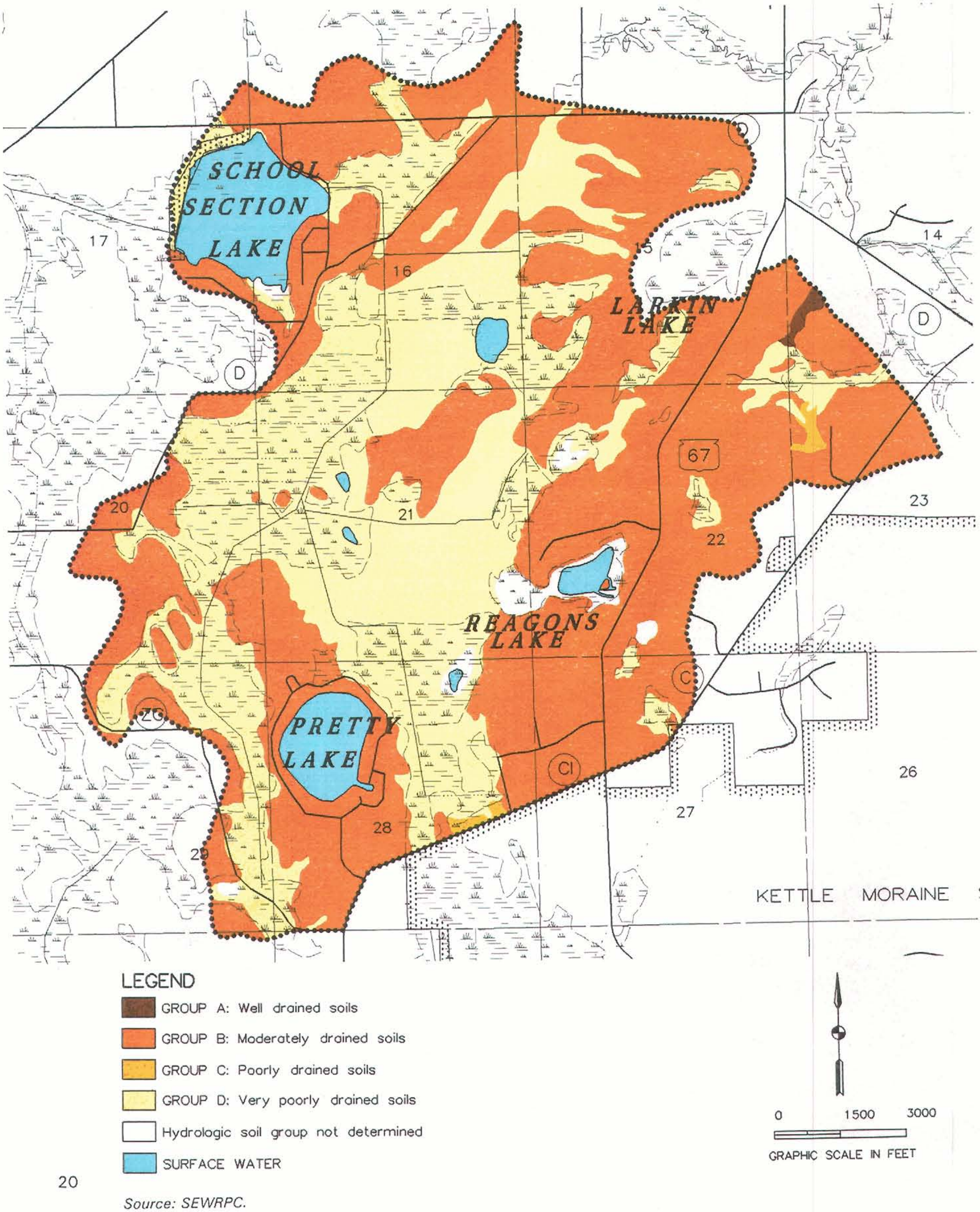
[12]*SEWRPC Planning Report No. 8,* Soils of Southeastern Wisconsin, *June 1966.*

[13]*Wisconsin Department of Natural Resources,* Pretty Lake Waukesha County Feasibility Study Results; Management Alternatives, *1982.*

Map 7

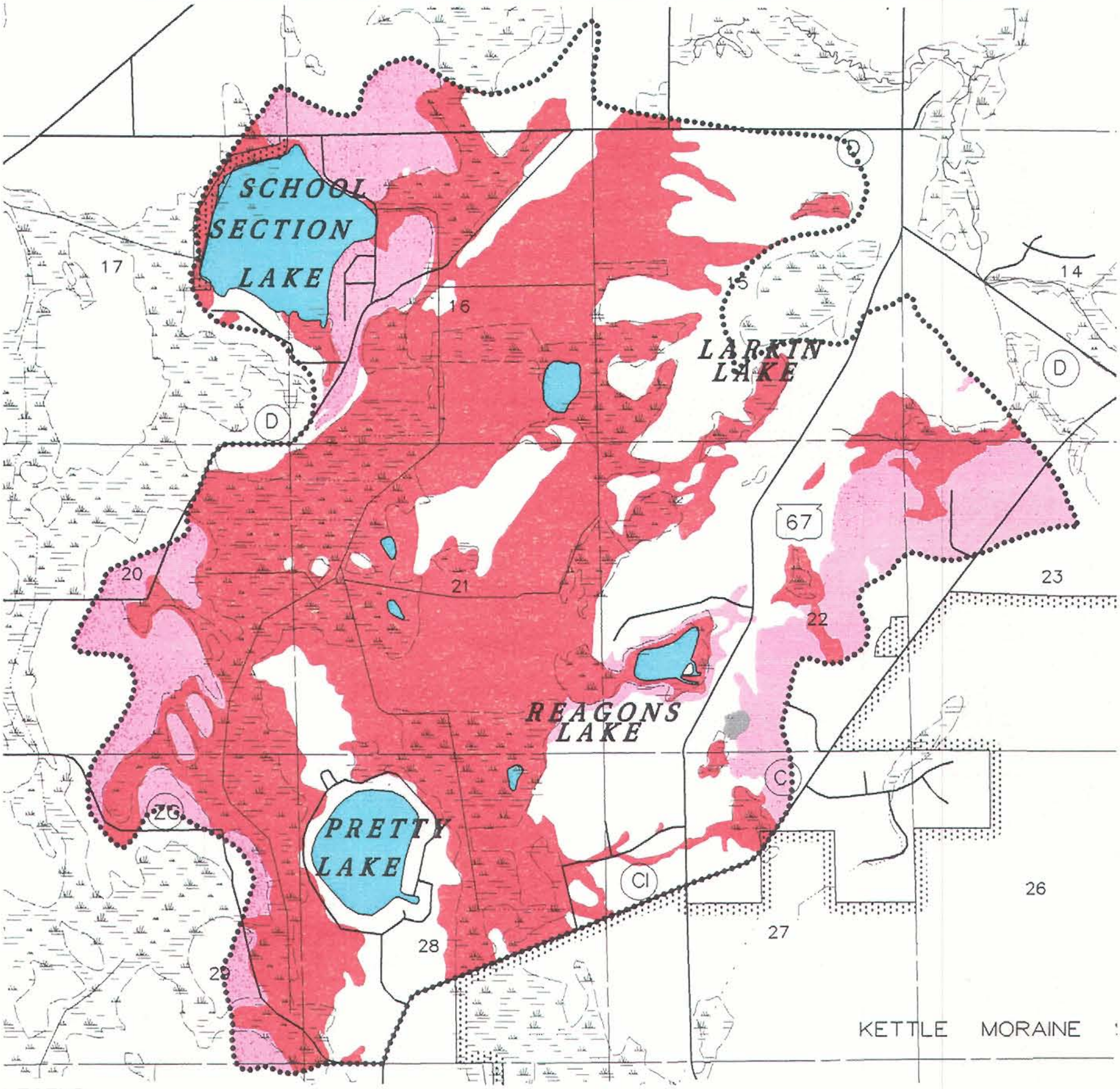
HYDROLOGIC SOIL GROUPS WITHIN THE PRETTY LAKE STUDY AREA



Source: SEWRPC.

Map 8

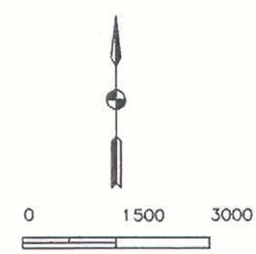
SUITABILITY OF SOILS WITHIN THE PRETTY LAKE STUDY AREA FOR CONVENTIONAL ONSITE SEWAGE DISPOSAL SYSTEMS UNDER CURRENT ADMINISTRATIVE RULES: FEBRUARY 1991



LEGEND

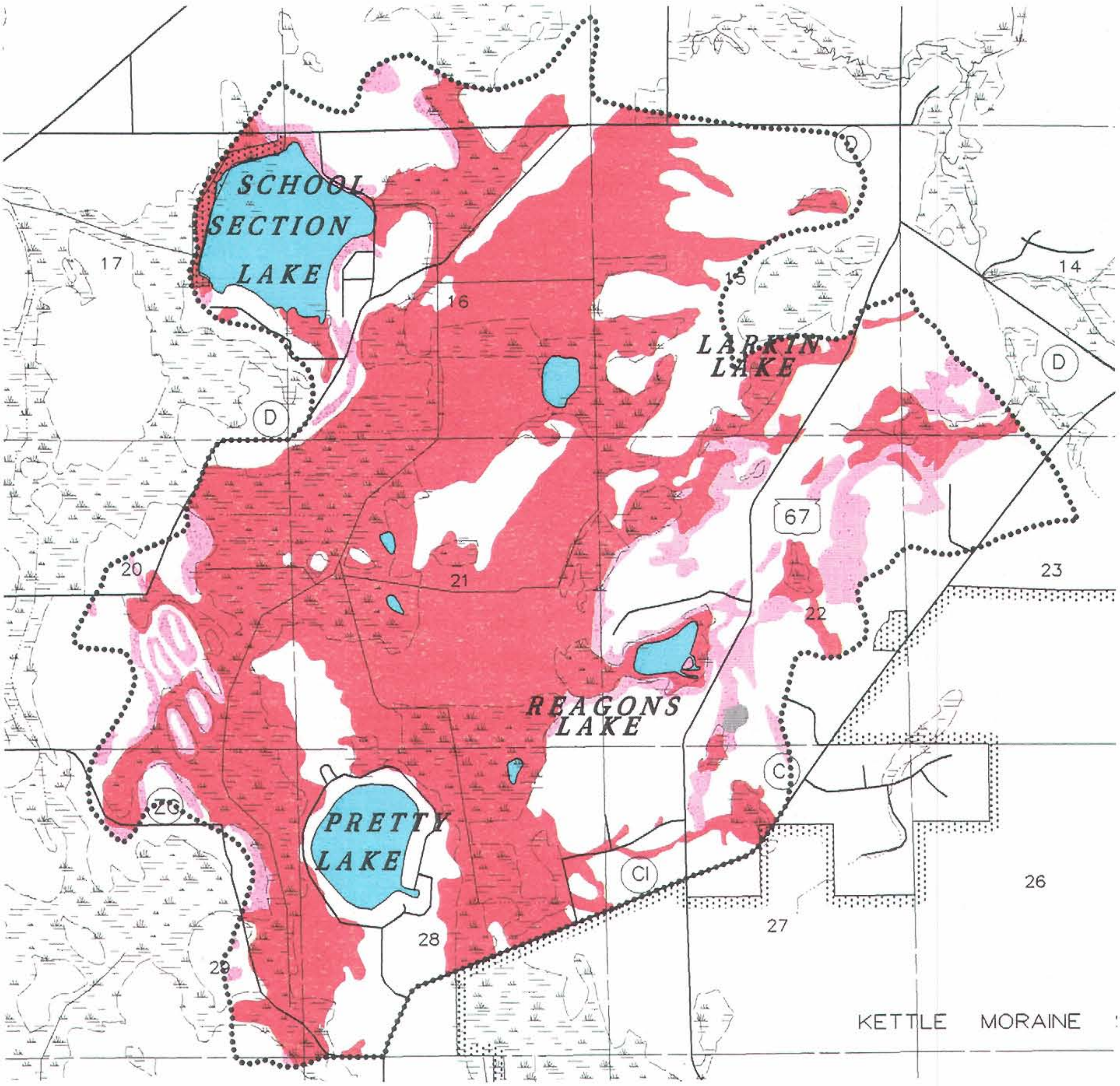
- UNSUITABLE: Areas covered by soils which have a high probability of not meeting the criteria of Chapter ILHR 83 of the Wisconsin Administrative Code governing conventional onsite sewage disposal systems.
- UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the criteria of Chapter ILHR 83 of Wisconsin Administrative Code governing conventional onsite sewage disposal systems so that no classification can be assigned.
- SUITABLE: Areas covered by soils having a high probability of meeting the criteria of Chapter ILHR 83 of the Wisconsin Administrative Code governing conventional onsite sewage disposal systems.
- OTHER: Areas consisting for the most part of disturbed land for which no interpretive data are available.
- SURFACE WATER

Source: SEWRPC.



Map 9

SUITABILITY OF SOILS WITHIN THE PRETTY LAKE STUDY AREA FOR MOUND SEWAGE DISPOSAL SYSTEMS UNDER CURRENT ADMINISTRATIVE RULES: FEBRUARY 1991



LEGEND

UNSUITABLE: Areas covered by soils which have a high probability of not meeting the criteria of Chapter ILHR 83 of the Wisconsin Administrative Code governing mound sewage disposal systems.

UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the criteria of Chapter ILHR 83 of the Wisconsin Administrative Code governing mound sewage disposal systems so that no classification can be assigned.

SUITABLE: Areas covered by soils having a high probability of meeting the criteria of Chapter ILHR 83 of the Wisconsin Administrative Code governing mound sewage disposal systems.

OTHER: Areas consisting for the most part of disturbed land for which no interpretive data are available.

SURFACE WATER

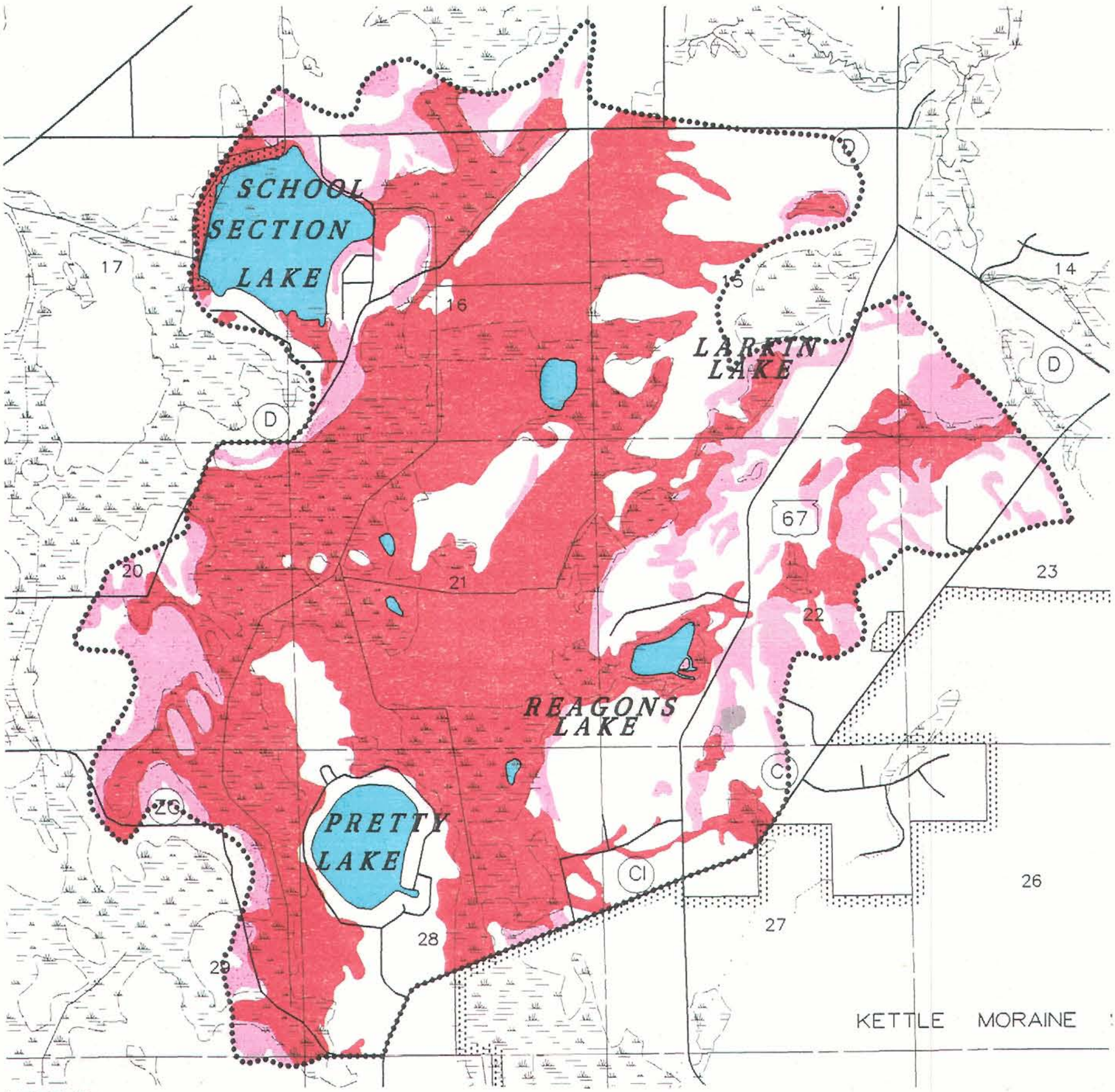
0 1300 2600

GRAPHIC SCALE IN FEET

Source: SEWRPC.

Map 10

SUITABILITY OF SOILS WITHIN THE PRETTY LAKE STUDY AREA FOR RESIDENTIAL DEVELOPMENT WITH PUBLIC SANITARY SEWER



LEGEND

Areas covered by soils which have SEVERE limitations for residential development with public sanitary sewer service.

Areas covered by soils having MODERATE limitations for residential development with public sanitary sewer service.

Areas covered by soils having SLIGHT limitations for residential development with public sanitary sewer service.

UNCLASSIFIED SOILS

SURFACE WATER

0 1500 3000

GRAPHIC SCALE IN FEET

Source: SEWRPC.

Table 5

COMMON AQUATIC PLANT SPECIES PRESENT IN SOUTHEASTERN WISCONSIN AND THEIR ECOLOGICAL SIGNIFICANCE

Aquatic Plant Species Present	Ecological Significance[a]
Chara vulgaris (chara or muskgrass)	Excellent producer of fish food, especially for young trout, bluegills, small and largemouth bass; stabilizes bottom sediments; and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis (waterweed)	Provides shelter and support for insects valuable as fish food
Myriophyllum spicatum (Eurasian water milfoil)	None known
Myriophyllum sp. (native milfoils)	Provides shelter and is a valuable food producer supporting many insects eaten by fish; fruits eaten by many wildfowl, a few eat foliage; sparingly eaten by muskrats and moose
Najas flexilis (bushy pondweed or slender naiad)	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Najas marina (spiney naiad)	Provides shelter and is a good food producer for fish; stems, foliage, and seeds important for ducks
Potamogeton amplifolius (large-leaved pondweed)	Provides support for insects and produces good food supply for fish and ducks
Potamogeton illinoensis (Illinois pondweed)	Provides some food for ducks and shelter for fish
Potamogeton nodosus (long-leaved pondweed)	Provides support for insects eaten by fish, sometimes important for wildfowl
Potamogeton pectinatus (sago pondweed)	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton praelongus (whitestem pondweed)	Provides feeding grounds for muskellunge; also good food producers for trout; good food producer for ducks
Potamogeton zosteriformis (flat-stemmed pondweed)	Provides some food for ducks
Vallisneria americana (eel grass or water celery)	Provides good shade and shelter, supports insects, and is valuable fish food

[a]*Information obtained from A Manual of Aquatic Plants, by Norman C. Fassett and Guide to Wisconsin Aquatic Plants, Wisconsin Department of Natural Resources.*

Source: SEWRPC.

during the 1982 survey, but not recorded during the 1997 field inspection, and spiney naiad, Illinois pondweed, flatstem pondweed, large-leaved pondweed and long-leaved pondweed were recorded during the 1997 field visit, but not reported in 1982. Both northern milfoil and Eurasian water milfoil, *Myriophyllum spicatum*, were documented as being present in the Lake, although not widespread. Eurasian water milfoil, one of the eight milfoil species found in Wisconsin, is an exotic, or nonnative species, known to have an incredible ability to regenerate. This exotic species often out competes the native aquatic vegetation of lakes in Southeastern Wisconsin, reduces the biodiversity of the lakes, and degrades the quality of fish and wildlife habitats.[14] While the distribution of this plant should be monitored

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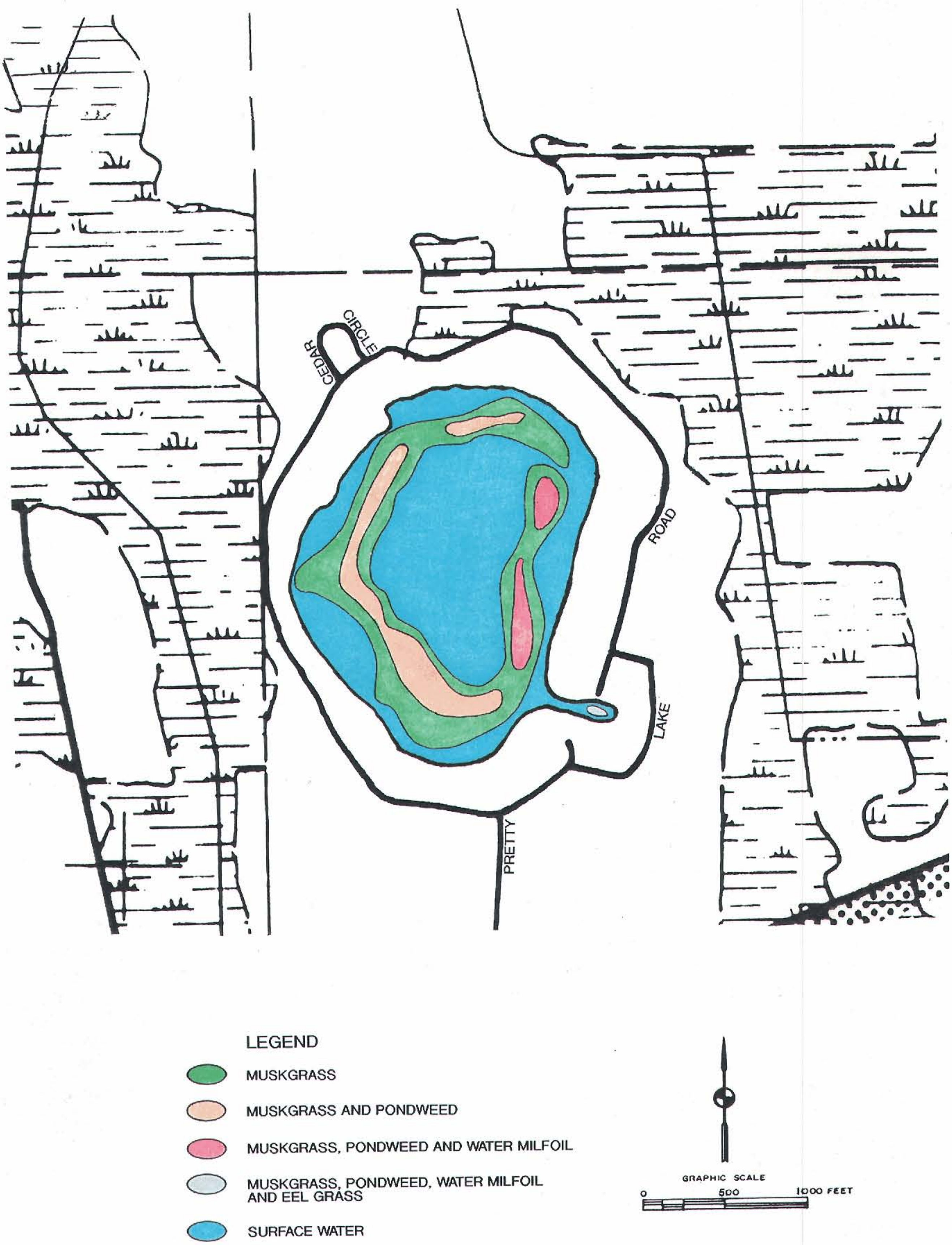
[14]*Wisconsin Department of Natural Resources,* Eurasian Water Milfoil in Wisconsin: A Report to the Legislature, *1993.*

Map 11

MACROPHYTE DISTRIBUTION IN PRETTY LAKE: 1982 AND 1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

as part of the proposed aquatic plant monitoring program under the Wisconsin Department of Natural Resources Self-Help Monitoring Program, the plant community at Pretty Lake, though somewhat sparse, appeared to be diverse and healthy, with diversity increasing since the 1982 survey conducted by the Wisconsin Department of Natural Resources. Representative illustrations of the major aquatic plant species found in the aquatic plant surveys are included in Appendix B.

Commission staff conducted surveys of the wetlands north of Pretty Lake during 1988 and in the spring of 1995. The wetland plant species identified during these vegetation surveys are set forth in the species lists in Appendix C. Commission staff concluded that the entire area had been subject to prior disturbances, including ditching, clear-cutting, and filling, but retained a diverse wetland vegetation comprised predominantly of native wetland species. No Federal or State designated rare, threatened, or endangered species were present in these wetlands, although the presence of an open bog in the southeast and northeast one-quarters of U.S. Public Land Survey Section 28 and the southeast one-quarter of U.S. Public Land Survey Section 21, Township 6 North, Range 17 East, Town of Ottawa, Waukesha County, was considered to be a rare occurrence in this portion of the State. The invasive wetland plant, purple loosestrife, was not reported from the vicinity of Pretty Lake during these surveys, and was not observed in the vicinity of the Lake during a 1997 field reconnaissance, conducted by Commission staff. However, as the plant is known to be present within the Scuppernong Creek subbasin of the Rock River drainage basin,[15] its potential presence and possible future distribution in the Pretty Lake study area, like that of Eurasian water milfoil, should be monitored.

FISHERIES

The Wisconsin Department of Natural Resources Publication No. FM-800-95REV, *Wisconsin Lakes*, 1995, indicates that northern pike are present, largemouth bass are common and the panfish are abundant within Pretty Lake. Wisconsin Department of Natural Resources surveys conducted annually between 1976 through 1978 further indicate the presence of walleyed pike, rock bass, yellow perch, black crappie, warmouth, brown and yellow bullhead, brook silverside, pumpkinseed, green sunfish, bluegill, bluntnose minnow, white sucker, and channel catfish, in addition to the northern pike and largemouth bass, in Pretty Lake.[16] Areas along the less steeply sloping shores of the Lake present suitable habitats for the spawning of bass and northern pike. Spawning takes place in spring, between the time of the spring thaw and mid-June. Pretty Lake currently has a regulated minimum size limit for bass of 16 inches, promulgated under Chapter NR 20, which is designed to encourage an increase in the number of large bass in the Lake. This fisheries management measure has been undertaken to thin out the numbers of panfish and, in turn, encourage the remaining panfish population to grow to a larger size.

WILDLIFE AND WATERFOWL

Given the single-family residential nature of the immediate shorelands along the Lake, only small upland game animals, such as rabbit and squirrel; predators, such as coyote, fox, and raccoon; game birds, such as pheasant; marsh furbearers, such as beaver and muskrat; migratory and resident song birds; and waterfowl generally inhabit these areas. A more diverse animal community and greater number of waterfowl make use of the wetland areas adjacent to the northeastern and western areas of the Lake, as well as the surrounding rural areas. White-tailed deer have also been reported in these areas. The character of wildlife species, along with the nature of the habitat, present in the planning area has undergone significant change since the time of European settlement and the subsequent clearing of forests, plowing of the prairie, and draining of wetlands for agricultural purposes. Modern practices that adversely affect wildlife and wildlife habitat include: the excessive use of fertilizers and pesticides, road salting, heavy traffic, the introduction of domestic animals, and the fragmentation and isolation of remaining habitat areas for urban and agricultural uses.

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[15] *See SEWRPC Memorandum Report No. 120,* A Lake Protection and Recreational Use Plan for Hunters Lake, Waukesha County, Wisconsin, *May 1997.*

[16] *D. Fago, Wisconsin Department of Natural Resources Research Report No. 148,* Retrieval and Analysis used in Wisconsin's Statewide Fish Distribution Survey, *2nd Edition, December 1988.*

As shown on Map 12, wildlife habitat areas in the Pretty Lake study area generally occur in association with existing surface water, wetland, and woodland resources located along Pretty Lake. Such areas covered about 1,930 acres, or about 50 percent of the study area. Of this total habitat acreage, about 910 acres, or 47 percent, were rated as Class I habitat; about 840 acres, or 44 percent, were rated as Class II habitat; and about 170 acres, or 9 percent, were rated as Class III habitat.[17]

The habitat areas shown on Map 12 are largely coincident with Commission-delineated environmental corridors in this watershed, and shown on Map 13. Primary environmental corridors extended over 1,650 acres, or 42 percent of the study area. Secondary environmental corridors and isolated natural resources features covered about 50 acres, or 47 percent of the Pretty Lake study area. The Commission recommends that, to the extent practicable, primary corridor lands should be maintained in essentially natural, open uses.[18]

RECREATIONAL USES AND FACILITIES

Pretty Lake is a multi-purpose waterbody serving all forms of recreation, including boating, waterskiing, swimming, and fishing during the summer months, and snowmobiling and ice-fishing during the winter. The Lake is used year-round as a visual amenity—walking, bird-watching, bicycling, and picnicking being popular passive recreational uses of the waterbody. As previously noted, four public access sites are located on Pretty Lake, including three boat launches, and one walk-in access, as shown on Map 2. Pretty Lake is considered as having adequate public access in terms of the criteria set forth in Chapter NR 1 of the *Wisconsin Administrative Code.*

Shoreline Protection Structures

Much of the shoreline of Pretty Lake is generally maintained in a natural state or as lawned areas abutting a natural beach, such that shoreland erosion is not a major problem. However, it is noteworthy that some structures have been built to protect the Lake's shoreline. These structures, shown on Map 14, were generally well maintained when inspected by Commission staff during 1995.

Local Ordinances

Pretty Lake is subject to a boating ordinance promulgated by the Town of Ottawa as Chapter 20, *Lakes and Beaches*, of the Town of Ottawa Ordinances. This ordinance provides generally applicable rules for all waters within the jurisdiction of the Town and allow for the enactment and enforcement of boating restrictions and limitations, as set forth in Appendix D. This ordinance requires power boats to operate in a counter-clockwise direction. It also requires motorized boats to operate at slow-no-wake speeds between the hours of 6:00 p.m. and 11:00 a.m. daily, and within a shoreland zone defined as within 100 feet of the shoreline. Rules specifically applicable to Pretty Lake are the prohibition of parking on both sides of Pretty Lake Road, and limitation of parking at the Pretty Lake public access sites to four vehicles between the hours of 6:00 a.m. and 10:00 p.m. daily. The ordinance conforms to State of Wisconsin boating and water safety laws pursuant to Chapter 30, *Wisconsin Statutes.*

The Town of Ottawa also has an erosion control ordinance that supplements a similar Waukesha County ordinance. These ordinances are based on the model ordinance developed by the League of Wisconsin Municipalities and the Wisconsin Department of Natural Resources.[19]

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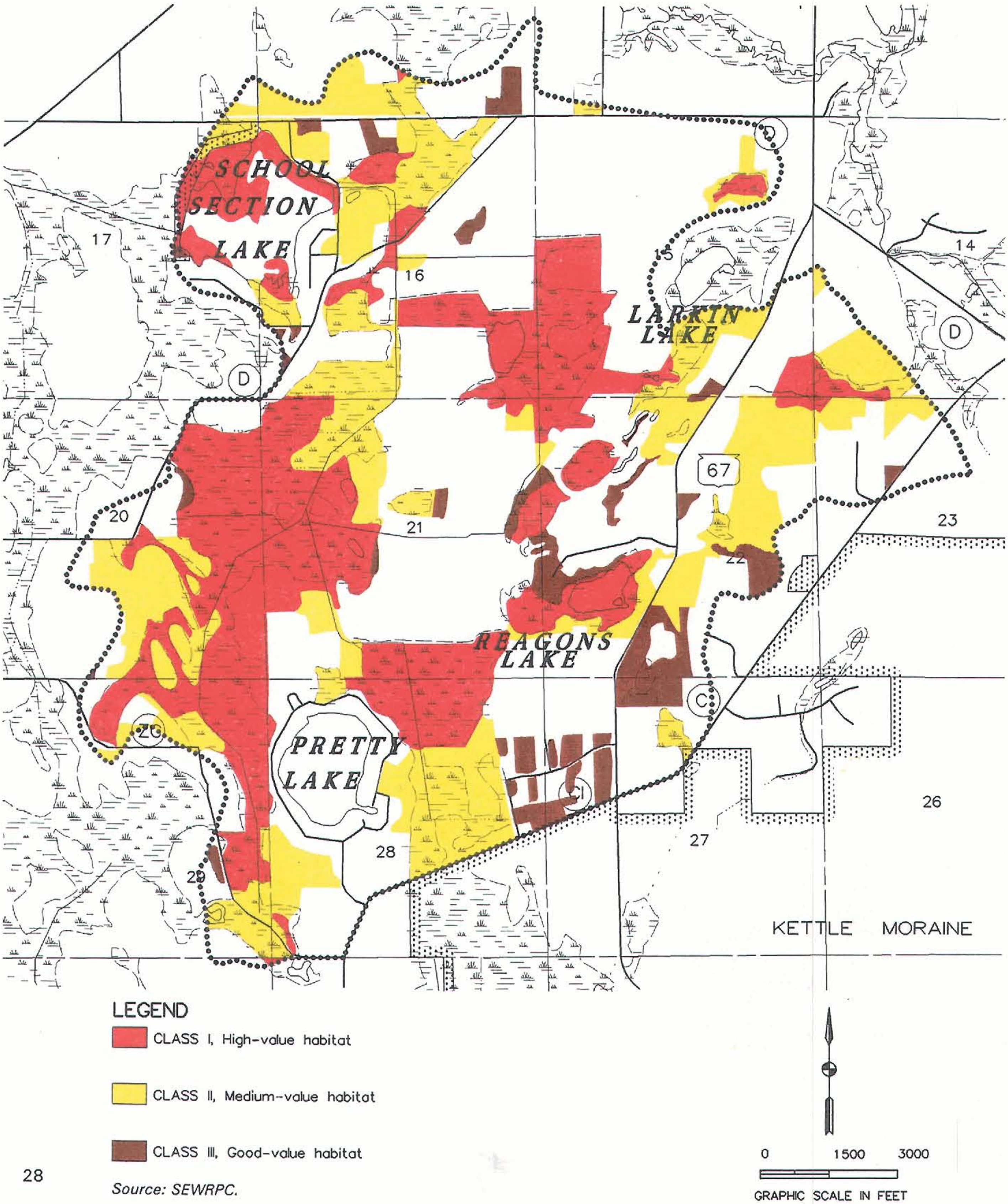
[17]*For details on these classifications, see SEWRPC Planning Report No. 40,* A Regional Land use Plan for Southeastern Wisconsin—2010, *January 1992.*

[18]*SEWRPC Planning Report No. 40,* A Regional Land Use Plan for Southeastern Wisconsin—2010, *January 1992.*

[19]*See Wisconsin Department of Natural Resources Publication No. WR-222-92,* Wisconsin Construction Site Best Management Practice Handbook, *1992: and Wisconsin Department of Natural Resources Briefing Memo for WPDES Permit No. WO-0067821-1,* Construction Site Erosion Control and Storm Water Management, *November 1992; and Wisconsin Department of Natural Resources Briefing Memo for WPDES Permit No. WI-0067849-1,* Draft General Permit to Discharge Storm Water Associated with Industrial Activity, *November 1992.*

Map 12

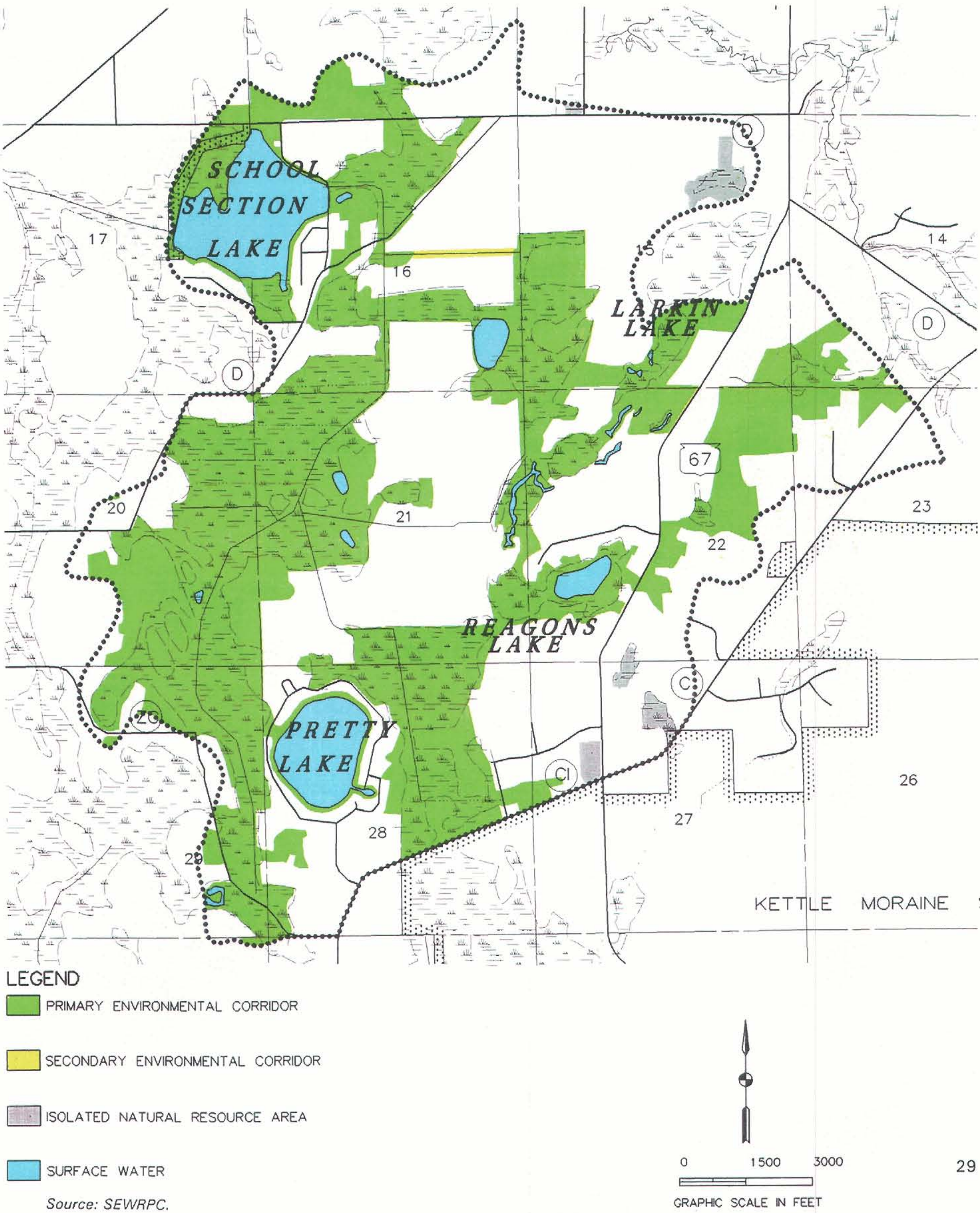
WILDLIFE HABITAT WITHIN THE PRETTY LAKE STUDY AREA



Source: SEWRPC.

Map 13

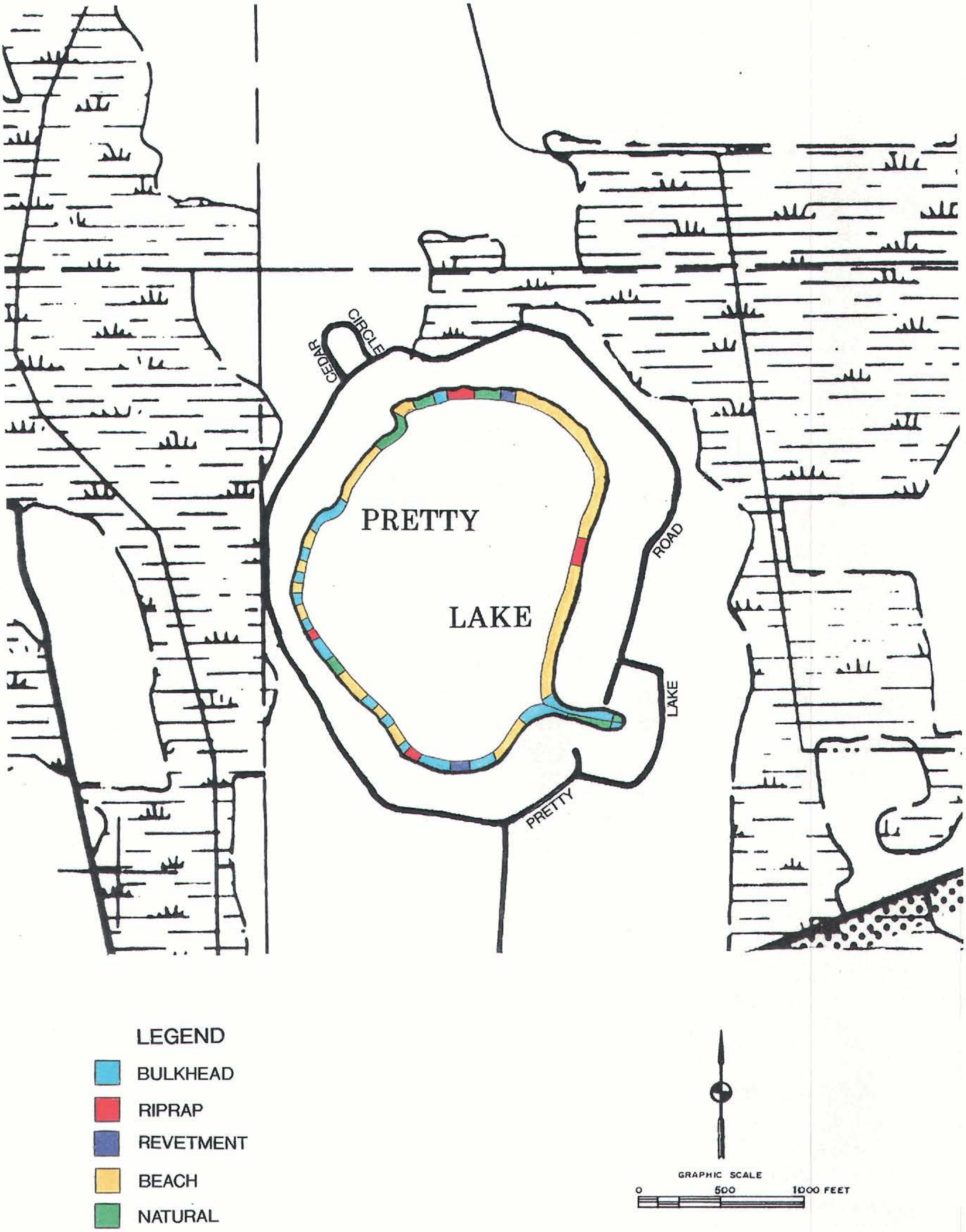
ECOLOGICALLY VALUABLE AREAS WITHIN THE PRETTY LAKE STUDY AREA



Source: SEWRPC.

Map 14

SHORELINE PROTECTION CONDITIONS ON PRETTY LAKE: 1996



Source: SEWRPC.

Chapter III

LAKE USE PROBLEMS AND CONCERNS

INTRODUCTION

Although Pretty Lake is in very good condition and is capable of supporting a wide variety of water uses, there are a number of existing and potential future problems and issues which should be addressed in this lake protection plan. These problems, or issues of concern, include ecologically valuable areas and aquatic plants, lake water levels, construction site erosion and nonpoint source pollution, wastewater treatment and disposal, shoreline erosion, and groundwater quantity and quality.

ECOLOGICALLY VALUABLE AREAS AND AQUATIC PLANTS

The ecologically valuable areas within the study area of Pretty Lake, as documented in Chapter II, include wetlands, woodlands, and wildlife habitat. Most of these areas are included in the land designated as primary environmental corridor. Critical sites within the Lake include prime fish spawning habitat, macrophyte beds—especially those containing a diverse native flora—and the shoreline areas supporting productive aquatic habitat. Some of these areas also serve as groundwater recharge areas. Protection of these areas is an important issue which should be considered.

The reported presence of Eurasian water milfoil in limited areas of the Pretty Lake basin represents another important issue which should be considered. Eurasian water milfoil often out competes native aquatic plants dominating the plant communities in the lakes of Southeastern Wisconsin to the detriment of fish and wildlife, and native species of plants. The dominance of Eurasian water milfoil in aquatic ecosystems in Southeastern Wisconsin degrades the natural resource base and commonly interferes with human recreational and aesthetic use of the natural resources. As discussed in Chapter II, this aquatic plant is not widespread in Pretty Lake, but its distribution should be monitored, and, hence, conduct of periodic aquatic plant surveys is an important issue which should be considered.

As discussed in Chapter II, the wetland communities to the north of Pretty Lake were surveyed by Commission staff in 1988 and 1995. These areas contained a diverse plant community consisting of flora that is typical of the Region, which provide important habitat for wildlife in addition to contributing to the scenic vistas which characterize the Pretty Lake study area. Shoreland wetlands also help to absorb flood waters, and, by retaining sediments and nonpoint source pollutants, can help to protect the Lake from degradation. Purple loosestrife was not observed in the vicinity of Pretty Lake, but is known to exist in the Scuppernong Creek subbasin of the Rock River watershed. Hence, monitoring for this plant is an important issue to be considered.

The environmental corridors in the Pretty Lake study area contain almost all of the best remaining woodlands, wetlands, and wildlife habitat. The protection of these resources from additional intrusion by incompatible land uses which degrade and destroy the environmental values of these sites, and the preservation of the corridors in an essentially open and natural state, is an important issue to be considered.

LAKE WATER LEVELS

Over the past several years, there have been marked fluctuations in the water levels of Pretty Lake. These fluctuations have generally involved a diminution of lake depth, resulting in large increases in shoreland, especially in the more shallowly sloping areas of the Lake. The extent of this diminution, at times, has been such that riparian boat owners have been left with difficult access to the Lake due to length of exposed lakebed between their properties and access sites, and the water's edge.

Being that Pretty Lake is a groundwater flow-through lake, limited alternatives exist in regards to fluctuating water levels. Historically, water levels in Pretty Lake have been subject to intermittent drawdowns, especially during periods of below average precipitation. Thus, remedial measures have focused on augmenting water levels to maintain sufficient depth to support water-based recreational activities, including swimming and boating. Concern over water level fluctuations in early 1989 prompted the District to initiate a study of groundwater flows through Pretty Lake. This study determined that the Lake is directly influenced—both in terms of water quantity and water quality—by activities in the Lake's watershed. One possible cause for the variation in water level, other than variations in precipitation, was determined to be the construction of new agricultural drainage ditches and the maintenance and altering of existing ditches down gradient from the Lake. In 1991, the Pretty Lake Protection and Rehabilitation District, in cooperation with the Wisconsin Department of Natural Resources and the U.S. Geological Survey, installed and operates, a groundwater pumping system designed to augment lake levels with water drawn from the sandstone aquifer. The District monitors the lake level and manually regulates the water inflow by starting and stopping the pump as lake levels fluctuate. The pump remains the most consistent means of maintaining a relatively constant lake level. Lake levels are currently maintained within limits prescribed by the Wisconsin Department of Natural Resources.

The Pretty Lake Protection and Rehabilitation District electors have expressed concerns regarding the impact of aquifer pumpage and surface drainage on the levels of Pretty Lake. This particular concern was considered further by U.S. Geological Survey staff using available groundwater data which were applied in the groundwater flow modeling program. The groundwater modeling program provided analyses demonstrating a variety of possible short- and long-term effects dependent upon different ecological circumstances.[1]

Based on these analyses, it appears that concerns regarding pumpage are unfounded. However, the analysis showed that certain drainage could potentially act to reduce lake levels. While the extensive network of tile drains to the north and east of Pretty Lake, shown in Map 15, were of greatest concern to the District, the groundwater flow analysis, summarized on Map 4, suggested that the impact of these drains is minimal. In contrast, the tile drain to the west of the Lake was found to exercise a significant potential influence on the level of Pretty Lake. In its present state of disrepair, the head differential between the lake surface and the water surface of the drain is minimal and the drain has a negligible effect on the lake water surface. However, should the tile drain be restored to its designed conditions, the groundwater flow analysis indicates that lake water levels in Pretty Lake could be reduced by up to 18 inches, which would create problems for boating and other public access and use in portions of Pretty Lake.[2] As noted above, this condition could be mitigated to some degree by artificially supplementing lake water by pumping of groundwater into the Lake.

In addition to the negative impacts on recreational lake use, such extensive declines in lake level can affect the water quality of the Lake. A fluctuation in water level can impair aquatic plant communities on the shorelines by exposing the plants to alternating cycles of inundation and desiccation. Under these conditions, many plant species lack the chance to establish and maintain themselves. Table 6 represents the species of aquatic plants most likely to be affected by changes in the water level. Those plants that do thrive under such conditions are generally those that are considered to impede recreational use of the waterbody. Further, a shortage of aquatic plants at shallower depths reduces the availability of sheltered areas where smaller fish can hide from predators, and may eliminate fish spawning areas. Thus, it is desirable, from the point of view of aquatic habitat, that water levels be maintained. For this reason, the District acquisition of operational control of this waterway and consideration of public acquisition of the surrounding land is an important management issue to be considered.

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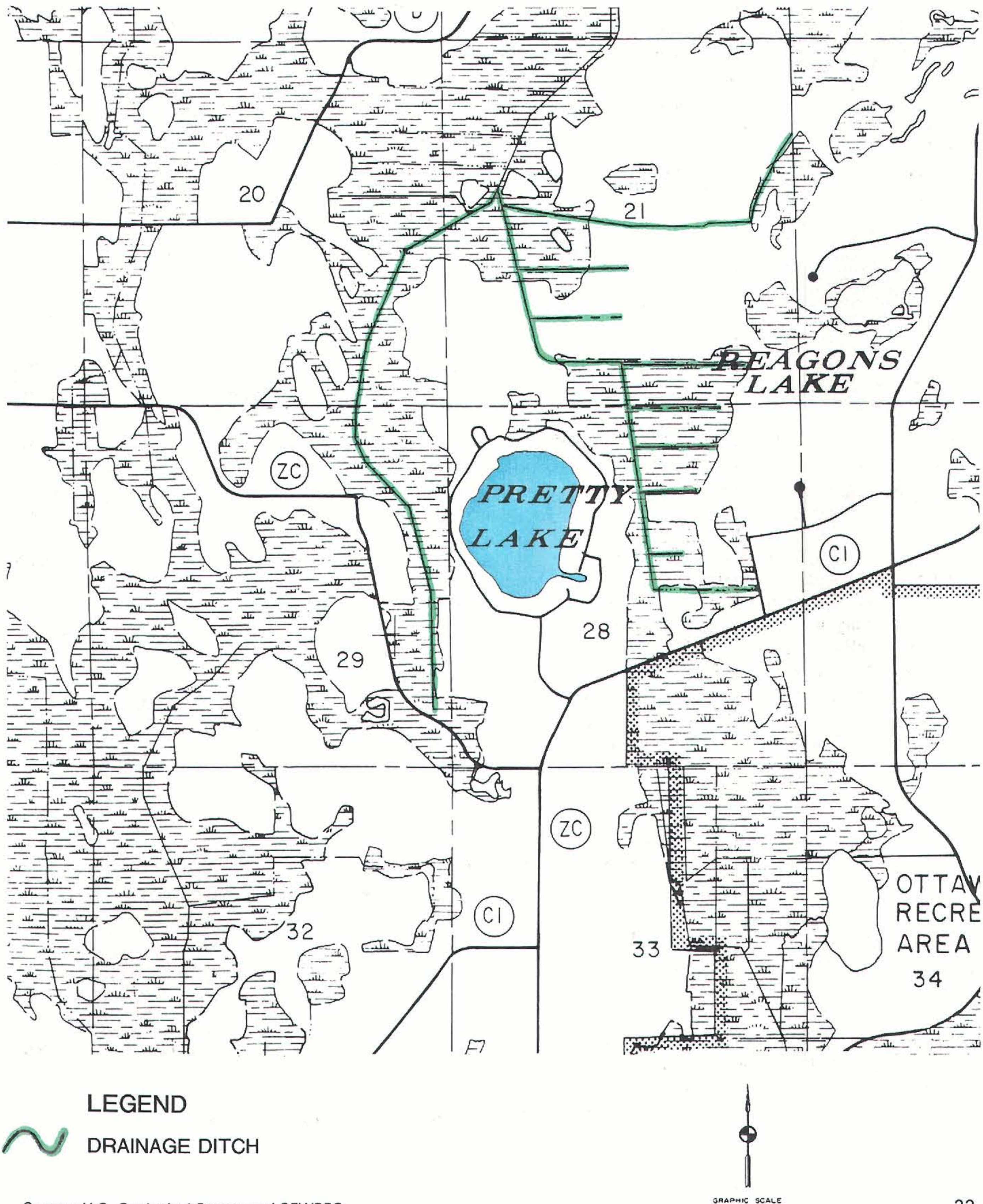
[1] *Vic Kelson and Henk Haitjema,* GFLOW Analytic Element Groundwater Flow Modeling Program, *Version 1.1, 1995.*

[2] *Randy J. Hunt and James T. Krohelski, "The Application of Analytic Element Model to Investigate Groundwater-Lake Interactions at Pretty Lake, Wisconsin,"* Journal of Lakes and Reservoir Management *12(4):487-495, 1996.*

Map 15

SURROUNDING DRAINAGE DITCHES WITHIN THE PRETTY LAKE AREA
AS REPRESENTED BY THE GFLOW MODELING PROGRAM



Source: U.S. Geological Survey and SEWRPC.

CONSTRUCTION SITE EROSION AND NONPOINT SOURCE POLLUTION

Erosion during construction and nonpoint source pollutants associated with new and existing urban development in the Pretty Lake study area represents a potentially significant threat to the Lake's water quality, especially with regard to nutrient loading and the contribution of heavy metals to Pretty Lake. Agricultural activities, together with construction site erosion, represent a potentially significant threat to the Lake's water quality with regard to sediment loading. Therefore, control of construction site erosion and stormwater nonpoint source pollution is an important issue.

Table 6

AQUATIC PLANTS AFFECTED BY LAKE DRAWDOWN

Common Name	Scientific Name
Coontail	Ceratophyllum demersum
Muskgrass or Chara	Chara sp.
Elodea	Elodea sp.
Milfoil	Myriophyllum spp.
American Lotus	Nelumbo lutea
Yellow Water Lily	Nuphar sp.
White Water Lily	Nymphaea odorata
White Water Lily	Nymphaea tuberosa
Clasping-Leaf Pondweed	Potamogeton robbinsii
Large-Leaved Pondweed	Potamogeton amplifolius
Bladderwort	Utricularia vulgaris
Wild Celery or Eel Grass	Vallisneria americana

Source: U.S. Environmental Protection Agency and SEWRPC.

WASTEWATER TREATMENT AND DISPOSAL

At present, the Pretty Lake study area is not included in a planned public sanitary sewer service area served by public wastewater treatment facilities, with the area served by the Village of Dousman system being the closest service area, about three miles to the northeast.[3] Thus, most of the study area, including the riparian development around Pretty Lake, is expected to continue in the immediate future to be served by onsite sewage disposal systems. While such systems represent only a relatively small potential source of pollution to Pretty Lake, they have a potential to cause localized water quality problems and are important considerations in groundwater quality protection. Thus, proper system maintenance and replacement as necessary is an important issue to be considered. In the long term, public sanitary sewer service may be the best means of providing sewage disposal. As of early 1998, a sewerage system plan[4] was being prepared for the northwestern Waukesha County area by an engineering firm under contract to the Southeastern Wisconsin Regional Planning Commission and guided by a Technical Advisory Committee composed of representatives of all of the general-purpose units of government involved. That study contains preliminary recommendations regarding areas to be provided with public sewer service based upon considerations such as identified onsite sewerage system problems, lot sizes, soils, and proximity to a public sewer system. The preliminary recommendations set forth in that plan provide for the continual reliance on onsite wastewater disposal system, including, in some cases, holding tanks or, in some cases, possibly the use of special small-scale treatment and soil absorption systems to serve the urban development surrounding Pretty Lake. That plan recommendation was made primarily due to the remote and isolated nature of the Pretty Lake community in relationship to an existing public sanitary sewer system even though there were problems identified with some of the existing onsite systems.

SHORELINE PROTECTION

A shoreline assessment survey was completed by Commission staff and shoreland erosion was not identified as a major problem on Pretty Lake. Much of the shoreline was in a natural state or consisted of lawned areas fronted by a beach. However, it is noteworthy that some structures have been built to protect the Lake's shoreline. Shoreline erosion may change over time depending upon water levels and lake usage and erosion-related problems could worsen in the future. Hence shoreline protection is an issue to be considered.

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[3]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[4]*Black & Veatch,* A Sanitary Sewerage System Plan for the Northwestern Waukesha County Area, *Draft, in preparation.*

Shoreline erosion not only interferes with such activities as swimming, but also results in the deposition of sediment and nutrients into the Lake itself. This deposition of sediment can in turn have a negative impact by contributing to the formation of bottom sediments suitable for supporting excessive aquatic plant growth. While construction of visually intrusive shoreland protection structures may be considered, other options may be preferred by lake residents seeking to conserve the ambience of Pretty Lake. These options are discussed further on in the plan.

GROUNDWATER QUANTITY AND QUALITY

As noted above, Pretty Lake has been subject to marked changes in lake level during the past several years. Being a groundwater-fed lake, these fluctuations have reflected changes in the volume of groundwater recharge due largely to natural climatic variations, which, in turn, have affected the volume of groundwater available to maintain the level of Pretty Lake. In part, these variations have been moderated, since 1991, by the installation and operation of an high-capacity, deep well, which augments surface water levels in Pretty Lake with groundwater drawn from the sandstone aquifer. However, concerns have been expressed regarding the potential for this deep aquifer to be overdrawn as the result of demands from elsewhere in Southeastern Wisconsin. Thus, the volume of groundwater available for lake level maintenance is an issue to be considered.

In addition to the use of groundwater to maintain lake levels, domestic water supplies to households at Pretty Lake are drawn from the Regional groundwater aquifer system. Unlike the supplemental water for the maintenance of Lake water levels, drawn from the deep, sandstone aquifer, domestic water supplies are drawn from the shallow, surfacial aquifer. Contamination of this aquifer by contaminants leaching into the groundwater from the land surface and from onsite sewage disposal systems remains an issue of concern in the Region. However, measures taken to minimize water quality degradation in the Pretty Lake watershed should also serve to protect the groundwater resources of the watershed from contamination. Conservation of the wetlands and other habitat areas in their natural state, as outlined above, will contribute to the protection of the groundwater in the Pretty Lake study area.

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Chapter IV

ALTERNATIVE AND RECOMMENDED LAKE PROTECTION PRACTICES

INTRODUCTION

Chapter III described six issues of concern to be considered as part of this lake protection plan. These issues are related to: 1) ecologically valuable areas and aquatic plants; 2) lake water levels; 3) construction site erosion and nonpoint source pollution; 4) wastewater treatment and disposal; 5) shoreline erosion; and 6) groundwater quantity and quality. Following a brief summary of the ongoing lake management program, alternatives, and recommended measures to assess each of these issues and concerns are described in this chapter. The alternatives and recommendations set forth herein are focused primarily on those measures which are applicable to the Pretty Lake Protection and Rehabilitation District and the Town of Ottawa, with lesser emphasis given to those measures which are applicable to others with jurisdiction within the broader study area of Pretty Lake.

PAST AND PRESENT LAKE MANAGEMENT PRACTICES

The residents of Pretty Lake, in conjunction with the Town of Ottawa, have long recognized the importance of informed and timely action in the management of Pretty Lake. The initial action in this regard was the formation of the Pretty Lake Protection and Rehabilitation District, which provides the forum for many of the lake management activities of the Lake's residents. The District undertakes regular water quality measurements under the auspices of the Wisconsin Department Natural Resources Self-Help Monitoring Program and operates a water level augmentation system based on groundwater pumpage during periods of low lake levels. The District also holds an annual Fish-o-rama which teaches safety while fishing to the younger children living in the vicinity of the Lake, in addition to other informational sessions, such as identifying different fish species, knot-tieing, casting, and preparation of fish. Subsequently, the community created the Kettle Moraine Conservation Foundation, Inc., as a land conservation trust to preserve the environmental quality of the Pretty Lake area.

These activities were supplemented by a U.S. Geological Survey water quality investigation which was conducted in 1993 and 1994 with support under the Chapter NR 190 Lake Management Planning Grant Program. The Town of Ottawa currently holds a Phase II Lake Management Planning Grant to cost-share assessments on the water balance of Pretty Lake and on the identification of environmentally sensitive lands within the groundwater transit area that could potentially impact the water quality of Pretty Lake. Both studies, in conjunction with the water quality data collected during Phase I will, ultimately, become components of a comprehensive lake management plan for Pretty Lake.

ECOLOGICALLY VALUABLE AREAS AND AQUATIC PLANTS

Pretty Lake and its study area contain relatively large tracts of ecologically valuable areas, including significant areas of diverse, native aquatic vegetation suitable for fish spawning which are located within and immediately adjacent to the Lake. As described in Chapter III, the potential problems associated with ecologically valuable areas in and near Pretty Lake include, the potential loss of wetlands and other important ecologically valuable areas due to urbanization or other encroachments; the degradation of wetlands and aquatic habitat due to the presence of invasive species (including Eurasian water milfoil); and disturbances associated with recreational boating.

Array of Protection Measures

Three measures to protect and maintain the biodiversity of Pretty Lake and its study area have been identified as being potentially viable; namely, 1) land use measures, 2) in-lake management measures, and 3) citizen information and education.

Land Management Measures

The recommended future condition land use plan for the Pretty Lake study area is set forth in the Waukesha County Development Plan.[1] That plan recommends the preservation of primary environmental corridor lands in essentially natural, open space use. Most of the wetlands and other ecologically valuable lands adjacent to Pretty Lake and within the Pretty Lake study area are included within these primary environmental corridors. The County development plan recommends that such protection be afforded through the placement of such lands in appropriate zoning districts, depending upon type and character of the natural resource features to be preserved and protected. All lakes, rivers, streams, wetlands, and associated undeveloped floodlands and shorelands are recommended to be placed in lowland conservancy or floodplain protection districts. The existing zoning for the lands in the vicinity of Pretty Lake and in the Pretty Lake study area is generally consistent with the recommended future buildout land use pattern set forth in the Waukesha County development plan. However, should urban development not proposed or envisioned under the County development plan threaten to destroy or degrade natural resources located within the primary environmental corridors, appropriate public or private agencies should consider the acquisition of such lands for resource and open space preservation purposes.

The purchase of specific critical properties or the acquisition of conservation easements, as a means of protecting them from encroachment or further degradation, or as a means of facilitating their rehabilitation and restoration, is possible through the Chapter NR 50/51 *Wisconsin Administrative Code* Stewardship Grant Program or the Chapter NR 191 Lake Protection Grant Program promulgation in the *Wisconsin Administrative Code*. Outright purchase, or the purchase of conservation easements, are both possible options. Lands proposed for purchase must be appraised using standard governmental land acquisition procedures as established by the Wisconsin Department of Natural Resources, and must be subject to a land management plan setting forth the process and procedures for their long-term maintenance and development. The Chapter NR 191 grant program provides State cost-share funding for the purchase up to a maximum State share of $200,000 at up to 75 percent State cost-share. The Chapter NR 50/51 grant program provides State cost-share funding up to a maximum State share of $100,000 at up to a 50 percent cost-share.

In-Lake Management Measures

Various potential in-lake management actions may be considered for purposes of control of aquatic plants. These actions include harvesting, chemical treatment, lake drawdown, and lake bottom covering. Because the current aquatic plant problems on Pretty Lake, as described in Chapters II and III, are limited in nature, these in-lake measures are generally not considered applicable. However, the distribution of Eurasian water milfoil in Pretty Lake, and the presence of purple loosestrife in the Scuppernong Creek drainage basin should be monitored. Should extensive infestations occur, the only in-lake measures related to aquatic plant management considered necessary are manual harvesting and limited chemical treatment of these two species. Notwithstanding, given the changes in aquatic plant populations noted between the 1982 Wisconsin Department of Natural Resources inventory and the 1997 Commission reconnaissance, indicates that a comprehensive aquatic plant survey be conducted of Pretty Lake in order to update the baseline from which future changes in aquatic plant community composition can be assessed.

Citizen Information and Education

As part of the overall citizen informational and educational programming to be conducted on Pretty Lake, residents and visitors in the vicinity of Pretty Lake should be made aware of the value of the ecologically significant areas in the overall structure and functioning of the ecosystems of Pretty Lake. Specifically, informational programming related to the protection of ecologically valuable areas in and around Pretty Lake should focus on need to minimize the spread of nuisance aquatic species, such as purple loosestrife into the wetlands and Eurasian water milfoil into the Lake. Citizens participating in water-based recreation on Pretty Lake should also be encouraged to participate in boater education programs. Other informational programming offered by the Wisconsin Department of Natural Resources, University of Wisconsin-Extension, and other agencies can contribute to an informed public, actively involved in the protection of ecologically valuable areas within the drainage area to, and lake basin of, Pretty Lake.

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[1]*SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996.*

Recommended Protection Measures
The following management actions are recommended for the management of ecologically valuable areas and aquatic plants.

1. The Pretty Lake Protection and Rehabilitation District should support the preservation of the primary environmental corridor lands in the Pretty Lake study area in essentially natural, open space uses, primarily through public land use controls. Such preservation should be promoted through the placement of such resources in appropriate conservancy zoning districts, and through the enforcement of existing regulation intended to protect such natural resources. In addition, it is recommended that the District support the development of a formal park/trail system through the study area as recommended in the Waukesha County development plan. The proposed trail system, portrayed in Appendix E, would extend from the existing Ice Age Trail via the trail system located within the Ottawa Lake State Forest Recreation Area, through ecologically valuable areas to the Pretty Lake area continuing up to School Section Lake which is adjacent to parkland on the northwest portion of the lake and ultimately connect to the Glacial Drumlins Trail.[2]

2. The Pretty Lake Protection and Rehabilitation District and the Kettle Moraine Conservation Foundation, Inc., should proceed with public or private acquisition of the lands indicated on Map 16. This land acquisition should be coordinated with the Pretty Section Trail acquisition and development recommended to be carried out by Waukesha County and the Wisconsin Department of Natural Resources. The land to the west of Pretty Lake is of the highest purchase priority due to its location within an ecologically valuable area, in addition to the significant potential influence this area has on the surface water level of Pretty Lake. The medium- and low-priority areas are recommended for acquisition due to their potential impact on the groundwater supply to Pretty Lake which was determined by the groundwater modeling program conducted for this planning program by the U.S. Geological Survey. Outright purchase, or the purchase of conservation easements, are both possible options. Public acquisition meets the criteria for cost-shared acquisition under the Chapter NR 191 Lake Protection Grant program administered by the Wisconsin Department of Natural Resources. Monies granted in terms of this program provide up to 75 percent of the purchase price, or the cost of acquisition of conservancy easement, subject to a cap of $200,000 on State share per parcel.

3. The Pretty Lake Protection and Rehabilitation District should conduct a comprehensive aquatic plant inventory of the aquatic plant community in Pretty Lake, and continue to monitor the Lake and its environs for the presence of nuisance plant species such as Eurasian water milfoil and purple loosestrife. Where necessary to control the encroachment of these species, the Wisconsin Department of Natural Resources should permit limited herbicide usage within Pretty Lake and its drainage basin to small areas for the control of Eurasian water milfoil in the Lake and of purple loosestrife in the study area. Selected manual harvesting of these plants is recommended.

4. The Town of Ottawa and the Pretty Lake Protection and Rehabilitation District, through a joint educational and informational program, should promote awareness by Lake residents and visitors of the invasive nature of species such as purple loosestrife and Eurasian water milfoil, and encourage participation in citizen-based control programs coordinated by the Wisconsin Department of Natural Resources and University of Wisconsin-Extension to limit their spread should such species be introduced into the Pretty Lake area.

LAKE WATER LEVELS

As discussed in Chapter III, fluctuations in the level of the water surface in Pretty Lake will affect the recreational boating use of the Lake. In addition, concerns have been expressed regarding the impact on the aquatic plant communities in Pretty Lake.

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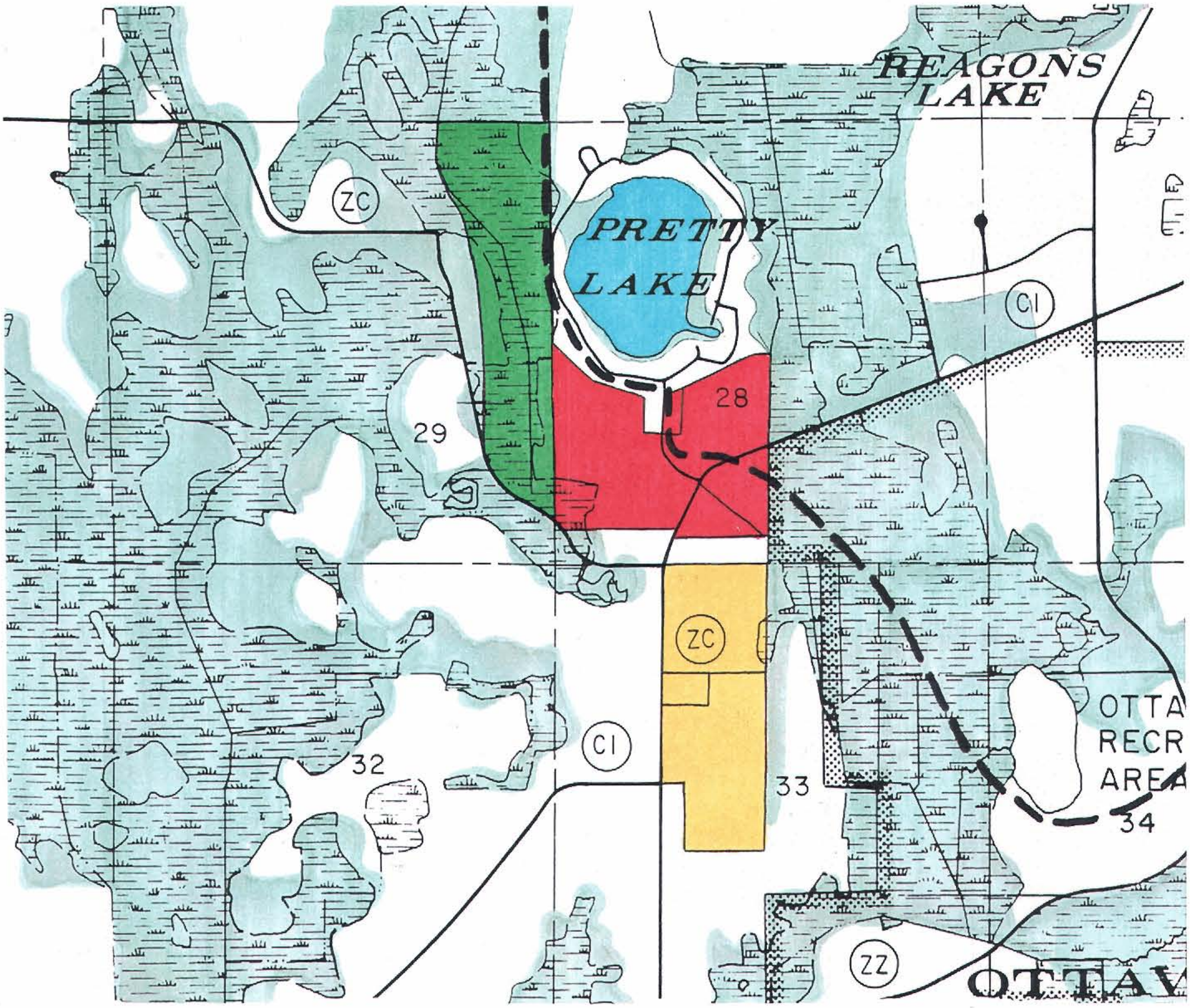
[2]*Ibid.*

Map 16

RECOMMENDED MANAGEMENT PLAN FOR PRETTY LAKE



LEGEND

LAND USE MANAGEMENT

- PROPOSED PRETTY-SECTION RECREATION TRAIL
- PROTECT ECOLOGICALLY VALUABLE AREAS

LAND ACQUISITION

- HIGH PRIORITY
- MEDIUM PRIORITY
- LOW PRIORITY

WATERSHED MANAGEMENT

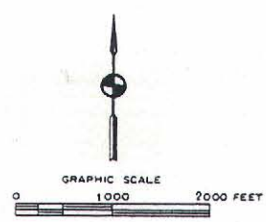
- ENFORCE CONSTRUCTION SITE EROSION AND STORMWATER POLLUTION ORDINANCES

MONITORING PROGRAM

- CONDUCT AQUATIC PLANT SURVEY
- CONTINUE WATER QUALITY MONITORING

SHORELINE PROTECTION

- MAINTAIN AND REPAIR EXISTING STRUCTURES
- PROTECT UNSTABLE AREAS



Source: SEWRPC.

Options Considered

Three options were considered regarding the potential control of water levels in Pretty Lake. Under the first option, no specific actions would be undertaken and the lake levels would be the result of natural fluctuations. Under the second option, the Pretty Lake Protection and Rehabilitation District would continue to operate the high-capacity well to provide supplementary inflow to the Lake. Under the third option, operational control over the drain tile located to the west of Pretty Lake would be acquired.

Natural Fluctuations

Under the first option considered, the variations in year-to-year rainfall amounts and the distribution of rainfall and associated runoff within the Region as well as artificial drainage of lands in the vicinity would continue to result in variations in inflows to Pretty Lake, and, consequently, to variations in lake levels. Without interventions, the level of Pretty Lake would vary as a result of the changes in precipitation and drainage. During past years this has resulted in the low water level problem noted previously.

Water Level Augmentation

Under the second option considered, the natural variations in Lake level would be mitigated by the provision of supplementary inflow to the Lake from deep groundwater sources through the operation of a high-capacity pumping system, previously installed at Pretty Lake. This system draws water from the sandstone aquifer underlying the region and discharges this water to the Lake in order to minimize the decline in water level within the Lake that occurs as the result of natural fluctuations in rainfall, runoff, and groundwater inflow from the surfacial aquifer. Use of this system is historically proven to be capable of maintaining the level of Pretty Lake at a sufficient elevation to allow recreational use of the Lake basin during traditionally low-water periods. However, a potential disadvantage of this system is that the deep sandstone aquifer within the Region may be being overdrawn as a result of withdrawals for domestic, industrial, and agricultural purposes. This may limit the use of water from this source at some time in the future. In addition, this system costs about $4,000 per year to operate and maintain.

Drainage Canal Operational Control

Under the third option considered, the modeling of the groundwater flows around and through Pretty Lake indicated that the western drain tile adjacent to Pretty Lake exercises a significant influence on water levels within the Pretty Lake basin. Model results suggest that, should this tile drain be restored to its intended design conditions, the water levels of Pretty Lake could decrease by up to 18 inches below current normal water levels in the absence of a supplemental water source. Thus, acquisition of operational control of this tile drain is considered a viable option. Alternatives could include acquisition of a conservation easement over the lands through which the tile drain runs, outright purchase of the lands through which the tile drain runs, or acquisition of another form of easement which provides the Pretty Lake Protection and Rehabilitation District with operational control over this drain. The former two alternatives would be grant eligible expenses under the Chapter NR 191 Lake Protection Grant Program and NR 50/51 Stewardship Grant Program as set forth in the *Wisconsin Administrative Code*, which provide State cost-sharing for land or conservation easement acquisition by governmental units and qualified nongovernmental organizations. Operational control potentially could be acquired under the latter alternative by creation of a Chapter 88, *Wisconsin Statutes*, Drainage District and by the Town of Ottawa acquiring drainage district powers.

Recommended Control Measures

Acquisition of control or ownership of the tile drain and adjacent lands situated to the west of Pretty Lake is recommended. As demonstrated through the groundwater model analysis of the Pretty Lake study area, this waterway has the greatest potential to negatively impact the recreational and other water uses of Pretty Lake. As noted above, acquisition of the lands riparian to this drain tile would have the added advantage of being well suited to the establishment and continuation of a trail system, as recommended in the county development plan, linking School Section Lake, Pretty Lake, and the Ottawa State Recreational Area, and, ultimately, the Ice Age National Scenic Trail and the Glacial Drumlins Trail. Thus, it is recommended that the Pretty Lake Protection and Rehabilitation District and the Kettle Moraine Conservation Foundation, Inc., proceed with public or private acquisition of the lands riparian to the western drain tile as the first step in creating the proposed Pretty-Section Trail and as a primary means of protecting lake levels within Pretty Lake from fluctuations other than those related to natural climatic variability. This land acquisition should be coordinated with the Pretty-Section Trail acquisition and development recommended to be carried out by Waukesha County and the Wisconsin Department of Natural Resources.

In addition, to the degree permitted and as may be deemed prudent and necessary to maintain the recreational usage of Pretty Lake, continued operation and maintenance of the water level augmentation system by the Pretty Lake Management District is recommended.

CONSTRUCTION SITE EROSION AND NONPOINT SOURCE POLLUTION

As described in Chapter II, the primary sources of pollutant loadings to Pretty Lake are nonpoint sources generated in the drainage area tributary to the Lake. In addition to the existing rural and urban sources of water pollution, the Waukesha County development plan provides for infilling of existing platted lots and some additional low-density, single-family residential development within the study area and in the vicinity of the Lake. Such development could result in a potential increase in the loads of some pollutants associated with urban development being transported into Pretty Lake from nonpoint sources and construction sites. Nonpoint source pollutant loadings from existing and future urban areas, and from rural areas, represent one controllable source of pollution to the Lake.

Array of Control Measures

Watershed management measures may be used to reduce nonpoint source pollutant loadings from such rural sources as runoff from cropland and pastureland; from such urban sources as runoff from residential, commercial, transportation, and recreational land uses; and from construction activities. The alternative, nonpoint source pollution control measures considered in this report are based upon the recommendations set forth in the regional water quality management plan,[3] the Waukesha County soil erosion control plan,[4] and information presented by the U.S. Environmental Protection Agency.[5]

Two options to control nonpoint source pollution to Pretty Lake and its tributary drainage area have been identified as being potentially viable; namely, 1) urban nonpoint source controls, and 2) rural nonpoint source controls.

Urban Nonpoint Source Controls

The regional water quality management plan recommends that the nonpoint source pollutant loadings from the urban areas tributary to Pretty Lake be reduced by about 25 percent in addition to reductions from urban construction erosion control, onsite sewage disposal system management, and streambank and shoreline erosion control measures.

Potentially applicable urban nonpoint source control measures include wet detention basins, grassed swales, and good urban "housekeeping" practices. Generally, the application of low-cost urban housekeeping practices may be expected to reduce nonpoint source loadings from urban lands by about 25 percent. Public educational programs can be developed to encourage such good urban housekeeping practices, to promote the selection of building and construction materials which reduce the runoff contribution of metals and other toxic pollutants, and to promote the acceptance and understanding of the proposed pollution abatement measures and the importance of lake water quality protection. Urban housekeeping practices and source controls include restricted use of fertilizers and pesticides; improved pet waste and

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[3]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin:2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; and Volume Three,* Recommended Plan, *June 1979.*

[4]*SEWRPC Community Assistance Planning Report No. 159,* Waukesha County Agricultural Soil Erosion Control Plan, *June 1988.*

[5]*U.S. Environmental Protection Agency, Report No. EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, *2nd Edition, August 1990; and its technical supplement, U.S. Environmental Protection Agency, Report No. EPA-841/R-93-002,* Fish and Fisheries Management in Lakes and Reservoirs: Technical Supplement to the Lake and Reservoirs Restoration Guidance Manual, *May 1993.*

litter control; the substitution of plastic for galvanized steel and copper roofing material and gutters; proper disposal of motor vehicle fluids; increased leaf collection; and reduced use of street deicing salt. Proper design and application of urban nonpoint source control measures, such as grassed swales and detention basins requires the preparation of a detailed stormwater management system plan that addresses stormwater drainage problems and controls nonpoint sources of pollution. Based on preliminary evaluation, however, it is estimated that the practices which could be effective in the existing urban areas within the immediate vicinity of Pretty Lake are limited largely to good urban housekeeping practices and grassed swales. However, structural measures could be considered for installation as part of the development process in urbanizing areas within the study area.

Developing areas can generate significantly higher pollutant loadings than established areas of similar size. Developing areas include a wide array of activities, including urban renewal projects, individual site development within the existing urban area, and new land subdivision development.

Construction sites, especially, may be expected to produce suspended solids and phosphorus loadings at rates several times higher than established urban land uses. Control of sediment loss from construction sites can be provided by measures set forth in the model ordinance developed by the Wisconsin Department of Natural Resources in cooperation with the Wisconsin League of Municipalities.[6] These controls are temporary measures taken to reduce pollutant loadings from construction sites by about 75 percent. Such practices are expected to have only a minimal impact on the total pollutant loading to the Lake due to relatively small amount of land proposed to be developed. However, such controls are important pollution control measures that can abate localized shore-term loadings of phosphorus and sediment from the drainage area of the Lake. The control measures include such revegetation practices as temporary seeding, mulching, sodding, and such runoff control measures as filter fabric fences, straw bale barriers, storm sewer inlet protection devices, diversion swales, sediment traps, and sedimentation basins.

Waukesha County has adopted a construction site erosion control ordinance which is administered and enforced by the County in both the shoreland and nonshoreland areas of the unincorporated areas of the Pretty Lake study area. The provisions of this ordinance apply to all development except single- and two-family residential construction. Single- and two-family construction erosion control measures are to be specified as part of the building permit process. In addition, the Town of Ottawa has construction site erosion control and stormwater management provisions within their Land Division and Development Ordinance, Chapter 10 of the Town's Zoning Ordinance. Because of the potential for development in the Pretty Lake study area, it is important that adequate construction erosion control programs, including enforcement, be in place in the entire study area.

Rural Nonpoint Source Controls

Upland erosion from agricultural and other rural lands is a contributor of sediment to streams and lakes in the drainage area to Pretty Lake. Estimated phosphorus and sediment loadings from croplands, woodlots, pastures, and grasslands in the Pretty Lake study area are set forth in Table 4. These loadings are recommended to be reduced to the target level of agricultural soil erosion control of three tons per acre per year identified in the Waukesha County agricultural soil erosion control plan as the tolerable levels which can be sustained without impairing productivity. Implementation of these recommendations is considered to be an important water quality management measure for Pretty Lake.

Detailed farm conservation plans will be required to adapt and refine erosion control practices for individual farm units. Generally prepared with the assistance of the U.S. Natural Resources Conservation Service or County Land Conservation Department staffs, such plans identify desirable tillage practices, cropping patterns, and rotation cycles, considering the specific topography, hydrology, and soil characteristics of the farm; identify the specific resources of the farm operator; and articulate the operator objectives of the owners and managers of the land.

Recommended Control Measures

The following management actions are recommended for the management of nonpoint source pollution sources.

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[6]*Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook, *1989.*

1. The stormwater and construction site erosion control ordinances adopted by Waukesha County and the Town of Ottawa should be strictly enforced to reduce sediment and contaminant loadings from the urbanizing areas in the Pretty Lake study area, especially in those areas nearest to the Lake. Observed failure to adhere to these ordinances should be reported to the Waukesha County Land Conservation Department.

2. The Pretty Lake Protection and Rehabilitation District, in conjunction with the Town of Ottawa, should assume the lead in the development of a public educational and informational program for the residents around and in the immediate vicinity of Pretty Lake, which encourage the institution of good urban housekeeping practices including, pesticide and fertilizer use management, improved pet waste and litter control, and yard waste management, as well as other lake management-related topics. It is recommended that informational programming related to nonpoint source pollution abatement and other lake management topics be included at the annual meetings of the Pretty Lake Protection and Rehabilitation District.

3. The Pretty Lake Protection and Rehabilitation District, in conjunction with the Waukesha County Department of Land Conservation, U.S. Department of Agriculture Natural Resources Conservation Service, University of Wisconsin-Extension, and other relevant agencies, promote sound farmland management practices within the drainage area directly tributary to Pretty Lake, including pesticide and fertilizer use management, and improved animal waste and agricultural waste management.

WASTEWATER TREATMENT AND DISPOSAL

Public sanitary sewer is not expected to be provided to the development in the Pretty Lake study area.[7] Thus, there is a need to manage the onsite sewage disposal systems in the Pretty Lake study area in order to avoid surface and groundwater pollution problems. As discussed in Chapter II, onsite sewage disposal systems are estimated to contribute only a very small portion of the pollutant loadings to Pretty Lake. However, failing or overloaded systems in the vicinity of the Lake can cause localized lake water quality problems. In addition such systems are a potential threat to groundwater quality.

Array of Control Measures

Three options to manage wastewater in the Pretty Lake study area have been identified; namely, 1) individual management of onsite sewage disposal systems, 2) community-based management of onsite sewage disposal systems, and 3) provision of a public sanitary sewerage system.

Given the expected continued use of onsite sewage disposal systems, consideration should be given to developing a management program. The basic objective of an onsite sewage disposal management program is to ensure the proper installation, operation, and maintenance of existing systems, and of any new systems that may be required to serve existing urban development in the Pretty Lake study area. Under the first option, the management program would be the responsibility of the individual property owners. The Pretty Lake Protection and Rehabilitation District could assist through an integrated homeowner information and education program. In addition, the Waukesha County Department of Parks and Land Use, Environmental Health Division, would serve as a resource in this program and would continue to perform its regulatory, permitting, and advisory functions related to onsite sewage systems.

Under the second option, the Pretty Lake Protection and Rehabilitation District or the Town of Ottawa could facilitate an onsite sewage disposal system management program by contracting with a hauler on behalf of all Pretty Lake residences, thereby potentially reducing the costs to individuals while ensuring community benefit. Under an expanded version of this option, the onsite sewage disposal system management program could potentially include the establishment of and active Sanitary District or Lake Management District with Sanitary District powers to raise and administer funds; inspect, design, and construct upgraded systems; and monitor the performance of systems.

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[7] *SEWRPC Memorandum Report No.93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

Under the third option, a public sanitary sewer system would be installed to serve urban development along the shoreline of Pretty Lake, as described in Appendix F. The nearest existing public sanitary sewerage system is the Village of Dousman system located about three miles to the northeast. It is unlikely that a new public sewage treatment plant to serve the Pretty Lake area would be cost-effective or implementable given current Wisconsin Department of Natural Resources policies which discourage construction of new small sewage treatment plants. However, connection to an existing sewerage system may be viable if there is an identified need to provide a public sewer system to serve the urban development surrounding the Lake, and if such a connection were to be carried out as part of a broader sewer service area plan. As noted in Chapter III, such a plan is currently being prepared for northwestern Waukesha County.

Recommended Control Measures

It is recommended that the Pretty Lake area continue to rely on the use of onsite sewage disposal systems, including, in some cases, holding tanks for wastewater disposal. The management of onsite sewage disposal systems be maintained as the primary responsibility of the private property owners and Waukesha County, as is currently the case. However, it is recommended that the Pretty Lake Protection and Rehabilitation District work with the Waukesha County Department of Parks and Land Use, Environmental Health Division, to develop a public informational and educational program to encourage property owners to have the onsite system inspected and to have any needed remediation measures undertaken. In the long term, it is recommended that the Pretty Lake Protection and Rehabilitation District take note of the recommendations set forth in the aforereferenced northwestern Waukesha County sanitary sewerage system master plan, and adopt an appropriate course of action to implement the applicable recommendations.

SHORELINE PROTECTION

Shoreland erosion is not a major problem on Pretty Lake, as much of the shoreline of Pretty Lake is kept in a fundamentally natural state. The need for maintenance of the shoreline in order to avoid erosion is important in order to protect the structure and functioning of the aquatic ecosystem of the Lake, and, especially, to preserve the nearshore and wetland aquatic vegetation in and around the Lake. Such protections also contribute to reserving and enhancing water quality and the essential structure and functioning of the waterbody and adjacent areas, and provide habitat for fishes and other aquatic life.

Alternative Protection Measures

Four alternative shoreline erosion control techniques are considered potentially viable: vegetative buffer strips, rock revetments, wooden bulkheads, and gabions. These alternatives, as shown in Figure 6, were considered because they can be constructed, at least partially, by local residents; because most of the construction materials involved are readily available; because the technique would, in most cases, enable the continued use of the immediate shoreline; and because the measures are visually "natural" or "semi-natural" and should not significantly affect the aesthetic qualities of the lake shoreline.

Recommended Protection Measures

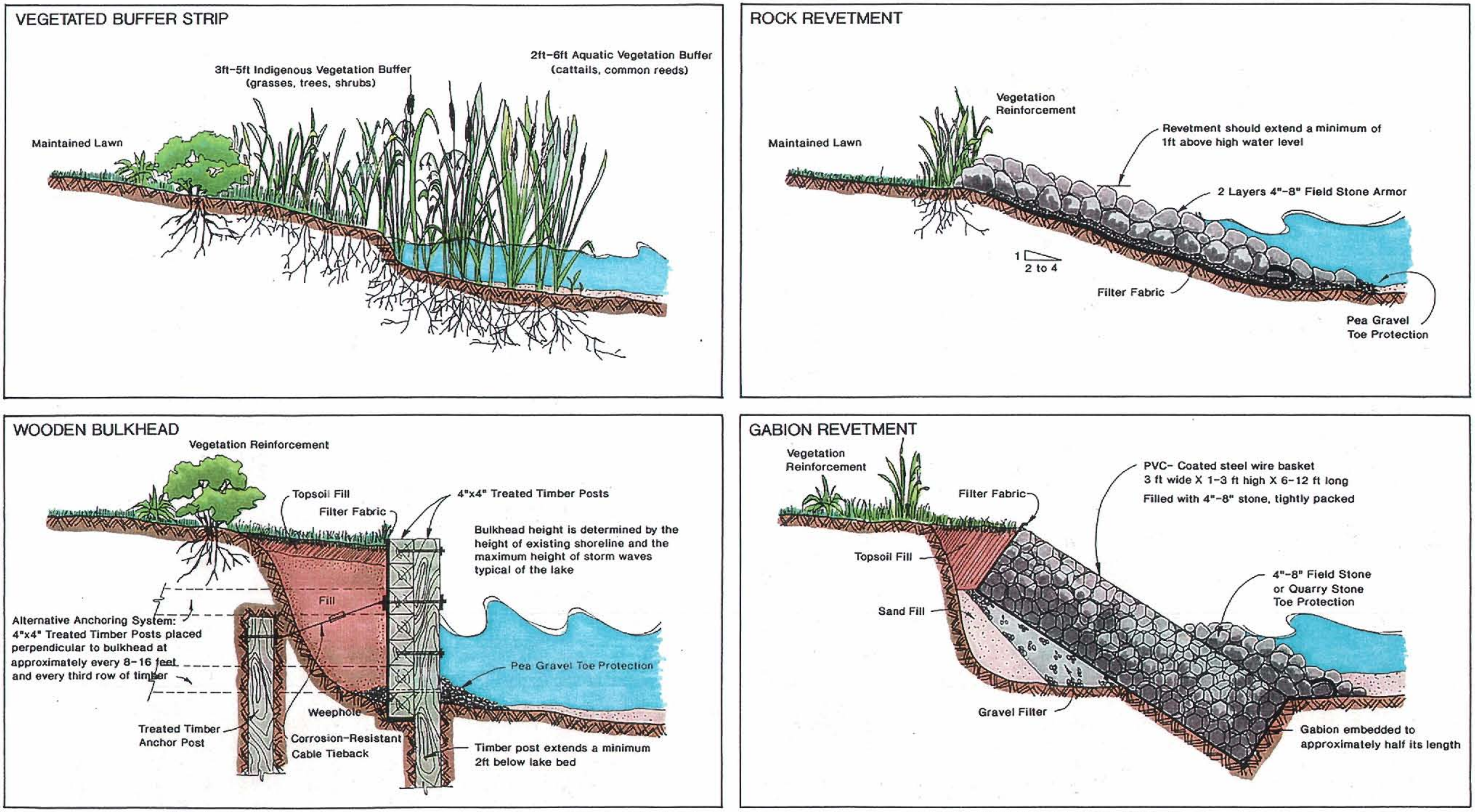
It is recommended that the Pretty Lake Protection and Rehabilitation District provide lakeshore residents with information on the methods of proper construction and maintenance of shoreland protection structures. Adoption of the vegetated buffer strips and riprap or rock revetment methods of shoreline protection is recommended. The proposed amendment of the boating ordinance, set forth above, should provide a further degree of protection to some of the unprotected shoreland area of the Lake by limiting boat usage in these areas.

GROUNDWATER QUANTITY AND QUALITY

Groundwater is the principal source of potable water to households in the Pretty Lake study area. In addition, groundwater recharge and discharge is an important component to the surface water system of Pretty Lake. Groundwater resource protection can best be accomplished through the protection of ecologically valuable areas which include groundwater recharge and discharge areas, and by managing onsite sewage disposal systems and nonpoint

Figure 6

PLAN ALTERNATIVES FOR SHORELINE EROSION CONTROL



NOTE: Design specifications shown herein are for typical structures. The detailed design of shore protection measures must be based on detailed analysis of local conditions.

Source: SEWRPC.

sources of pollution. Recommendations on these management actions are described earlier, and include the recommendations that:

1. The Pretty Lake Protection and Rehabilitation District and the Kettle Moraine Conservation Foundation, Inc., should consider public or private acquisition of the lands indicated on Map 16. This land acquisition should be coordinated with the Pretty-Section Trail acquisition and development recommended to be carried out by Waukesha County and the Wisconsin Department of Natural Resources. The land to the west of Pretty Lake is of the highest purchase priority due to its location within an ecologically valuable area, in addition to the significant potential influence this area has on the surface water level of Pretty Lake. The medium- and low-priority areas are recommended for acquisition due to their potential impact on the groundwater supply to Pretty Lake which was determined by the groundwater modeling program conducted for this planning program by the U.S. Geological Survey. Outright purchase, or the purchase of conservation easements, are both possible options. Public acquisition meets the criteria for cost-shared acquisition under the Chapter NR 191 Lake Protection Grant program administered by the Wisconsin Department of Natural Resources. Monies granted in terms of this program provide up to 75 percent of the purchase price, or the cost of acquisition of conservancy easement, subject to a cap of $200,000 on State share per parcel.

2. The Pretty Lake Protection and Rehabilitation District, in conjunction with the Town of Ottawa, should assume the lead in the development of a public educational and informational program for the residents around and in the immediate vicinity of Pretty Lake, which encourage the institution of good urban housekeeping practices including, pesticide and fertilizer use management, improved pet waste and litter control, and yard waste management, as well as other lake management-related topics. It is recommended that informational programming related to nonpoint source pollution abatement and other lake management topics be included at the annual meetings of the Pretty Lake Protection and Rehabilitation District.

3. The Pretty Lake Protection and Rehabilitation District, in conjunction with the Waukesha County Department of Land Conservation, U.S. Department of Agriculture Natural Resources Conservation Service, University of Wisconsin-Extension, and other relevant agencies, promote sound farmland management practices within the drainage area directly tributary to Pretty Lake, including pesticide and fertilizer use management, and improved animal waste and agricultural waste management.

4. The private property owners and Waukesha County retain primary responsibility for onsite sewage disposal systems, as is currently the case; however, the Pretty Lake Protection and Rehabilitation District should work with the Waukesha County Department of Parks and Land Use, Environmental Health Division, to develop a public informational and educational program to encourage property owners to have the onsite system inspected and to have any needed remediation measures undertaken. In the long term, it is recommended that the Pretty Lake Protection and Rehabilitation District take note of the recommendations set forth in the aforereferenced northwestern Waukesha County sanitary sewerage system master plan, and adopt an appropriate course of action to implement the applicable recommendations.

The only other specific recommendation is for the inclusion of public information on the responsible storage and use of household and agricultural chemicals in the overall lake management public informational and educational program. As described in Chapter III, the problems associated with groundwater result from the potential contamination of groundwater sources by onsite sewage disposal systems and land use activities.

AUXILIARY PLAN RECOMMENDATIONS

Public information, education, and involvement remains an important component of any lake management program. It is recommended that informational brochures and pamphlets, of interest to homeowners and supportive of the recommendations contained herein be provided to homeowners and supportive of the recommendations contained herein be provided to homeowners through direct distribution of targeted civic center outlets such as Town Hall.

Further, it is recommended that public meetings convened by the Town of Ottawa and the Pretty Lake Protection and Rehabilitation District at regular intervals be continued, and that informational issues identified above be presented as a regular part of such meetings. This plan and its subsequent iterations should be made available for public inspection at the Districts annual meetings.

Continued participation in the Wisconsin Department of Natural Resources Self-Help programs is also recommended as a means of assessing the health of Pretty Lake on a regular basis. These programs can provide an early warning of undesirable changes in lake water quality and aquatic species composition and initiate appropriate responses in a timely manner. Such data can supplement and be coordinated with data gathered by the Wisconsin Department of Natural Resources under the current surface water monitoring strategy developed to conduct monitoring activities and to perform basic assessments for each watershed in the Region on an approximately five- to seven-year rotating cycle.[8]

It is also recommended that the Wisconsin Department of Natural Resources, in cooperation with the Town of Ottawa and the Pretty Lake Protection and Rehabilitation District, conduct a fish survey of Pretty Lake and its tributaries to update information of fish species composition and condition. Such data has not been collected since 1978. It is recommended that such a survey be conducted on a five- to 10-year frequency in order to assess any significant changes in the fishery resource and to examine the need for additional fishery enhancement measures.

This plan, which documents the findings and recommendations of a study requested by the Town Board of the Town of Ottawa and the Pretty Lake Protection and Rehabilitation District, examines existing and anticipated water quality and recreation problems encountered by users of Pretty Lake and presents a recommended plan for the resolution of these problems.

Costs for the Pretty Lake protection plan were estimated and are set forth in Table 7. With the exception of the provision of buoyage to demarcate ecologically valuable areas within the Lake and potential land acquisitions, such costs are primarily administrative costs, to be borne by the District and by units of government. The cost of buoyage could potentially be off-set through the use of grants-in-aid provided under a cost-share program operated by the Wisconsin Waterways Commission and Wisconsin Department of Natural Resources, while the cost of land acquisitions could potentially be off-set through the use of grants-in-aid provided under cost-share programs operated by the Wisconsin Department of Natural Resources.

SUMMARY

This plan, which documents the findings and recommendations of a study requested by the Town Board of the Town of Ottawa and the Pretty Lake Protection and Rehabilitation District, examines existing and anticipated conditions and potential management problems of Pretty Lake and presents a recommended plan for the resolution of these problems.

Pretty Lake was found to be an oligo-mesotrophic, largely deep water of relatively good water quality located in close proximity to the Milwaukee Metropolitan area and adjacent to a progressively urbanizing part of Waukesha County in which its tributary drainage area is wholly located. Surveys indicated that the Lake and its study area contain significant areas of ecological value, including numerous wetlands and high-quality wildlife habitat.

The Pretty Lake protection and recreational use plan, summarized on Table 7 and Map 16, recommends actions be taken to limit further human impacts on the in-lake macrophyte beds and reduce human impacts on the ecologically valuable areas adjacent to the Lake and in its study area. The plan recommends immediate actions be taken to reduce further impacts on the ecologically valuable areas adjacent to the Lake and in its watershed. Specifically, these actions include possible acquisition of lands to the west of the Lake as a measure of protection of Pretty Lake's surface water level as well as water quality. Further, consideration of public acquisition of, or acquisition of conservation easements over, lands within the primary environmental corridors to ensure the protection and preservation of these ecologically

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[8]*Ibid.*

Table 7

RECOMMENDED MANAGEMENT PLAN ELEMENTS FOR PRETTY LAKE

Issue	Recommended Management Alternative	Location	Management Measures	Management Responsibility	Initial Estimated Cost
Ecologically Valuable Areas and Aquatic Plants	Protection of environmentally sensitive lands[a]	Town of Ottawa	Protect wetlands, wildlife habitat, and environmental corridors; develop and maintain trail systems as set forth in the Waukesha County park and open space plan component of the county development plan	Pretty Lake Protection and Rehabilitation District and Kettle Moraine Conservation Foundation, Inc., in coordination with Waukesha County and DNR	$ 205,000[b]
	Aquatic plant monitoring	Entire Lake	Participate in the DNR Self-Help Aquatic Plant Monitoring Program	Pretty Lake Protection and Rehabilitation District and private property owners	$ 500[c]
	Manual harvesting and limited chemical treatment	Affected in-lake areas and affected areas in tributary drainage area	Encourage and protect native aquatic plant growth; monitor exotic aquatic plant growth; control Eurasian water milfoil and purple loosestrife in the lake and wetland areas as necessary	Pretty Lake Protection and Rehabilitation District	- -[d]
Lake Water Levels	Operational control of drain tile[a]	Western portion of watershed	Acquisition of lands riparian to the western drain tile	Pretty Lake Protection and Rehabilitation District, Kettle Moraine Conservation Foundation	- -[b]
	Water level augmentation	Entire Lake	Continued operation of high-capacity well as necessary	Pretty Lake Protection and Rehabilitation District	$7,500[e]
Construction Site Erosion and Nonpoint Source Pollution	Land use plan implementation	Entire watershed	Support implementation of in Waukesha County development plan, including protection of environmental corridors	Waukesha County and Town of Ottawa	- -[f]
	Urban nonpoint source controls[a]	Entire watershed	Implement and maintain recommended urban good housekeeping practices	Waukesha County, Town of Ottawa, and Pretty Lake Protection and Rehabilitation District	- -[d]
	Construction site erosion control	Entire watershed	Continue to enforce existing ordinances	Waukesha County, all general-purpose units of government in drainage area, and private property owners	- -[g]
	Rural nonpoint source controls[a]	Entire watershed	Implement and maintain rural land best management practices	Waukesha County	- -[h]
Wastewater Treatment and Disposal	Maintenance of onsite sewage disposal systems[a]	Urban development surrounding Lake	Develop informational and educational program to promote sound maintenance practices and periodic inspections Review, and adopt and implement as appropriate, recommended actions set forth in the sewer service master plan for Northwestern Waukesha County	Waukesha County, Pretty Lake Protection and Rehabilitation District, and private property owners	- -[d]
Shoreland Protection	Maintain structures	Entire Lake	Maintain existing structures	Pretty Lake Protection and Rehabilitation District and private property owners	- -[d]
Water Quality Management	Water quality monitoring	Entire Lake	Continue to participate in the DNR Self-Help Water Quality Monitoring Program	Pretty Lake Protection and Rehabilitation District	- -[d,i]

Table 7 (continued)

Issue	Recommended Management Alternative	Location	Management Measures	Management Responsibility	Initial Estimated Cost
Fish Management	Fish survey	Entire Lake	Implement citizen-based creel survey with assistance from the DNR	Pretty Lake Protection and Rehabilitation District and DNR	$2,000[b,j]
Information Program	Public informational programming	Town of Ottawa in vicinity of Lake	Continue public awareness and information programming	Town of Ottawa and Pretty Lake Protection and Rehabilitation District	$ 500[k]

[a]*Implementation of this plan element contributes to the protection of groundwater quantity and quality.*

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

[c]*This cost is based upon surveys conducted at about five-year intervals at $2,500 per survey. This cost could be reduced or eliminated of the Pretty Lake Protection and Rehabilitation District joined the DNR Self-Help Aquatic Plant Monitoring Program in which volunteers are trained to complete aquatic plant surveys on their lake.*

[d]*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.*

[e]*Cost includes $1,500 per year for capital replacement of pump and $6,000 per year for operations and maintenance.*

[f]*Recommendation set forth in county development plan. No specific cost allocation for Pretty Lake.*

[g]*Cost varies with amount of land under development in any given year.*

[h]*costs vary and will depend upon preparation of individual farm plans.*

[i]*The DNR Self-Help Monitoring Program involves no cost but does entail a time commitment from the volunteer.*

[j]*Periodic additional surveys are recommended at five- to 10-year intervals.*

[k]*Expenditures used for compiling and distributing newsletters and other public informational and educational materials.*

Source: SEWRPC.

valuable areas was suggested. The plan recommends only limited aquatic plant management action, including selected manual removal and surveillance activities at this time, mainly in the cases where Eurasian water milfoil and purple loosestrife are present. The plan also recommends that the macrophyte beds that contain Eurasian water milfoil be marked as motor exclusionary zones to attenuate the further proliferation of this plant. An initial, and periodic future, fishery surveys are also recommended.

The recommended plan includes continuation of an ongoing program of public information and education providing riparian residents and lake users. For example, additional options regarding 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 alternatives to traditional alternatives and activities. The plan also recommends continued reliance on onsite sewage disposal systems for wastewater management.

The recommended plan seeks to balance the demand for high-quality residential and recreational opportunities at Pretty Lake with the requirements for environmental protection.

APPENDICES

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Appendix A

DETAILED DESCRIPTION OF GROUNDWATER FLOW MODEL AS APPLIED TO PRETTY LAKE

The Application of an Analytic Element Model to Investigate Groundwater-Lake Interactions at Pretty Lake, Wisconsin

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ABSTRACT

Hunt, R. J. and Krohelski, J. T. 1996. The application of an analytic element model to investigate groundwater-lake interactions in Pretty Lake, Wisconsin. Lake and Reserv. Manage. Vol. 12(4):487-495.

Pretty Lake is a 64 acre, sandy-bottomed groundwater flow-through lake that has a history of hydrologic disturbance. Residents and regulators require a better understanding of lake-groundwater interaction to develop measures to protect the lake's hydrologic system and water quality. A groundwater flow model was constructed as a tool to synthesize field data collected at the site, delineate recharge areas that supply groundwater to the lake, and predict the effect of dredging an adjacent drainage ditch. The one layer, two-dimensional steady-state areal model used analytic element (AE) methods because they are quick to apply and include sophisticated simulation of groundwater-surface water interaction. The model calibrated well to groundwater heads (mean absolute difference = 0.05 m), lake stage (within 0.05 m) and ditch fluxes (mean absolute difference = 0.0023 $m^3 \cdot s^{-1}$). Model results showed that a single 1000 m wide recharge area supplies all the groundwater inflow to the lake. In addition, the model predicted that dredging an adjacent ditch by 3.0 m would lower the lake level by 0.31 m. The analytic element model was verified using a widely accepted finite-difference (FD) code; differences were less than ±0.015 m near the lake area and reached a maximum of 0.08 m at far corners of the FD grid. These differences are likely a result of the nodal interpolation inherent to FD techniques and error associated with applying a discrete boundary to the AE infinite aquifer. Although developed recently, AE methods have great potential to aid characterizations of groundwater-lake systems.

Key Words: analytic element methods, groundwater flow modeling, groundwater-lake interaction.

Pretty Lake, located in southeastern Wisconsin, has a history of hydrologic disruption. The lake is a sandy-bottomed groundwater flow-through lake of about 64 acres that is used for swimming, boating and fishing by lake shore residents and the public. The surrounding land is flat and composed of surficial deposits of outwash commonly mantled by peat. Many areas adjacent to the lake have been filled to enhance residential development and adjacent land to the north has been extensively ditched to provide drainage for sod farming (Fig. 1). To the east and west, the land is also ditched but is forested or is agricultural land that is not cropped; land south of the lake has been developed into private residences.

Most of the ditches were dug in 1914 to drain the land for agriculture. Tree ages, the lack of dredge spoil adjacent to the ditches, and the amount of silt in the ditch beds, indicate the ditches east of Pretty Lake have not been maintained for the last 20 years and that ditches to the west have not been maintained for a greater period of time. The ditches to the northeast and north, however, have been recently maintained and new lateral ditches have been constructed. Two dams were installed on the north and northeast ditches around 1917 to raise groundwater levels in the watershed, and restore historic lake levels in Pretty Lake (Dale Simon, pers. comm., Wisconsin Department of Natural Resources (DNR), 1987). As recently as the 1980s, a small dam on the east ditches was constructed but has since been abandoned. In addition, anecdotal evidence suggests that the lake is experiencing increasing sedimentation of organic material that may be due to local land use changes. As a result, residents and regulators require a better understanding of the lake-groundwater interaction in order to develop measures to protect the lake's hydrologic system and water quality.

The effect of nearby ditching on Pretty Lake levels is inherently difficult to determine because groundwater flow-through lakes naturally fluctuate more than other lake types. The water level of a typical groundwater flow-through lake can be expected to be 0.43 m above

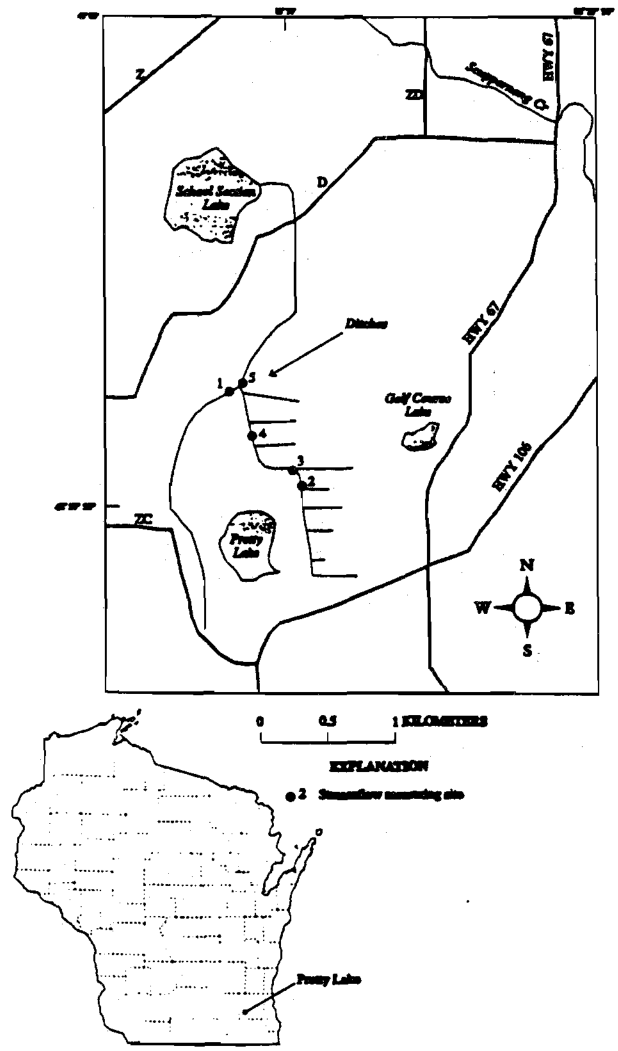

Figure 1.– Location of Pretty Lake. Locations of ditch-discharge measurements are also shown.

or below the lake's long-term mean level about 10 percent of the time (House 1985). A historical review of the Wisconsin Department of Natural Resources' (DNR) Water Regulation and Zoning records indicate that complaints of low water levels in Pretty Lake were received by the Department in 1958, 1963 and 1969 (Dale Simon, DNR, pers. comm., 1987).

Several studies were conducted by the DNR and the U.S. Geological Survey (USGS) to characterize the hydrologic setting. Studies and surveys of the lake and ditches conducted by the DNR include measurement of the ditch discharge and ditch and lake levels (Dale Simon, DNR, written comm., 1987 and 1988). These studies also estimated the lake hydrologic budget components and included groundwater level measurements and displacement-recovery tests from ten piezometers installed adjacent to the lake (DNR 1982). In 1989, the USGS investigated the effects of pumping groundwater from a nearby irrigation well into the lake by measuring lake and groundwater levels in several piezometers along sections radiating from the lake. These measurements were made prior to, during and after pumping groundwater into the lake and were used to estimate a seepage rate of lake water entering the groundwater system (Vernon Norman, USGS, written comm., 1989). Lake water quality has been monitored periodically by USGS and the DNR (Steve Field, USGS, written comm., 1992-1993).

In 1994, the USGS, South Eastern Wisconsin Regional Planning Commission (SEWRPC), Pretty Lake District and the DNR initiated a study to produce a comprehensive lake management plan. The USGS study objective was to quantify the hydrologic relationship of Pretty Lake to its watershed. To address this objective, a calibrated groundwater flow model was used to 1) synthesize the data collected in the previous studies, 2) define lake recharge areas (i.e., areas of groundwater inflow into the lake) and 3) provide a tool for assessing the effects of hydrologic management scenarios on lake levels.

Groundwater flow models have been historically used to assess groundwater-lake interaction (e.g., McBride and Pfannkuch 1975; Winter 1978; Rinaldo-Lee and Anderson 1980; Anderson and Munter 1981; Pfannkuch and Winter 1984; Krabbenhoft et al. 1990). This work has focused on quantifying steady-state fluxes and delineating stagnation points in the groundwater system. Recently, Cheng and Anderson (1993) modified a finite-difference groundwater flow model to include a "Lake-Stage Package" that explicitly couples lake water budgets to the groundwater system. This module includes all the components of the water budget, including inlet and outlet streams, thus allowing for direct simulation of lake stage within the groundwater flow model. As is often true in finite-difference methods, this type of detailed lake modeling requires more time, field data and calibration than what is needed for most simple groundwater-lake problem objectives.

Methods

In this study, an alternative approach using the analytic element model GFLOW (Haitjema 1995) was used to simulate the Pretty Lake system. Analytic element (AE) methods are relatively new in their application and are based on superposition (i.e., addition or subtraction) of analytic functions, each representing a particular aquifer feature (Strack 1989; Haitjema 1995). AE assumes infinite aquifer extent, and model boundaries consist of internal rivers, creeks, lakes, etc. that are easily identified from topographic maps. In contrast to other numerical techniques (e.g., finite-difference), heads can be computed at any point in the problem domain without nodal interpolation (i.e., averaging over the node area) and without rigid grid discretization, thus regional-scale solutions can be "collapsed" and used to constrain the local gradient for the site-scale problem. Because the method is relatively new, a widely used finite-difference code MODFLOW (McDonald and Harbaugh 1988) was used to verify the AE model in the site area.

The approach used in this paper differs from traditional approaches in the way the lake system was included into the model. Most modeling has included the lake as simply a source or sink to the system (i.e., only adding and removing water). Thus lakes were included as either a "constant head" boundary (i.e., the head in the aquifer below the lake was not allowed to vary) if they were fully penetrating, or a "head-dependent flux" boundary if the lake was partially penetrating. In either case, the head *in the lake* (or lake stage) is fixed, and does not vary in response to stresses applied to the hydrologic system. As is well known, this simplifying assumption is not strictly true, and groundwater-lake systems are truly "coupled." Therefore, this study was designed so that lake stage could vary in response to changes in the groundwater system.

A two-dimensional steady-state groundwater flow model was constructed to encompass the Pretty Lake area (Fig. 2) using the parameters shown in Table 1.

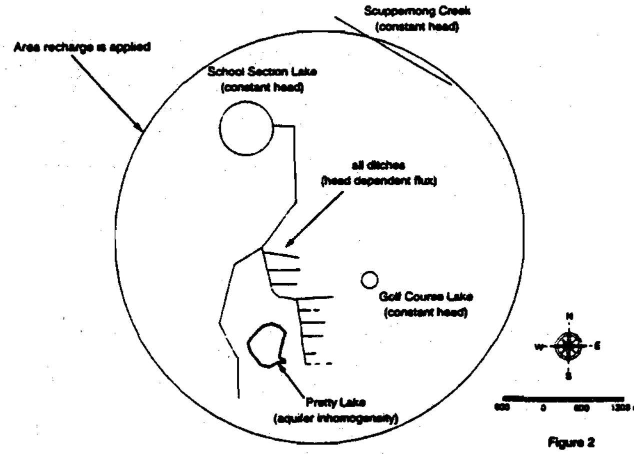

Figure 2.–Location and type of analytic elements used in the AE model.

The flow model is considered a simplified representation of the natural system due to the following assumptions:

- The flow system is two-dimensional (i.e., the vertical component of flow and three-dimensional nature of the geologic deposits can be neglected);
- Recharge is represented by a single uniform recharge rate over the entire model;
- The aquifer system is represented by a single value of hydraulic conductivity;
- The system is at steady-state (i.e., water levels are not changing over time).

Table 1. —Parameters used in analytic element and finite-difference models.

Aquifer thickness (allowed to vary depending on water table elevation)	up to 43 (m)
Aquifer horizontal hydraulic conductivity	
measured	8 ($m \cdot d^{-1}$)
used in model	76 ($m \cdot d^{-1}$)
Lake inhomogeneity hydraulic conductivity	76,200 ($m \cdot d^{-1}$)
Aquifer base	219 (m above mean sea level)
Recharge rate	15 ($cm \cdot yr^{-1}$)
Bed resistance	
eastern ditches	0.5 to 1.5 ($m \cdot d^{-1} \cdot m^{-1}$)
western ditches (base case)	3.0 ($m \cdot d^{-1} \cdot m^{-1}$)
western ditches (predictive mode)	0.5 ($m \cdot d^{-1} \cdot m^{-1}$)
Thickness of bed sediments	
eastern ditches	0.3 (m)
western ditches (base case)	1.2 (m)
western ditches (predictive mode)	0.6 (m)
Rate of water lost from Pretty Lake (=estimated evapotranspiration - annual precipitation)	10 ($cm \cdot yr^{-1}$)

As a result of the scale dependence of hydraulic conductivity (Bradbury and Muldoon 1989), global hydraulic conductivity of the unconsolidated sediments was determined to be one order of magnitude higher than slug tests conducted in wells in the site area (Table 1). The system was modeled using one homogeneous, isotropic layer (representing the high conductivity glacial sediments) overlying an impermeable base. Although the bedrock is not truly impermeable, it has a hydraulic conductivity value two orders of magnitude lower than the overlying sediments. Therefore top of the bedrock was considered to be the base of the shallow system in order to simplify the system. Groundwater recharge (precipitation minus runoff and evapotranspiration) was assumed to be approximately one-fifth of annual precipitation or 15 cm · yr^{-1}. The recharge was applied uniformly over the modeled area and had an areal extent consistent with the surface watershed so that simulated fluxes represented only water derived within the basin. Significant regional hydrologic features (lakes, streams, ditches, etc.) were entered into the model (Fig. 2) until the observed water table gradient was roughly matched.

In the site area, the groundwater flow system is controlled by the adjacent ditch network. These features were put into the model using stream elements. These elements are head-dependent flux elements that include streamflow analysis that assesses whether or not losing reaches of streams have enough flow derived upstream to infiltrate the amount of water calculated by the groundwater solution. The head dependent flux boundary input must specify the width and the resistance of the bottom sediments, where the resistance is defined as the vertical conductivity of the sediments divided by the thickness of the sediments. Heads in the ditches were measured in the field area during November 1987 at five locations (Fig. 1). Resistance values were used as a model calibration parameter (changed during the modeling process to obtain a better fit of the simulated results to the measured data). However, the range and zoning of resistance was based upon field observation of stream-bed properties. Ditch width was measured at

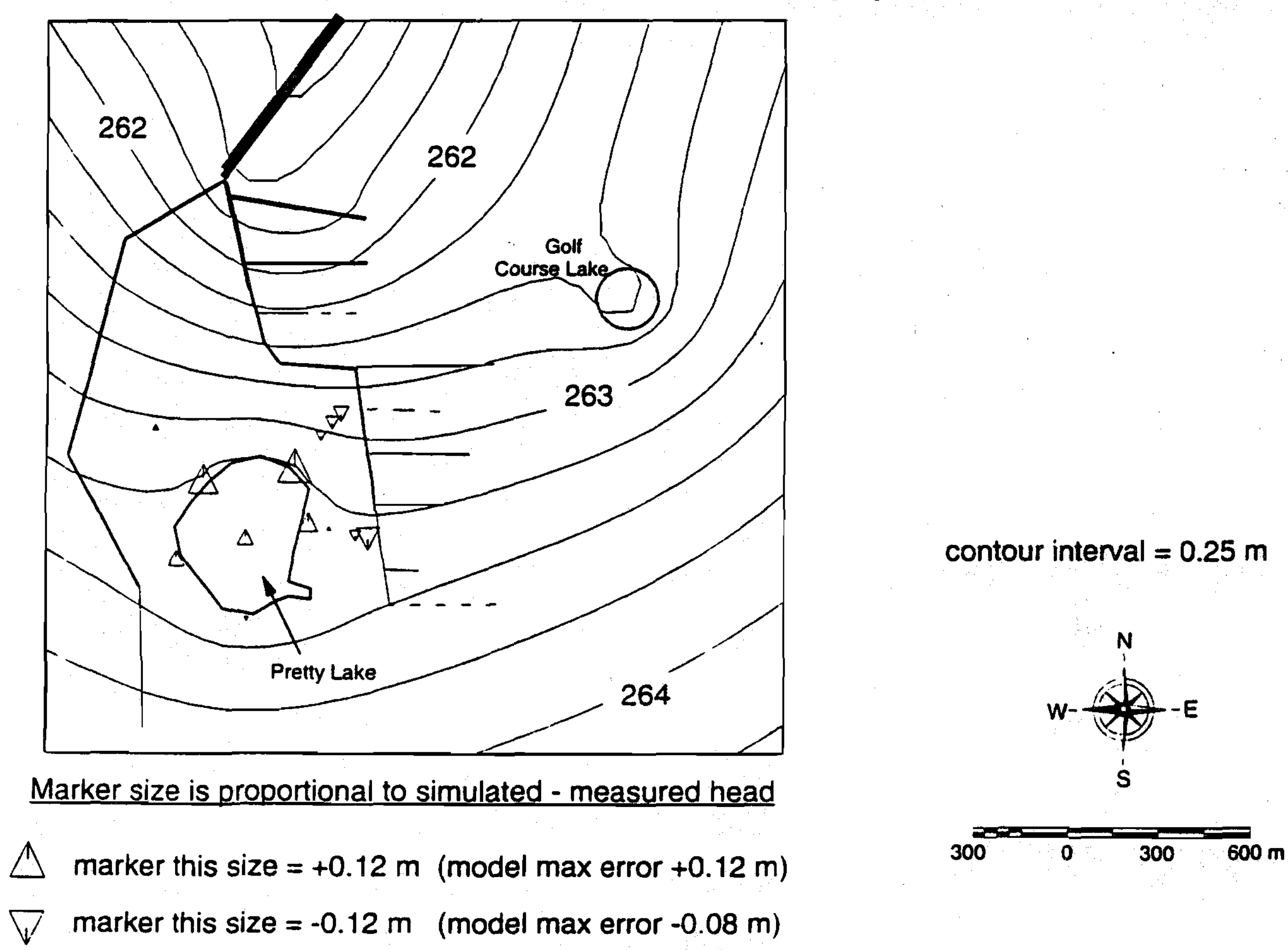

Figure 3.–Simulated heads in the site area. Line width of the ditches is proportional to ditch streamflow. Ditches that are dry are indicated by dashed lines. The markers near the Pretty Lake area represent head calibration points whose size is proportional to the difference between simulated and measured head. An upward-pointing triangle represents simulated heads are larger than measured heads; a downward-pointing triangle represents simulated heads are lower than measured heads. The marker in Pretty Lake represents the simulated lake stage which is 0.05 m higher than measured lake stage; the mean absolute difference of all simulated - measured heads is 0.05 m.

all locations where ditch stage was determined, and extrapolated between measurements.

Previous numerical modeling studies generally model lakes as constant head or head-dependent flux boundaries. Lakes away from the study area (Golf Course Lake and School Section Lake shown in Fig. 1) are designated in the model as constant head nodes (i.e., are considered fully-penetrating through the aquifer). This designation does not mean that the lake itself extends to the base of the model, rather the head in the lake is manifested *hydraulically* throughout the aquifer, even below the lake bottom. Lake stage in these locations is specified *a priori* from USGS topographic maps and is not directly solved for by the model. Similarly, Scuppernong Creek (Fig. 1) is also located away from the study area and is input into the model using constant heads.

Pretty Lake was input into the model as a zone of high conductivity in order to allow water to move freely within the lake and to solve for lake stage. Its conductivity (76,200 m $\cdot$ d^{-1}) is three orders of magnitude higher than the surrounding aquifer thus precluding the development of a gradient within the lake (Table 1). In keeping with the assumptions inherent in two-dimensional modeling, the lake was entered into the model using a high conductivity cylinder shaped to resemble the lake shoreline (Fig. 2); this feature is an "inhomogeneity" element. As the name implies, this element represents a zone of differing hydrologic properties than the surrounding aquifer material. In the real world, the lake would have infinite conductivity, and the aquifer material underlying the lake has hydrologic properties similar to the aquifer. Although it is impossible to average an infinite conductivity, at large contrasts there is no effect on the modeled system.

Water was removed from the inhomogeneity to represent the net loss of water caused by the deficit of annual precipitation minus an estimated annual evapotranspiration (Table 1). Because Pretty Lake is a small, shallow lake, evapotranspiration was assumed to be 0.9 times the Class A pan evaporation rate of 100 cm $\cdot$ yr^{-1} reported by Dunne and Leopold (1978). The model is steady-state, therefore seasonal variations in precipitation and evapotranspiration cannot be modeled. This representation of the lake system includes all the appropriate components of the lake's water budget, and also allows the lake stage to be calculated directly by the model. This allows the modeler to ascertain the effects of various hydrologic stress scenarios (e.g., What if a pumping well was installed next to the lake? What are the effects if adjacent ditches were dredged to increase their depth and hydrologic connection?).

In addition, AE codes have an integrated particle tracking routine that can be used to delineate recharge areas, travel times and groundwater flow paths. Particle tracking consists of placing an imaginary particle of water into the groundwater system and numerically calculating the path the particle takes based on the simulated gradient of the flow system. This type of numerical particle tracking was performed on the simulated groundwater-lake system to delineate the lake's groundwater recharge area.

Results

The simulated flow system derived from surface water boundary features was compared to the overall flow system configuration (heads and fluxes) measured in the field. Generally, the model calibrated very closely to heads measured in 12 wells, lake stage and ditch fluxes (Figs. 3 and 4). Although the mean absolute difference error in heads was small (MAD=0.05 m), the differences in the head residuals were not randomly distributed in space. As shown in Figure 3, heads were too high near Pretty Lake and too low near the ditches. The model calculated lake stage for Pretty Lake was also 0.05 m higher than the observed data. The differences in simulated and measured head are likely due to the different periods that head and flux measurements were taken (March 1988 and November 1987, respectively). The system near the lake was likely not at complete steady-state in March due to the proximity to the spring recharge event and lake ice out. Simulated ditch fluxes were also very similar to DNR-measured ditch discharges (Fig. 4) with a MAD of 0.0023 m^3 $\cdot$ s^{-1}.

The results of numerical particle tracking (Fig. 5) shows the presence of a groundwater divide between the ditches and the lake. In the case of Particle Trace Set A, a particle of water that enters the system at A1 will

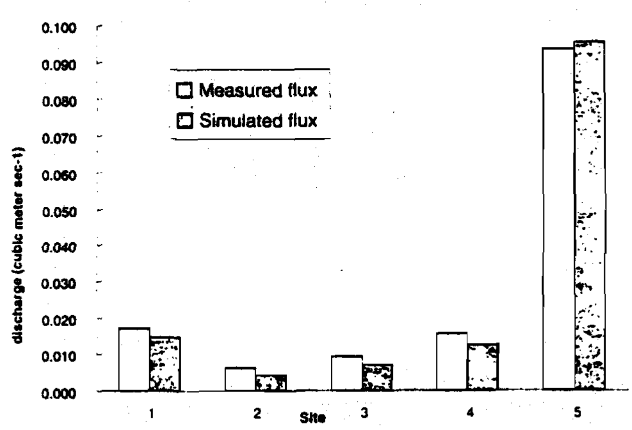

Figure 4.--Simulated and measured flux measurements for the locations shown in Fig. 1.

move to the north and enter Pretty Lake before being intercepted by a downgradient ditch; a particle of water starting at A2 will flow directly to the downgradient ditch system. Note that because the ditches are simulated head dependent flux elements, the ditches may or may not be fully penetrating. As a result, particles may flow under one ditch and be captured by another ditch downgradient (e.g., A2 in Fig. 5). At the divide delineated by Particle Trace Set B, a particle of water starting at the water table at B1 flows toward the downgradient ditch system; a particle of water that starts at B2 will flow into Pretty Lake. Particle B3 demonstrates that groundwater recharged west of the ditch will be captured by the ditch and will not enter the lake. All particles entered between the A1 and B2 will be captured by Pretty Lake. This zone represents the "capture zone" of the lake (Fig. 5), and represents the area where adjacent land use will have the largest effect on lake water quality and quantity. As a result, this area should be of greatest concern to those interested in protecting lake water quality from adverse effects of surrounding land use.

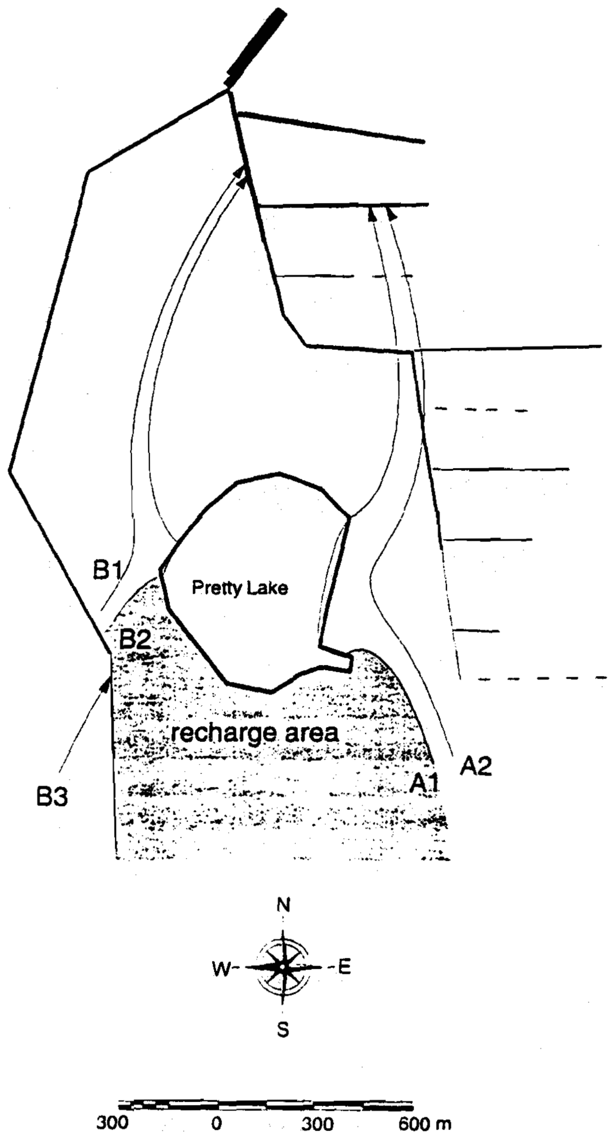

Figure 5.–Results of numerical particle tracking. Arrowheads represent the location where the particle leaves the groundwater system and enters the surface water system. The recharge area of the lake is shown by the shaded area.

An example of using the model in predictive mode is shown in Fig. 6. As described previously, the western ditch is presently not maintained, has a poor hydraulic connection to the aquifer, and has a high resistive layer in the model (Table 1). As is shown in Table 1, the ditch bed thickness and resistance were lowered to simulate the removal of the dredge spoil and the associated increased hydraulic connection. In addition, the head in the ditch was lowered by 0.6 m from the base case to simulate the lower stage that results from the more efficient removal of ditch discharge. As shown in Fig. 6, the modifications do affect the lake system, and decreased the Pretty Lake stage by 0.31 m. In addition, the increased streamflow (as evidenced by the increased line width) in the western ditch has reduced flow in the eastern ditches. This quantitative prediction of effects can be broadened to include any combination of steady-state stress such as well effects and reduction in groundwater recharge due to drought. This model is being used by the SEWRPC to assess these types of scenarios (Jeff Thornton, pers. comm., SEWRPC 1995).

MODFLOW model

Because AE techniques have been developed relatively recently, the AE methodology is not as widely utilized as the other numerical techniques (most notably finite-difference techniques). While the basic underlying groundwater flow equations are similar, the solution schemes for solving various hydrologic features differ in the formulation of the equation and the coding of the conceptual model. We constructed a finite-difference model of the site area using MODFLOW (McDonald and Harbaugh 1988). The basic differences between the FD model (MODFLOW) and the AE model (GFLOW) can be summed as follows:

1) FD requires explicit discretization of the problem domain, AE does not;

2) AE assumes an aquifer of infinite extent, FD requires the input of outer boundaries;

3) In FD the effect of a point feature (e.g., a well) is averaged over the entire node it resides in, a point feature is not averaged in AE;

4) FD is suited for extremely heterogeneous

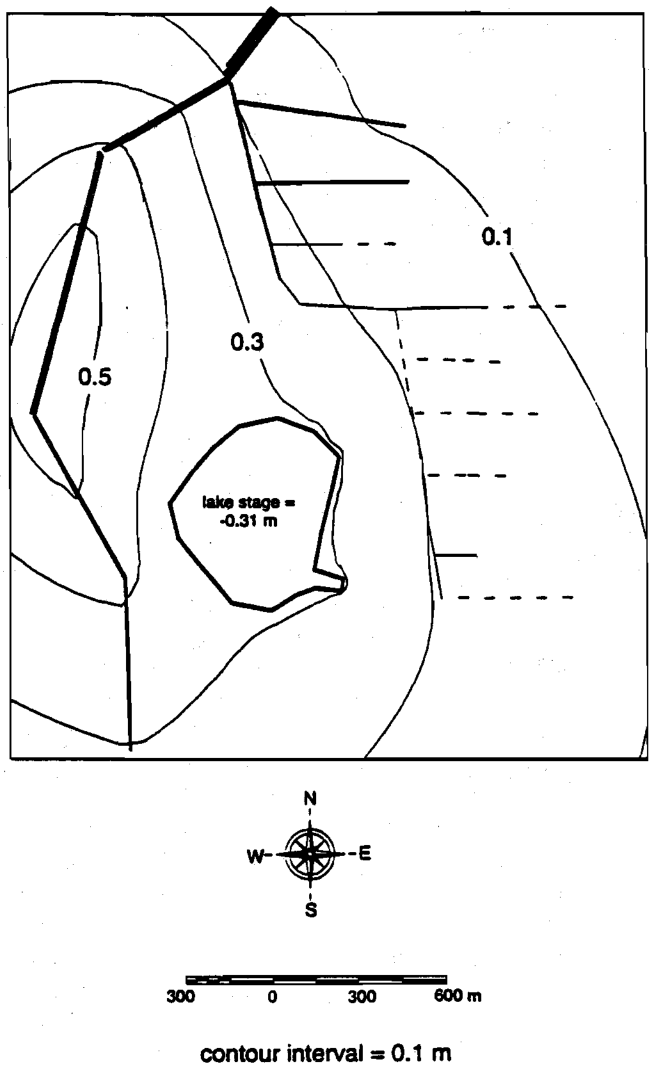

Figure 6.–Results of predictive modeling simulating the dredging of the upper 0.6 m of sediment from the western ditch. Heads in the ditch were lowered by 0.6 m, resistance of the ditch sediments was decreased from 3.0 to 0.5 m · d^{-1} · m^{-1}, sediment thickness in the ditch was reduced from 1.2 m to 0.6 m. Note the increased line thickness representing increased streamflow captured from the eastern ditches which have reduced flows. Dashed lines represent ditch segments that do not carry enough water to sustain the loss to groundwater; these segments are removed from the groundwater solution and are considered "dry."

settings, AE is better suited for less heterogeneous settings;

5) FD is able to solve steady-state and transient problems, AE is limited to primarily steady-state problems.

The first two points result in AE models being simpler and quicker to construct than an equivalent FD model. The first three points allow for easy construction of a regional model for the large-scale flow field, with subsequent "zooming in" to concentrate on site-scale problems (e.g., as was done between Figs. 2 and 3). The fourth and fifth points illustrate the most significant limitations of AE methods.

An extended version of the AE code GFLOW (Haitjema 1995) includes a graphical analytic element processor or GAEP (Kelson et al. 1993) that creates simple MODFLOW data sets directly from the GFLOW analytic element model. The post-processor translates aquifer properties, inhomogeneities, regional flow and head dependent flux boundaries into the appropriate MODFLOW format. The resulting FD model is highly specified by GFLOW-derived constant head or constant flux boundaries on the four edges of the grid, therefore the data sets are often modified by other third-party MODFLOW processors for more complex modeling problems. As used in this paper, however, these unmodified MODFLOW input files allow a quick and easy check on the accuracy of the GFLOW solution in the area of interest.

The simple MODFLOW grid obtained from the post-processor is shown in Fig. 7a. The area of interest was discretized into a 100 x 100 grid using uniform 30 m grid spacing. We used specified flux boundaries to bound the problem domain; all other model parameters were the same as used by the AE model. It should be noted that a FD model domain should include a constant head condition in order to give a reference elevation from which to calculate head (Anderson and Woessner 1992). In this model, we included an internal constant head boundary condition at Golf Course Lake (Fig. 7) to meet this condition.

The resulting simulated heads are shown in Fig. 7b and compare well with the AE simulated heads (Fig. 3). Differences between the FD and AE solution are shown in Fig. 7c and Fig. 8. The difference between the two solution techniques was small, ranging from -0.05 to +0.08 m in localized areas near corners of the model

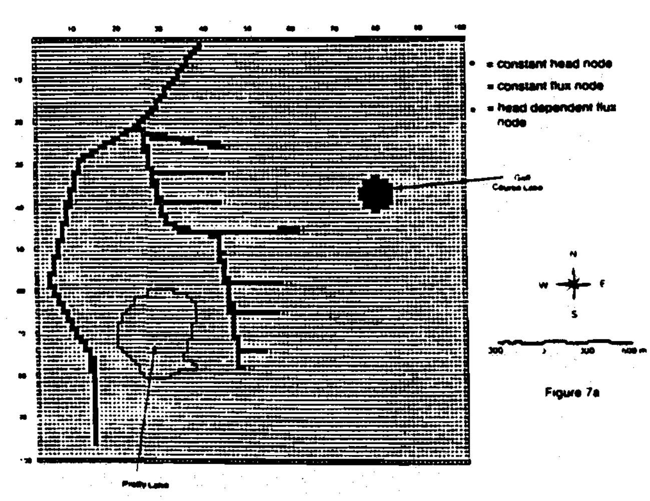

Figure 7a.–Schematic diagram of the finite-difference MODFLOW grid used in the submodel of the site area.

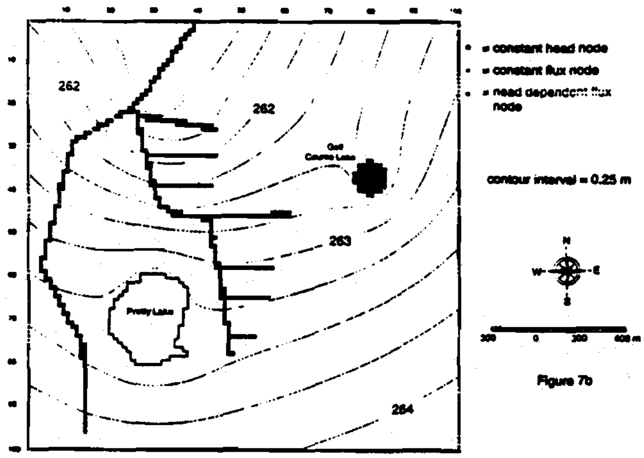

Figure 7b.–Head distribution calculated by the MODFLOW model. This figure is comparable to the head distribution calculated by AE methods shown in Fig. 3.

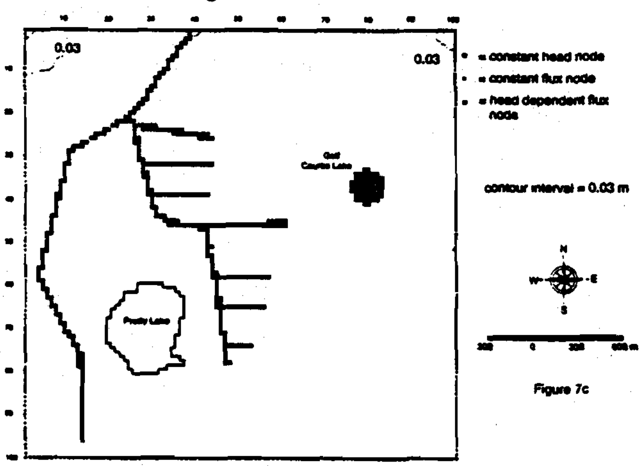

Figure 7c.–Contour plot of differences between the AE and FD models. Positive numbers indicate the MODFLOW heads interpolated over the node are greater than the GFLOW head calculated at the node center.

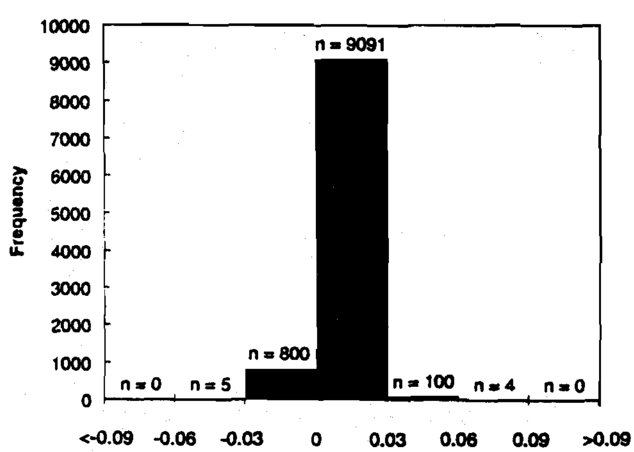

Figure 8.–Histogram of the difference between AE minus FD simulated heads. Positive numbers indicate the MODFLOW heads interpolated over the node are greater than the GFLOW head calculated at the node center.

domain and less than 0.015 m over most of the problem domain. This difference in solutions is an artifact of 1) FD discretization (i.e., a smaller grid spacing results in smaller differences) and 2) differences in flow associated with the addition of the FD boundary constraint on the AE infinite aquifer. While modeling this problem using constant head boundaries along the edges of the grid would further reduce the difference by creating a highly specified flow field, this range of difference shown in Fig. 8 is considered to be within the accuracy expected from this modeling application.

Summary and Conclusions

GFLOW, an analytic element groundwater flow model, has been shown to be a quick and powerful tool that can be used by lake managers to delineate lake inflow areas, predict effects of hydrologic stress, and explicitly solve for lake stage. The model calibrated well to steady-state conditions as shown by 1) the MAD between simulated and measured heads equal to 0.05 m, 2) simulated lake stage being within 0.05 m of measured lake stage, and 3) the MAD between simulated and measured ditch fluxes was 0.0023 $m^3 \cdot s^{-1}$. The model was used to delineate a 1000 m wide recharge area south of the lake. The model also predicted that dredging an adjoining, poorly maintained ditch would lower lake levels by 0.3 m. Because AE methods are relatively new, the GFLOW code was verified using a MODFLOW finite-difference model of the lake area. During this verification, it was noted that small discrepancies between the model solutions can exist near the finite-difference grid corners. These differences were less than 0.015 m away from the FD boundaries, however, and did not significantly affect the model results. Due to their ease of construction, and their ability to explicitly calculate lake stage particle track, and simulate a variety of potential hydrologic stresses, AE methods have great potential to aid lake managers to characterize lake-groundwater interactions, and assess potential effects caused by changes in surrounding land use.

ACKNOWLEDGEMENTS: The authors would like to thank B. Dale Simon, Bob Wakeman, Vic Kelson and Jeff Thornton for their help and insight. The manuscript was improved as a result of thoughtful review by Mary Anderson, Dave Krabbenhoft and two anonymous reviewers. This study was funded cooperatively by the Pretty Lake District through a Wisconsin Department of Natural Resources Lake Grant and the U.S. Geological Survey.

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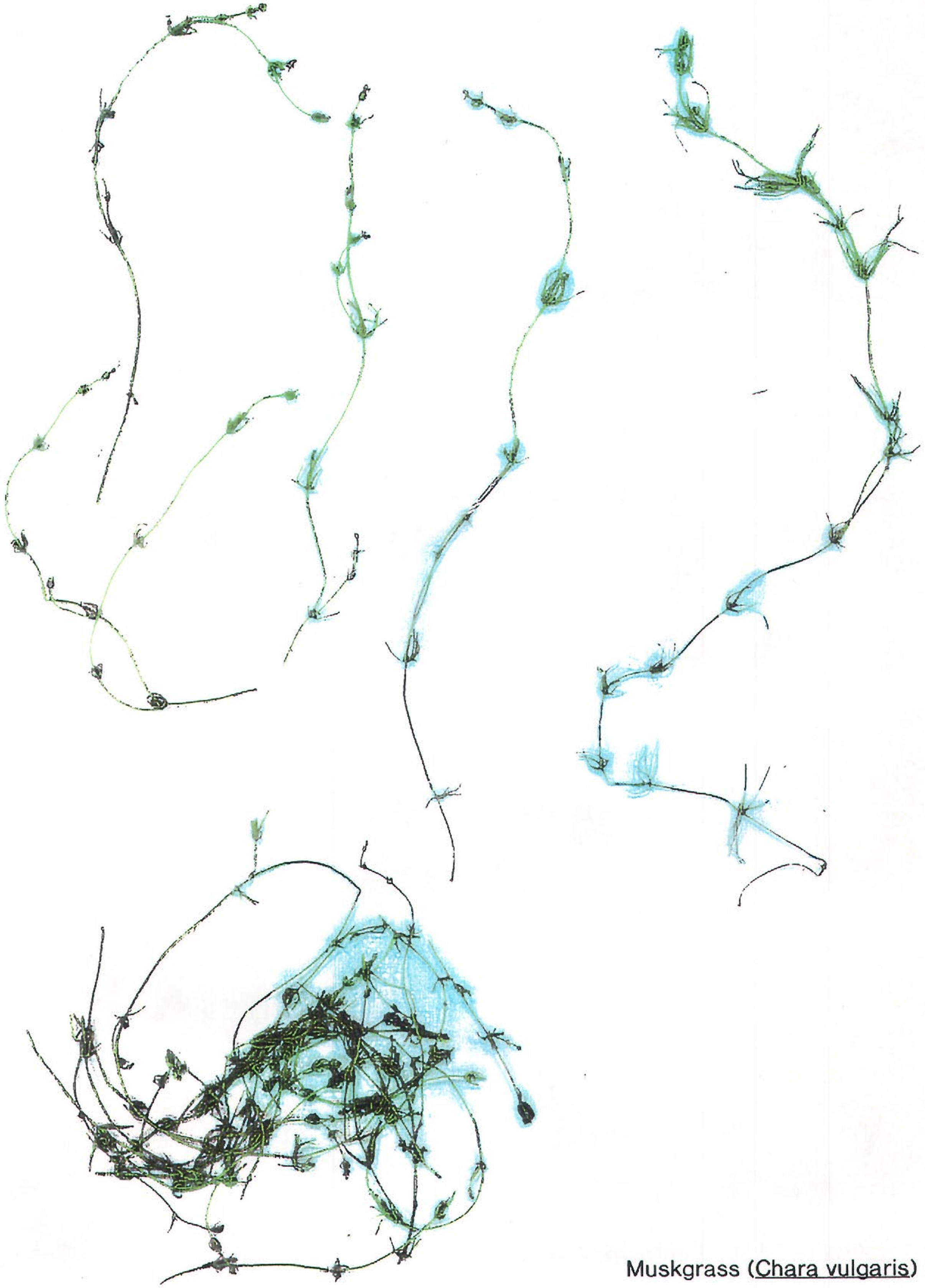
Appendix B

REPRESENTATIVE ILLUSTRATIONS OF AQUATIC PLANTS FOUND IN PRETTY LAKE

Waterweed (Elodea canadensis)

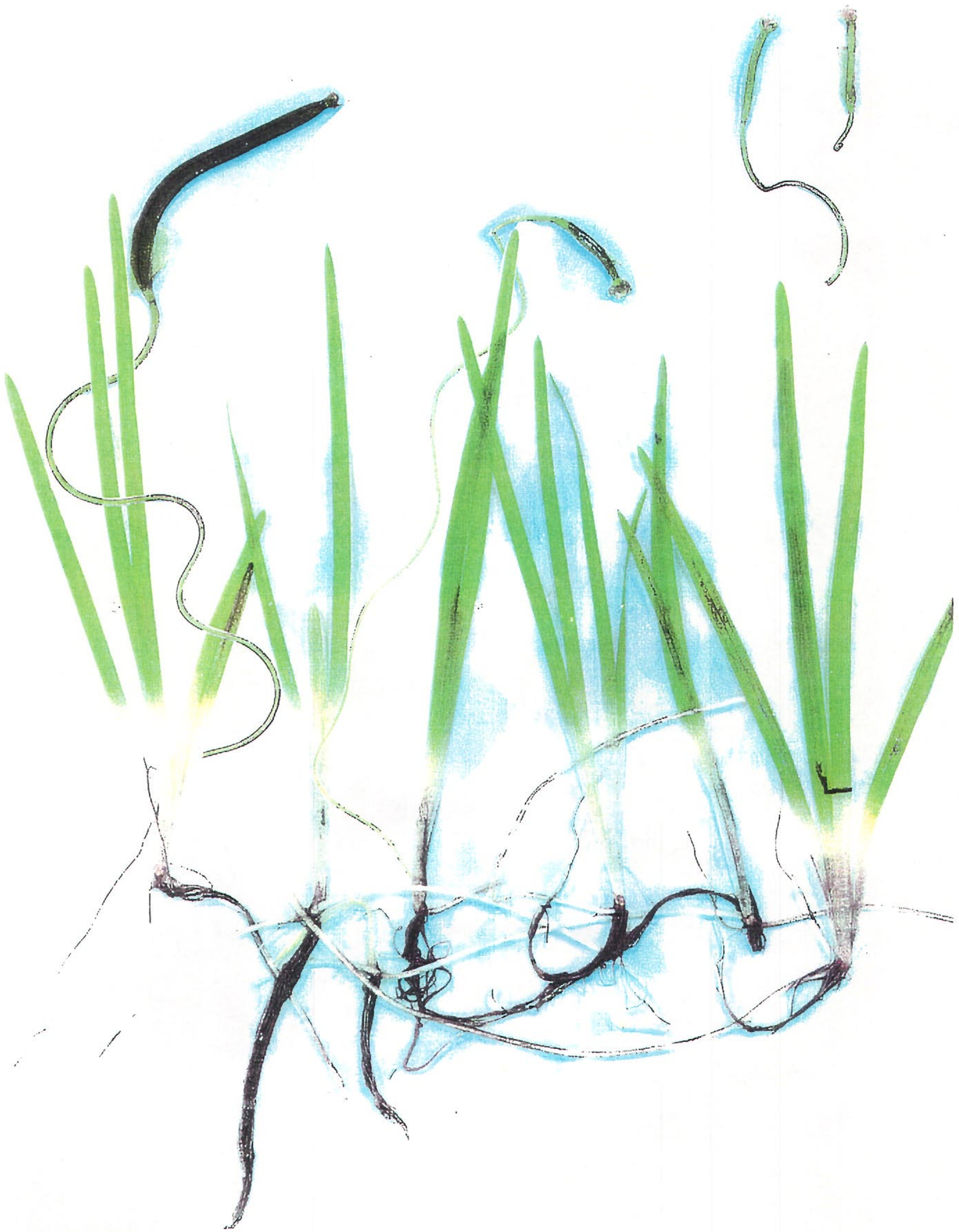


Muskgrass (Chara vulgaris)

Eurasian Water Milfoil (Myriophyllum spicatum)

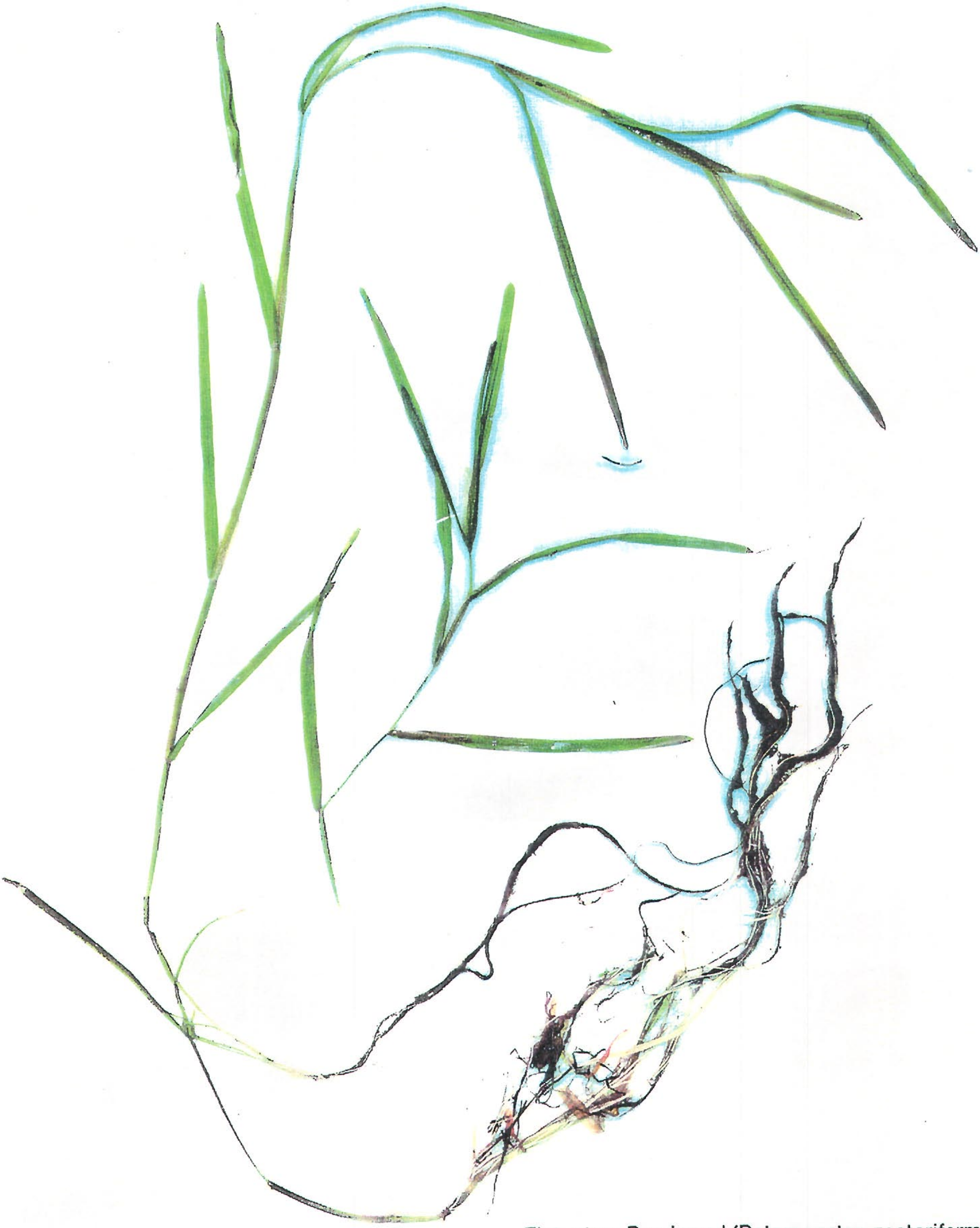
Native Water Milfoil (Myriophyllum sp.)

Bushy Pondweed (Najas flexilis)



Eel Grass/ Wild Celery (Vallisneria americana)

Sago Pondweed (Potamogeton pectinatus)



Flat-stem Pondweed (Potamogeton zosteriformis)

Spiney Naiad (Najas marina)

Illinois Pondweed (<u>Potamogeton illinoensis</u>)

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Appendix C

SEWRPC LETTER REPORT
PRELIMINARY VEGETATION SURVEY: PRETTY LAKE

EXHIBIT A

PRELIMINARY VEGETATION SURVEY
SCHARDT, MACKLIN, AND MODZELEWSKI PROPERTY WETLANDS

DATE: October 19, 1988

OBSERVER: Donald M. Reed, Principal Biologist
Rachel E. Lang, Assistant Biologist
Southeastern Wisconsin Regional Planning Commission

LOCATION: In the Southeast and Northeast one-quarters of U.S. Public Land Survey Section 28 and Southeast one-quarter of U.S. Public Land Survey Section 21, Township 6 North, Range 17 East, Town of Ottawa, Waukesha County, Wisconsin.

SPECIES LIST:

Plant Community Area No. 1

Sphagnaceae

Sphagnum sp.--Sphagnum moss

Equisetaceae

Equisetum arvense--Common horsetail

Polypodiaceae

Onoclea sensibilis--Sensitive fern

Pinaceae

Larix laricina--Tamarack

Pinus sp.[1]--Pine

Typhaceae

Typha latifolia--Broad-leaved cat-tail

Gramineae

Calamagrositis canadensis--Canada bluejoint grass

Muhlenbergia mexicana--Leafy satin grass

Phalaris arundinacea[2]--Reed canary grass

Cyperaceae

Scirpus cyperinus--Wool grass

Carex stricta--Tussock sedge

Carex sp.--Sedge

Salicaceae

Populus tremuloides--Quaking aspen

Salix interior--Sand-bar willow

Caprifoliaceae

Viburnum trilobium--High-bush cramberry

Sambucus canadensis--Elderberry

Lonicera X bella[2,3]--Hybrid honeysuckle

Compositae

Bidens sp.--Beggar's ticks

Ambrosia trifida--Giant ragweed

Solidago gigantea--Giant goldenrod

Solidago altissima--Tall goldenrod

Solidago graminifolia--Grassleaf goldenrod

Aster simplex--Marsh aster

Eupatorium maculatum--Joe-pye weed

Eupatorium perfoliatum--Boneset

Eupatorium rugosum--White snakeroot

Arctium minus[2,3]--Burdock

Carduus nutans[2,3]--Nodding thistle

Total number of plant species: 49
Number of alien, or non-native, plant species: 7 (14%)

This approximately 60-acre wetland plant community area consists of coniferous and open bog, shrub-carr, and southern wet to wet-mesic lowland hardwoods. Disturbance to the wetland include clear cutting for silvaculture practices and plowing of portions of this plant community area, as well as water level changes due to diking, ditching and channel realignment. No federal- or state-designated rare, threatened, or endangered species were observed during the field inspection. However, bogs located south of the vegetative tension zone in Wisconsin are rare.

---

[1]Planted pine seedlings.

[2]Alien, or non-native, plant species.

[3]Growing along the wetland edge.

Plant Community Area No. 3

Equisetaceae

Equisetum arvense--Common horsetail

Polypodiaceae

Onoclea sensibilis--Sensitive fern

Gramineae

Poa sp.--Bluegrass

Cyperaceae

Carex sp.--Sedge

Ulmaceae

Ulmus americana--American elm

Polygonaceae

Polygonum scandens--Climbing false buckwheat

Rosaceae

Rubus occidentalis--Black raspberry

Aceraceae

Acer saccharinum--Silver maple

Acer negundo--Boxelder

Cornaceae

Cornus amomum--Silky dogwood

Cornus racemosa--Grey dogwood

Solanaceae

Solanum dulcamara[1]--Deadly nightshade

Caprifoliaceae

Viburnum lentago--Nannyberry

Compositae

Bidens. sp.--Bidens

Arctium minus[1]--Common burdock

Total number of plant species: 15
Number of alien, or non-native, plant species: 2 (8%)

This approximately 9.0-acre wetland plant community consists of southern wet to wet-mesic lowland hardwoods with areas of shrub-carr along the edge. Disturbances to this area include past agricultural use and water level changes due to ditching and channel realignment. No federal- or state designated rare, threatened, or endangered species were observed during the field inspection.

---

[1]Alien, or non-native, plant species.

Plant Community Area No. 5

Equisetaceae

Equisetum arvense--Common horsetail

Pinaceae

Pinus resinosa[1]--Red pine

Gramineae

Poa pratensis--Kentucky bluegrass

Salicaceae

Populus tremuloides--Quaking aspen

Fagaceae

Quercus borealis--Northern red oak

Quercus borealis X _velutina_--Hybrid oak

Ulmaceae

Ulmus americana--American elm

Saxifragaceae

Ribes americanum--Wild black current

Aceraceae

Acer saccharum--Sugar maple

Rhamnaceae

Rhamnus catharticus[2]--Common buckthorn

Tiliaceae

Tilia americana--Basswood

Umbellifera

Daucus carota[2]--Queen Anne's lace

Caprifoliaceae

Lonicera X _bella_[2]--Hybrid honeysuckle

Total number of plant species: 13
Number of alien, or non-native, plant species: 3 (23%)

This approximately 23-acre plant community consists of a second growth southern mesic hardwoods and mature pine plantation. Disturbances to this area include past clear cutting for pine plantings and possible agricultural uses. No federal- or state designated rare, threatened, or endangered species were observed during the field inspection.

---

[1]Planted species.

[2]Alien, or non-native, plant species.

EXHIBIT A

PRELIMINARY VEGETATION SURVEY
TUTKOWSKI PROPERTY WETLAND

DATE: December 6, 1988

OBSERVER: Donald M. Reed, Principal Biologist
Rachel E. Lang, Assistant Biologist
Southeastern Wisconsin Regional Planning Commission

LOCATION: In the Northwest one-quarter of U.S. Public Land Survey Section 28, Township 6 North, Range 17 East, Town of Ottawa, Waukesha County, Wisconsin.

SPECIES LIST: Plant Community Area No. 1

Polypodiaceae

Thelypteris palustris--Marsh fern

Gramineae

Calamagrostis canadensis--Canada bluejoint grass

Phalaris arundinacea[1]--Reed canary grass

Setaria sp.[1]--Foxtail grass

Cyperaceae

Carex stricta--Tussock sedge

Salicaceae

Populus tremuloides--Quaking aspen

Populus deltoides--Cottonwood

Salix interior--Sand-bar willow

Salix sp.--Willow

Fagaceae

Quercus borealis[2]--Northern red oak

Ulmaceae

Ulmus americana--American elm

Urticaceae

Urtica dioica--Stinging nettle

Polygonaceae

Polygonum scandens--Climbing false buckwheat

Polygonum sp.--Smartweed

Cruciferae

Barbarea vulgaris[1]--Yellow rocket

This approximately 3.5-acre wetland plant community area consists of southern sedge meadow and shrub-carr, with lowland hardwoods along the edge. Disturbance to the wetland includes filling along the edge. No federal- or state-designated rare, threatened, or endangered species were observed during the field inspection.

---

[1]Alien, or non-native, plant species.

[2]Growing along the wetland edge.

Plant Community Area No. 2

Cupressaceae

Juniperus virginiana--Red cedar

Cyperaceae

Carex blanda--Wood sedge

Carex sp.--Sedge

Salicaceae

Populus tremuloides--Quaking aspen

Fagaceae

Quercus borealis--Northern red oak

Roasceae

Geum canadense--White avens

Rubus occidentalis--Black raspberry

Prunus serotina--Black cherry

Aceraceae

Acer saccharum--Sugar maple

Acer negundo--Boxelder

Rhamnaceae

Rhamnus catharticus[1]--Common buckthorn

Cornaceae

Cornus racemosa[2]--Grey dogwood

Labiatae

Leonurus cardiaca[1]--Motherwort

Caprifoliacea

Lonicera x _bella_[1]--Hybrid honeysuckle

Compositae

Cirsium vulgare[1]--Bull thistle

Total number of plant species: 15
Number of alien, or non-native, plant species: 4 (27%)

This approximately 0.75-acre plant community area consists of southern wet-mesic to mesic hardwood forest on an upland knoll and berm. Disturbances to this area include possible past fill. No federal or state-designated rare, threatened or endangered species were observed during the field inspection.

---

[1]Alien, or non-native, plant species.

[2]Growing along the wetland edge.

EXHIBIT A

PRELIMINARY VEGETATION SURVEY
W. NEWMANN PROPERTY WETLANDS

Date: May 11, 1995

Observers: Donald M. Reed, Chief Biologist
Rachel E. Lang, Senior Specialist-Biologist
Southeastern Wisconsin Regional Planning Commission

Location: Town of Ottawa in the parts of U.S. Public Land Survey Sections 20, 21, and 29, Township 6 North, Range 17 East, Waukesha County, Wisconsin.

Species List:

OSMUNDACEAE
Osmunda (cinnamomea?)--Cinnamon fern

POLYPODIACEAE
Adiantum pedatum--Maidenhair fern
(Thelypteris palustris?)--Marsh fern
Dryopteris sp. [1]--Shield fern

PINACEAE
Larix laricina--Tamarack

CUPRESSACEAE
Juniperus virginiana--Red-cedar

GRAMINEAE
Glyceria striata--Fowl manna grass
Calamagrostis canadensis--Canada bluejoint
Phalaris arundinacea[2]--Reed canary grass

CYPERACEAE
Carex amphibola--Sedge
Carex stricta--Tussock sedge
Carex lacustris--Lake sedge
Carex spp. --Sedges

ARACEAE
Arisaema triphyllum--Jack-in-the-pulpit

LILIACEAE
Lilium (michiganense?)--Turk's-cap lily
Maianthemum canadense--Canada mayflower
Uvularia sp. --Bellwort
Trillium cernuum--Nodding trillium

SALICACEAE

Populus deltoides--Cottonwood
Salix nigra--Black willow
Salix bebbiana--Beaked willow
Salix sp. --Willow

BETULACEAE

Betula alleghaniensis--Yellow birch

FAGACEAE

Quercus macrocarpa[1]--Bur oak
Quercus rubra[1]--Northern red oak

ULMACEAE

Ulmus americana--American elm

URTICACEAE

Urtica dioica--Stinging nettle

RANUNCULACEAE

Caltha palustris--Marsh marigold
Ranunculus abortivus--Small-flowered buttercup
Ranunculus septentrionalis--Swamp buttercup
Ranunculus sp. --Buttercup
Thalictrum dasycarpum--Tall meadow rue
Anemone quinquefolia--Wood anemone

BERBERIDACEAE

Podophyllum peltatum[1]--Mayapple
Caulophyllum thalictroides--Blue cohosh

CRUCIFERAE

Cardamine bulbosa--Cardamine
Dentaria laciniata[1]--Toothwort
Barbarea vulgaris[1,2]--Yellow rocket
Alliaria officinalis[2]--Garlic-mustard

SAXIFRAGACEAE

Saxifraga pensylvanica--Swamp saxifrage
Ribes americanum--Wild black currant

ROSACEAE

Fragaria virginiana--Wild strawberry
Potentilla fruticosa--Shrubby cinquefoil
Geum canadense--White avens
Rubus occidentalis--Black raspberry
Rubus strigosus--Red raspberry
Rubus pubescens--Dwarf blackberry
Agrimonia gryposepala--Agrimony
Rosa multiflora[1,2]--Multiflora rose
Rosa sp. --Wild rose
Prunus serotina[1]--Black cherry

ROSACEAE cont'

Pyrus sp.[1,2] --Apple
Crataegus sp. --Hawthorn
Amelanchier laevis[1]--Allegheny serviceberry

GERANIACEAE

Geranium maculatum[1]--Wild geranium

RUTACEAE

Zanthoxylum americanum[1]--Prickly-ash

ANACARDIACEAE

Rhus radicans--Poison ivy

ACERACEAE

Acer saccharinum--Silver maple
Acer negundo--Boxelder

BALSAMINACEAE

Impatiens biflora--Jewelweed

RHAMNACEAE

Rhamnus cathartica[2]--Common buckthorn

VITACEAE

Vitis riparia--River-bank grape

TILIACEAE

Tilia americana[1]--Basswood

VIOLACEAE

Viola cucullata--Blue marsh violet
Viola pubescens--Downy yellow violet

ONAGRACEAE

Circaea quadrisulcata--Enchanter's nightshade

UMBELLIFERAE

Osmorhiza claytoni--Sweet cicely
Osmorhiza longistylis--Anise-root

CORNACEAE

Cornus amomum--Silky dogwood
Cornus stolonifera--Red osier dogwood
Cornus racemosa--Grey dogwood

OLEACEAE

Fraxinus pennsylvanica--Green ash
Fraxinus nigra--Black ash

ASCLEPIADACEAE

Asclepias incarnata--Marsh milkweed

CONVOLVULACEAE

Cuscuta glomerata--Dodder

LABIATAE

Nepeta cataria[1,2]--Catnip
Glecoma hederacea[2]--Creeping Charlie
Leonurus cardiaca[1,2]--Motherwort

SCROPHULARIACEAE

Mimulus ringens--Monkey flower

RUBIACEAE

Galium spp. --Cleavers

CAPRIFOLIACEAE

Viburnum lentago--Nannyberry
Sambucus canadensis--Elderberry
Lonicera X bella[1,2]--Hybrid honeysuckle

CUCURBITACEAE

Echinocystis lobata--Wild cucumber

COMPOSITAE

Achillea millefolium[1,2]--Yarrow
Solidago gigantea--Giant goldenrod
Solidago altissima[1]--Tall goldenrod
Aster lucidulus--Swamp aster
Eupatorium maculatum--Joe-pye weed
Arctium minus[1,2]--Common burdock
Taraxacum officinale[2]--Common dandelion

Total number of plant species: 91+
Number of alien, or non-native, plant species: 13 (14 percent)

This approximately 76-acre plant community area is part of a larger wetland complex and consists of Southern sedge meadow, fresh (wet) meadow, shrub-carr (willow thicket), and second growth, Southern wet to wet-mesic lowland hardwoods. Disturbances to the plant community area include water level changes due to ditching and draining; side casting of dredge spoil material; clearing of vegetation; past selective cutting of timber; past grazing; and siltation and sedimentation due stormwater runoff from adjacent agricultural lands. No federal- or state-designated rare, threatened, or endangered species were observed during the field inspection.

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[1]Growing along the wetland edge.
[2]Alien, or non-native, plant species.

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Appendix D

BOATING ORDINANCE APPLICABLE TO PRETTY LAKE

CHAPTER 20

LAKES AND BEACHES

20.01 BOAT TRAFFIC. (1) Sections 30.50 through 30.71 inclusive, and §30.80 (1) and (2), Wis. Stats., are hereby adopted by reference except where the provisions of this chapter are more restrictive and in that event the provisions of this chapter shall control.

(2) No person shall swim more than 150' from shore unless accompanied by an escort boat.

(3) All power boats must travel in counter-clockwise direction at all times.

(4) No motor boat shall operate at a speed in excess of slow-no-wake under the following conditions:

(a) Before 11 a.m. and after 6 p.m.

(b) When closer than 100' to any bathing beach or anchored boat.

(5) No person shall water ski between rafts and shorelines.

(6) No person shall operate any boat unless such boat shall be equipped with U.S. Coast Guard approved personal flotation devices as required under §NR 5.13, Wis. Adm. Code.

(7) All waterskiers shall wear U.S. Coast Guard approved life jackets, Type I, II or III, (PFD).

20.02 PUBLIC ACCESS POINTS. (1) PARKING. (a) Parking shall be prohibited on both sides of Pretty Lake Road at all times.

(b) Parking shall be permitted for 4 vehicles only at designated public access points leading to Pretty Lake between 6 a.m. and 10 p.m. Parking at points which are not designated and at all other times not specified herein is prohibited.

(2) RESTRICTIONS. No person shall do any of the following on public access points and areas leading to public access points within the Town:

(a) Consume beverages or food.

(b) Camp or picnic.

(c) Have pets or livestock including horses.

(d) Litter.

20.03 HENRIETTA LAKE AND UTICA LAKE. (1) APPLICATION. The provisions of this ordinance shall apply to the waters of Henrietta Lake and Utica Lake, within the jurisdiction of the Town of Summit and the Town of Ottawa. The provisions of this ordinance shall be enforced by the officers of the Water Safety Patrol Unit and police of the jurisdiction of the Town of Summit.

(2) STATE BOATING AND WATER SAFETY LAWS ADOPTED.

(a) Except as otherwise specifically provided in this ordinance, the current and future statutory provisions describing and defining regulations with respect to water traffic, boats, boating, and relating water activities in §§30.50 up to and including 30.71, of the Wisconsin Statutes, exclusive of any provisions therein relating to the penalties to be imposed or the punishment for violation of said statutes, are hereby adopted and by reference made a part of this ordinance as if fully set forth herein. Any act required to be performed or prohibited by any current or future statute incorporated herein by reference is required or prohibited by this ordinance. Any further additions, amendments, revisions or modifications of the statute incorporated herein are intended to be made part of this ordinance in order to secure uniform state-wide regulation of the waterways of the State.

(b) All rules and orders created by the Wisconsin Department of Natural Resources, modifying or supplementing the foregoing provisions of State Law or which may be adopted or made in the future, are hereby incorporated in and made a part of this ordinance by deferring to the same as if they are or were to be set out herein verbatim.

(3) OPERATION OF MOTOR BOATS. No motor boat shall be operated on Henrietta Lake and Utica Lake at any time at a speed in excess of slow no wake.

(4) SWIMMING REGULATIONS. No person, unless said person is engaging in activities and subject to the provisions of §30.70, Wisconsin Statutes, entitled Skin Diving, shall:

(a) Swim from any unmanned boat, unless such boat is anchored, or

(b) Swim more than 150 feet from the shoreline unless is a designated swimming zone or unless accompanied by a competent person in a boat, or

(c) Swim more than 150 feet from the shoreline between sunset and sunrise.

(5) PENALTY.

(a) STATE BOATING AND WATER SAFETY LAWS AND ALL OTHER VIOLATIONS AS SET FORTH IN §2 OF THIS ORDINANCE.

Any forfeiture for violation of the State statute, rule or order adopted by reference in §2 of this ordinance shall conform to the forfeiture permitted to be imposed for violation of such statutes as set forth in the Uniform Wisconsin Deposit and Bail Schedule for Conservation, Boating, Snowmobile, and ATV Violations, including any variations or increases for subsequent offenses, which schedule is adopted by reference.

(b) LOCAL BOATING LAWS AS SET FORTH IN §§3, 4 and 5 OF THIS ORDINANCE.

Any person 16 years or older violating the provisions of this ordinance shall be subject to a forfeiture of not more than $500 plus court costs and penalty assessment. Failure to pay any forfeiture hereunder shall subject the violator to imprisonment in the County Jail or loss of license.

Any person 14 or 15 years of age shall be subject to a forfeiture of not less than $10 nor more than $25 plus court costs and penalty assessment per each offense or referred to the proper authorities as provided in Chapter 48, Wisconsin Statutes. Failure to pay any forfeiture hereunder shall subject the violator to the provisions of §48.17(2), Wisconsin Statutes.

Any person under the age of 14 shall be referred to the proper authorities as provided in Chapter 48, Wisconsin Statutes.

(6) ENFORCEMENT.

(a) Enforcement Procedure. The statutory provisions of §§66.115, 66.119, 66.12, 30.29, 30.50 to 30.71, and Chapter 799, Wisconsin Statutes, are adopted and by reference made a part of this ordinance as if fully set herein. Any act required to be performed or prohibited by any statute incorporated herein by reference is required or prohibited by this ordinance. Any future additions, amendments, revisions or modifications of the statutes incorporated herein are intended to be made part of this ordinance in order to secure uniform state-wide regulation and enforcement of boating ordinance violations. Further, the Town of Summit and the Town of Ottawa specifically elect to use the citation method of enforcement.

(b) Deposits.

1. Schedule of Deposits. The schedule of cash deposits shall be as follows:

§2: Applicable sections of Uniform Wisconsin Deposit and Bail Schedule for Conservation, Boating, Snowmobile and ATV Violations plus current assessment fees and current court costs if applicable.

§§3, 4 and 5: $50 plus court costs and assessments plus current assessment fees and current court costs if applicable.

2. Deposit for Repeat Offenses. Any person found guilty of violating this ordinance or any part thereof who was previously convicted of the same section within the last year shall forfeit twice the deposit delineated above plus court costs and penalty assessment.

3. Non-Scheduled Deposit. If a deposit schedule has not been established for a specific violation, the arresting officer shall require the alleged offender to deposit not less than the maximum forfeiture permitted hereunder.

4. Depository. Deposits should be made in cash, money order, or certified check to the Clerk of Municipal Court, who shall issue a receipt therefore as required by Wisconsin Statute. If the deposit is mailed, the signed statement required by Wisconsin Statute shall be mailed with the deposit.

(c) Nonexclusivity.

1. Other Ordinances. Adoption of this ordinance does not preclude the Town Boards from adopting any other ordinance or providing for the enforcement of any other law or ordinance relating to the same or other matter.

2. Other Remedies. The issuance of a citation hereunder shall not preclude the Town Boards or any authorized office from proceedings under any other ordinance of law or by any other enforcement method to enforce any ordinance, regulation or order.

20.04 SCHOOL SECTION LAKE. (1) APPLICATION. The provisions of this ordinance shall apply to the waters of School Section Lake.

(2) OPERATION OF MOTOR BOATS.

(a) No boats shall be operated at a speed greater than slow, no wake, between the hours of sunrise and sunset.

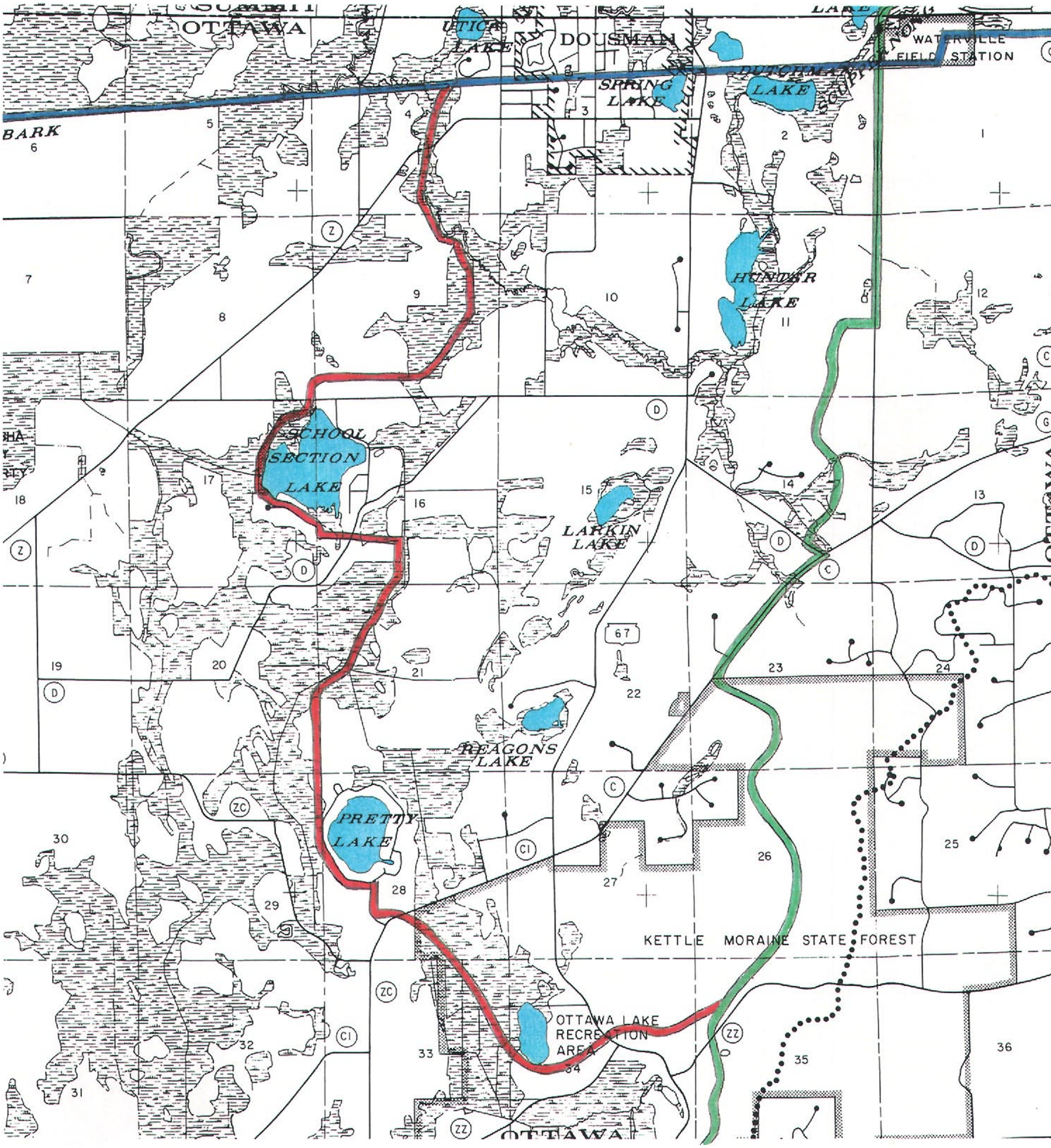
(b) No motor boats whatsoever shall be allowed to operate between the hours of sunset and sunrise.

(3) ADDITIONAL RESTRICTIONS. The restrictions contained in this subsection are in addition to all other boating regulations contained within the Town of Ottawa Town Code. In the event there is a conflict between the restrictions contained in this subsection and restrictions contained elsewhere in the Town of Ottawa Town Code, the restrictions of this particular subsection shall apply.

20.05 PENALTY. Except as otherwise provided, any person who shall violate any provision of this chapter, or any regulation, rule or order made hereunder, shall be subject to a penalty as provided in §25.04 of this General Code.

Appendix E

PROPOSED TRAIL SYSTEM FOR THE PRETTY LAKE AREA



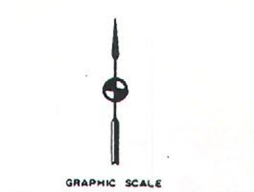
LEGEND

PRETTY-SECTION RECREATION TRAIL

ICE AGE NATIONAL SCENIC TRAIL

GLACIAL DRUMLINS STATE TRAIL

Source: SEWRPC.



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Appendix F

SEWRPC STAFF MEMORANDUM

EVALUATION OF PROVISION OF PUBLIC SANITARY SEWER SERVICE TO THE PRETTY LAKE AND SCHOOL SECTION LAKE COMMUNITIES WAUKESHA COUNTY, WISCONSIN

BACKGROUND

The regional water quality management plan identified the lands along the shorelines of Pretty and School Section Lakes in the Town of Ottawa, Waukesha County, Wisconsin, as lands having urban density development outside of the planned sanitary sewer service areas.[1] The Waukesha County development plan[2] included these two lake areas as rural service areas where public sanitary sewer service and other public utilities are not envisioned to be provided. Nevertheless, the regional water quality management plan also recommended that sewerage needs in these communities be periodically reevaluated in light of changing circumstances.

Given the foregoing, an evaluation of alternative sewerage system plans for the Pretty Lake and School Section Lake areas was conducted under the northwestern Waukesha County sewerage system planning program. The exercise was intended to serve as a guide for evaluating the potential use of a public sanitary sewer system for other similar areas in the northwestern Waukesha County sewerage system plan study area. The findings of this study are intended to be used along with other data, such as soils and subsurface conditions, lot sizes, existing problems, and housing unit density, to develop recommendations for currently unsewered areas proposed to be served by public sanitary sewer systems during the planning period. This evaluation was based upon inventories conducted by Commission staff pursuant to the preparation of the lake protection plan for Pretty Lake, and discussions with the Pretty Lake Protection and Rehabilitation District Commission, as well as inventory data collected for the northwestern Waukesha County sewerage system planning program.

This memorandum sets forth the findings of a preliminary feasibility study of the potential means and costs of providing a public sanitary sewer system in the Pretty Lake and School Section Lake areas within the Town of Ottawa, Waukesha County.

ALTERNATIVE PLANS

For analytical purposes, the study area was divided into two subareas. Area 1 encompasses the residential development riparian to Pretty Lake contained within the boundaries of the Pretty Lake Protection and Rehabilitation District, and includes about 120 residences. Area 2 encompasses the residential development riparian to School Section Lake contained within the boundaries of the School Section Lake Management District, and includes about 55 residences. About 85 percent of these residences are occupied year around. With the exception of lands anticipated to be developed at suburban residential densities located along the northeastern shoreline of School Section Lake and the infill of a limited number of previously platted lots, both areas evaluated may be considered to be fully developed to the extent

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[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Two,* Alternative Plans, *February 1979.*

[2]*SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996.*

envisioned under the adopted County development plan.[3] The lands proposed for suburban residential development located on the northeastern shoreline of School Section, being on lots sized between three and five acres in areal extent, were assumed to continue the use of onsite systems for sewage disposal and not be served by the public sanitary sewers evaluated under the alternatives considered in this memorandum.

Alternative plans were considered for connecting Area 1 and Area 2 individually, and Areas 1 and 2 jointly, to the Village of Dousman sewerage system via the existing trunk sewer located at the intersection of CTH Z and CTH ZD in that Village. An alternative of continued reliance upon the use of onsite sewage disposal systems, including, in some cases, holding tanks for wastewater disposal, was also considered.

Map F-1 shows the extent of the currently approved sewer service area of the Village of Dousman sewage treatment facility as documented in SEWRPC Community Assistance Planning Report No. 192, *Sanitary Sewer Service Area for the Village of Dousman, Waukesha County, Wisconsin*, dated December 1990. Neither lake community considered herein is included in the service area. Map F-1 also shows the proposed route of the Pretty-Section Trail, a nine-mile trail recommended to be developed by Waukesha County in cooperation with the Wisconsin Department of Natural Resources to connect the Ice Age Trail in the Southern Unit of the Kettle Moraine State Forest with the Glacial Drumlin Trail.[4] The trail is largely situated on lands designated as primary environmental corridor, which lands are recommended to remain essentially in open space uses. It is assumed herein that the trail corridor will be the primary alignment of a sanitary sewer force main route between Pretty Lake and School Section Lake, since this would limit the need for corridor disruption associated with linear facilities construction.

The analyses conducted was based upon the assumption that initially capacity would be available in the Village of Dousman sewage treatment plant. The existing treatment plant has a capacity of approximately 0.35 million gallons per day (mgd) on an average daily flow basis. The current 1995 loading to the plant is about 0.21 mgd on an average daily flow basis.[5] The hydraulic loading from both lake areas is estimated to be about 0.05 mgd on an average daily basis. Thus, the loadings from the entire study area would be less than 15 percent of the treatment plant design capacity, and about 30 percent of the available unused capacity. Should the costs for provision of a public sewer system be found to be similar or lower than the cost for onsite sewage disposal for either area considered, additional analysis considering treatment plant capital costs would be needed. Such an analysis would consider the impact of the connection on the timing of a plant expansion, which is estimated to be needed, in any case, before the year 2010 as a result of urban development in the sewer service area.[6]

Preliminary sanitary sewer system plans were developed for both subareas concerned as a basis for estimating the cost entailed in providing sanitary sewer service. Sanitary sewer system plans, as shown on Maps F-2 and F-3, were developed for two alternative means of providing for the conveyance of sewage to the Village of Dousman sewerage system. Under the first alternative, sewer service would be provided to each Lake individually, as shown on Maps F-2 and F-3. Under the second alternative, sewer service would be provided to both Lakes jointly as shown on Map F-4. Under the third alternative, both areas would continue to rely on onsite sewage disposal systems. The estimated capital and annual operation and maintenance costs entailed under each of the three alternative are provided in Table F-1. These costs are inclusive of all costs for the local sewer system, including, where appropriate, allowances for building sewers to the individual houses, as well as for modification of the household plumbing system and abandonment of the existing septic tanks. Under the third alternative, the cost includes the maintenance and replacement, as needed, of onsite sewage disposal systems, as well as pumping costs associated with holding tanks for wastewater disposal.

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[3]*Ibid.*

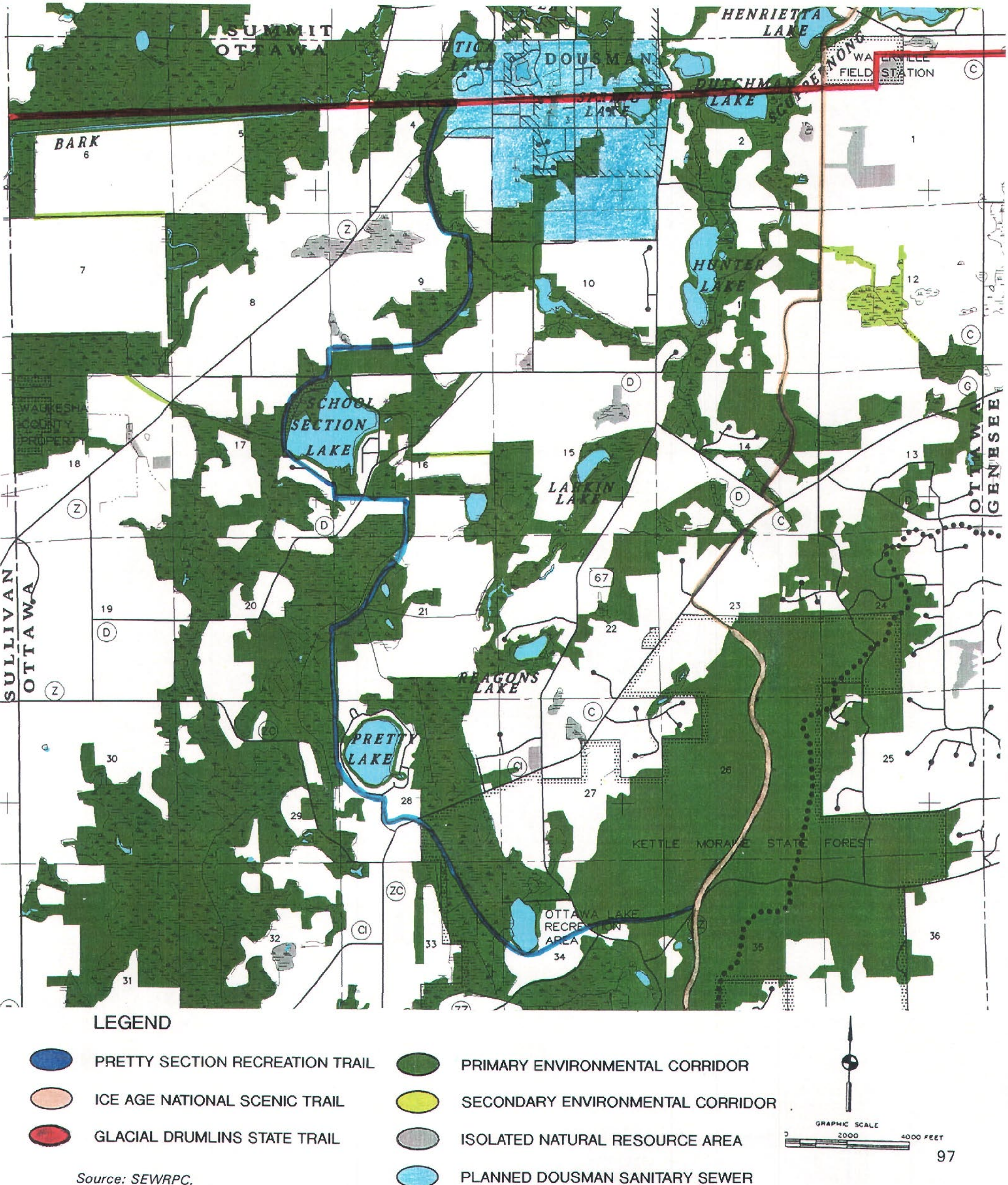
[4]*Ibid.*

[5]*SEWRPC Memorandum Report No.93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995; and Village of Dousman* 1995 Compliance Maintenance Annual Report.

[6]*SEWRPC Memorandum Report No. 93, op. cit.*

Map F-1

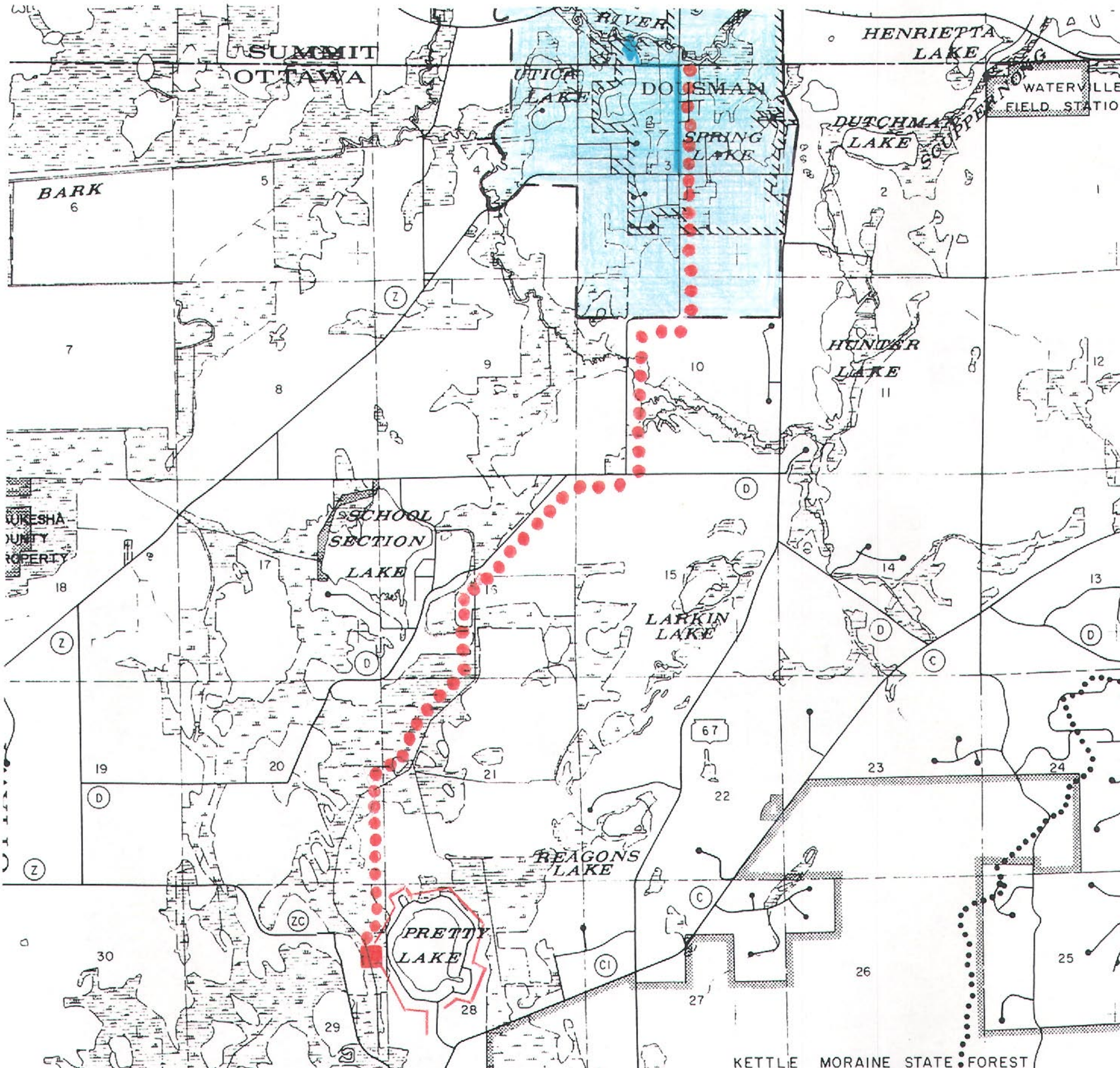
PROPOSED TRAIL SYSTEM FOR THE PRETTY LAKE AREA



Source: SEWRPC.

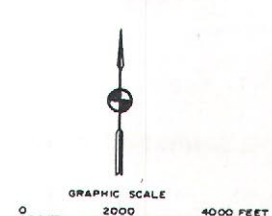
Map F-2

ALTERNATIVE 1
PROVISION OF PUBLIC SANITARY SEWER SERVICE TO AREA 1—PRETTY LAKE
(revised January 26, 1998)



LEGEND

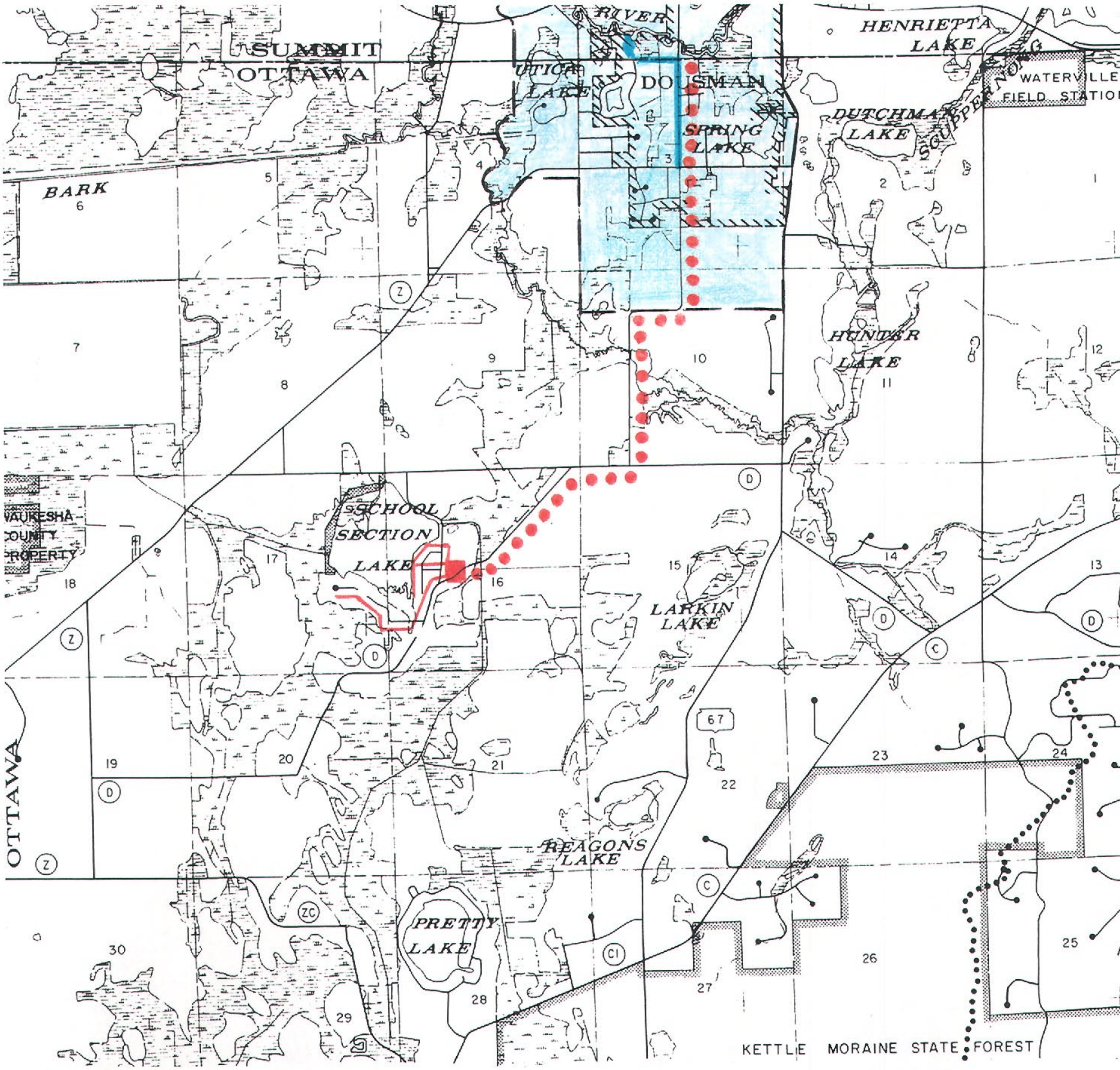
- PROPOSED FORCE MAIN
- PROPOSED GRAVITY SEWER
- PROPOSED PUMPING STATION
- EXISTING GRAVITY SEWER
- EXISTING SEWAGE TREATMENT PLANT
- PLANNED DOUSMAN SANITARY SEWER SERVICE AREA



Source: SEWRPC.

Map F-3

ALTERNATIVE 1
PROVISION OF PUBLIC SANITARY SEWER SERVICE TO AREA 1—SCHOOL SECTION LAKE
(revised January 26, 1998)



LEGEND

PROPOSED FORCE MAIN

PROPOSED GRAVITY SEWER

PROPOSED PUMPING STATION

EXISTING GRAVITY SEWER

EXISTING SEWAGE TREATMENT PLANT

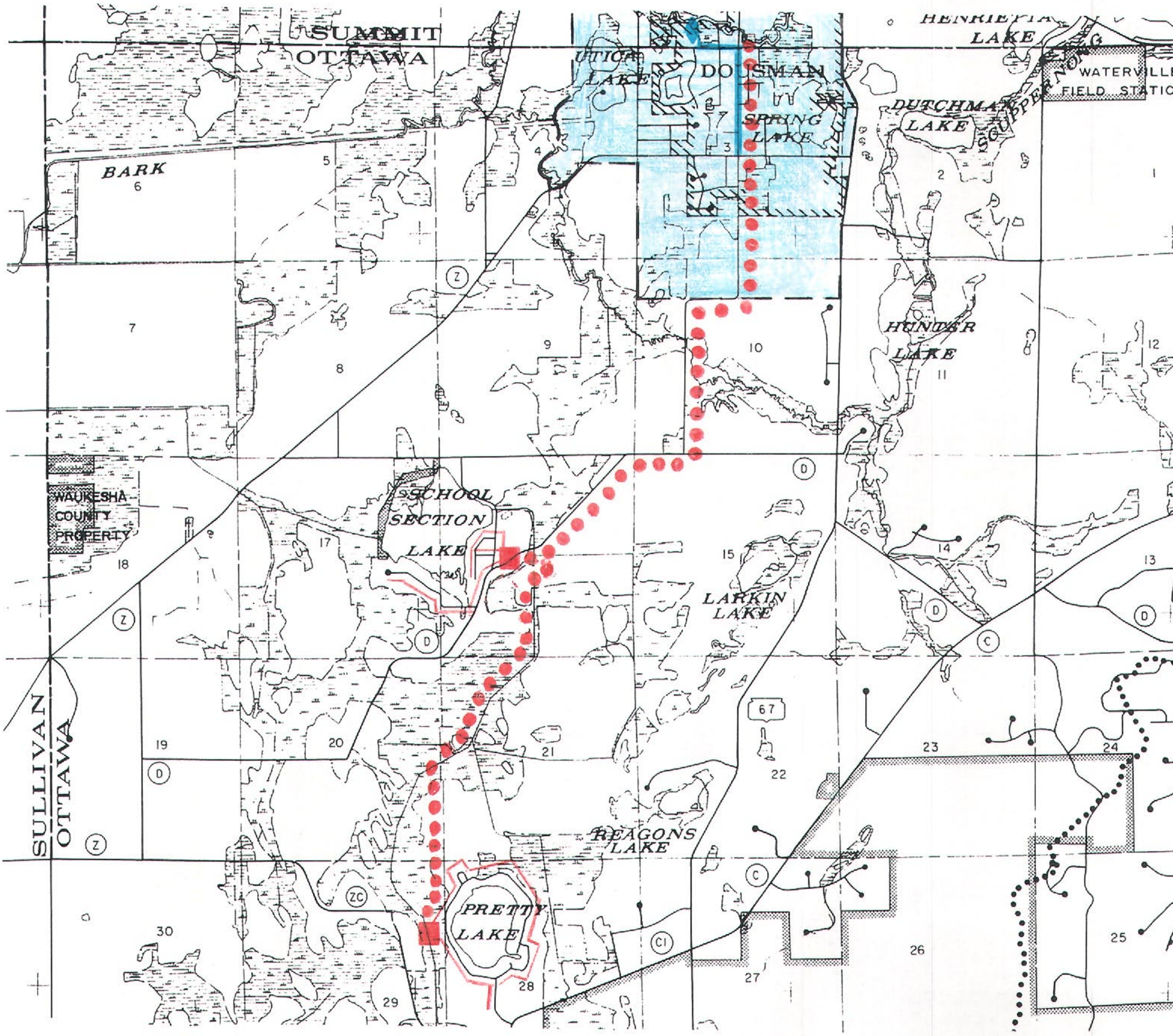
PLANNED DOUSMAN SANITARY SEWER SERVICE AREA

GRAPHIC SCALE
0 2000 4000 FEET

Source: SEWRPC.

Map F-4

ALTERNATIVE 1
PROVISION OF PUBLIC SANITARY SEWER SERVICE TO
AREAS 1 AND 2—PRETTY LAKE AND SCHOOL SECTION LAKE
(revised January 26, 1998)



LEGEND

PROPOSED FORCE MAIN

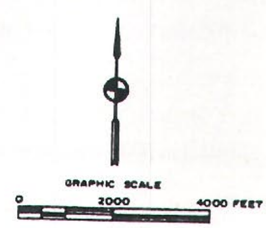
PROPOSED GRAVITY SEWER

PROPOSED PUMPING STATION

EXISTING GRAVITY SEWER

EXISTING SEWAGE TREATMENT PLANT

PLANNED DOUSMAN SANITARY SEWER SERVICE AREA



Source: SEWRPC.

Table F-1

ALTERNATIVE 1
PRELIMINARY COST ESTIMATE FOR PUBLIC SANITARY SEWER SYSTEM
FOR THE PRETTY LAKE AND SCHOOL SECTION LAKE AREAS

Component	Capital Cost	Annual Operation and Maintenance Cost
Area 1—Pretty Lake		
• Public System		
8-Inch Gravity Sewer (9,500 linear feet)	$ 522,500	$ 3,800
4-Inch Force Main (28,000 linear feet)	672,000	11,200
Pumping Station (1)	61,000	13,000
Subtotal Public System	$1,255,500	$28,000
• Building Sewers (8,400 linear feet)[a]	$ 252,000	- -
• Incremental Cost of Treatment	- -	$ 1,800
• Engineering, Contingencies, Etc., at 20 Percent	287,000	- -
Total Area 1	$1,794,500	$29,800
Area 2—School Section Lake		
• Public System		
8-Inch Gravity Sewer (8,000 linear feet)	$ 440,000	$ 3,200
4-Inch Force Main (16,000 linear feet)	384,000	6,400
Pumping Station (1)	41,000	11,000
Subtotal Public System	$ 865,000	$20,600
• Building Sewers (3,850 linear feet)[a]	$ 115,500	- -
• Incremental Cost of Treatment	- -	$ 800
• Engineering, Contingencies, Etc., at 20 Percent	181,500	- -
Total Area 2	$1,162,000	$21,400
Total Areas 1 and 2	$2,956,500	$51,200

[a]Includes estimated cost for building sewer and an allowance for plumbing connection and septic tank abandonment, where applicable.

Source: SEWRPC.

Each of the systems was configured on a preliminary basis, and the designs would have to be refined in a more detailed engineering study if it is decided to proceed further in this matter.

Under Alternative 1, the collection sewer system serving Area 1 would be connected to a main pumping station serving the Pretty Lake area only, and the sewer system serving Area 2 would be connected to a separate pumping station, as shown on Maps F-2 and F-3. Each pumping station would pump wastewater through separate force mains to the Village of Dousman sewerage system. As shown in Table F-1, under this alternative, the total capital cost of the system to serve both subareas would approximate $3.0 million, and the operation and maintenance costs would approximate $51,000 per year.

Under Alternative 2, pumping stations serving each of the two subareas would be connected to a common force main to convey wastewater to the Village of Dousman sewerage system, as shown on Map F-4. As shown in Table F-2, under this alternative, the total capital cost of the system to serve both subareas would approximate $2.6 million, and the operation and maintenance costs would approximate $45,000 per year.

Table F-2

ALTERNATIVE 2
PRELIMINARY COST ESTIMATE FOR PUBLIC SANITARY SEWER SYSTEM
FOR THE PRETTY LAKE AND SCHOOL SECTION LAKE AREAS

Component	Capital Cost	Annual Operation and Maintenance Cost
Area 1—Pretty Lake		
• Public System		
8-Inch Gravity Sewer (9,500 linear feet)	$ 522,500	$ 3,800
4-Inch Force Main (12,000 linear feet)	288,000	4,800
Pumping Station (1)	61,000	13,000
Subtotal Public System	$ 871,500	$21,600
• Building Sewers (8,400 linear feet)[a]	$ 252,000	- -
Subtotal Area 1	$1,123,500	$21,600
Area 2—School Section Lake		
• Public System		
8-Inch Gravity Sewer (8,000 linear feet)	$ 440,000	$ 3,200
6-Inch Force Main (16,000 linear feet)	480,000	6,400
Pumping Station (1)	41,000	11,000
Subtotal Public System	$ 961,000	$20,600
• Building Sewers (3,850 linear feet)[a]	$ 115,500	- -
Subtotal Area 2	$1,076,000	$20,600
• Incremental Cost of Treatment	- -	$ 2,600
• Engineering, Contingencies, Etc., at 20 Percent of Subtotal Areas 1 and 2	$ 422,000	- -
Total Areas 1 and 2	$2,621,500	$44,800

[a]Includes estimated cost for building sewer and an allowance for plumbing connection and septic tank abandonment, where applicable.

Source: SEWRPC.

Under Alternative 3, the sewerage system needs of both of the subareas would continue to be served by onsite sewage disposal systems, including, as needed, holding tanks. Under this alternative, it is assumed, for analysis purposes, that 30 percent of the existing onsite sewage disposal systems will be required to be replaced immediately, with a subsequent replacement of 75 percent of the remainder of the onsite sewage disposal systems during the planning period. Based upon a review of the hydrologic soil groups within the Pretty Lake and School Section Lake areas, and the extent of existing onsite sewage disposal system problems as identified in Chapter IV of the draft of the northwestern Waukesha County sewerage system plan, it was assumed, for analysis purposes, that, of the 30 percent of systems requiring immediate replacement, one-half of the replacement onsite sewage disposal systems would be mound systems and one-half would be holding tank systems. Of the remaining systems requiring replacement during the 20-year planning period, one-third of the replacement onsite sewage disposal systems were assumed to be conventional onsite sewage disposal systems, one-third were assumed to be mound systems, and one-third were assumed to be holding tank systems. As shown in Table F-3, under this alternative, the total capital cost of the onsite systems to serve both Areas would approximate $1.1 million, and the operation and maintenance costs would approximate $111,000 per year. The operation and maintenance costs are primarily associated with the cost of pumping

Table F-3

ALTERNATIVE 3
PRELIMINARY COST ESTIMATE FOR ONSITE SEWAGE DISPOSAL SYSTEMS
FOR THE PRETTY LAKE AND SCHOOL SECTION LAKE AREAS

Component[a]	Capital Cost	Annual Operation and Maintenance Cost
Area 1—Pretty Lake		
• Private Systems—120 Onsite Disposal Systems	- -	$ 77,000
21 Conventional Replacement Systems	$ 94,500	- -
39 Mound Replacement Systems	429,000	- -
39 Holding Tank Replacement Systems	234,000	- -
Total Area 1	$ 757,500	$ 77,000
Area 2—School Section Lake		
• Private Systems—55 Onsite Disposal Systems	- -	$ 34,400
10 Conventional Replacement Systems	45,000	- -
18 Mound Replacement Systems	198,000	- -
18 Holding Tank Replacement Systems	108,000	- -
Total Area 2	$ 351,000	$ 34,400
Total Areas 1 and 2	$1,108,500	$111,400

[a]*Of the total number of onsite sewage disposal systems, it is assumed that 30 percent will be required to be replaced at the beginning of the planning period. Of the remaining systems, it is assumed that 75 percent will be required to be replaced during the planning period. These replacement systems are anticipated to comprise both conventional and other types of onsite sewage disposal systems: of the initial 30 percent of systems being replaced, one-half are assumed to be mound or pressure systems, and one-half holding tanks; of the 75 percent of systems being replaced, one-third are assumed to be conventional onsite sewage disposal systems, one-third mound or pressure systems, and one-third holding tanks.*

Source: SEWRPC.

holding tanks which were assumed to comprise about 38 percent of the system by the end of the 20-year planning period.

EVALUATION OF ALTERNATIVE PLANS

Alternative 3 has the lowest capital cost of the alternatives considered, with Alternative 1 having the highest capital cost. It should be noted that Alternatives 1 and 2 would also have an additional capital cost for future treatment plant construction which was considered only qualitatively for this evaluation. Alternative 2 has the lowest operation and maintenance costs of the alternatives considered. An economic analysis of the alternatives is presented in Table F-4 and summarized in Table F-5. Alternative 3 has the lowest present worth cost, from 22 to 73 percent less than the other alternatives.

A preliminary estimate of the fiscal impacts of providing public sanitary sewers within the subject areas is provided in Table F-6. In order to develop this information, assumptions had to be made regarding land uses, bond terms, initial payments, and, where appropriate, charges by the Village of Dousman reflecting the incremental costs of wastewater treatment at the Dousman treatment facility. For the purposes of this study, it was assumed that the analysis considered only the existing residences as system contributors in Areas 1 and 2, and amortization of the capital costs over a 20-year period at a 6 percent interest rate. The fiscal analysis may be considered to present conservatively high costs. Furthermore, if there were grants or low interest loans available, fiscal impact costs could be lowered. The initial capital costs of the public sewerage system for building sewer connections, septic tank abandonment, and plumbing

Table F-4

ECONOMIC ANALYSES COST ESTIMATES FOR ALTERNATIVE SEWERAGE SYSTEM PLANS FOR THE PRETTY LAKE AND SCHOOL SECTION LAKE AREAS

Alternative	Initial Capital Cost 1997-2017	Operation and Maintenance 1997-2017	Present Worth: 1997-2047[a]			Equivalent Annual Cost: 1997-2047		
			Construction	Operation and Maintenance	Total	Construction	Operation and Maintenance	Total
Alternative 1: Public Systems								
Area 1—Pretty Lake	$1,794,500	$ 29,800	$1,794,500	$ 469,700	$2,264,200	$113,900	$ 29,800	$143,700
Area 2—School Section Lake	1,162,000	21,400	1,162,000	337,300	1,499,300	73,700	21,400	95,100
Total	$2,956,500	$ 51,200	$2,956,500	$ 807,000	$3,763,500	$187,600	$ 51,200	$238,800
Alternative 2: Public System Areas 1 and 2	$2,621,500	$ 44,800	$2,621,500	$ 706,100	$3,327,600	$166,300	$ 44,800	$211,100
Alternative 3: Private Systems[b]								
Area 1—Pretty Lake	$757,500	$ 77,000	$ 558,100	$1,218,600	$1,776,700	$ 35,400	$ 77,300	$112,800
Area 2—School Section Lake	351,000	34,400	256,000	556,200	812,200	16,200	35,300	51,500
Total Areas 1 and 2	$1,108,500	$111,400	$ 814,100	$1,774,800	$2,588,900	$ 51,600	$112,600	$164,300

[a] *The economic analysis was conducted assuming a 50 year period and a 6 percent interest rate.*

[b] *Alternative 3 includes immediate replacement of 30 percent of systems; one-half of which are estimated to be replaced by mound or pressure systems and one-half by holding tanks. Alternative 3 also includes the replacement of 75 percent of the remaining systems during the planning period, deferred for ten years; one-third of which are estimated to be replaced by conventional systems, one-third of which by mound or pressure systems, and one-third by holding tanks.*

Source: SEWRPC.

modifications, in addition to the construction costs of the sewerage system and pump stations, were estimated to range in total from $135 to $203 per household per month assuming an initial $3,000 up-front payment. This compares to an average of about $80 per month for Alternative 3 providing for continued use of onsite sewage disposal systems. As previously noted, this cost is relatively high due to the assumption that holding tanks would be required for about 38 percent of the system over the 20-year planning period.

Alternatives 1 and 2 have the advantage of providing for more flexible household operations by providing no limitations on water usage. The installation of a public system could also have positive impacts on property values. These alternatives also offer the most protection for lake and groundwater quality. However, no significant problems with water quality related to onsite sewage disposal systems have been documented.

Alternative 3 has the disadvantage of requiring trucking of septage and holding tank wastes on Town roadways.

Alternatives 1 and 2 have the potential to cause secondary impacts by promoting additional development in the two lake areas and the land between the Lakes and the Village of Dousman. However, the current County-Town zoning is consistent with the Waukesha County development plan. Accordingly, such secondary impacts may not be significant.

CONCLUSIONS

The nonmonetary factors considered tend to favor the use of a public sanitary sewerage system to serve the Pretty Lake and School Section Lake areas. However, the cost of providing for a public sanitary sewer system are significantly higher than continued reliance on onsite sewage disposal systems, even if holding tanks were required for a substantial portion of the system. Given the potential fiscal impacts, it is unlikely that development of a public sanitary sewer

Table F-5

SUMMARY OF ECONOMIC ANALYSIS OF ALTERNATIVE SEWERAGE SYSTEM PLANS FOR THE PRETTY LAKE AND SCHOOL SECTION LAKE AREAS

Area and Alternative	Equivalent Annual Cost	Ratio to Lowest Cost Alternative
Pretty Lake Area Only		
Alternative 1—Separate Public System	$143,700	1.27
Alternative 3—Onsite Sewerage System	112,800	1.00
School Section Lake Area Only		
Alternative 1—Separate Public System	$ 95,100	1.85
Alternative 3—Onsite Sewerage System	51,500	1.00
Pretty Lake and School Section Lake Areas		
Alternative 1—Separate Public System	$238,800	1.45
Alternative 2—Combined Public System	211,100	1.28
Alternative 3—Onsite Sewerage System	164,300	1.00

Source: SEWRPC.

system would be implementable, unless there is a demonstrated need based upon lake or groundwater quality conditions or property value impacts. No such problems have been documented. Thus, it is assumed that the Pretty Lake and School Section Lake areas will continue to rely on onsite sewage disposal systems through the year 2020.

Consideration of the need to provide capacity at the public sewage treatment plant for septage and holding tank waste generated from the areas will be included in the northwestern Waukesha County sewage system planning considerations.

Table F-6

PRELIMINARY FISCAL IMPACTS COST ANALYSIS FOR PUBLIC SANITARY SEWER SYSTEM FOR THE PRETTY LAKE AND SCHOOL SECTION LAKE AREAS

Fiscal Impact Components[a]	Public System			Private Systems[b]	
	Alternative 1		Alternative 2	Alternative 3	
	Area 1	Area 2	Areas 1 and 2	Area 1	Area 2
Initial Capital Cost	$1,794,500	$1,162,000	$2,621,500	$757,500	$351,000
Capital to be Raised Using Assumed Initial $3,000 Charge per Household (n = number of households assessed)[c]	360,000 (n = 120)	165,000 (n = 55)	525,000 (n = 175)	297,000 (n = 99)	138,000 (n = 48)
Initial Capital Cost to be Amortized Assuming $3,000 Initial Investment	1,434,500	997,000	2,096,500	460,500	213,000
Assumed Initial Assessment Cost per Property (n = number of households assessed)	$ 3,000 (n = 120)	$ 3,000 (n = 55)	$ 3,000 (n = 175)	$ 2,475 (n = 120)	$ 2,510 (n = 55)
Initial Cost per Property for System	11,950	18,130	11,980	3,800	3,900
Total Assumed Initial Capital Cost per Household	14,950	21,130	14,980	6,275	6,410
Annual Capital Cost for Amortized Amount[d]	$ 125,000	$ 86,900	$ 182,800	$ 40,100	$ 18,600
Annual Operation and Maintenance Costs					
Direct Costs	29,800	21,400	44,800	77,000	34,400
Indirect Costs[e]	6,700	3,300	10,000	--	--
Total Annual Cost	161,500	111,600	237,600	117,100	53,000
Cost per Household per Month[f] (n = number of households assessed)	135 (n = 120)	203 (n = 55)	136 (n= 175)	81 (n = 120)	80 (n = 55)

[a] *This fiscal cost analysis is a preliminary estimate based upon the three Alternatives identified in Tables F-1 through F-3 which will have to be refined by negotiations between the parties involved if this sewer system analysis were to be carried forward.*

[b] *Capital cost under Alternatives 1 and 2 is based upon the number of existing households in the study area—120 households at Pretty Lake and 55 households at School Section Lake; capital cost under Alternative 3 is based upon the 30 percent of households estimated as having onsite systems requiring immediate replacement during the planning period, plus 75 percent of remaining systems requiring replacement during the planning period, deferred for 10 years—99 households at Pretty Lake and 46 households at School Section Lake.*

[c] *Initial $3,000 assessment based upon full community participation in public sewerage system alternatives, and upon participation by the total estimated number of households (n) considered as having to replace onsite sewage disposal systems during the planning period as set forth in Footnote b above.*

[d] *Annual cost of capital based upon a 20-year repayment at a 6 percent interest rate.*

[e] *Direct costs include utility, fuel and chemical costs; indirect costs include labor, transportation, administration, and property costs.*

[f] *Cost per Household per Month is based upon the cost being distributed across the entire community; in the case of private systems, some persons would pay only the maintenance components, while others would pay both the maintenance component, plus the capital cost of replacement systems.*

Source: SEWRPC.