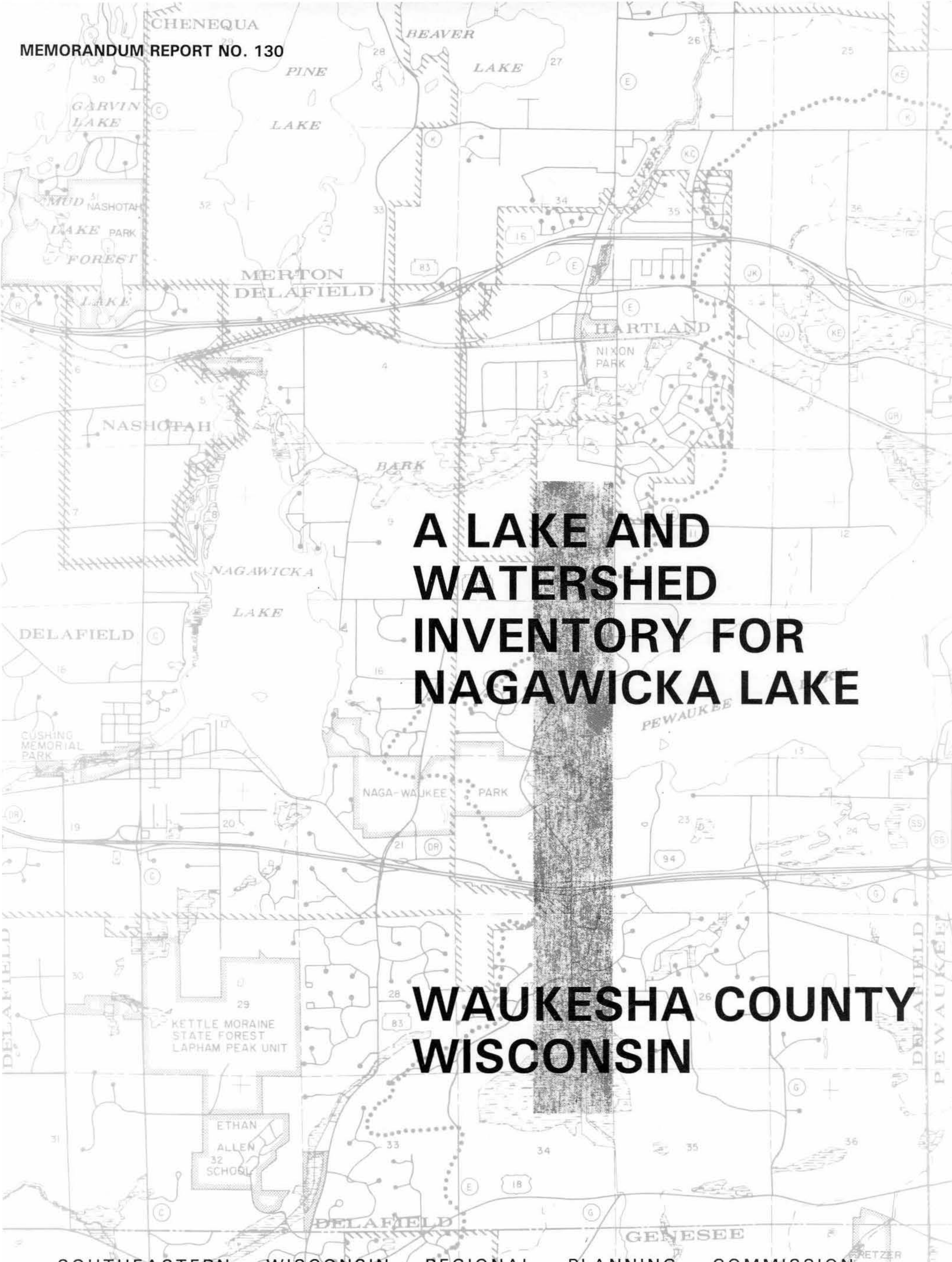
MEMORANDUM REPORT NO. 130

A LAKE AND WATERSHED INVENTORY FOR NAGAWICKA LAKE

WAUKESHA COUNTY WISCONSIN



SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgment is due to Dr. Jeffrey A. Thornton, CLM, SEWRPC Principal Planner, Ms. Christine M. Hinz, SEWRPC Planner, and Mr. Edward J. Schmidt, SEWRPC Research Analyst, for their contributions to the conduct of this study and the preparation of this report.

MEMORANDUM REPORT
NUMBER 130

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WAUKESHA COUNTY, WISCONSIN

Prepared by the

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Chapter I

INTRODUCTION

Nagawicka Lake, is a drainage lake, located on the Bark River within U.S. Public Land Survey Sections 5, 8, 9, 16, 17, 20, and 21, Township 7 North, Range 18 East, City of Delafield and Village of Nashotah, Waukesha County. The Lake offers a variety of water-based recreational opportunities and is the focus of the community surrounding the Lake. During recent years, the Lake has experienced various management problems, including surface water use conflicts and aquatic plant growth nuisance conditions. In addition, concerns have been raised by lake residents and users regarding variable water quality conditions, accumulation of silt, contamination of lake waters by nonpoint source pollution, loss of riparian wetlands, and the potential impacts of increased residential and commercial development within the drainage area directly tributary to the Lake and shoreland modifications.

Previous lake management planning efforts relating to Nagawicka Lake have included the preparation of a regional water quality management plan,[1] and river basin water quality management plan.[2] These plans identified surface water quality problems within the Region and the Bark River watershed; identified the major sources of pollution; and provided recommendations for abating those sources to achieve specified water use objectives and attendant water quality standards, which, in the case of Nagawicka Lake, included measures designed to minimize livestock-related nutrient loading, nutrient loading from onsite sewage disposal systems, and sediment loading from rural lands and urban construction sites. The regional plan also recommended the construction of a new sewage treatment plant to serve the Delafield-Hartland area and the abandonment of the then existing Hartland sewage treatment plant. The new plant effluent discharge would be downstream of Crooked Lake on the Bark River. This plan element has now been fully implemented. Currently, Nagawicka Lake is included in the Wisconsin Department of Natural Resources (WDNR) Long-Term Trend Monitoring Program.[3] In addition, other studies which have been prepared related to lake water quality and lake use include an aquatic plant survey and management plan prepared by Aron & Associates,[4] a WDNR fisheries creel survey,[5] and a quantification of the contaminant loadings to the Lake, as an intermediate body of water upstream of Upper Nemahbin Lake, by the Southeastern Wisconsin Regional Planning Commission (SEWRPC).[6]

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[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *February 1979; and SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[2]*Wisconsin Department of Natural Resources Publication No. PUBL-WT-280-98REV,* Lower Rock River Basin Water Quality Management Plan, A Five-Year Plan to Protect and Enhance Our Water Resources, *October 1998.*

[3]*Wisconsin Department of Natural Resources Report,* Nagawicka Lake, Waukesha County, Long Term Trend Lake: 1986, *1986; Wisconsin Department of Natural Resources Report,* Nagawicka Lake, Waukesha County, Long Term Trend Lake: 1987, *1987.*

[4]*Aron & Associates,* Nagawicka Lake Plant Management Plan, *August 1993.*

[5]*Wisconsin Department of Natural Resources Fish Management Report No. 131,* Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County, Summer 1982, *February 1987.*

[6]*SEWRPC Memorandum Report No. 101,* Upper Nemahbin Lake Watershed Inventory Findings, Waukesha County, Wisconsin, *May 1995.*

Seeking to improve the management and usability of Nagawicka Lake, the City of Delafield formed the Lake Welfare Committee, in cooperation with the Village of Nashotah, to deal with issues surrounding water quality, lake uses, and landowner concerns, and provide advice to the Delafield City Council. Since its formation, the City of Delafield Lake Welfare Committee has undertaken a program to evaluate water quality conditions and identify specific management measures needed to improve the water quality and recreational use potential of Nagawicka Lake.

This lake and watershed inventory represents an ongoing commitment by the City of Delafield Lake Welfare Committee to sound environmental planning pursuant to recommendations set forth in the regional and river basin water quality management plans, and forms the basis for the development of a comprehensive lake management plan for Nagawicka Lake. This inventory was prepared by the Regional Planning Commission in cooperation with the Lake Welfare Committee and it incorporates the data and analyses developed in the aforementioned lake management related studies. This report describes the physical, chemical, and biological characteristics of the Lake and pertinent related characteristics of the tributary watershed, as a basis for conducting an assessment of the feasibility of various watershed and in-lake management measures which may be applied to enhance the water quality conditions, biological communities, and recreational opportunities of the Lake.

The primary objectives of this inventory are: 1) to contribute to the overall conservation and wise use of the Nagawicka Lake through the compilation of information on the physical characteristics and natural resources of the Lake and its watershed; 2) to identify and document the water-based recreational experiences of residents and visitors to the Lake; and 3) to quantify the severity of nuisance resulting from recurring excessive aquatic macrophyte and impacts of sediments in portions of the Lake basin. The objectives of this inventory are set within the longer-term objective of improving water quality, water-based recreation, and the aesthetic value of the Lake, and to enhance its resource value. Further, it is an objective of this inventory to contribute to the identification and quantification of point and nonpoint sources of water pollution within the drainage area tributary to Nagawicka Lake, as recommended in the adopted regional water quality management plan, in order to provide a technically sound basis for developing a program of lake protection. This inventory should serve as a component of a lake management plan that will guide lake management actions on Nagawicka Lake over time and in such a way as to contribute to achieving the lake management objectives established for the Lake in a technically sound manner.

Chapter II

PHYSICAL DESCRIPTION

INTRODUCTION

The physical characteristics of a lake and its watershed are important factors in any evaluation of existing and probable future lake water quality conditions and lake uses, including recreational uses. Characteristics such as watershed topography, lake morphometry, and local hydrology ultimately influence water quality conditions and the composition of plant and fish communities within the lake. Therefore, these characteristics must be considered during the lake management planning process. Accordingly, this chapter provides pertinent inventory information on the physical characteristics and on the climate and hydrology of Nagawicka Lake and its watershed. Subsequent chapters deal with the land use conditions and chemical and biological environments of the Lake.

WATERBODY CHARACTERISTICS

Nagawicka Lake is located in the heart of the City of Delafield, as shown on Map 1. The Lake is a natural lake with a single deep basin and a kettle at the extreme north end of the Lake. The “Kettle,” which was historically known as Lake Minnehaha, was connected to Nagawicka Lake following the construction of a series of low head dams and a mill race on the Bark River in the vicinity of CTH C. The lake level is currently controlled by two outlet structures located on the southwestern shore of the Lake. These outlet structures currently have a system of radial gates and lift gates which maintain a mean depth of about 36 feet in the Lake. The original lake basin and the northern kettle of Nagawicka Lake were formed as the Michigan and Green Bay Lobes of the continental glacier retreated from Southeastern Wisconsin during the late Wisconsin stage of glaciation.

Nagawicka Lake is fed and drained by the Bark River. The hydrographical characteristics of the Lake are summarized in Table 1 and the bathymetry of the Lake is shown on Map 2. The inclusion or exclusion of the “kettle” on the northern extreme of the Lake, and of the artificial lakeside channels constructed along the western shoreline of the Lake, has resulted in various hydrographical and morphometric data being published for Nagawicka Lake. The Wisconsin Department of Natural Resources[1] documents the lake surface area as 917 acres. As the data presented by the Wisconsin Department of Natural Resources are the data used for regulatory purposes, including the determination of public recreational boating access standards pursuant to Chapter NR 1 of the *Wisconsin Administrative Code*, these data are used in Chapter VI for establishing lake access standards. The adopted regional water quality management plan[2] and aquatic plant management plan[3] document the lake surface area as 1,026 acres. The regional water quality management plan update and status report[4] and Waukesha County

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[1]*Wisconsin Department of Natural Resources Publication PUBL-FM-800 95 REV,* Wisconsin Lakes*, 1995; also Wisconsin Department of Natural Resources Publication PUBL-WT-280 98 REV,* Lower Rock River Basin Water Quality Management Plan: A Five-Year Plan to Protect and Enhance Our Water Resources*, October 1998.*

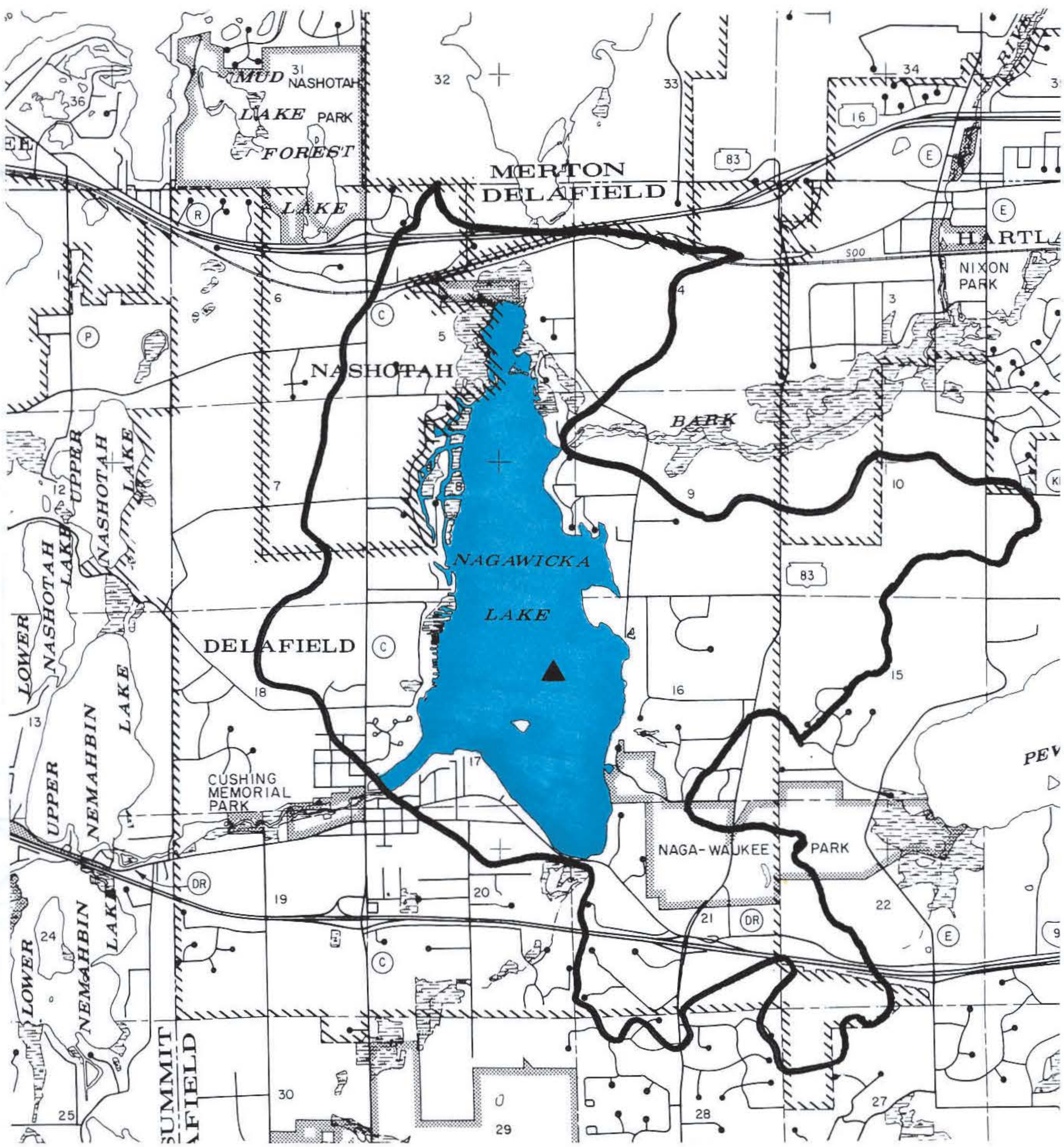
[2]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000*, Volume Two,* Alternative Plans*, February 1979.*

[3]*Aron & Associates,* Aquatic Plant Management Plan for Nagawicka Lake*, 1995.*

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

Map 1

LOCATION MAP OF NAGAWICKA LAKE



Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 1

HYDROLOGY AND MORPHOMETRY
OF NAGAWICKA LAKE

Parameter	Measurement
Size (total)	
Surface Area	957 acres
Total Drainage Area	28,952 acres
Direct Drainage Area	4,763 acres
Volume	45,936 acre-feet
Residence Time[a]	1.6 years
Shape	
Maximum Length of Lake	2.8 miles
Length of Shoreline	8.6 miles
Maximum Width	1.1 miles
Shoreline Development Factor[b]	1.65
Depth	
Mean Depth	48 feet
Maximum Depth	90 feet

[a]*Residence time: time required for a volume equivalent to full volume replacement by inflowing waters to enter the lakes.*

[b]*Shoreline development factor: ratio of shoreline length to that of a circular lake of the same area.*

Source: SEWRPC.

development plan[5] document the lake surface area as 957 acres, based upon more recent measurements of the lake surface. That lake area is presented in Table 1, and is used throughout the report other than in Chapter VI relating to lake access requirements. Such variations in lake area reflect the classifications of the kettle and artificial channels as either lake or wetland, and variations in lake water levels at the time of the surface area determinations—higher water levels would result in a larger surface area while lower water levels would reduce the lake surface area. Further, the bathymetric profile has been slightly modified as a result of limited dredging conducted since the date of the lake survey. Notwithstanding, such variations in Lake morphometry are unlikely to have a significant effect on the analyses set forth herein.

Nagawicka Lake is about three miles long in the north-south direction, and about one mile wide, with a shoreline length of about seven miles. The shoreline of Nagawicka Lake, except for the northern and portions of the southern shores, is almost entirely developed for residential uses. Because of its size and shape, the Lake has a large amount of shoreline that was augmented during the 1920s by the dredging of lakeside channels by a developer, as has been noted. The northern basin is composed of an undisturbed wetland area surrounding the kettle, while a portion of the eastern shore is in public ownership and forms a unit of Waukesha County's Nagawaukee Park.

Erosion of shorelines results in the loss of land, damage to shoreland infrastructure, and interference with access and lake use. Such erosion is usually caused by wind-wave erosion, ice movement, and motorized boat traffic. A survey of the Nagawicka Lake shoreline, conducted during the summer of 1997 by the Commission staff, identified existing shoreline protection conditions around this lake, as shown on Map 3. Most were in a good state of repair. In 1997, much of the developed shoreland of Nagawicka Lake had some form of shoreline protection although portions of shoreline, especially in the northern and northwestern portions of the Lake, remained in a natural or vegetated state. The limited evidences of shoreland erosion which were observed were possibly the result of elevated water levels experienced during the spring and summer of 1997, which overtopped some existing shoreline structures.

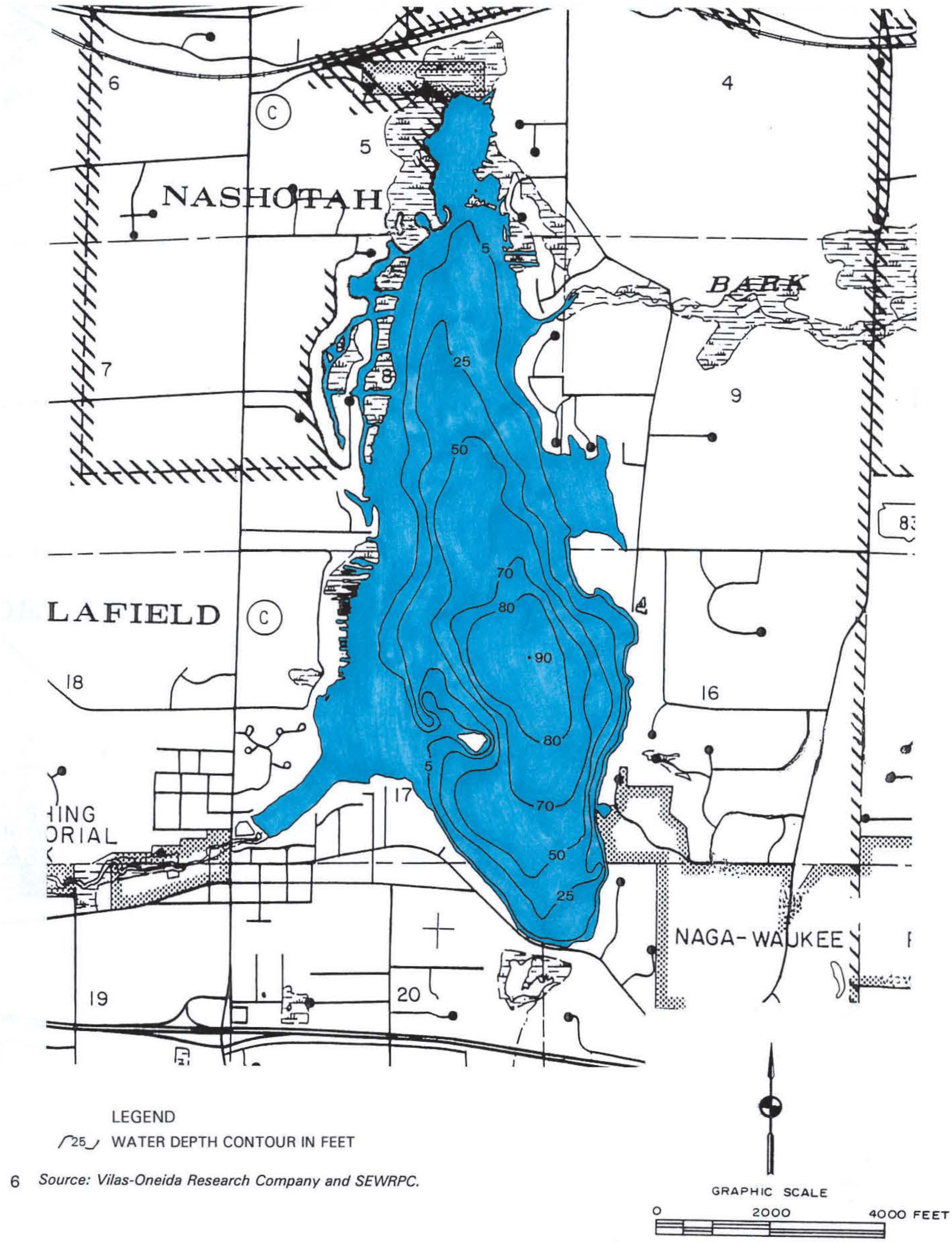
WATERSHED CHARACTERISTICS

Because of the importance of the Bark River to the hydrology and water quality of the Lake, the area drained by the Bark River has been included in the total drainage area considered in this study, as shown on Map 4. The total

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

Map 2

BATHYMETRIC MAP OF NAGAWICKA LAKE



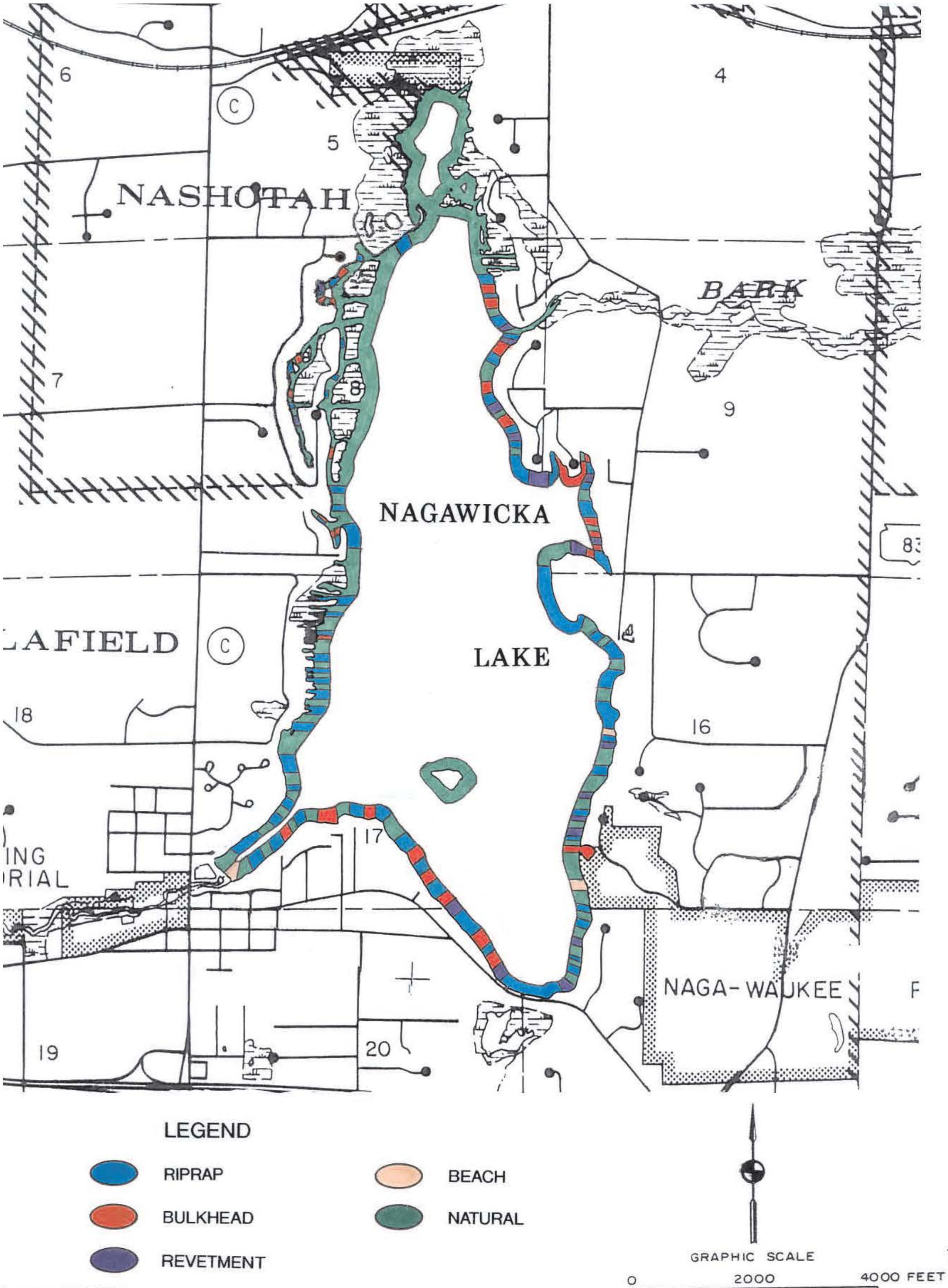
LEGEND

25 WATER DEPTH CONTOUR IN FEET

 Source: Vilas-Oneida Research Company and SEWRPC.

Map 3

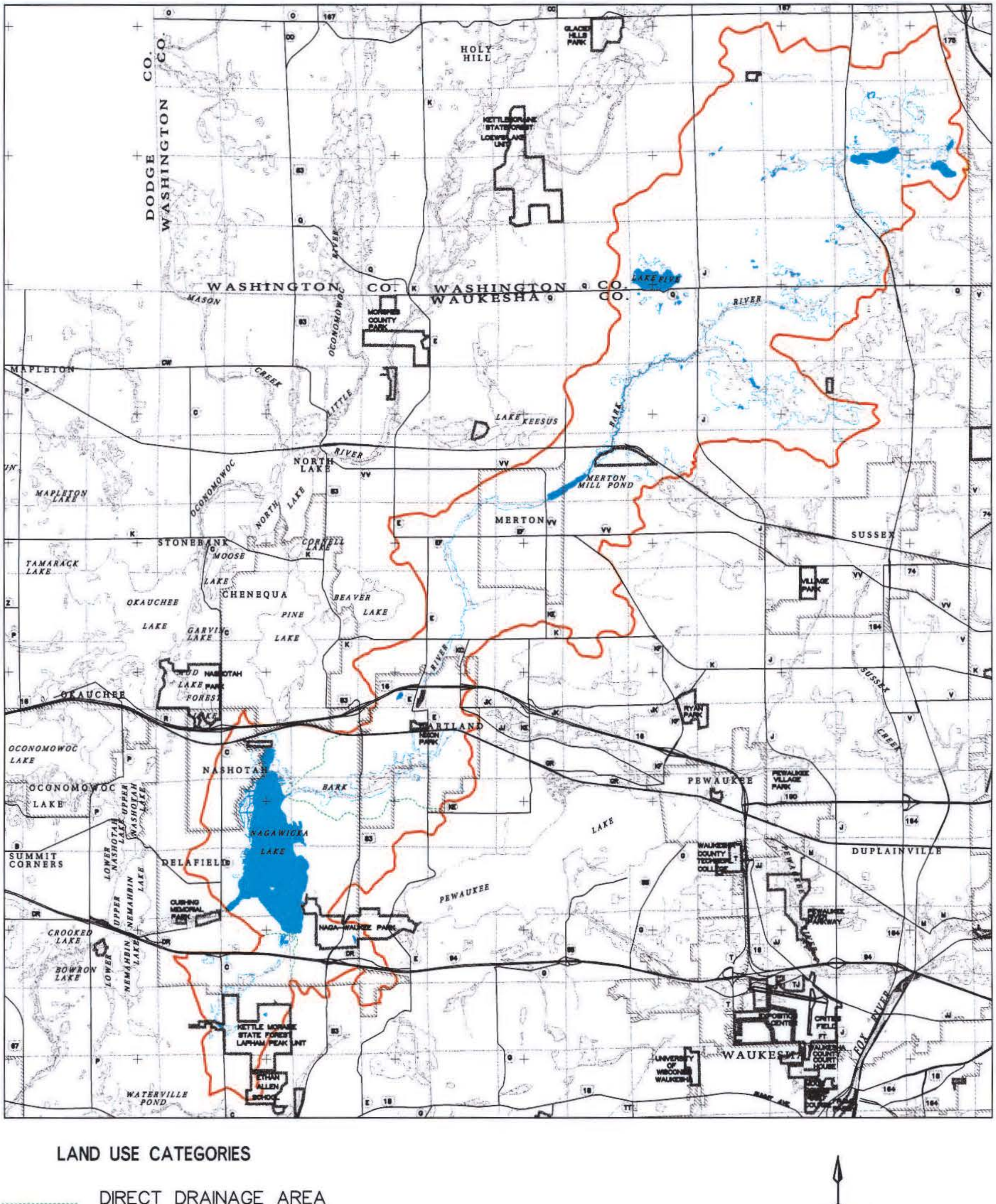
SHORELINE PROTECTION CONDITIONS ON NAGAWICKA LAKE



Source: SEWRPC.

Map 4

NAGAWICKA LAKE TOTAL TRIBUTARY DRAINAGE AREA



LAND USE CATEGORIES

DIRECT DRAINAGE AREA

TOTAL TRIBUTARY DRAINAGE AREA

0 1 2
Scale in miles

Source: SEWRPC.

drainage area tributary to the Lake, including the entire area upstream of Nagawicka Lake drained by the Bark River, is about 45 square miles in areal extent. Nagawicka Lake has a watershed-to-lake ratio of about 32:1.

The hydrology of Nagawicka Lake is modified by the presence of the structures at the Lake outlet as previously described. Map 5 shows the 1891 plat map of the Nagawicka Lake area. A comparison of the present surface area of Nagawicka Lake, as shown on Map 1, with the 1891 map, graphically indicates the extent to which the lake area has expanded since the river was dammed.

Soil Types and Conditions

Soil type, land slope, and land use and management practices are among the more important factors determining lake hydrology and 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 to erosion.

The U.S. Natural Resources Conservation Service, under contract to the Southeastern Wisconsin Regional Planning Commission, completed a detailed soil survey

of the entire seven-county planning region, including the Nagawicka Lake area in 1966.[6] The soil survey contained interpretations for planning and engineering applications and for suitability for various types of urban land uses, as well as for agricultural applications. Using the regional soil survey, an assessment was made of hydrologic characteristics of the soils in the total drainage area tributary to Nagawicka Lake. The suitability of the soils for urban residential development was assessed using three common development scenarios: development with conventional onsite sewage disposal systems such as septic tank systems; development with alternative onsite sewage disposal systems such as mound systems; and development with public sanitary sewers.

Soils within the total drainage area tributary to Nagawicka Lake were categorized into four main hydrologic soil groups, as well as an "other" category, as indicated in Table 2. The areal extent of these soils and their locations within the watershed are shown on Map 6. About 67 percent of the total drainage area tributary to Nagawicka is covered by the moderately well-drained soils, about 15 percent by poorly drained soils, and about 11 percent by very poorly drained soils. The remaining area of the drainage area are covered by water and materials for which no hydrologic category was determined.

As already noted, the regional soil survey included interpretations of the suitability of the mapped soils for various types of urban and rural development with conventional onsite sewage disposal systems, alternative onsite sewage disposal systems, and public sanitary sewerage. The suitability ratings of the various soils for use of onsite sewage disposal systems were updated by the Regional Planning Commission based upon soil characteristics determined by the detailed soil surveys and the experience of County and State technicians responsible for overseeing the location and design of such systems. The new ratings reflect the current soil and site specifications set forth in Chapter Comm 83, formerly ILHR 83, of the *Wisconsin Administrative Code*.

With respect to residential development utilizing conventional onsite sewage disposal systems, as shown on Map 7, about 31 percent of the total drainage area tributary to Nagawicka Lake is covered by soils suitable for such development. About 18 percent of the drainage area is covered by soils unsuitable for such development. The soil suitability could not be determined without further field surveys for about 45 percent of the land in the drainage area. The remainder of the area considered is covered by surface water, about 4 percent, or disturbed land, about 2 percent, for which no interpretive data were available.

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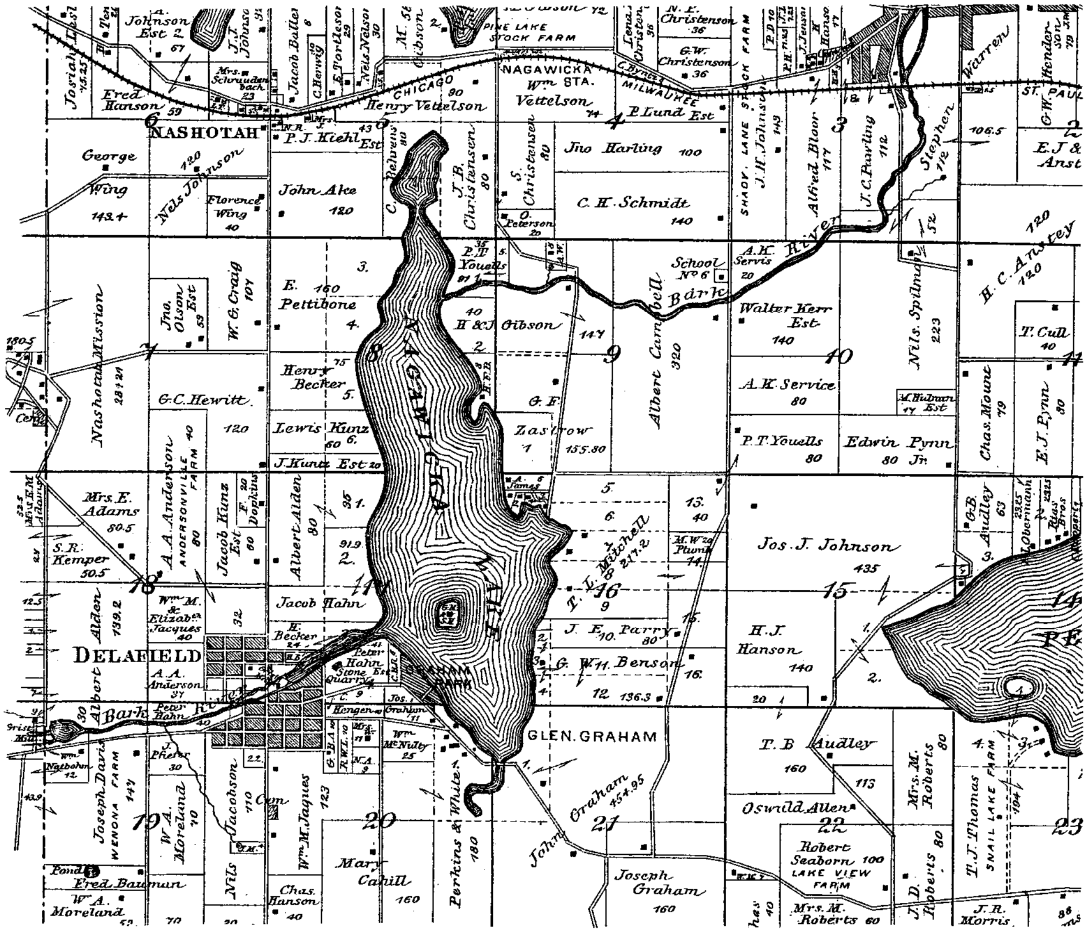
[6]*See SEWRPC Planning Report No. 8,* Soils of Southeastern Wisconsin, *June 1966.*

Map 5

HISTORIC UNITED STATES PLAT MAP FOR NAGAWICKA LAKE: 1891



Source: Waukesha County 1891 Plat Book by Balliet and Volk.

Use of alternative onsite sewage disposal systems, such as mound systems, as shown on Map 8, yields additional land which may be suitable for urban residential development: about 63 percent of the total drainage area tributary to Nagawicka Lake is covered by soils suitable for such development and about 19 percent by soils unsuitable for such development. Soil suitability could not be determined without further field surveys for about 16 percent of the drainage area. The remainder of the areas considered were covered by surface water or disturbed land for which no interpretive data are available.

Soil limitations for residential development utilizing sanitary sewer service are shown on Map 9. About 70 percent of the total drainage area tributary to Nagawicka Lake is covered by soils suitable, with slight to moderate limitations, for such development. About 24 percent by soils, with severe limitations, were unsuitable for development utilizing sanitary sewer service. The remainder of the areas considered were covered by surface water or disturbed land for which no interpretive data are available.

The existing 1995 sanitary sewer service areas in the total drainage area tributary to Nagawicka Lake, and those proposed for the year 2010 in the adopted regional water quality management plan as amended, are delineated on Map 10. The regional plan calls for virtually all of the direct drainage area to be served by sanitary sewers by the

Table 2

GENERAL HYDROLOGIC SOIL TYPES WITHIN THE DRAINAGE AREA TRIBUTARY TO NAGAWICKA LAKE

Group	Soil Characteristics	Direct Tributary Drainage Area (acres)	Percent of Total	Total Tributary Drainage Area (acres)	Percent of Total
A	Well drained; very rapidly to rapid permeability; low shrink-swell potential	- -	- -	75	<1
B	Moderately well drained; texture intermediate between coarse and fine; moderately rapid to moderate permeability; low to moderate shrink-swell potential	3,312	70	19,514	67
C	Poorly drained; high water table for part or most of the year; mottling, suggesting poor aeration and lack of drainage, generally present in A to C horizons	153	3	4,319	15
D	Very poorly drained; high water table for most of the year; organic or clay soils; clay soils having high shrink-swell potential	23	<1	3,089	11
Other	Group not determined	289	6	649	2
- -	Water	985	21	1,306	5
- -	Total	4,763	100	28,952	100

Source: SEWRPC.

year 2010. All of the riparian residential lands and most of the adjacent lands in the direct drainage area are served by public sanitary sewer.[7] The remaining areas are served by private onsite sewage disposal systems.

Climate and Hydrology

Long-term average monthly air temperature and precipitation values for the Nagawicka Lake area are set forth in Table 3. In addition, Table 3 provides monthly air temperature, runoff, and precipitation data for the 1997 study year (October 1996 through September 1997) during the period that lake hydrology data were obtained for use in this report. Table 3 also provides runoff data for both periods—long-term and the 1997 study year—derived from U.S. Geological Survey flow records for the Bark River, station number 05426250, at Rome, Jefferson County, Wisconsin.

The mean summer and winter temperatures of 60.2°F and 29.6°F at Oconomowoc are similar to those of other recording locations in Southeastern Wisconsin. Mean annual precipitation at Oconomowoc is 33.5 inches. More than half of the normal yearly precipitation falls during the growing season, from May through September. Runoff rates are generally low during this period because evapotranspiration rates are high, vegetation cover is abundant, and soils are not frozen. Normally, about 15 percent of the summer precipitation becomes surface runoff, but intense summer storms occasionally produce higher percentages of runoff. Peak runoff usually occurs during winter and early spring when about 30 percent of the annual precipitation, in the form of snowmelt and/or rain, falls on frozen ground.

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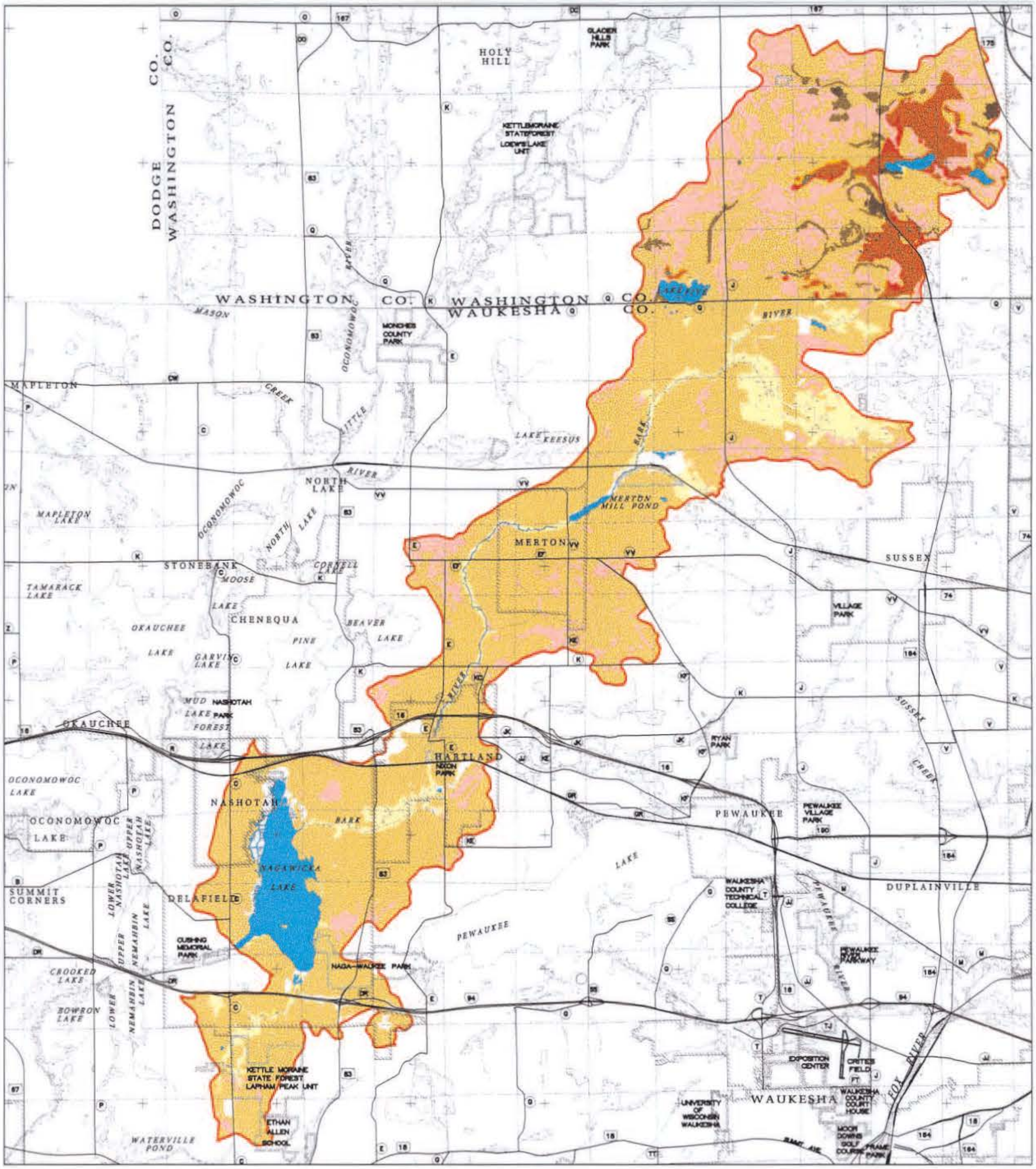
[7]*SEWRPC Community Assistance Planning Report No. 127,* Sanitary Sewer Service Area for the City of Delafield and the Village of Nashotah and Environs, Waukesha County, Wisconsin, *November 1992.*

Map 6

HYDROLOGIC SOIL GROUPS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE



HYDROLOGIC SOIL GROUPS

- GROUP A: Well–drained
- GROUP A/B: Well–drained soil/Moderately drained [1]
- GROUP A/D: Well–drained soil/Very poorly drained soil [2]
- GROUP B: Moderately drained soil
- GROUP B/D: Moderately drained soil/Very poorly drained soil [3]
- GROUP C: Poorly drained soil
- GROUP C/D: Poorly drained soil/Very poorly drained soil [4]
- GROUP D: Very poorly drained soil
- Surface Water
- Hydrologic soil group not determined

1 Well–drained soil if water table is lowered through provision of a drainage system. Moderately drained soil if water table is not lowered.

2 Well–drained soil if water table is lowered through provision of a drainage system. Very poorly drained soil if water table is not lowered.

3 Moderately drained soil if water table is lowered through provision of a drainage system. Very poorly drained soil if water table is not lowered.

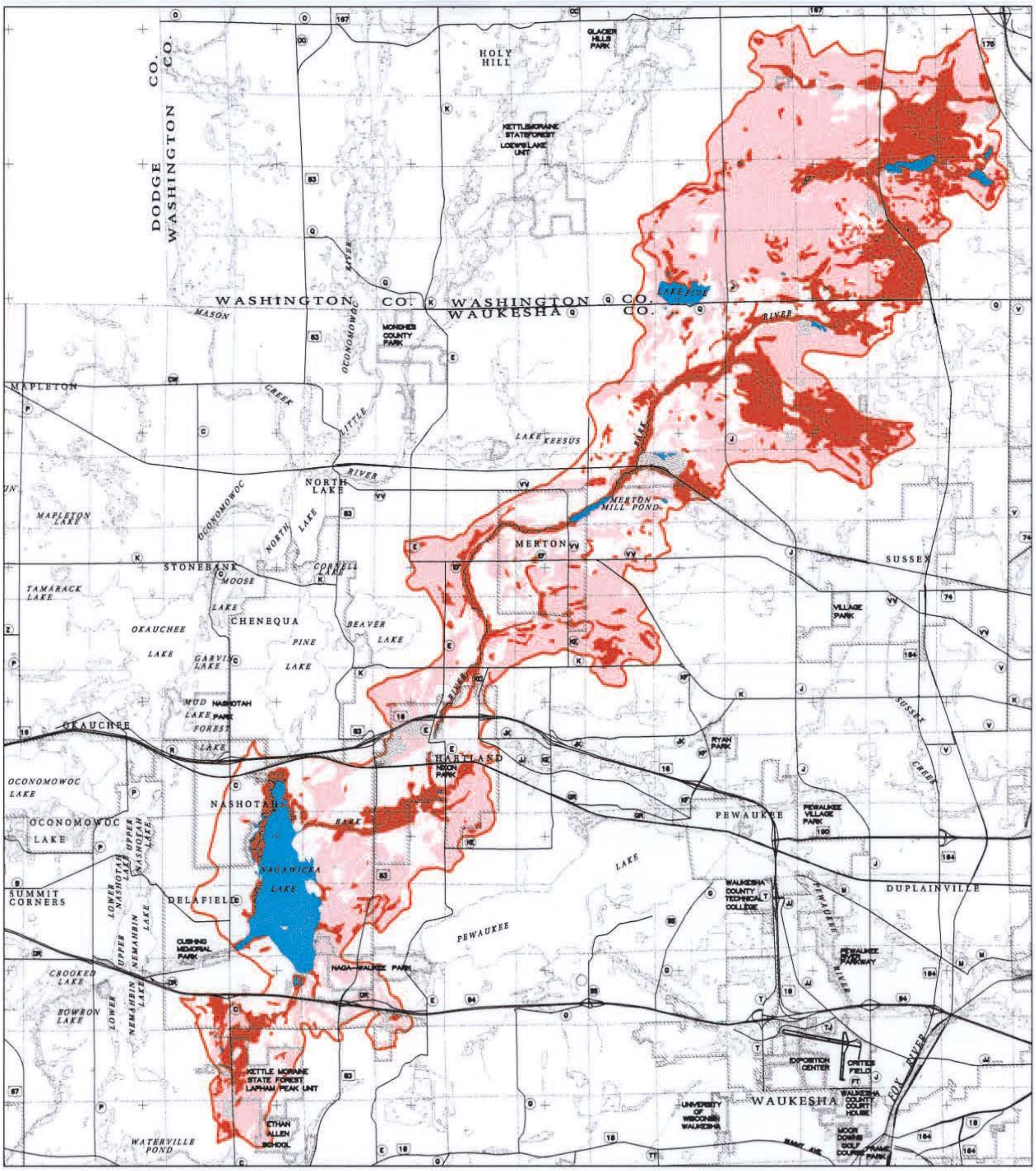
4 Poorly drained soil if water table is lowered through a provision of a drainage system. Very poorly drained soil if water table is not lowered.

0 1 2
Scale in miles

Source: SEWRPC.

Map 7

SUITABILITY OF SOILS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE FOR CONVENTIONAL ONSITE SEWAGE DISPOSAL SYSTEMS UNDER CURRENT ADMINISTRATIVE RULES: FEBRUARY 1991



SOIL SUITABILITY CATEGORIES

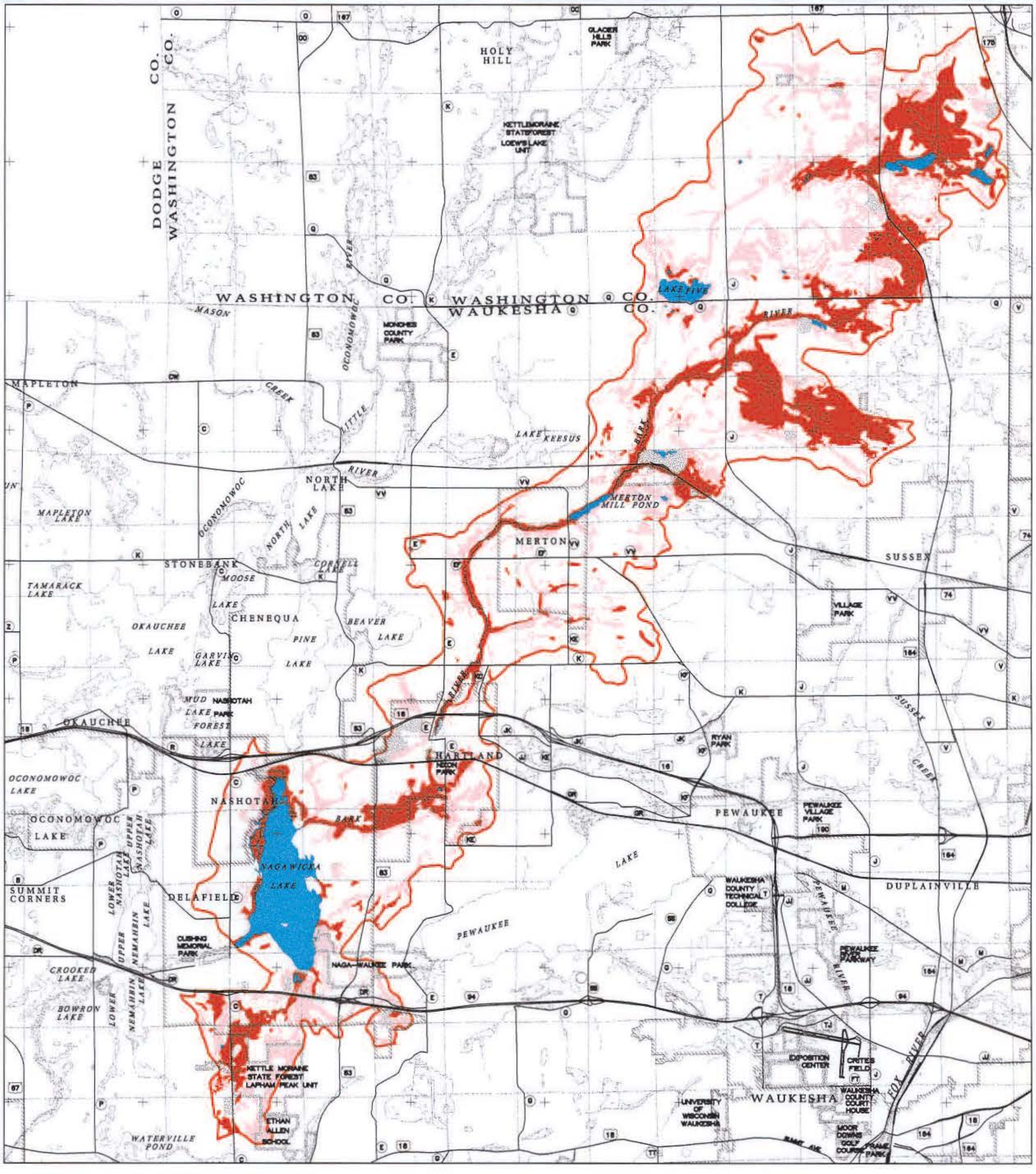
- UNSUITABLE: Areas covered by soils which have a high probability of not meeting the criteria of Chapter Comm 83 of the Wisconsin Administrative Code governing conventional onsite sewage disposal systems.
- UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the criteria of Chapter Comm 83 of the 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 Comm 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

0 1 2
Scale in miles

Source: SEWRPC.

Map 8

SUITABILITY OF SOILS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE FOR MOUND SEWAGE DISPOSAL SYSTEMS UNDER CURRENT ADMINISTRATIVE RULES: FEBRUARY 1991



SOIL SUITABILITY CATEGORIES

UNSUITABLE: Areas covered by soils which have a high probability of not meeting the criteria of Chapter Comm 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 Comm 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 Comm 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.

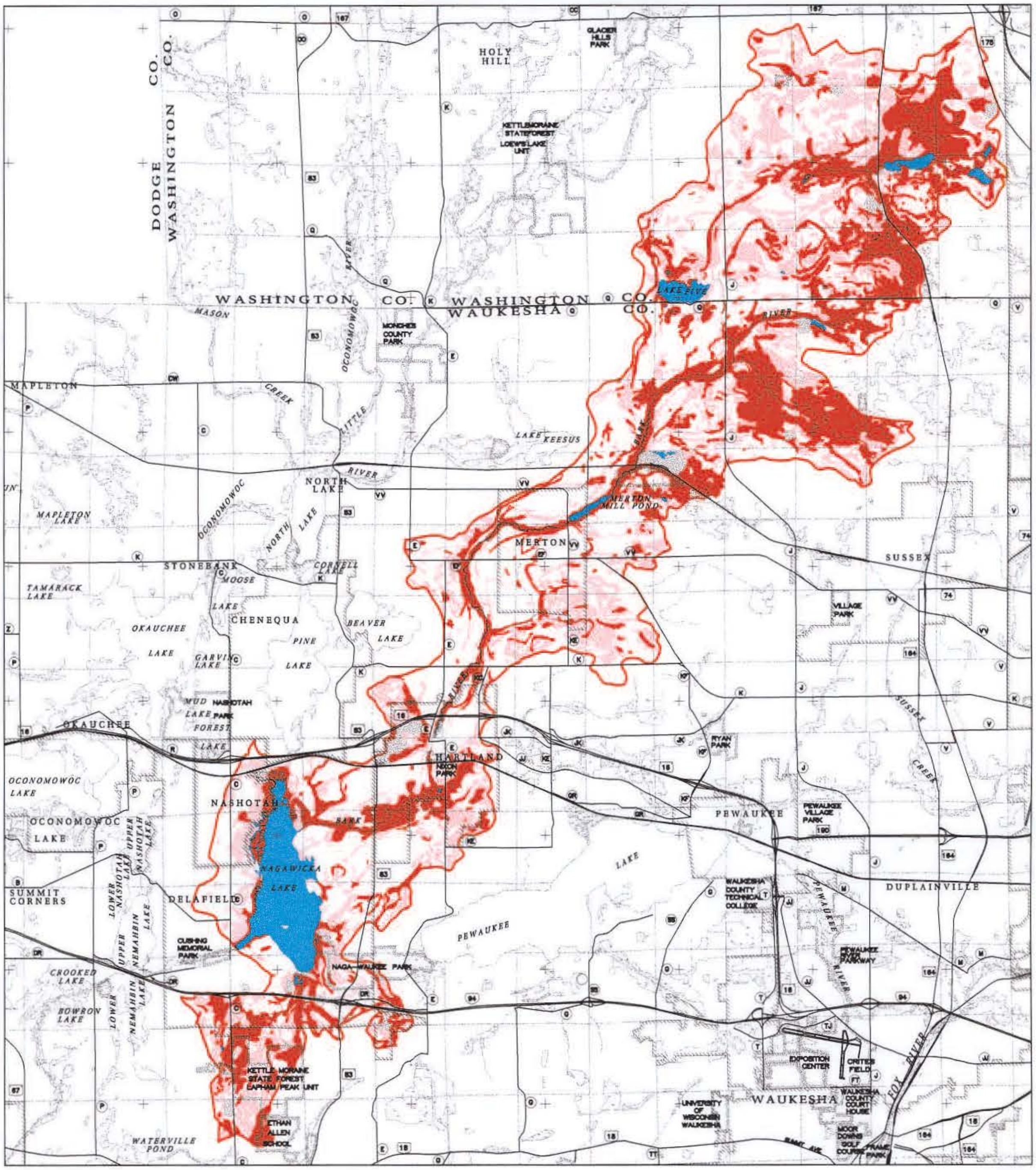
SURFACE WATER

Source: SEWRPC.

0 1 2
Scale in miles

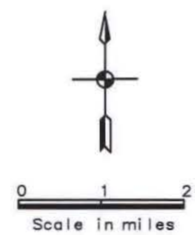
Map 9

SUITABILITY OF SOILS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE FOR DEVELOPMENT WITH PUBLIC SANITARY SEWER SERVICE UNDER CURRENT ADMINISTRATIVE RULES: FEBRUARY 1991



SOIL SUITABILITY CATEGORIES

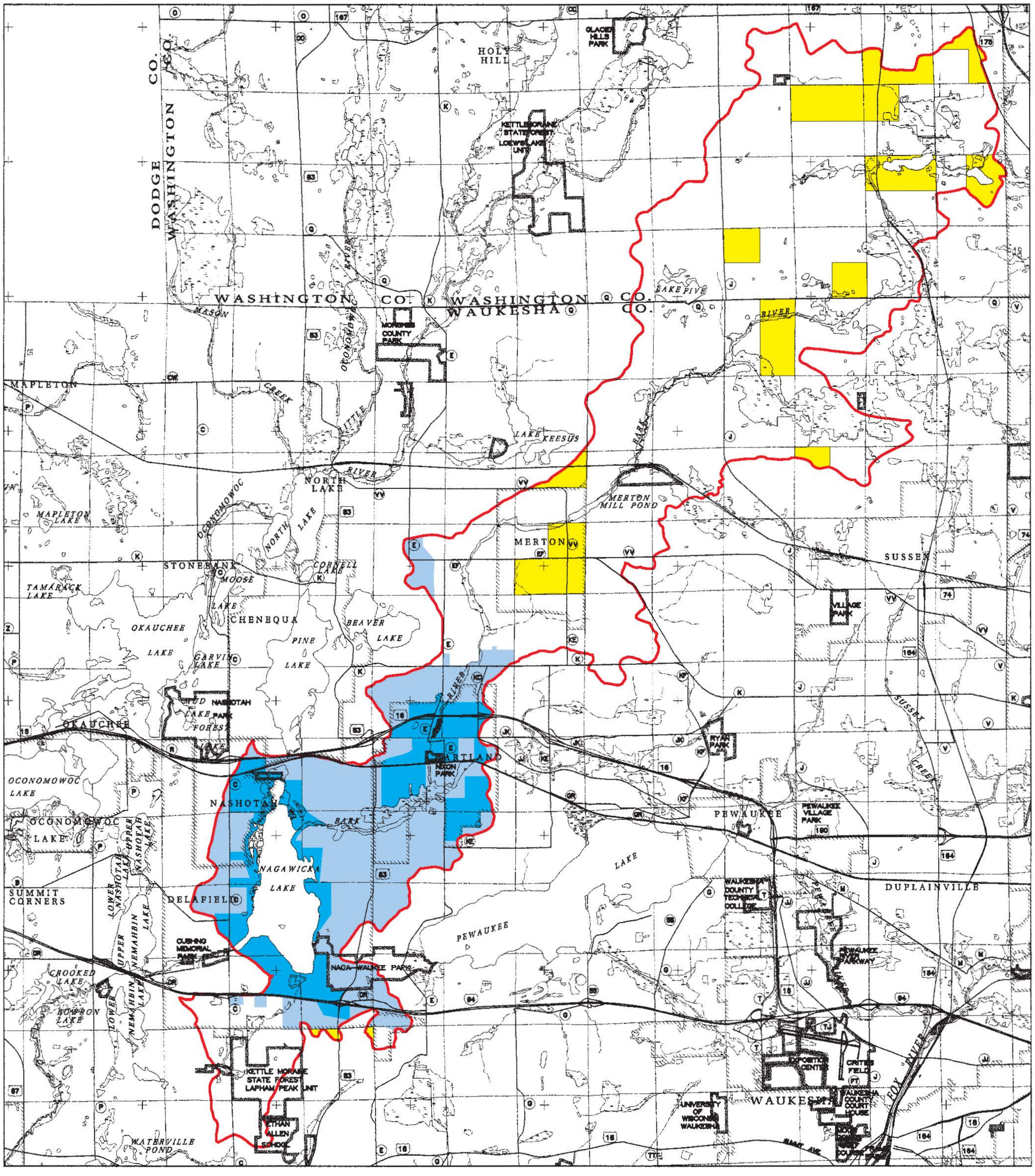
- Areas covered by soils which have SEVERE limitations for residential development with public sanitary sewer service.
- Areas covered by soils having MODERATE limitations for residential development with public sanitary sewer service.
- Areas covered by soils having SLIGHT limitations for residential development with public sanitary sewer service.
- UNCLASSIFIED soils
- SURFACE WATER



Source: SEWRPC.

Map 10

SEWER SERVICE AREAS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE:1990



LEGEND

SANITARY SEWER SERVICE AREA (EXISTING)

SANITARY SEWER SERVICE AREA (PLANNED)

1975 URBAN-DENSITY DEVELOPMENT OUTSIDE OF THE INITIAL PLAN SEWER SERVICE AREA

N

GRAPHIC SCALE

0 1 2 MILES

Source: SEWRPC.

Table 3

LONG-TERM AND 1997 STUDY YEAR CLIMATOLOGICAL, PRECIPITATION, AND RUNOFF DATA FOR THE NAGAWICKA LAKE AREA

Climatological													
Air Temperature Data (EF)	October	November	December	January	February	March	April	May	June	July	August	September	Mean
Long-Term Mean Monthly[a]	49.0	35.5	21.4	15.2	19.4	31.9	45.4	57.5	66.7	71.7	68.8	60.1	45.2
1997 Study Year Mean Monthly	50.5	29.3	23.3	15.5	24.7	34.3	43.8	51.4	67.6	70.5	66.2	61.9	44.9
Departure from Long-Term Mean	1.5	-6.2	1.9	0.3	5.3	2.4	-1.6	-6.1	0.9	-1.2	-2.6	1.8	-0.3

Precipitation														
Precipitation Data (inches)	October	November	December	January	February	March	April	May	June	July	August	September	Mean	Total
Long-Term Mean Monthly[a]	2.5	2.1	1.7	1.0	0.9	1.9	2.8	2.9	3.6	3.8	3.9	3.9	2.6	33.5
1997 Study Year Mean Monthly	4.0	0.8	1.5	1.7	3.0	1.4	1.5	3.5	5.3	6.1	5.6	1.6	3.0	39.0
Departure from Long-Term Mean	1.5	-1.3	-0.2	0.7	2.1	-0.5	-1.3	0.6	1.7	2.4	1.7	-2.3	0.4	5.5

Runoff													
Runoff Data (inches)	October	November	December	January	February	March	April	May	June	July	August	September	Mean
Long-Term Mean Monthly[a]	0.69	0.89	0.80	0.65	0.65	1.24	1.34	0.95	0.65	0.61	0.62	0.65	9.88
1997 Study Year Mean Monthly	0.50	0.68	0.62	0.63	0.92	1.57	1.02	1.08	0.87	1.05	0.78	0.67	10.75
Departure from Mean Monthly	-0.19	-0.21	-0.18	-0.02	0.27	0.33	-0.32	0.13	0.22	0.44	0.16	0.02	0.87

[a]Runoff data reported at U.S. Geological Survey gauging station 05426250 on the Bark River at Rome, Wisconsin, for the period 1980 through 1997.

Source: National Oceanic and Atmospheric Administration and U.S. Geological Survey.

As Table 3 indicates, during the 1997 hydrological year, precipitation was 39.0 inches, or about 5.5 inches above the long-term average at Oconomowoc. During June, July, and August, the wettest months, 5.3, 6.1, and 5.6 inches of precipitation, or 1.7, 2.4, and 1.7 inches above the long-term average, were experienced, respectively. Below normal precipitation was experienced during November, December, March, April, and September. The net result of the three months of heavy rainfall was above normal runoff volumes at the U.S. Geological Survey streamflow gauge located on the Bark River at Rome, Wisconsin.

Review of the groundwater elevations in the vicinity of Nagawicka Lake indicates that groundwater flow has a flat gradient in the vicinity of the Lake.[8] This would suggest little horizontal movement of groundwater to or from the Lake. However, some flow can be expected from south to north at the south end of the Lake.

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[8]*U.S. Geological Survey Water-Resources Investigations Open-File Report No. 79-43,* Water Table Map of Waukesha County, Wisconsin, *May 1979.*

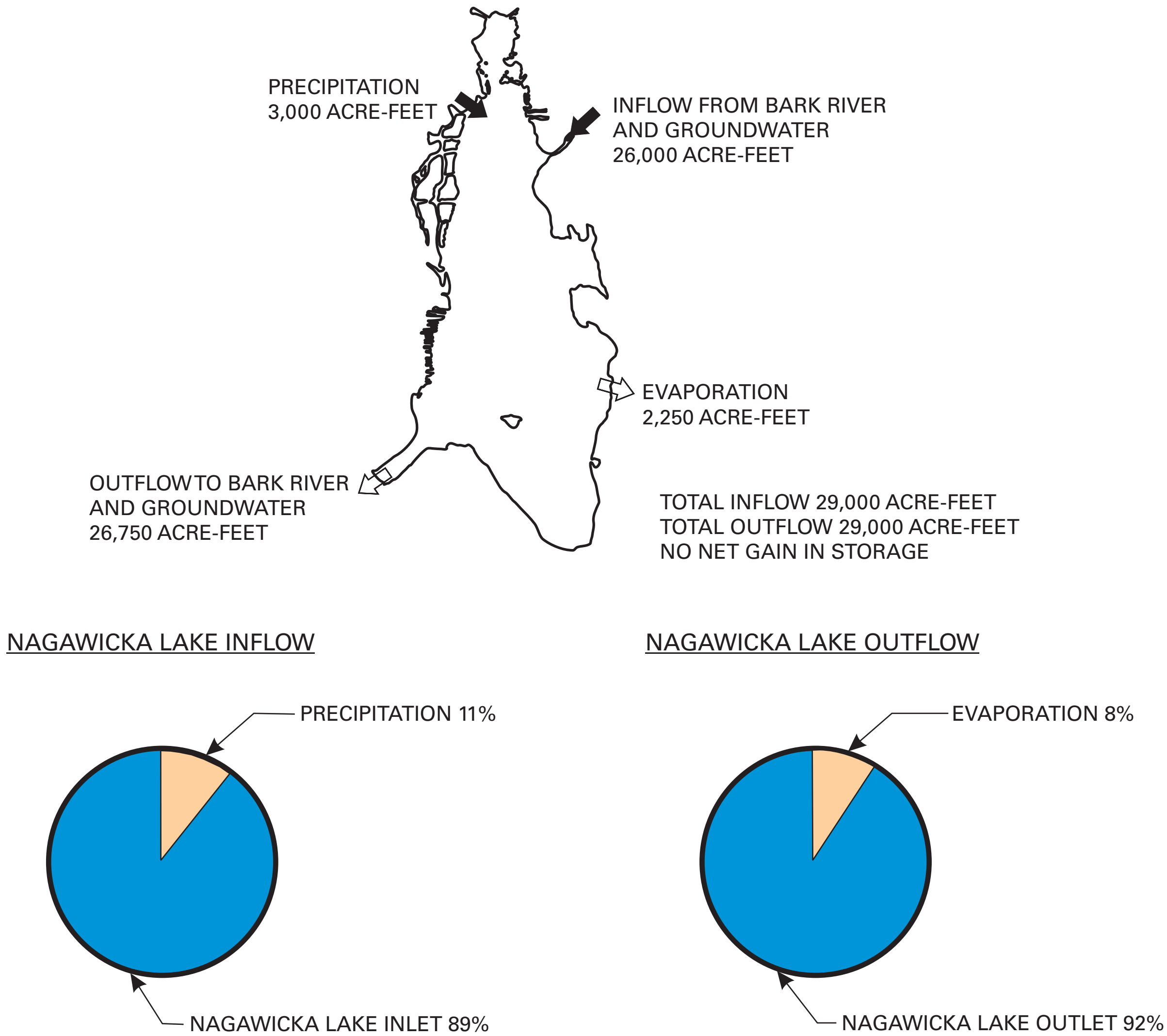
Water Budget

Based upon available data, an analysis of the available hydrologic and climate data discussed previously, an average annual water budget for Nagawicka Lake was computed and is set forth in Figure 1. During the 12-month period, October 1996 through September 1997, an estimated 26,000 acre-feet of water entered the Lake from the Bark River and other surface water sources. A further 3,000 acre-feet of water, or about 10 percent of the known inflow, came from direct precipitation onto the lake surface. An estimated 2,250 acre-feet of water was lost from the Lake via evaporation from the lake surface. As the net gain of water in Nagawicka Lake was assumed to be negligible over the annual cycle, the balance of the inflow, an estimated 26,750 acre-feet of water, was estimated to be lost from the Lake by other means, most likely through the Bark River outflow. Loss of water by groundwater outflows was also assumed to be negligible. Lesser volumes of inflow—about 24,000 acre-feet via the river and 2,500 acre-feet via direct precipitation—and outflow—about 2,200 acre-feet via evaporation and 24,300 acre-feet via the river—are estimated based upon longer-term hydrological measurements in the Bark River. Further, while localized flooding in time and space is becoming an issue of concern, especially downstream of the Nagawicka Lake, the general balance between inflow and outflow over an annual cycle is expected over the longer term.

The hydraulic residence time, or the time required for a volume equivalent to the full volume of the Lake to enter the lake basin, was approximately 1.6 years during the study period and is estimated to be 1.7 years during an average year. The hydraulic residence time is important in determining the expected response time of the Lake to increased or decreased nutrient and pollutant loadings. The smaller the lake volume and/or greater the rate of inflow, the shorter the hydraulic residence time will be. The residence time of Nagawicka Lake is long enough that the influences of the Bark River on water quality are moderated due largely to the relatively large size of the waterbody. The water residence time is sufficiently long for the lake water to develop a lacustrine character. However, given the volumes of water involved and the relatively large watershed to lake area ratio, the water quality of Nagawicka Lake is likely to also be influenced to a degree by the quality of the Bark River inflow.

Figure 1

HYDROLOGIC BUDGET FOR NAGAWICKA LAKE: 1996-1997



Source: SEWRPC.

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Chapter III

HISTORICAL, EXISTING, AND PLANNED LAND USE

INTRODUCTION

Water pollution problems, recreational use conflicts, and the deterioration of the natural environment are, in part, a function of the human activities which occur within the drainage area tributary to the waterbody. Likewise, the ultimate solutions to these problems typically are to be found within the drainage area. This is especially true with respect to lakes that are highly susceptible to deterioration because of relatively long pollutant retention times, and which cater to a variety of often conflicting uses. Furthermore, urban development is often concentrated in the shorelands of lakes and in the drainage areas directly tributary to them, where there are no intermediate stream segments to attenuate pollutant runoff and loadings. Accordingly, land use and land management in the drainage area directly tributary to a lake must be an important consideration in any lake management efforts.

Notwithstanding, given the extent of the drainage area of the Bark River upstream of Nagawicka Lake, and the dominant role of this river system in the hydrological balance of Nagawicka Lake, consideration should also be given to land use and land management within the total tributary drainage area to the Lake. Human activities within this larger drainage area determine to a large degree the quality and quantity of the inflowing water to Nagawicka Lake. Modifications of water quality and quantity as a result of changing land use and land management practices will be reflected in the water quality of Nagawicka Lake and affect the hydrology of the Bark River system.

Civil Divisions

The geographic extent and functional responsibilities of civil divisions and special-purpose units of government are important factors related to land use and management. Local units of government provide the basic structure of the decision-making framework within which land use development and redevelopment must be addressed. Superimposed on the Nagawicka Lake drainage area are the local civil division boundaries shown on Map 11. The Lake basin is totally encompassed by the City of Delafield and the Village of Nashotah. However, the drainage area directly tributary to the Lake extends over a larger area and includes portions of the City of Delafield, the Villages of Chenequa, Hartland, and Nashotah, and the Town of Delafield, all in Waukesha County. The area and proportion of the drainage area lying within each jurisdiction concerned, as of 1990, is set forth in Table 4. The total land area draining to Nagawicka Lake, including those areas draining to the Lake through portions of stream draining to other upstream waterbodies, includes portions of the Town of Richfield, in Washington County, and the Village of Merton and Towns of Lisbon and Merton, in Waukesha County, as shown on Map 12.

Land Use

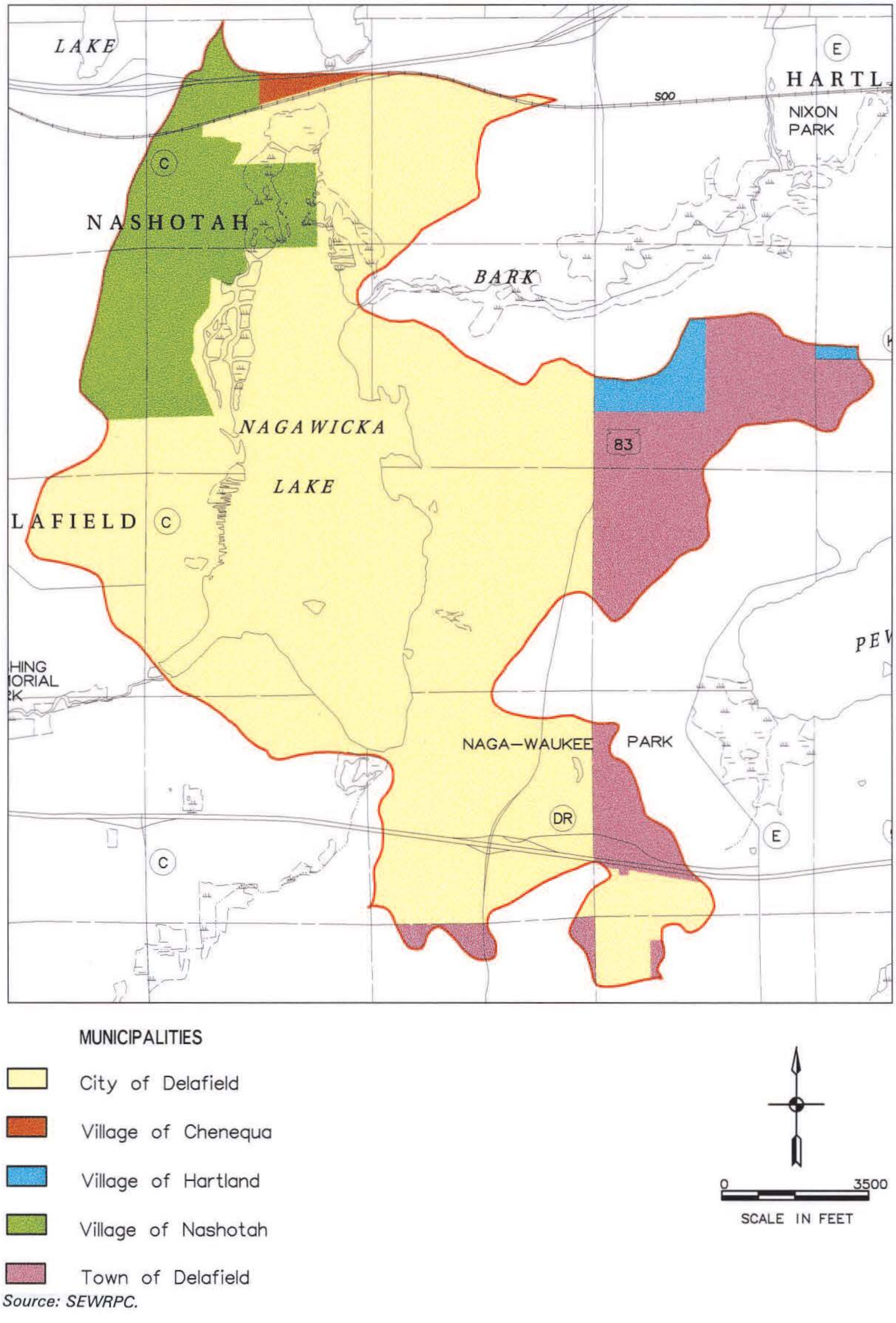
The type, intensity, and spatial distribution of the various land uses within the Nagawicka Lake drainage area are important determinants of lake water quality and hydrology, and recreational use demands. The current and planned future land use patterns, placed in context of the historical development in the area are, therefore, important considerations in any lake management planning effort for Nagawicka Lake.

The movement of European settlers into the Southeastern Wisconsin Region began in earnest about 1830. Completion, within Southeastern Wisconsin, of the U.S. Public Land Survey in 1836, and the subsequent sale of public lands in Wisconsin brought an influx of settlers into the area.

Urban development began to occur in the drainage area directly tributary to Nagawicka Lake shortly after the completion of the U.S. Public Land Survey. Early development occurred largely within the current City of Delafield area. Map 13 and Table 5 indicate the historical urban growth pattern in the drainage area directly tributary to the Lake since 1850. The most rapid increase in urban land use development in the direct tributary

Map 11

CIVIL DIVISIONS WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1990



Source: SEWRPC.

Table 4

AREAL EXTENT OF CIVIL DIVISION BOUNDARIES WITHIN THE DRAINAGE AREA TRIBUTARY TO NAGAWICKA LAKE

Civil Division	Civil Division Area within Study Area (acres)	Percent of Direct Tributary Drainage Area within Civil Division	Percent of Total Tributary Drainage Area within Civil Division
Waukesha County			
Village of Chenequa	21.4	<1	<1
Village of Nashotah	570.9	12	2
Village of Hartland	1,861.7	2	6
City of Delafield	4,659.3	73	16
Town of Delafield	1,795.8	12	6
Village of Merton	1,414.0	- -	5
Town of Lisbon	8,921.5	- -	31
Town of Merton	2,268.3	- -	8
Washington County			
Town of Richfield	7,438.7	- -	25
Total	28,951.6	100	100

Source: SEWRPC.

drainage area occurred between 1963 and 1990, when an average of over 40 acres per year were converted from rural to urban land uses. As shown on Map 14, the urban development of the lands within the total drainage area tributary to Nagawicka Lake occurred largely between 1940 and 1950, and, again, in recent years since 1970.

The existing land use pattern in the drainage area directly tributary to Nagawicka Lake, as of 1990, is shown on Map 15, and is quantified in Table 6. About 1,340 acres, or about 28 percent of the drainage area, were devoted to urban land uses. The dominant urban land use was residential, encompassing 954 acres, or about 70 percent of the area in urban use. As of 1990, about 3,400 acres, or about 72 percent of the Nagawicka Lake direct drainage area, were still devoted to rural land uses. About 1,280 acres, or about 40 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface water, including the surface area of Nagawicka Lake, accounted for approximately 1,730 acres, or about 50 percent of the area in rural uses.

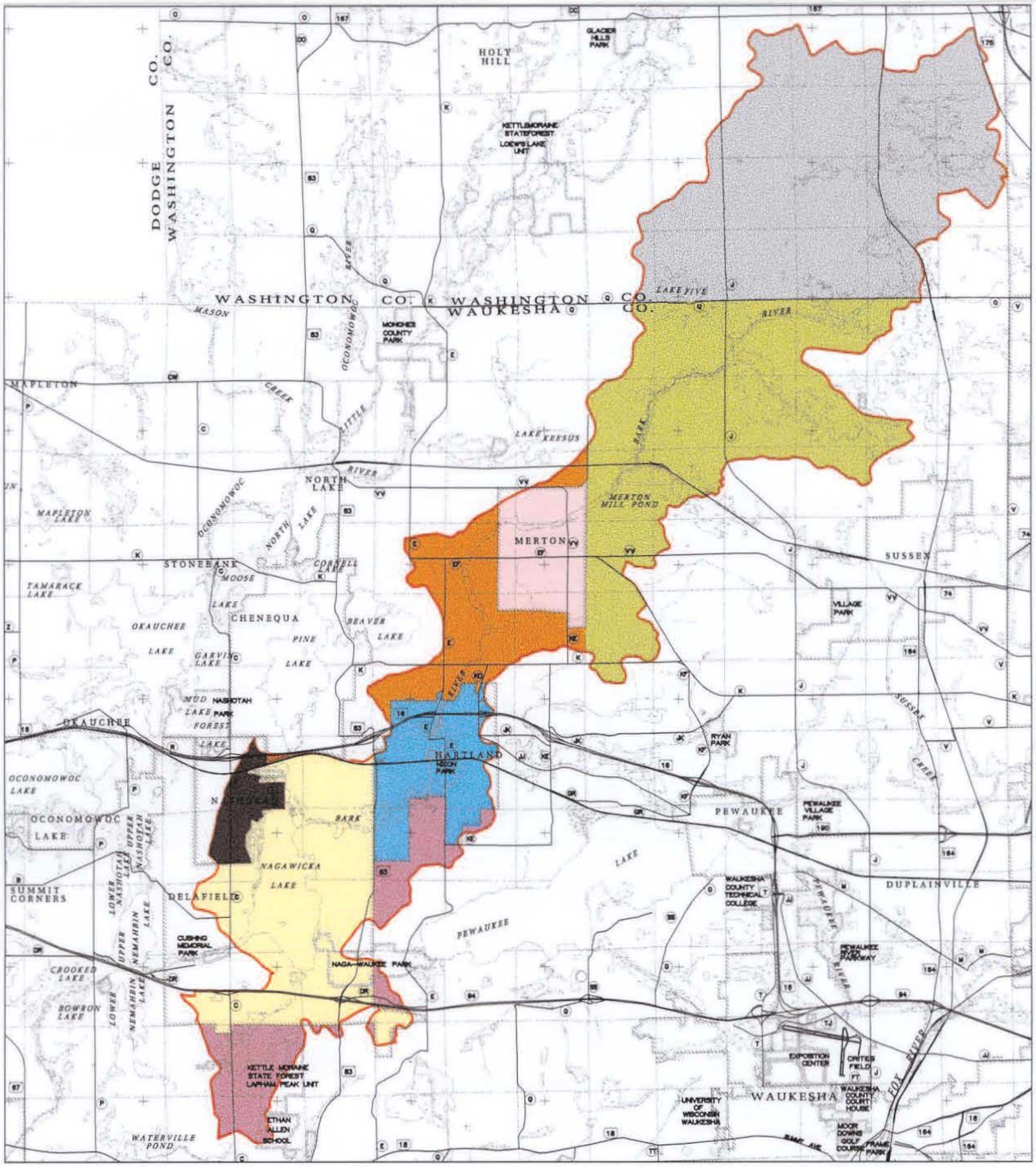
Under buildout conditions, nearly all of the remaining agricultural and open lands, excepting the environmentally sensitive lands within the drainage area directly tributary to Nagawicka Lake, are anticipated to be converted to urban usage, with residential land uses continuing to be the dominant urban land use, as shown on Map 16 and in Table 7.[1]

The existing land use pattern in the total drainage area tributary to Nagawicka Lake, as of 1990, is shown on Map 17, and is quantified in Table 7. As indicated in Table 7, about 6,250 acres, or about 22 percent of the total drainage area, were devoted to urban land uses. The dominant urban land use remained residential, encompassing almost 5,000 acres, or about 80 percent of the area in urban use. As of 1990, about 22,500 acres, or about 78 percent of the Nagawicka Lake drainage area, were still devoted to rural land uses. About 12,800 acres, or about 60 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface water,

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

Map 12

CIVIL DIVISIONS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1990



MUNICIPALITIES

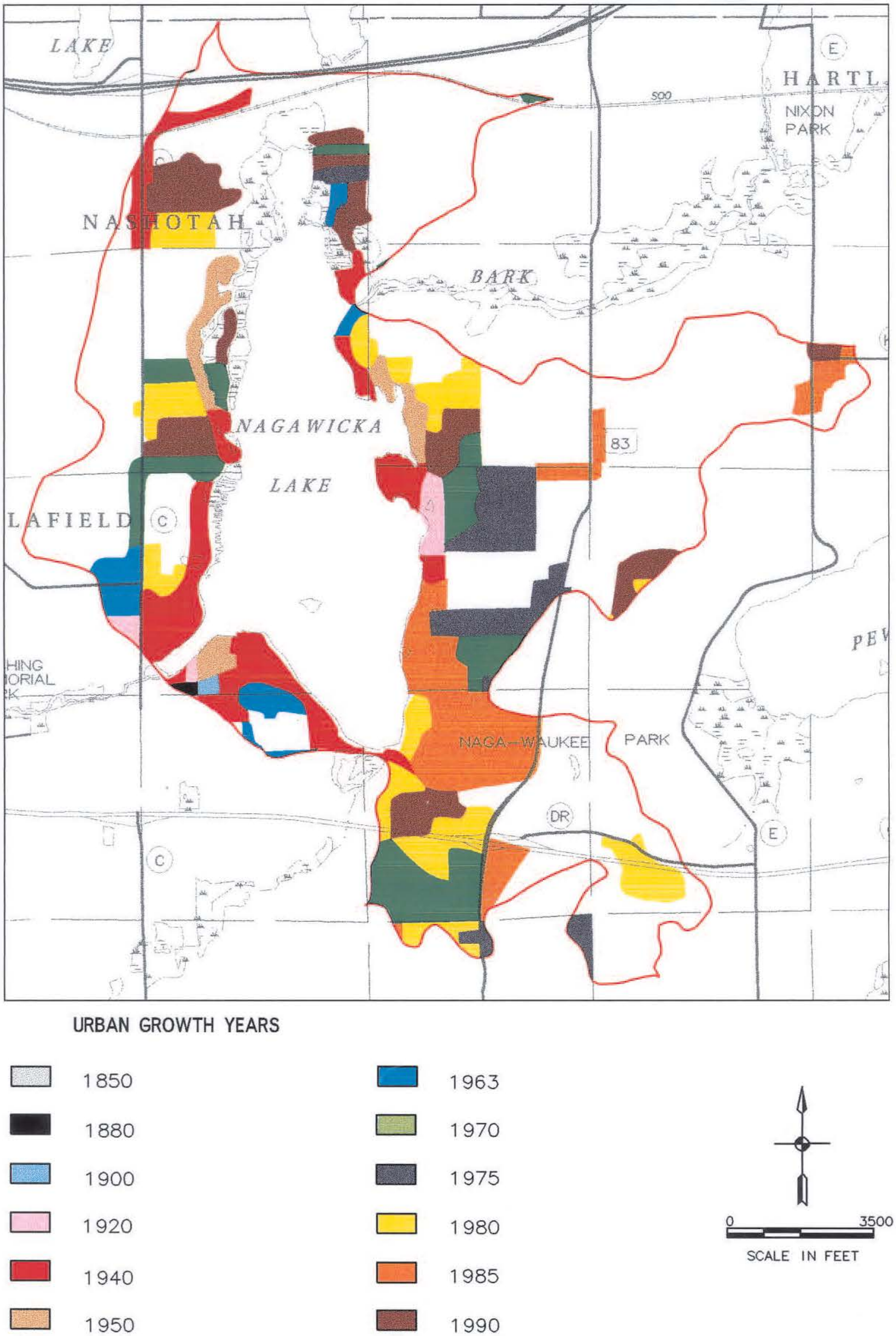
- City of Delafield
- Village of Chenequa
- Village of Hartland
- Village of Merton
- Village of Nashotah
- Town of Richfield
- Town of Delafield
- Town of Lisbon
- Town of Merton

0 1 2
Scale in miles

Source: SEWRPC.

Map 13

HISTORIC URBAN GROWTH WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1850-1990



Source: SEWRPC.

Table 5

EXTENT OF URBAN GROWTH WITHIN THE
DIRECT DRAINAGE AREA TRIBUTARY TO NAGAWICKA LAKE: 1880-1990

Year	Direct Drainage Area		Total Drainage Area	
	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]
1880	3	3	77	77
1900	5	8	35	112
1920	35	43	107	219
1940	262	305	405	624
1950	78	383	189	813
1963	75	458	416	1,229
1970	230	688	925	2,154
1975	158	846	1,074	3,228
1980	276	1,122	1,831	5,059
1985	270	1,392	957	6,016
1990	226	1,618	779	6,795

[a]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered in this analysis.*

Source: U.S. Bureau of the Census and SEWRPC.

including the surface area of Nagawicka Lake, accounted for approximately 7,000 acres, or about 30 percent of the area in rural uses.

Under buildout conditions, the trend toward more intense urban land usage is also expected to be reflected in the total drainage area tributary to the Lake.[2] Again, agricultural lands are likely to be converted to urban lands, primarily for residential use and commercial uses, as shown on Map 18. In addition, the redevelopment of properties and the reconstruction of existing single-family homes may be expected on lakeshore properties.

Recent surveillance indicates that large-lot subdivision development is occurring in the drainage area tributary to Nagawicka Lake. The areas, either under development for urban use or committed to development for such use, since 1990, with densities of one to two dwelling units per acre are shown on Maps 17 and 18. If this trend continues, much of the open space areas remaining in the drainage area will be replaced over time with urban development. This type of urbanization has the potential to significantly increase the pollutant loadings and modify the character of such loadings to the Lake. Associated commercial and industrial developments and increased pressures for the recreational use of the Lake also may be anticipated. Under the full buildout condition envisioned under the Waukesha County development plan[3] completed in 1996, most of the undeveloped lands

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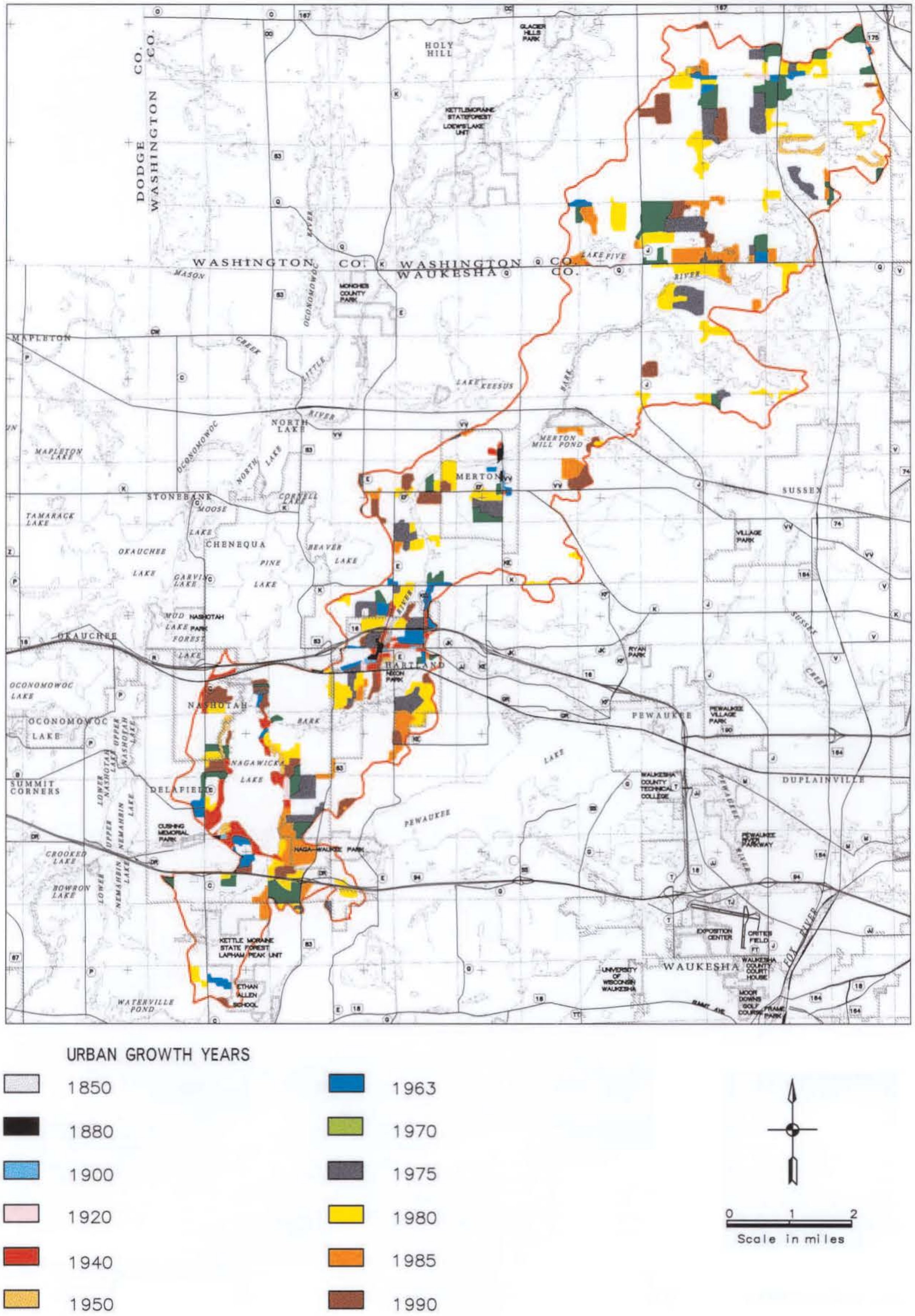
[2]*SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997.*

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

Map 14

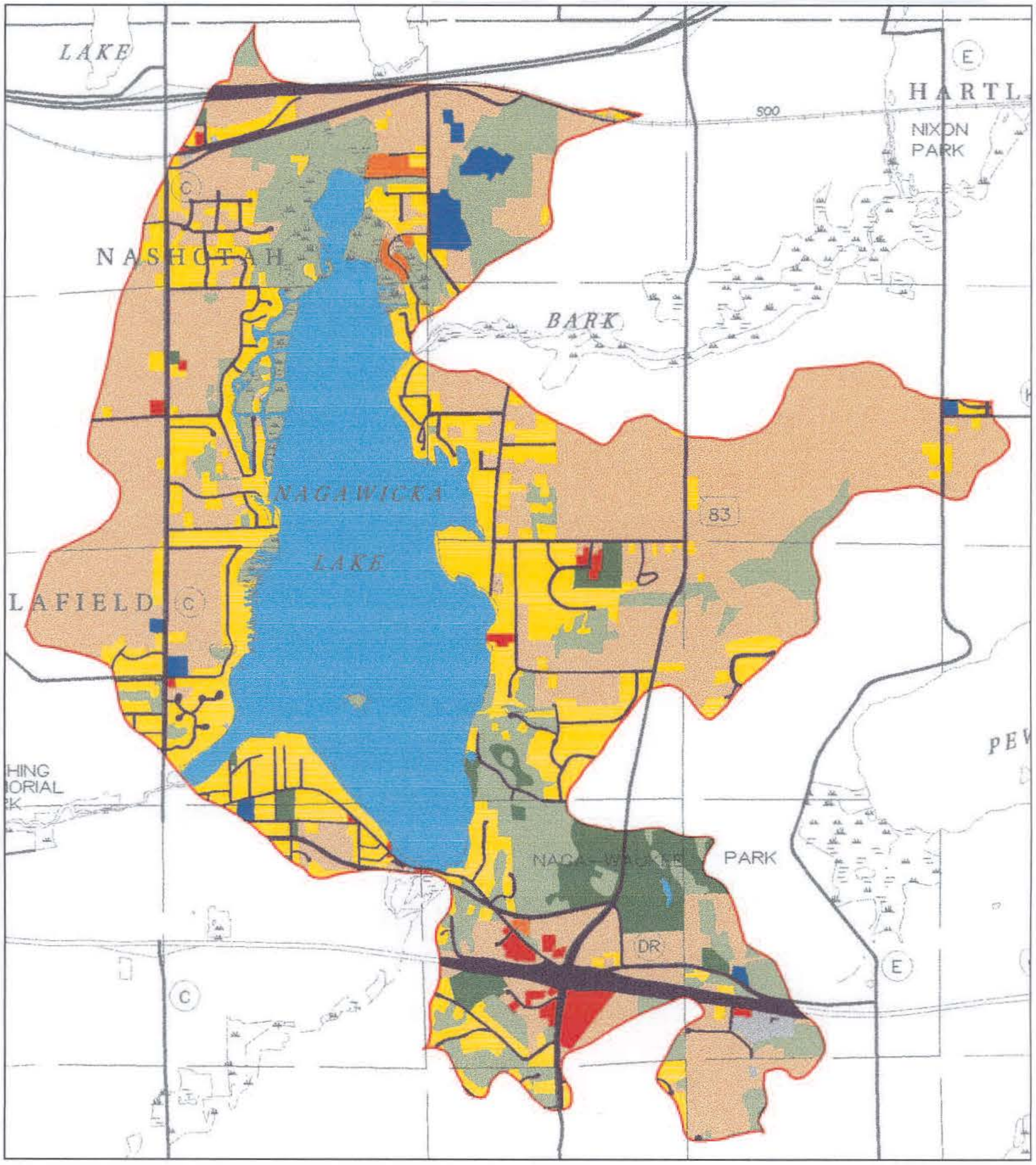
HISTORIC URBAN GROWTH WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1850-1990



Source: SEWRPC.

Map 15

GENERALIZED LAND USE WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1990



LAND USE CATEGORIES

- Single-family residential
- Multi-family residential
- Commercial
- Industrial
- Transportation, communications, and utilities
- Government and institutional
- Recreation
- Surface water
- Wetlands and woodlands
- Agricultural, unused, and other open lands
- Extractive and landfill

0 3500
SCALE IN FEET

Source: SEWRPC.

Table 6

EXISTING LAND USE WITHIN THE DIRECT DRAINAGE AREA TRIBUTARY TO NAGAWICKA LAKE

Land Use Categories	1990		Buildout	
	Acres	Percent of Direct Drainage Area	Acres	Percent of Direct Drainage Area
Urban				
Residential	954	20.0	2,263	47.5
Commercial	61	1.3	440	9.2
Industrial	18	0.4	31	0.7
Governmental	51	1.1	51	1.1
Transportation, Communication, and Utilities	97	2.0	97	2.0
Recreation	158	3.3	158	3.3
Subtotal	1,339	28.1	3,040	63.8
Rural				
Agricultural	1,277	26.8	- -	- -
Wetlands	146	3.1	146	3.1
Woodlands	536	11.3	503	10.6
Water	1,044	21.9	1,044	21.9
Landfill	- -	- -	- -	- -
Other Open Land	421	8.8	30	0.6
Subtotal	3,424	71.9	1,723	36.2
Total	4,763	100.0	4,763	100.0

Source: SEWRPC.

outside the environmental corridors and other environmentally sensitive areas, could potentially be developed for urban uses. If this development occurs in the form of residential clusters on smaller lots, portions of the remaining open space can be preserved and, thus, reduce the potential impacts on the Lake.[4]

Two areas of urban growth currently have caused specific concern among the Nagawicka Lake community. These include the ongoing commercial development along STH 83 at its intersections with IH 94 and STH 16. These development areas have a high potential to generate increased quantities of surface runoff and associated nonpoint source pollutant loadings. The latter site, the Village of Hartland Industrial Park, occupies a site adjacent to an extensive wetland area on the Bark River at the debouchment of the Bark River into Nagawicka Lake. Concerns expressed by the Nagawicka Lake community relate to the discharge of stormwater from the industrial site to the wetland complex on the Bark River without the benefit of stormwater management planning or facilities designed to address water quality issues. In this regard, the Village of Hartland has recently adopted a stormwater ordinance applicable to the lands within the Village that is identical to that adopted by the City of Delafield and applicable to the lands within the City.

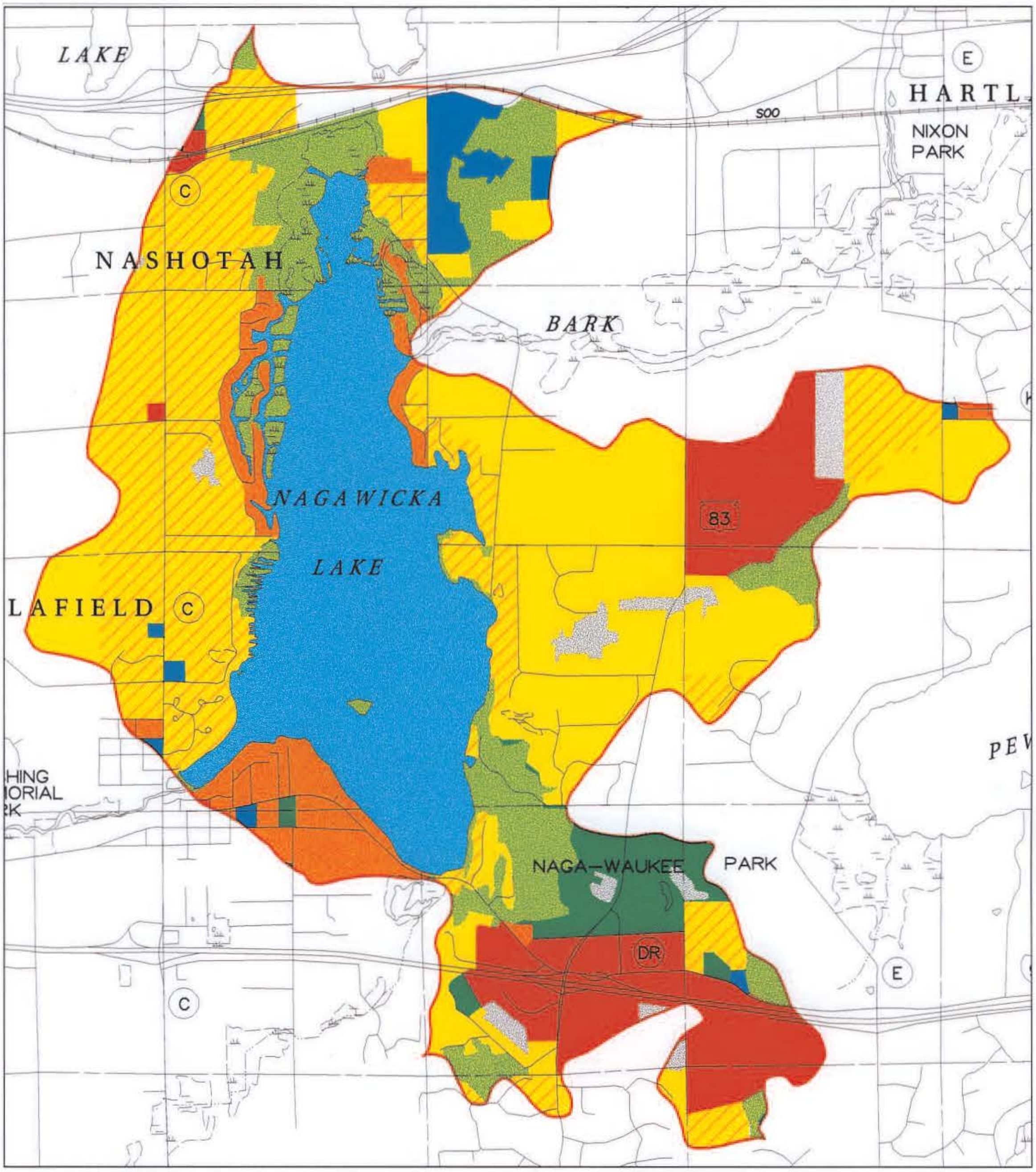
LAND USE REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. Local zoning regulations

[4]*SEWRPC Planning Guide No. 7,* Rural Cluster Development Guide, *December 1996.*

Map 16

RECOMMENDED LAND USE PLAN FOR WAUKESHA COUNTY WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE



RECOMMENDED LAND USES

- Medium density residential (6,000–19,999 square feet of lot area per dwelling unit)
- Low density residential (20,000 square feet to 1.49 acres of lot area per dwelling unit)
- Suburban I density residential (1.5 to 2.9 acres of lot area per dwelling unit)
- Rural density residential and other agricultural lands
- Commercial
- Industrial
- Government and Institutional
- Recreational
- Primary environmental corridor
- Isolated natural resource area
- Surface water

0 3500
SCALE IN FEET

Source: SEWRPC

Table 7

EXISTING LAND USE WITHIN THE TOTAL DRAINAGE AREA TRIBUTARY TO NAGAWICKA LAKE

Land Use Categories	1990		Buildout	
	Acres	Percent of Total Tributary Drainage Area	Acres	Percent of Total Tributary Drainage Area
Urban				
Residential	4,971	17.2	8,890	30.7
Commercial	199	0.7	669	2.3
Industrial	117	0.4	285	1.0
Governmental	347	1.2	372	1.3
Transportation, Communication, and Utilities	344	1.2	344	1.2
Recreation	276	0.9	395	1.3
Subtotal	6,254	21.6	10,955	37.8
Rural				
Agricultural	12,810	44.2	9,144	31.6
Wetlands	2,774	9.6	2,774	9.6
Woodlands	2,998	10.4	2,900	10.0
Water	1,364	4.7	1,364	4.7
Extractive	701	2.4	1,361	4.7
Other Open Land	2,051	7.1	454	1.6
Subtotal	22,698	78.4	17,997	62.2
Total	28,952	100.0	28,952	100.0

Source: SEWRPC.

include general, or comprehensive, zoning regulations and special-purpose regulations governing floodland and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land use must take into consideration the provisions of both general and special-purpose zoning. As already noted, the drainage area tributary to Nagawicka Lake includes portions of the City of Delafield, the Villages of Chenequa, Hartland, Merton, and Nashotah, and the Towns of Delafield, Lisbon, and Merton in Waukesha County, and the Town of Richfield in Washington County. The ordinances administered by these units of government are summarized in Table 8.

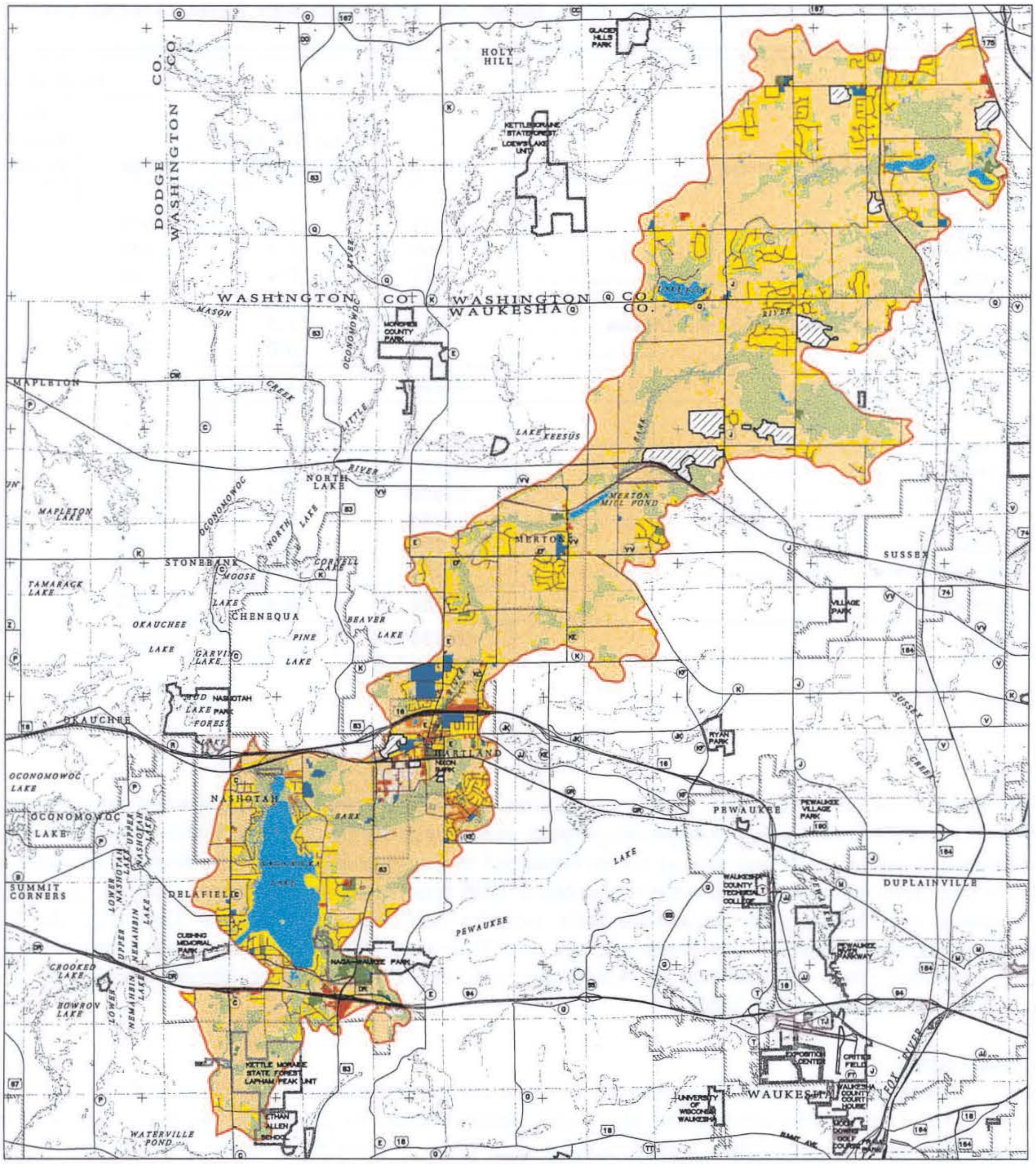
General Zoning

Cities in Wisconsin are granted comprehensive, or general, zoning powers under Section 62.23 of the *Wisconsin Statutes*. The same powers are granted to villages under Section 61.35 of the *Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.97 of the *Statutes*. However, a county zoning ordinance becomes effective only in those towns which ratify the county ordinance. Towns which have not adopted a county zoning ordinance may adopt village powers and subsequently utilize the city and village zoning authority conferred in Section 62.23 subject, however, to county board approval where a general-purpose county zoning ordinance exists. Alternatively, a town may adopt a zoning ordinance under Section 60.61 of the *Statutes* where a general-purpose county zoning ordinance has not been adopted, but only after the county board fails to adopt a county ordinance at the petition of the governing body of the town concerned.

General zoning is in effect in all communities in Waukesha County. All three towns in Waukesha County within the total drainage area tributary to Nagawicka Lake had adopted their own zoning ordinances under village powers. The Town of Richfield in Washington County, likewise, has adopted its own zoning ordinances under village powers.

Map 17

GENERALIZED LAND USE WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1990



LAND USE CATEGORIES

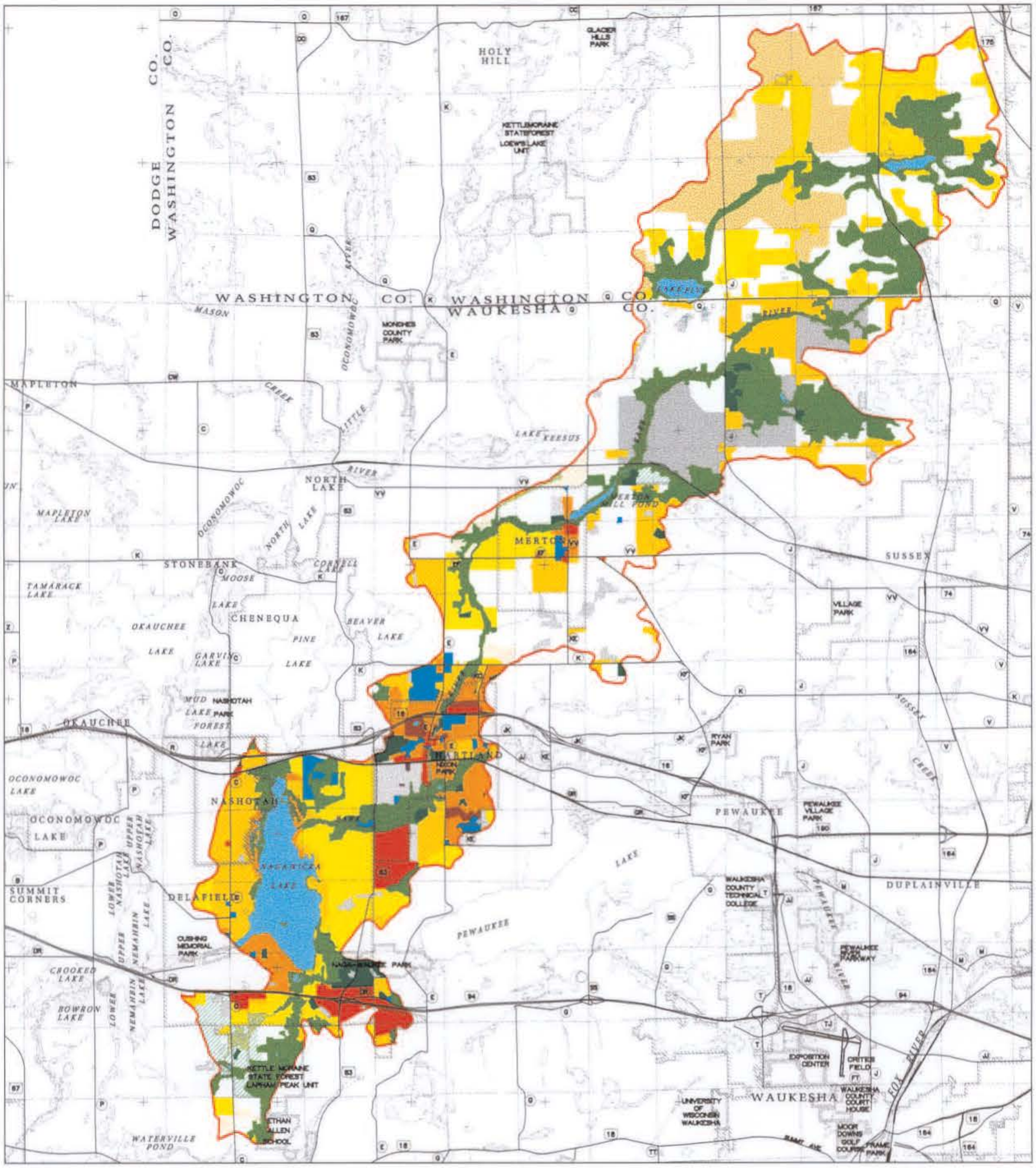
- Single–family residential
- Multi–family residential
- Commercial
- Industrial
- Transportation, communications, and utilities
- Government and institutional
- Recreation
- Surface water
- Wetlands and woodlands
- Agricultural, unused, and other open lands
- Extractive and landfill

Scale in miles: 0 1 2

Source: SEWRPC.

Map 18

RECOMMENDED LAND USE PLAN FOR WAUKESHA COUNTY WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE



RECOMMENDED LAND USES

- 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 1.49 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
- Government 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 land
- Surface water

0 1 2
Scale in miles

Source: SEWRPC.

Table 8

LAND USE REGULATIONS WITHIN THE DRAINAGE AREA TRIBUTARY TO NAGAWICKA LAKE IN WAUKESHA AND WASHINGTON COUNTIES BY CIVIL DIVISION: 1998

Community	Type of Ordinance				
	General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Waukesha County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
City of Delafield	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Chenequa	Adopted	None[a]	Adopted	None	Adopted[b]
Village of Hartland	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Merton	Adopted	Adopted	Adopted	Adopted	None
Village of Nashotah	Adopted	None[a]	Adopted and Wisconsin Department of Natural Resources approved	Adopted	Adopted
Town of Delafield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Lisbon	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Merton	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Washington County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
Town of Richfield	Adopted	County ordinance	County ordinance	Adopted	County ordinance

[a]*No flood hazard areas have been identified or mapped.*

[b]*Erosion control ordinance only.*

Source: SEWRPC.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that cities, villages, and counties, with respect to their unincorporated areas, adopt floodland zoning to preserve the floodwater conveyance and storage capacity of floodplain areas and to prevent the location of new flood damage-prone development in flood hazard areas. The minimum standards which such ordinances must meet are set forth in Chapter NR 116 of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area subject to inundation by the 100-year recurrence interval flood event, the event which has a 1 percent probability of occurring in any given year. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 100-year recurrence peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the 100-year recurrence flood. Permitting the filling and development of the flood fringe area, however, reduces the floodwater storage capacity of the natural floodplain, and may thereby increase downstream flood flows and stages. It should be noted that towns may enact floodland zoning regulations which may be more restrictive than those in the County Shoreland and Floodland Protection Zoning Ordinance. However, all of the towns within the drainage area tributary to Nagawicka Lake currently are regulated only by the county ordinance for floodplain zoning.

Floodland ordinances are in effect within all parts of the total drainage area tributary to Nagawicka Lake, except the Villages of Chenequa and Nashotah, which have no identified flood hazard areas identified and mapped within their boundaries.

Shoreland Zoning
Under Section 59.971 of the *Wisconsin Statutes*, counties in Wisconsin are required to adopt zoning regulations within statutorily defined shoreland areas, those lands within 1,000 feet of a navigable lake, pond, or flowage, or 300 feet of a navigable stream, or to the landward side of the floodplain, whichever distance is greater, within their unincorporated areas. Minimum standards for county shoreland zoning ordinances are set forth in Chapter NR 115 of the *Wisconsin Administrative Code*. Chapter NR 115 sets forth minimum requirements regarding lot sizes and building setbacks; restrictions on cutting of trees and shrubbery; and restrictions on filling, grading, lagooning, dredging, ditching, and excavating that must be incorporated into county shoreland zoning regulations. In addition, Chapter NR 115 requires that counties place all wetlands five acres or larger and within the statutory shoreland zoning jurisdiction area into a wetland conservancy zoning district to ensure their preservation after completion of appropriate wetland inventories by the Wisconsin Department of Natural Resources.

In 1982, the State Legislature extended shoreland-wetland zoning requirements to cities and villages in Wisconsin. Under Sections 62.231 and 61.351, respectively, of the *Wisconsin Statutes*, cities and villages in Wisconsin are required to place wetlands five acres or larger and located in statutory shorelands into a shoreland-wetland conservancy zoning district to ensure their preservation. Minimum standards for city and village shoreland-wetland zoning ordinances are set forth in Chapter NR 117 of the *Wisconsin Administrative Code*.

It should be noted that the basis for identification of wetlands to be protected under Chapters NR 115 and NR 117 is the Wisconsin Wetlands Inventory. Mandated by the State Legislature in 1978, the Wisconsin Wetlands Inventory resulted in the preparation of wetland maps covering each U.S. Public Land Survey township in the State. The inventory was completed for counties in Southeastern Wisconsin in 1982, the wetlands being delineated by the Regional Planning Commission on its 1980, one inch equals 2,000 feet scale, ratioed and rectified aerial photographs as discussed in Chapter V.

County shoreland zoning ordinances are in effect in all unincorporated areas of Waukesha and Washington Counties. All of the incorporated municipalities within the total drainage area tributary to Nagawicka Lake have adopted shoreland-wetland zoning ordinances. The County shoreland ordinances and the local shoreland-wetland zoning ordinance of the Village of Nashotah have been approved by the Wisconsin Department of Natural Resources.

Subdivision Regulations
Chapter 236 of the *Wisconsin Statutes* requires the preparation of a subdivision plat whenever five or more lots of 1.5 acres or less in area are created either at one time or by successive divisions within a period of five years. The *Statutes* set forth requirements for surveying lots and streets, for plat review and approval by State and local agencies, and for recording approved plats. Section 236.45 of the *Statutes* allows any city, village, town, or county that has established a planning agency to adopt a land division ordinance, provided the local ordinance is at least as restrictive as the State platting requirements. Local land division ordinances may include the review of other land divisions not defined as "subdivisions" under Chapter 236, such as when fewer than five lots are created or when lots larger than 1.5 acres are created.

The subdivision regulatory powers of towns and counties are confined to unincorporated areas. City and village subdivision control ordinances may be applied to extraterritorial areas, as well as to the incorporated areas.[5] It is possible for both a county and a town to have concurrent jurisdiction over land divisions in unincorporated areas, or for a city or village to have concurrent jurisdiction with a town or county in the city or village extraterritorial plat approval area. In the case of overlapping jurisdiction, the most restrictive requirements apply. Each of the

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[5]*Under Section 236.02 of the* Wisconsin Statutes, *the extraterritorial plat approval jurisdiction is the area within three miles of the corporate limits of a first-, second-, or third-class city and within 1.5 miles of a fourth-class city or a village.*

incorporated communities within the tributary drainage area to Nagawicka Lake, except the Village of Chenequa, has adopted its own subdivision ordinance. The subdivision control ordinances adopted and administered by Waukesha and Washington Counties apply only to the unincorporated statutory shoreland areas of the Counties.

Construction Site Erosion Control and Stormwater Management Regulations

Section 62.23 of the *Wisconsin Statutes* grants authority to cities and villages in Wisconsin to adopt ordinances for the prevention of erosion from construction sites and the management of stormwater runoff from lands within their jurisdictions. Towns may adopt village powers and subsequently utilize the authority conferred on cities and villages under Section 62.23 to adopt their own erosion control and stormwater management ordinances, subject, however, to county board approval where a county ordinance exists.

Construction site erosion control and stormwater management ordinances were in effect in all communities within the tributary drainage area to Nagawicka Lake in 1998. The City of Delafield and the Villages of Hartland, Merton, and Nashotah had adopted both construction site erosion control regulations and stormwater management regulations, while the Village of Chenequa had adopted only construction site erosion control regulations. The Towns of Delafield, Lisbon, and Merton in Waukesha County, and the Town of Richfield in Washington County, likewise, have adopted construction site erosion control and stormwater management ordinances by reference to the County ordinances. With the exception of the Village of Chenequa ordinance, which addresses only construction site erosion control, the local construction site erosion control and stormwater management ordinances of the incorporated municipalities mirror the requirements of the prevailing county ordinances. The City of Delafield and the Village of Hartland have adopted similar ordinance language in an effort to better protect the water resources shared by these neighboring communities. These ordinances differ from that of the County only in that they are applicable to sites of 4,000 square feet or more in areal extent, rather than sites of 3,000 square feet or more.

Both Washington and Waukesha Counties have adopted construction erosion control and stormwater management ordinances. These ordinances apply to the unincorporated towns within each county. The Waukesha County construction site erosion control ordinance applies to all lands requiring a subdivision plat or certified survey, to sites upon which construction activities will disturb 3,000 square feet or more and/or 400 cubic yards or more of material, and to sites where pipeline placement operations disturb 300 linear feet or more of land surface. The Washington County construction site erosion control ordinance applies to lands upon which construction activities will disturb 4,000 square feet or more, and/or 400 cubic yards or more of material, and/or to sites where pipeline placement operations disturb 100 linear feet or more of land surface, and/or other lands where there is a high risk of soil erosion. These ordinances require persons engaging in land disturbing activities to employ soil erosion control practices on affected sites that are consistent with those set forth in the *Wisconsin Construction Site Best Management Practice Handbook*[6] or equivalent practices. In general, these practices are designed to minimize soil lost from disturbed sites through prior planning and phasing of land disturbing activities and use of appropriate onsite erosion control measures.

The Waukesha County stormwater management ordinance applies to residential lands of five acres or more in areal extent, residential lands of between three and five acres in areal extent where there is at least 1.5 acres of impervious surface, nonresidential lands of 1.5 acres in areal extent where there is at least 0.5 acre of impervious surface, or other lands on which development activities may result in stormwater runoff likely to harm public property or safety. Lands within an area covered by an approved stormwater management plan are specifically exempted from the Waukesha County ordinance. The Washington County stormwater management ordinance applies to lands where an existing tax parcel is divided into five parcels of five acres or less in areal extent within

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[6]*Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook*, latest revision November 1993.*

a common plan of development, sites where new public or private roads are being constructed, sites that add a total of 20,000 square feet or more of impervious surface within a common plan of development, and other sites that may result in stormwater runoff likely to harm public property, public safety, or environmentally sensitive areas. One- and two-family residences, falling under the provisions of Section Comm 21.125 of the *Wisconsin Administrative Code*, are specifically exempted from the provisions of the Washington County ordinance, but are required to meet the provisions of the Wisconsin Uniform Dwelling Code. The stormwater ordinances establish performance standards to manage both rate and volume of stormwater flows from regulated sites and water quality. Performance standards adopted in these ordinances and the resultant design of appropriate management practices are based on calculation procedures and principles set forth in *Urban Hydrology for Small Watersheds*.[7]

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[7]*U.S. Department of Agriculture Technical Release 55,* Urban Hydrology of Small Watersheds, *June 1986 (Washington County), or June 1992 (Waukesha County).*

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Chapter IV

WATER QUALITY

INTRODUCTION

The earliest, definitive data on water quality conditions in Nagawicka Lake were collected by the Wisconsin Department of Natural Resources in the 1970s. Data collected during that monitoring effort indicated water quality problems in Nagawicka Lake, with evidence of nutrient enrichment being recorded. Over time, the residents of the Nagawicka Lake community have continued to express concerns about water quality conditions in the Lake, and, in 1990, the Nagawicka Lake Welfare Committee of the City of Delafield initiated the development of a lake management plan to address these, and other, citizen concerns regarding the state of the Lake.

The Wisconsin Department of Natural Resources (WDNR) has included Nagawicka Lake in their Long-Term Trends Monitoring Program, and has conducted an intensive water quality monitoring program on Nagawicka Lake from 1986 through 1998. This study involved the determination of physical and chemical characteristics of the lake's water, including dissolved oxygen and water temperature profiles, pH, specific conductance, water clarity, and nutrient and chlorophyll-a concentrations. Additional data are currently continuing to be collected. The data obtained under this program, from April 1986 through July 1998, and under earlier investigations, have been used in the development of this lake and watershed inventory.

EXISTING WATER QUALITY CONDITIONS

The data collected during the period 1972 through 1997 were used to determine water quality conditions in the Lake and to characterize the suitability of the Lake for recreational use and the support of fish and aquatic life. Water quality samples were taken seasonally from the main basin of the Lake. The primary sampling station was located at the deepest point in the Lake, as shown on Map 1 in Chapter II. The findings are summarized in Table 9 and Figure 2. More detailed information on these water quality data, including locations and procedures, may be found in reports published by the WDNR.[1]

Thermal Stratification

Thermal and dissolved oxygen profiles for Nagawicka Lake are shown in Figure 3. Water temperatures ranged from approximately 32°F during the winter to approximately 80°F during the summer. The Lake was dimictic, which means that it mixes completely two times per year and is subject to thermal stratification during summer and winter.

Thermal stratification is the result of differential heating of lake water and the resulting water temperature-density relationships that develop at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit of volume, at about 39°F. The development of summer thermal stratification begins in early summer, reaches its maximum in late summer, and disappears in the fall. Stratification may also occur in winter under ice cover.

As summer begins, a lake absorbs solar energy at the surface. Wind action and, to some extent, internal heat transfer mechanisms transmit this energy to the underlying portions of the waterbody. As the upper layer of water is heated by solar energy, a physical barrier begins to form between the warmer surface water and the colder,

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[1]*See, for example, Wisconsin Department of Natural Resources,* Nagawicka Lake, Waukesha County Long Term Trend Lake, 1986*; and Wisconsin Department of Natural Resources,* Nagawicka Lake, Waukesha County Long Term Trend Lake, 1987.

Table 9

SEASONAL WATER QUALITY DATA FOR NAGAWICKA LAKE: 1972-1997

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	32.0-37.8 (12)	33.6-41.0 (22)	34.9-74.1 (16)	34.9-55.8 (20)	59.5-81.5 (31)	37.0-69.8 (63)
Mean	33.8	36.5	47.8	43.2	72.7	50.5
Dissolved Oxygen (mg/l)						
Range	11.8-16.5 (11)	0.3-12.7 (21)	7.5-14.4 (16)	1.7-13.6 (20)	6.2-11.6 (31)	0-10.6 (63)
Mean	13.1	7.3	11.6	10.1	8.7	2.9
Specific Conductivity (μS/cm at 25°C)						
Range	316-588 (7)	355-637 (13)	412-678 (15)	410-682 (18)	392-644 (27)	477-712 (55)
Mean	407	470	552	545	564	602
Alkalinity (mg/l)						
Range	224-244 (2)	244-288 (4)	234-262 (12)	236-262 (11)	212-287 (3)	205-254 (5)
Mean	234	261	249	250	242	232
Hardness, as $CaCO_3$ (mg/l)						
Range	365-411 (2)	252-473 (4)	260-320 (11)	250-509 (14)	261-361 (2)	202-440 (4)
Mean	388	353	298	331	311	322
pH (standard units)						
Range	7.2-8.3 (12)	6.9-8.3 (22)	7.6-8.5 (16)	7.7-8.4 (20)	7.0-8.7 (30)	7.1-8.3 (62)
Mean	8.0	7.8	8.2	8.1	8.1	7.8
Secchi-Disk (feet)						
Range	1.6-35.1 (11)	- -	8.2-18 (12)	- -	4.9-19.7 (29)	- -
Mean	19.0		13.1		10.5	
Turbidity (Nephelometric turbidity units)						
Range	1.1-1.8 (2)	0.9-1.3(4)	0.7-2.8 (12)	0.8-6.1 (11)	0.6-6.9 (5)	1.5-8.1 (5)
Mean	1.5	1.2	1.2	2.2	1.6	1.8
Nitrate Nitrogen (mg/l)						
Range	0.05-0.06 (2)	0.11-1.06 (4)	0.06-1.30 (14)	0.7-1.3 (16)	0.02-1.24 (4)	0.09-1.62 (5)
Mean	0.05	0.68	1.00	1.00	0.61	0.68
Ammonia Nitrogen (mg/l)						
Range	0.31-0.36 (2)	0.26-1.30 (4)	0.14-0.19 (14)	0.02-0.26 (16)	0.00-0.19 (4)	0.00-1.21 (5)
Mean	0.34	0.63	0.09	0.12	0.08	0.56
Total Nitrogen, as N (mg/l)						
Range	1.36-1.47 (2)	0.69-2.82 (4)	0.50-2.09 (12)	0.50-2.10 (14)	0.98-1.93 (4)	0.58-2.31 (5)
Mean	1.42	1.74	0.82	0.93	1.54	1.83
Total Phosphorus, as P (mg/l)						
Range	0.01-0.12 (12)	0.01-0.58 (23)	0.004-0.11 (15)	0.01-0.12(20)	0.01-0.22 (35)	0.01-0.34 (69)
Mean	0.03	0.07	0.02	0.03	0.02	0.06
Orthophosphorus, as PO_4P (mg/l)						
Range	.004-.092 (3)	0.003-0.410 (6)	0.002-0.091 (13)	0.002-0.092 (15)	0.013-0.191 (3)	0.006-0.317 (7)
Mean	0.006	.130	0.020	0.020	0.070	0.120
Calcium, as Ca (mg/l)						
Range	57-74 (2)	48-87 (4)	54-116 (13)	54-118 (15)	70-76 (2)	43-109 (4)
Mean	66	65	65	68	73	78
Magnesium, as Mg (mg/l)						
Range	54-55 (2)	32-62 (4)	29-40 (12)	29-52 (15)	21-42 (2)	19-41 (4)
Mean	55	47	36	39	32	31
Sodium, as Na (mg/l)						
Range	13-14 (2)	10-16 (4)	9-25 (12)	10-25 (15)	3-8 (2)	1-9 (4)
Mean	13	13	19	19	5	4
Potassium, as K (mg/l)						
Range	4.2-4.9 (2)	3.6-5.4 (4)	0.8-2.5 (13)	1.1-2.9 (14)	1.2-2.5 (2)	0.7-2.9 (4)
Mean	4.6	4.9	2.1	2.3	1.9	1.8
Chloride, sd Cl (mg/l)						
Range	19-25 (2)	23-26 (4)	24-55 (3)	23-56 (4)	22-23 (2)	19-24 (4)
Mean	22	25	34	31	23	22

Table 9 (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
Sulfate, as SO_4 (mg/l)						
Range	28-36 (2)	32-37 (4)	25-36 (13)	25-35 (14)	27-39 (2)	25-38 (4)
Mean	32	35	31	30	33	32
Chlorophyll-a						
Range	0.5-11.0 (8)	- -	2.0-14.0 (14)	- -	0.4-9.0 (35)	16.8 (1)
Mean	3.2		6.9		4.8	16.8
Iron, as Fe (μg/l)						
Range	- -	- -	0.02-0.1 (9)	0.01-0.1 (9)	- -	- -
Mean			0.05	0.05		

NOTE: Number in parentheses represents number of samples.

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

Source: Wisconsin Department of Natural Resources and SEWRPC.

heavier bottom water, as shown in Figure 4. This "barrier" is marked by a sharp temperature gradient known as the thermocline and is characterized by a 1°C drop in temperature per three feet of depth that separates the warmer, lighter, upper layer of water (called the epilimnion) from the cooler, heavier, lower layer (called the hypolimnion). Although this barrier is readily crossed by fish, provided sufficient oxygen exists, it essentially prohibits the exchange of water between the two layers. This condition, which is discussed further in this report, has a major impact on both the chemical and biological activity in a lake.

The autumnal mixing period occurs when air temperatures cool the surface water and wind action results in the erosion of the thermocline: as the surface water cools, it becomes heavier, sinking and displacing the now relatively warmer water below. The colder water sinks and mixes under wind action until the entire column of water is of uniform temperature, as shown in Figure 4. This action, which follows summer stratification, is known as "fall turnover."

When the water temperature drops to the point of maximum water density, 39.2°F, the waters at the lake surface become more dense than the now warmer, less dense bottom waters, and "sink" to the bottom. Eventually, the water column is cooled to the point where the surface waters, cooled to about 32°F, are now lighter than the bottom waters which remain at about 39°F. The lake surface may then become ice covered, isolating the lake water from the atmosphere for a period of up to four months. On Nagawicka Lake, ice cover typically exists from December until early April. As shown in Figure 4, winter stratification occurred as the colder, lighter water and ice remained at the surface, separated from the relatively warmer, heavier water near the bottom of the lake.

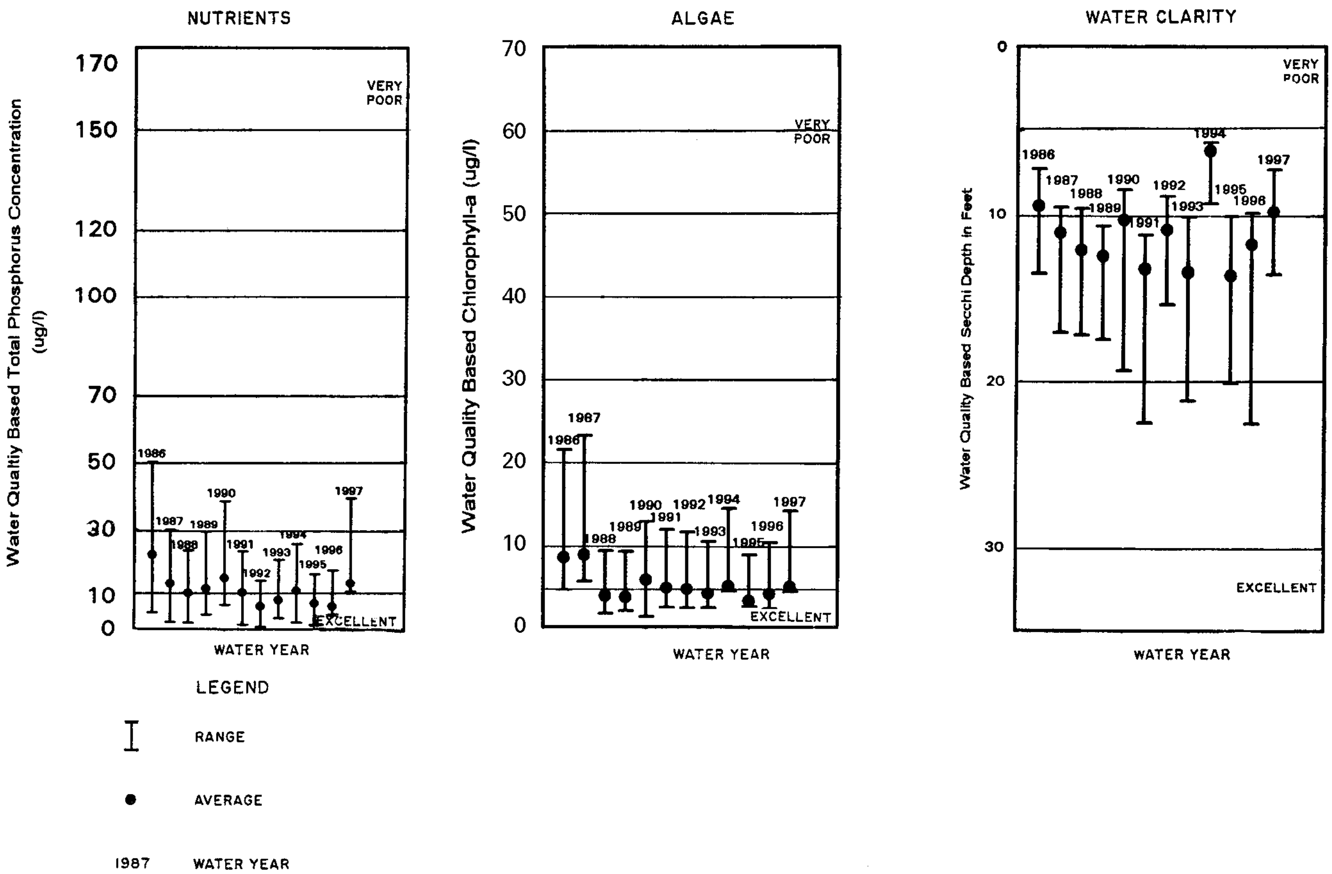
Spring brings a reversal of the process. As the ice thaws and the upper layer of water warms, it becomes more dense and begins to approach the temperature of the warmer, deeper water until the entire water column reaches the same temperature from surface to bottom. This is referred to as "spring turnover" and usually occurs within weeks after the ice goes out, as shown in Figure 4. After spring turnover, the water at the surface again warms and becomes lighter, causing it to float above the colder, deeper water. Wind and resulting waves carry some of the energy of the warmer, lighter water to lower depths, but only to a limited extent. Thus begins the formation of the thermocline and another /period of summer thermal stratification. The entire process is illustrated diagrammatically in Figure 4.

Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake ecosystem. As shown in Figure 3, dissolved oxygen levels were generally higher at the surface of Nagawicka Lake, where there was an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant

Figure 2

NAGAWICKA LAKE PRIMARY WATER QUALITY INDICATORS: 1986-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

photosynthesis. Dissolved oxygen levels were lowest on the bottom of the lake, where decomposer organisms and chemical oxidation processes utilized oxygen in the decay process.

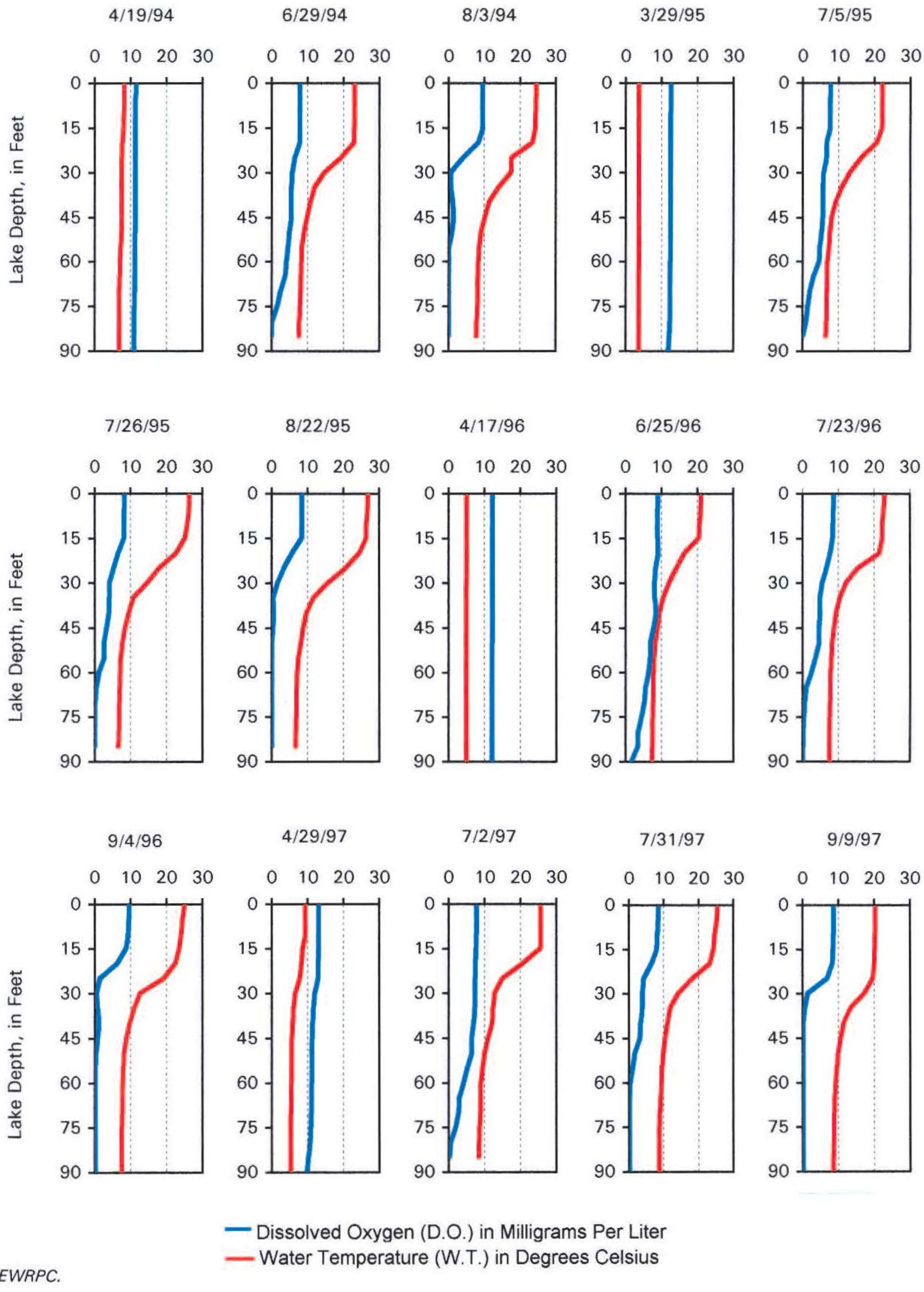
When any lake becomes thermally stratified, as described above, the surface supply of dissolved oxygen to the hypolimnion is cut off. Gradually, if there is not enough dissolved oxygen to meet the total demands from the bottom dwelling aquatic life and decaying organic material, the dissolved oxygen levels in the bottom waters may be reduced, even to zero, a condition known as anoxia or anaerobiasis, as shown in Figure 5.

The hypolimnion of Nagawicka Lake becomes anoxic during summer stratification. Dissolved oxygen concentrations at the bottom of the Lake fall to zero by mid- to late-June, as shown in Figure 3. Even at a depth of approximately 30 feet, oxygen concentrations were at or below the recommended concentration of five milligrams per liter (mg/l), the minimum level necessary to support many species of fish during most years studied.

Fall turnover, between September and October in most years, naturally restores the supply of oxygen to the bottom water, although hypolimnetic anoxia can be reestablished during the period of winter thermal stratification. Winter anoxia is more common during the years of heavy snowfall, when snow covers the ice, reducing the degree of light penetration and reducing algal photosynthesis that takes place under the ice. In some lakes in the Region, hypolimnetic anoxia can also occur during winter stratification. Under these condition,

Figure 3

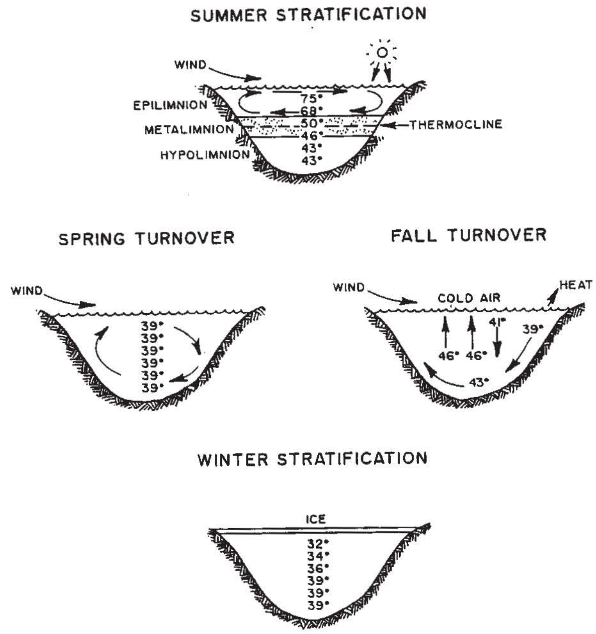
TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR NAGAWICKA LAKE: 1994-1997



Source: SEWRPC.

Figure 4

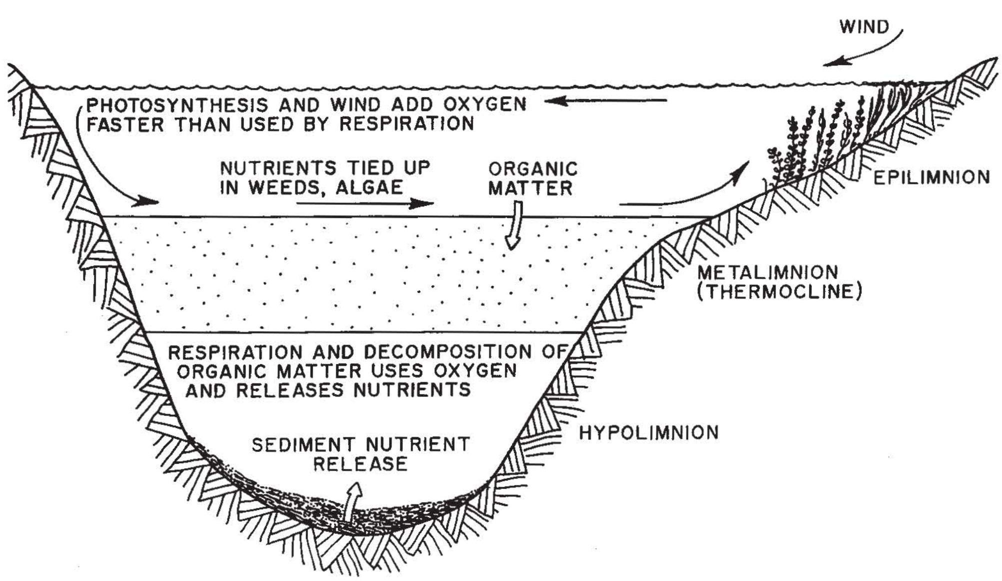
THERMAL STRATIFICATION OF LAKES



Source: University of Wisconsin-Extension and SEWRPC.

Figure 5

LAKE PROCESS DURING SUMMER STRATIFICATION



Source: University of Wisconsin-Extension and SEWRPC.

anoxia can contribute to the winter-kill of fish. Although dissolved oxygen levels in the hypolimnion of Nagawicka Lake were found to be below the five mg/l level during winter, a relatively large volume of the Lake retained adequate dissolved oxygen concentrations to sustain fish populations throughout the winter. At the end of winter, dissolved oxygen concentrations in the bottom waters of the Lake were restored during the period of spring turnover, which generally occurs between March and May.

Hypolimnetic anoxia is common in many of the lakes in Southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion cause fish to move upward, nearer to the surface of the lakes, where higher dissolved oxygen concentration exist. This migration, when combined with temperature, can select against some fish species which prefer the cooler water temperatures that generally prevail in the lower portions of the lakes. When there is insufficient oxygen at these depths, these fish are susceptible to summer-kills, or, alternatively, are driven into the warmer water portions of the lake where their condition and competitive success may be severely impaired.

In addition to these biological consequences of anaerobiasis, the lack of dissolved oxygen at depth can enhance the development of chemoclines, or chemical gradients, with an inverse relationship to the dissolved oxygen concentration. For example, the sediment-water exchange of elements such as phosphorus, iron and manganese is increased under anaerobic conditions, resulting in higher hypolimnetic concentrations in these elements. Under anaerobic conditions, iron and manganese change oxidation state enabling the release of phosphorus from the iron and manganese complexes to which they are bound under aerobic conditions. This "internal loading" can affect water quality significantly if these nutrients and salts are mixed into the epilimnion, especially during early summer when these nutrients can become available for algal plant growth.

Specific Conductance

Specific conductance is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. During periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion, referred to as "internal loading." As shown in Table 9, the specific conductance of Nagawicka Lake during spring of 1972 through 1997 ranged from 316 to 712 microSiemens per centimeter (ΦS/cm) at 25°C, which is within the normal range for lakes in Southeastern Wisconsin.[2] Significant surface to bottom conductivity gradients were observed, especially during the summer period when specific conductance increased with depth from between 392 and 660 ΦS/cm at the surface to between 480 and 712 ΦS/cm at depth.

Chloride

Chloride concentrations in Nagawicka Lake ranged from 19 to 56 mg/l, as shown in Table 9. The most important anthropogenic source of chlorides is believed to be the salts used on streets and highways for winter snow and ice control. The concentrations measured in Nagawicka Lake were within the normal range of lakes in Southeastern Wisconsin.[3]

Alkalinity and Hardness

Alkalinity is an index of the buffering capacity of a lake, or the capacity of a lake to absorb and neutralize acids. The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity because of the types of soil covering, and the bedrock underlying, the watersheds. In contrast, water hardness is a measure of the multivalent metallic ions, such as calcium and magnesium, present in the lake. Hardness is usually reported as an equivalent concentration of

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

[3]*Ibid.*

calcium carbonate ($CaCO_3$). Applying these measures to the study lake, Nagawicka Lake may be classified as a hard-water alkaline lake. During the spring, alkalinity averaged about 250 mg/l, while hardness averaged about 300 mg/l, as shown in Table 9. These values were within the normal range of lakes in Southeastern Wisconsin.[4]

Hydrogen Ion Concentration (pH)

The pH is a logarithmic measure of hydrogen ion concentration on a scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, and a pH below 7 indicates acidic water. In Nagawicka Lake, the pH was found to range between 7.0 and about 9.0 standard units, as shown in Table 9. Since Nagawicka Lake has a high alkalinity, or buffering capacity, the pH does not fluctuate below 7 and the Lake is not considered to be susceptible to the harmful effects of acidic deposition.

Water Clarity

Water clarity, or transparency, provides an indication of overall water quality; clarity may decrease because of turbidity caused by high concentrations of suspended materials, such as algae and zooplankton, or because of color caused by high concentrations of dissolved organic substances. Water clarity is measured with a Secchi-disk, a black-and-white, eight-inch-diameter disk, which is lowered into the water until a depth is reached at which the disk is no longer visible. This depth is known as the "Secchi-disk reading." Such readings comprise an important part of the Wisconsin Department of Natural Resources Self-Help Monitoring Program in which citizen volunteers assist in lake water quality monitoring efforts.

Water clarity generally varies throughout the year as algal populations increase and decrease in response to changes in weather conditions and nutrient loadings. These same factors make Secchi-disk readings vary from year to year as well. Secchi-disk readings for Nagawicka Lake were between 1.6 and 35.1 feet, with an average of about 14.2 feet. As shown in Figure 2, during recent years these values indicate poor to good water quality compared to other lakes in Southeastern Wisconsin.[5]

Chlorophyll-a

Chlorophyll-a is the major photosynthetic ("green") pigment in algae. The amount of chlorophyll-a present in the water is an indication of biomass or amount of algae in the water. Chlorophyll-a concentrations in Nagawicka Lake ranged from 0.5 to 16.8 micrograms per liter (Φg/l). These values were within the range of chlorophyll-a concentrations recorded in other lakes in the Region[6] and indicate fair to very good water quality, as illustrated in Figure 2.

Nutrient Characteristics

Aquatic plants and algae require such nutrients as phosphorus, nitrogen, carbon, calcium, chloride, iron, magnesium, sulfur, and silica for growth. In hard-water alkaline lakes, most of these nutrients are generally found in concentrations which exceed the needs of growing plants. However, in lakes where the supply of one or more of these nutrients is limited, plant growth is limited by the amount of that nutrient available. Two of the most important nutrients, in this respect, are phosphorus and nitrogen.

The ratio of total nitrogen to total phosphorus in lake water, or the N:P ratio, can indicate which nutrient is likely to be limiting plant growth. A nitrogen-to-phosphorus ratio greater than 14 to 1, indicates that phosphorus is probably the limiting nutrient, while a ratio of less than 10 to 1 indicates that nitrogen is probably the limiting

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[4]*Ibid.*

[5]*Ibid.*

[6]*Ibid.*

nutrient.[7] As shown in Table 10, the nitrogen-to-phosphorus ratios in samples collected from Nagawicka Lake were always greater than 10. This indicates that plant production was most likely consistently limited by phosphorus. Other factors, such as light, turbulence, and through-flow, may also limit plant growth. These factors are considered further below.

Both total phosphorus and soluble phosphorus concentrations were measured for Nagawicka Lake. Soluble phosphorus, being dissolved in the water column, is readily available for plant growth. However, its concentration can vary widely over short periods of time as plants take up and release this nutrient. Therefore, total phosphorus is usually considered a better indicator of nutrient status. Total phosphorus includes the phosphorus contained in plant and animal fragments suspended in the lake water, phosphorus bound to sediment particles, and phosphorus dissolved in the water column.

The Southeastern Wisconsin Regional Planning Commission recommends that total phosphorus concentrations in lakes not exceed 0.020 mg/l during the period of spring mixing, or turnover. This is the level considered necessary to prevent nuisance algal and macrophyte growths. During the study years, the total spring phosphorus concentrations in Nagawicka Lake were generally found to be greater than 0.02 mg/l, as shown in Table 11. Throughout the study period, total phosphorus in the surface waters of Nagawicka Lake averaged 0.02 mg/l, indicating good water quality, as illustrated in Figure 2.

Total phosphorus concentrations were found to be higher in the bottom waters, ranging from about 0.01 to 0.20 mg/l, as shown in Tables 9 and 11. The average bottom water total phosphorus concentration in Nagawicka Lake during the study period was 0.06 mg/l.

When aquatic organisms die, they usually sink to the bottom of the lake, where they are decomposed. Phosphorus from these organisms is then either stored in the bottom sediments or rereleased into the water column. Because phosphorus is not highly soluble in water, it readily forms insoluble precipitates with calcium, iron, and aluminum under aerobic conditions and accumulates, predominantly, in the lake sediments. If the bottom waters become depleted of oxygen during stratification, however, certain chemical changes occur, especially the change in the oxidation state of iron from the insoluble Fe^{3+} state to the more soluble Fe^{2+} state. The effect of these chemical changes is that phosphorus becomes soluble and is more readily released from the sediments. This process also occurs under aerobic conditions, but generally at a slower rate than under anaerobic conditions. As the waters mix, this phosphorus may be widely dispersed throughout the lake waterbody and become available for algal growth.

The data indicated that there was internal loading of phosphorus from the bottom sediments of Nagawicka Lake. As shown in Table 9, the dissolved phosphorus concentrations in the bottom waters were relatively high, ranging from 0.1 to 0.2 mg/l for samples collected during the summer, when such releases of phosphorus are most likely to occur. While the magnitude of the this release and its concomitant effects in contributing to algal growth in the surface waters of the Lake may be moderated by a number of circumstance, including the rate of mixing during the spring and fall overturn events, the contribution of phosphorus from the bottom waters of Nagawicka Lake should be considered in terms of the total phosphorus load.

CHARACTERISTICS OF BOTTOM SEDIMENT

The sediments of Nagawicka Lake consist largely of muck. Core samples taken from four sites within the Lake basin were analyzed during 1992 by Swanson Environmental, Inc.[8] Analyses of sediment cores from the four

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[7]*M.O. Alum, R.E. Gessner, and J.H. Gokstatter,* An Evaluation of the National Eutrophication Data*, U.S. Environmental Protection Agency Working Paper No. 900, 1977.*

[8]*Swanson Environmental, Inc.,* Nagawickas [sic] Lake Sediment Sampling and Analysis*, May 1990.*

Table 10

NITROGEN-PHOSPHORUS RATIOS
FOR NAGAWICKA LAKE

Date	Nutrient Levels		
	Nitrogen (mg/L)	Phosphoru s (mg/L)	N:P Ratio
April 21, 1986	1.20	0.03	40
April 7, 1987	0.57	0.02	25
April 14, 1988	0.60	0.01	46
April 27, 1989	0.70	0.02	37
April 10, 1990	0.75	0.02	33
April 25, 1991	0.60	0.02	40
April 13, 1992	0.65	0.01	100
April 19, 1994	0.55	0.01	41
March 29, 1995	0.85	0.01	77
April 17, 1996	0.50	0.01	45
April 29, 1997	0.65	0.01	54

Source: Wisconsin Department of Natural Resources and SEWRPC.

locations within the Lake were conducted to determine the levels of various nutrients and metals at increasing sediment depths. Table 12 lists the concentrations recorded at the referenced locations. Limited additional sediment analyses for heavy metals and pesticides were conducted by Swanson Environmental, Inc., during 1995 on sediment samples obtained from the northeastern portion of the Lake.[9]

Ammonia-nitrogen was the most common form of nitrogen in the lake sediments with concentrations ranging from 111 milligrams per kilograms (mg/kg) to 147 mg/kg. Nitrite-nitrogen was the only other commonly observed nitrogen fraction found in the Nagawicka Lake sediments ranging from 0.27 mg/kg to 0.44 mg/kg. Nitrate-nitrogen was determined to be present in trace amounts. Total nitrogen concentrations ranged from 1,530 mg/kg to 3,570 mg/kg, suggesting that the majority of the nitrogen in the lake sediments was associated with organic matter. This is consistent with the concentrations of organic carbon measured at the sample sites, which ranged from 205 mg/kg to 1.021 mg/kg. The concentration of ammonia-nitrogen exceeded the Lowest Effect Level (LEL) established by the Wisconsin Department of Natural Resources sediment screening criteria, probably due to the highly organic nature of the sediments. However, while some toxic affects on bottom-dwelling organisms may occur, the net impact of this is not anticipated to be significant.

Arsenic and copper concentrations varied within the lake sediments, with concentrations ranging from 0.7 mg/kg to 2.1 mg/kg, and from 6 mg/kg to 11 mg/kg, respectively. The concentrations of both of these elements are below the lowest effect levels set forth in WDNR draft sediment quality screening criteria. These criteria are summarized in Table 13.

The origin of the sediment arsenic is likely to have been, at least in part, the sodium arsenite-based herbicides applied to Nagawicka Lake to control aquatic plant growth in the lake basin between 1950 and 1967. Sodium arsenite applications occurred annually, except during 1952, and are summarized in Table 19 in Chapter V. About 87,200 pounds of the herbicide were applied to Nagawicka Lake during this period. No applications of sodium arsenite have taken place in the Lake since 1967. Similarly, about 11,500 pounds and 165 gallons of copper sulfate-based algicides have been applied to the Lake during the period from 1950 through 1992. Some of this copper is likely to be the origin of a portion of the sediment copper reported in Table 12, the balance being from naturally occurring geologic sources.

POLLUTION LOADINGS AND SOURCES

Currently, there are no significant point source discharges of pollutants to Nagawicka Lake or to the surface waters tributary to Nagawicka Lake. Nonpoint sources of water pollution include urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities; and rural sources, such a runoff from agricultural lands and onsite sewage disposal systems. The tributary drainage area of Nagawicka Lake

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[9] *Swanson Environmental, Inc.,* Nagawickas [sic] Lake, *August 1994.*

Table 11

NAGAWICKA LAKE SPRING OVERTURN WATER QUALITY: 1986-1997

Water Quality Parameter	April 21, 1986		April 7, 1987		April 14, 1988		April 27, 1989		April 10, 1990		April 25, 1991	
	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Depth of Sample (feet)	0	90	0	87	0	90	0	90	0	95	0	87
Specific Conductance (μS/cm)	490	490	450	430	500	500	482	482	412	410	460	450
pH	8.0	8.1	8.3	8.2	8.2	8.1	8.1	8.0	7.9	8.1	7.9	7.9
Water Temperature (°C)	46.2	44.2	42.8	40.6	44.6	53.2	50.0	41.0	40.1	40.1	48.2	41.9
Color (platinum-cobalt scale)	15	15	20	- -	10	15	15	15	15	- -	10	10
Turbidity (Nephelometric turbidity units)	0.8	4.6	2.8	- -	0.8	0.8	1.0	3.7	0.9	- -	0.8	1.3
Secchi Disk (feet)	8.3	- -	9.9	- -	9.9	- -	13.2	- -	16.5	- -	18.2	- -
Dissolved Oxygen	11.8	10.6	12.8	12.2	11.6	4.6	11.9	10.8	12.2	12.3	11.2	9.5
Hardness, as $CaCO_3$	305	307	307	316	306	303	300	300	296	299	290	310
Calcium	66.0	67.0	67.0	67.0	63.0	62.0	57.0	59.0	56.0	57.0	61.0	60.0
Magnesium	34.0	34.0	34.0	36.0	36.0	36.0	38.0	38.0	38.0	38.0	34.0	39.0
Sodium	16.0	16.0	17.0	17.0	18.0	17.0	19.0	19.0	19.0	19.0	19.0	20.0
Potassium	2.0	- -	2.0	2.0	2.4	2.4	2.3	2.3	2.5	2.5	2.5	2.7
Alkalinity, as $CaCO_3$	256	256	246	- -	262	262	246	247	243	- -	247	248
Chloride	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Sulfate	34	34	26	25	30	30	36	35	35	- -	35	35
Dissolved Solids	400	402	386	- -	394	396	396	396	- -	- -	394	400
Nitrate/Nitrite Nitrogen	1.20	1.20	1.30	1.30	1.00	1.00	0,80	0.70	0.70	0.80	0.60	0.60
Ammonia Nitrogen	0.02	0.07	0.20	0.20	0.13	0.16	0.09	0.18	0.05	0.05	0.11	0.16
Total Nitrogen	- -	- -	0.5	0.6	0.6	0.6	0.6	0.8	- -	- -	0.6	0.6
Total Phosphorus	- -	0.03	0.02	0.04	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02
Orthophosphorus	0.004	0.006	0.006	0.006	- -	0.002	0.005	0.005	0.012	0.009	0.004	0.009
Iron (μg/l)	- -	- -	- -	- -	<0.10	<0.10	0.05	0.05	0.05	0.05	0.05	0.05
Manganese (μg/l)	40.0	40.0	- -	- -	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Chlorophyll-a (μg/l)	14.0	- -	17.0	- -	5.0	- -	3.0	- -	4.0	- -	3.0	- -

is about 45.2 square miles in size, including about 7.4 square miles that drains to the Lake without passing through any upstream waterbodies. As already noted, inflow to Nagawicka Lake is primarily through the Bark River.

In order to estimate the amount of pollution contributed by these sources to Nagawicka Lake, annual loading budgets for phosphorus were developed for the watershed using the Wisconsin Lake Model Spreadsheet (WILMS) version 2.00.[10] The forecast data compared relatively well within the expected range of the observed phosphorus levels within the Lake. The resulting estimated phosphorus budget for Nagawicka Lake, is shown in Table 14. A total annual phosphorus loading of between 9,850 and 19,100 pounds, with a most likely total phosphorus loading of about 13,000 pounds, is estimated to be contributed to Nagawicka Lake. Of the most likely annual total phosphorus load, it is estimated that 9,400 pounds per year, or 72 percent of the total loading, was

[10]*Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-96 REV,* Wisconsin Lake Model Spreadsheet Version 2.00 User's Manual*, August 1996.*

Table 11 (continued)

Water Quality Parameter	April 13, 1992		May 6, 1993		April 19, 1994		March 29, 1995		April 17, 1996		April; 29, 1997	
	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Depth of Sample (feet)	0	85	1	90	0	90	0	90	0	85	1	90
Specific Conductance (μS/cm)	638	500	525	579	669	670	672	677	666	665	678	682
pH	8.3	8.3	8.3	8.2	8.4	8.4	8.2	8.2	8.4	8.4	8.5	8.2
Water Temperature (°C)	34.9	34.9	60.4	53.2	46.8	44.2	38.5	38.5	40.8	70.0	34.2	35.6
Color (platinum-cobalt scale)	10	10	- -	- -	15	15	15	15	10	10	- -	- -
Turbidity (Nephelometric turbidity units)	0.8	0.9	- -	- -	1.5	1.5	0.8	0.9	0.7	1.2	1.2	1.1
Secchi Disk (feet)	14.9	- -	14.9	- -	8.3	- -	15.2	- -	15.8	- -	12.2	12.2
Dissolved Oxygen	14.4	13.5	11.7	13.6	11.6	10.9	12.6	11.8	12.3	12.1	13.1	9.7
Hardness, as $CaCO_3$	310	300	- -	- -	260	250	320	320	- -	- -	310	310
Calcium	60.0	59.0	- -	- -	54.0	54.0	63.0	64.0	61.0	61.0	63.0	64.0
Magnesium	39.0	38.0	- -	- -	29.0	29.0	40.0	40.0	38.0	36.0	37.0	37.0
Sodium	20.0	20.0	- -	- -	18.0	18.0	23.0	23.0	24.0	24.0	25.0	25.0
Potassium	2.3	2.1	- -	- -	2.1	2.2	2.4	2.6	2.5	2.5	2.3	2.3
Alkalinity, as $CaCO_3$	246	244	- -	- -	267	267	257	259	253	253	261	262
Chloride	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	55	56
Sulfate	34	34	- -	- -	28	28	27	27	28	28	25	25
Dissolved Solids	392	392	- -	- -	430	434	- -	- -	- -	- -	- -	- -
Nitrate/Nitrite Nitrogen	1.00	1.00	1.00	1.10	1.30	1.30	0.80	0.80	1.10	1.10	1.10	1.10
Ammonia Nitrogen	0.11	0.11	0.03	0.08	0.04	0.06	0.13	0.16	0.14	0.13	0.14	0.13
Total Nitrogen	0.6	0.7	0.6	0.7	0.6	0.5	0.8	0.9	0.5	0.5	0.7	0.6
Total Phosphorus	0.01	0.01	<0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.02
Orthophosphorus	0.002	0.002	0.002	0.005	0.002	0.004	0.002	0.003	0.002	0.002	0.002	0.002
Iron (μg/l)	0.05	0.05	- -	- -	0.07	0.08	0.02	0.01	<0.02	<0.02	- -	- -
Manganese (μg/l)	40.0	40.0	- -	- -	40.0	40.0	5.7	12.0	4.0	5.0	4.0	8.0
Chlorophyll-a (μg/l)	4.0	- -	4.4	- -	11.8	- -	6.1	- -	4.9	- -	10.9	- -

Source: Wisconsin Department of Natural Resources and SEWRPC.

contributed by runoff from rural land; and 3,500 pounds per year, or 27 percent, was contributed by runoff from urban land. The remaining phosphorus loading was contributed by onsite sewage disposal systems, about 160 pounds, and precipitation, about 80 pounds. Phosphorus release from the lake bottom sediments—internal loading—may also contribute phosphorus to the Lake. However, this loading was assumed to be negligible given the good agreement between predicted and observed phosphorus concentrations.

Under buildout conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual total phosphorus load to the Lake is not anticipated to change significantly. The most likely annual total phosphorus load to the Lake is estimated to be 13,000 pounds. However, the distribution of the sources of this phosphorus load is expected to change, with approximately equal masses of phosphorus being contributed from urban and rural sources.

Given the concerns expressed by t he Nagawicka Lake community, especially with regard to continuing development along STH 83, a specific analysis of the respective subbasins was conducted by Commission staff. For the development at the STH 83 and IH 94 intersection, located within the subbasin designated as BR-28 in the regional water quality management plan, the forecast changes in nutrient and contaminant loadings between 1990

Table 12

CONCENTRATIONS OF METALS AND NUTRIENTS IN SEDIMENTS IN NAGAWICKA LAKE: 1995

Parameter	Sediment Sample Analytical Results (mg/kg)			
	Sample 1	Sample 2	Sample 3	Sample 4
Arsenic	0.7	1.8	1.6	2.1
Copper	6.0	7.0	9.0	11.0
Ammonia Nitrogen	119.0	147.0	126.0	111.0
Kjeldahl Nitrogen	3,340.0	2,450.0	3,570.0	1,530.0
Nitrate Nitrogen	<1.0	<1.0	1.0	<1.0
Nitrite Nitrogen	0.4	0.4	0.4	0.3
Oil and Grease	211.0	141.0	304.0	110.0
Total Solids (percent)	13.6	25.3	15.1	36.2
Total Organic Carbon	960.0	1,021.0	304.0	205.0

Source: Swanson Environmental, Inc., and SEWRPC.

Table 13

WISCONSIN DEPARTMENT OF NATURAL RESOURCES DRAFT SEDIMENT QUALITY SCREENING CRITERIA[a]

Chemical	Lowest Effect Level (LEL)	Medium Effect Level (MEL)	Severe Effect Level (SEL)
Arsenic	6	33	85
Copper	25	110	390
Lead	31	110	250
Mercury	0.15	0.2	1.3
Ammonia-Nitrogen	75	- -	- -

[a]*Units are in mg/kg dry sediment.*

Source: Wisconsin Department of Natural Resources.

land use conditions and anticipated buildout conditions are set forth in Table 15. Under buildout conditions, forecast contaminant loads are anticipated to increase by between 35 and 460 percent of the loads generated under 1990 land use conditions. The greatest increases in loadings are forecast among the heavy metals, which are produced as a result of the use of nonferrous metals for vehicles, building materials, and related, primarily urban-type applications. This pollutant loading analysis is an approximation of the changes in loadings, based upon generalized land use changes. The analysis assumes no specific stormwater management measures are in place to remove nonpoint source pollutants. Such measures as have been installed in compliance with City stormwater management ordinance provisions, provided primarily for managing water quantity, also may reduce the impacts shown in Table 14. With stormwater quality management measures designed for water quality purposes in place, sediment and phosphorus loadings would not be expected to increase significantly, while metals may be expected to increase in any case due to the increase in urbanization. While there is some increase expected, the phosphorus loading from this site represents only about 3 percent of the total loading to the Lake.

For the development at the STH 83 and STH 16 intersection, located within the subbasin designated as BR-24 in the regional water quality management plan, the forecast changes in nutrient and contaminant loadings between 1990 land use conditions and anticipated buildout conditions are set forth in Table 16. Under buildout conditions,

Table 14

ESTIMATED TOTAL PHOSPHORUS LOADS TO NAGAWICKA LAKE: 1995 AND BUILDOUT

Pollution Source	1995 Land Use		Buildout Land Use	
	Total Loading (pounds per year)	Percent Distribution	Total Loading (pounds per year)	Percent Distributio n
Urban Runoff				
Residential	1,770	13	3,165	24
Commercial and Industrial	1,520	12	2,700	21
Recreational and Open Lands	200	2	75	1
Subtotal	3,490	27	5,940	46
Rural Runoff				
Agricultural	9,120	70	6,510	50
Woodlands and Wetlands	250	2	190	1
Surface Water	10	<1	10	<
Subtotal	9,380	712	6,710	51
Atmospheric	80	<1	80	1
Onsite Sewage Disposal Systems	160	<1	200	2
Total	13,110	100	12,930	100

Source: SEWRPC.

Table 15

ESTIMATED CONTAMINANT LOADS TO NAGAWICKA LAKE FROM URBAN DEVELOPMENT WITHIN SUBBASIN BR-28

Land Use	1990						Buildout					
	Area (acres)	Sediment (pounds)	Phosphoru s (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (pounds)	Phosphoru s (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Multi-Family Residential	3.5	760	2	1	1	0	3.5	760	2	1	1	0
Single-Family Residential	84.0	760	3	0	1	0	119.0	1,310	5	0	1	0
Commercial	38.0	36,400	57	8	57	1	221.0	211,500	330	49	330	2
Open Lands	288.5	870	9	- -	- -	- -	288.5	870	9	- -	- -	- -
Agricultural	218.0	98,100	187	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total	632.0	136,890	258	9	59	1	632.0	214,440	346	50	332	2

Source: SEWRPC.

forecast contaminant loads are anticipated to increase by between 25 and 300 percent of the loads generated under 1990 land use conditions. As previously noted, this pollutant loading analysis is an approximation of the changes in loadings, based upon generalized land use changes. The installation of specific stormwater management measures designed for water quality purposes may reduce the impacts shown in Table 15. With such measures in place, sediment and phosphorus loadings are not expected to increase significantly, while metals may be expected to increase in any case due to the increase in urbanization. While there is some increase expected, the loading from this site represents only about 5 percent of the total loading to the Lake.

As noted in Chapter III, the City of Delafield and the Village of Hartland have recently refined their stormwater management ordinances affecting new development within their jurisdictions. Both municipalities have adopted

Table 16

ESTIMATED CONTAMINANT LOADS TO NAGAWICKA LAKE FROM URBAN DEVELOPMENT WITHIN SUBBASIN BR-24

Land Use	1990						Buildout					
	Area (acres)	Sediment (pounds)	Phosphoru s (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (pounds)	Phosphoru s (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Multi-Family Residential	87	18,800	50	2	12	0	234	63,900	162	10	65	<1
Single-Family Residential	111	1,200	4	0	1	0	202	2,000	8	0	2	0
Commercial	29	27,750	40	6	43	<1	73	70,000	109	16	109	1
Industrial	133	127,300	200	30	198	1	272	260,300	405	60	405	3
Wetlands	279	840	8	- -	- -	- -	279	840	8	- -	- -	- -
Woodlands	174	520	5	- -	- -	- -	26	78	1	- -	- -	- -
Open Lands	19	18,000	30	4	28	<1	- -	- -	- -	- -	- -	- -
Agricultural	254	114,300	220	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total	1,086	308,710	557	42	282	1	1,086	397,118	693	86	581	4

Source: SEWRPC.

similar ordinance requirements. These requirements primarily address stormwater runoff quantity issues, but, through their requirement for the provision of onsite detention of stormwater, can promote improved water quality in the runoff from the two subbasins identified above, and other subbasins within their jurisdictions. The extent of the improvements that can be anticipated with the implementation of stormwater management measures pursuant to the refined ordinances can range from between 50 and 90 percent of the pollutant load, as measured by suspended sediment and total phosphorus concentrations. The range of stormwater management measures will be set forth in the lake management plan developed during Phase II of this lake management planning program, the scope of which is set forth in the project description appended hereto as Appendix A.

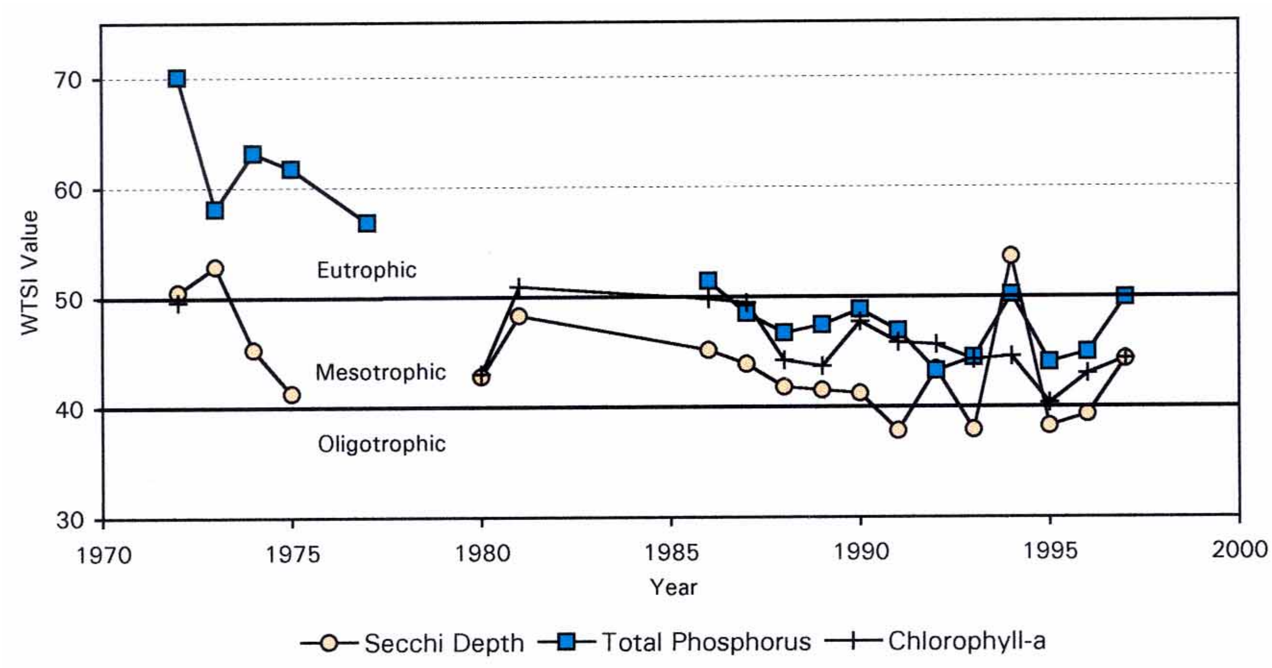
Sewage Disposal

As of 1995, portions of the drainage area tributary to Nagawicka Lake were served by onsite sewage disposal systems. Approximately 4,500 onsite sewage disposal systems exist in the riparian residential land area surrounding Nagawicka Lake. These systems are estimated to contribute approximately one percent of the total phosphorus loading to the Lake, or about 160 pounds. The lakeshore itself is served by a public sanitary sewer system operated by the City and connected to the Delafield-Hartland Water Pollution Control Commission (Dela-Hart) sewerage system for treatment purposes. The Dela-Hart sewage treatment plant discharges treated wastewater downstream of Nagawicka, Crooked, and the Nemahbin Lakes. The combined effects of constructing the Dela-Hart sewerage system with the concomitant abandonment of the Hartland sewage treatment plant, and the diversion of the treated effluent to a discharge point downstream of Nagawicka Lake is illustrated in Figure 6. This figure shows a substantial reduction in trophic state index values after 1980, when the Dela-Hart facilities became operational.

Onsite sewage disposal systems are designed to remove phosphorus by adsorption to soil in the drainfield. The removal capacity decreases with increasing soil particle size; and all soils have a fixed adsorptive capacity that can eventually become exhausted. Onsite sewage disposal systems include conventional septic tank systems, mound systems, and holding tanks. Holding tanks store wastewater temporarily until it is pumped and conveyed by tank truck to a sewage treatment plant, storage lagoon, or land disposal site. All other types of onsite systems discharge effluent to the groundwater reservoir. Provided that the systems are located, installed, used, and maintained properly, the onsite sewage disposal systems may be expected to operate with few problems for periods of about 20 to 25 years. Failure of a conventional septic tank system occurs when the soil surrounding the seepage area will no longer accept or properly stabilize the septic tank effluent.

Figure 6

TROPHIC STATE INDICES FOR NAGAWICKA LAKE: 1972-1997



Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.

While many older onsite sewage disposal systems may have met *Wisconsin Administrative Code* requirements when installed, these requirements have changed over the years, with the effect that many older systems no longer conform to present practices. Also, some installations, designed for vacation or seasonal home use are now in use year-round and are potentially subject to overloading. Notwithstanding, the potential impacts of onsite sewage disposal systems on Nagawicka Lake are considered to be minimal.

In-Lake Sinks

Of the annual total phosphorus load entering Nagawicka Lake, it is estimated that 67 percent of the total phosphorus load, or 8,600 pounds, is retained within the Lake. This mass of phosphorus is either used by the biomass within the Lake or deposited in the lake sediments.[11] The balance of the phosphorus entering the Lake is transported downstream. The phosphorus mass retained in the Lake is typically reduced by the City of Delafield aquatic plant harvesting program, which removes phosphorus from the Lake as a component of the aquatic plant biomass.[12]

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[11]*D.P. Larsen and H.T. Mercier, "Phosphorus retention capacity of lakes,"* Journal of the Fisheries Research Board of Canada, *Volume 33, pp. 1742-1750, 1976.*

[12]*T.M. Burton, D.L. King, and J.L. Ervin, "Aquatic Plant Harvesting As A Lake Restoration Technique,"* Proceedings of the U.S. Environmental Protection Agency National Lake Restoration Conference, *EPA 440/5-79-OD1, 1979. See also, U.S. Environmental Protection Agency Report No. EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual—Second Edition, *August 1990.*

Drainage Area Sinks

Based upon the WILMS analysis and upon the inventory findings previously reported from the Bark River watershed with respect to Upper Nemahbin Lake, situated immediately downstream of Nagawicka Lake,[13] the annual total phosphorus loads to Nagawicka Lake are moderated within the drainage area tributary to the Lake. The most likely basis for the moderation of these loads is the presence of riparian wetland systems throughout the upper reaches of the Bark River, although some degree of phosphorus reduction is achieved as a consequence of phosphorus retention within Bark Lake, situated in the headwater portion of the drainage basin. It is estimated that these wetland systems reduce the effective phosphorus load to Nagawicka Lake by between 25 and 50 percent on an annual basis, based upon estimates applied to the WILMS model outputs.

Figure 7 summarizes the total phosphorus balance for Nagawicka Lake.

RATING OF TROPHIC CONDITION

Lakes are commonly classified according to their degree of nutrient enrichment or trophic status. The ability of a lake to support a variety of recreational activities and healthy fish and aquatic life communities is often correlated to the degree of nutrient enrichment that has occurred. There are three terms usually used to describe the trophic status of a lake: oligotrophic, mesotrophic, and eutrophic. Oligotrophic lakes are nutrient-poor lakes. These lakes characteristically support relatively few aquatic plants and often do not contain productive fisheries. Because of the naturally fertile soils and the intensive land use practices employed in the Southeastern Wisconsin Region, there are relatively few oligotrophic lakes in Southeastern Wisconsin. Mesotrophic lakes are moderately fertile lakes that support abundant aquatic plant growths and may support productive fisheries. Nuisance growths of algae and weeds are usually not exhibited by mesotrophic lakes. Many of the cleaner lakes in Southeastern Wisconsin are classified as mesotrophic.

Eutrophic lakes are defined as nutrient-rich lakes. These lakes are often characterized by excessive growths of aquatic weeds and frequent algal blooms. Many eutrophic lakes support very productive fisheries. In shallow eutrophic lakes, fish winterkills may also be common. Many of the more polluted lakes in Southeastern Wisconsin are classified as eutrophic. Extremely eutrophic lakes may be described by a further descriptor, hypertrophic or hypereutrophic.

Several numeric “scales,” based on one or more water quality indicators, have been developed to define the trophic condition of a lake. Because trophic state is actually a continuum from very nutrient poor to very nutrient rich, a numeric scale is useful for comparing lakes and for evaluating trends in water quality conditions. Care must be taken, however, that the particular scale used is appropriate for the lake to which it is applies. In this case, two indices, specific to Wisconsin lakes, have been used; namely, the Vollenweider-OECD open-boundary trophic classification system,[14] and the Carlson Trophic State Index (TSI).[15] In addition, the Wisconsin Trophic State Index value (WTSI) is presented.[16] The WTSI is a refinement of the Carlson TSI designed to account for the

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[13]*SEWRPC Memorandum Report No. 101,* Upper Nemahbin Lake Watershed Inventory Findings, Waukesha County, Wisconsin, *May 1995.*

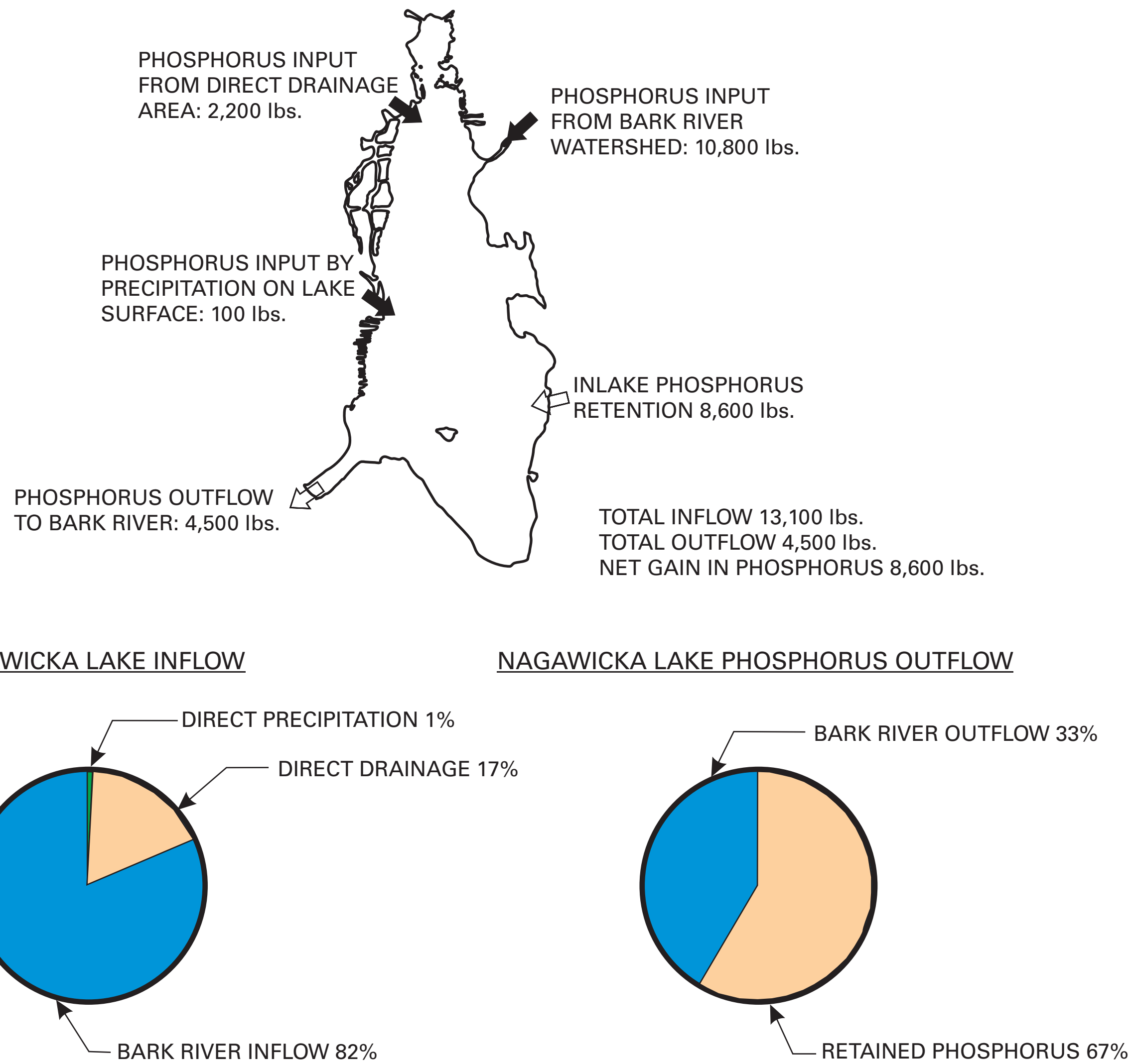
[14]*H. Olem and G. Flock,* The Lake and Reservoir Restoration Guidance Manual, Second Edition*, U.S. Environmental Protection Agency Report EPA-440/4-90-006, Office of Water (WH-553), Washington, D.C., August 1990.*

[15]*R.E. Carlson, “A Trophic State Index for Lakes,”* Limnology and Oceanography*, Vol. 22, No. 2, 1977.*

[16]*See 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.*

Figure 7

TOTAL PHOSPHORUS BUDGET FOR NAGAWICKA LAKE: 1996-1997



Source: SEWRPC.

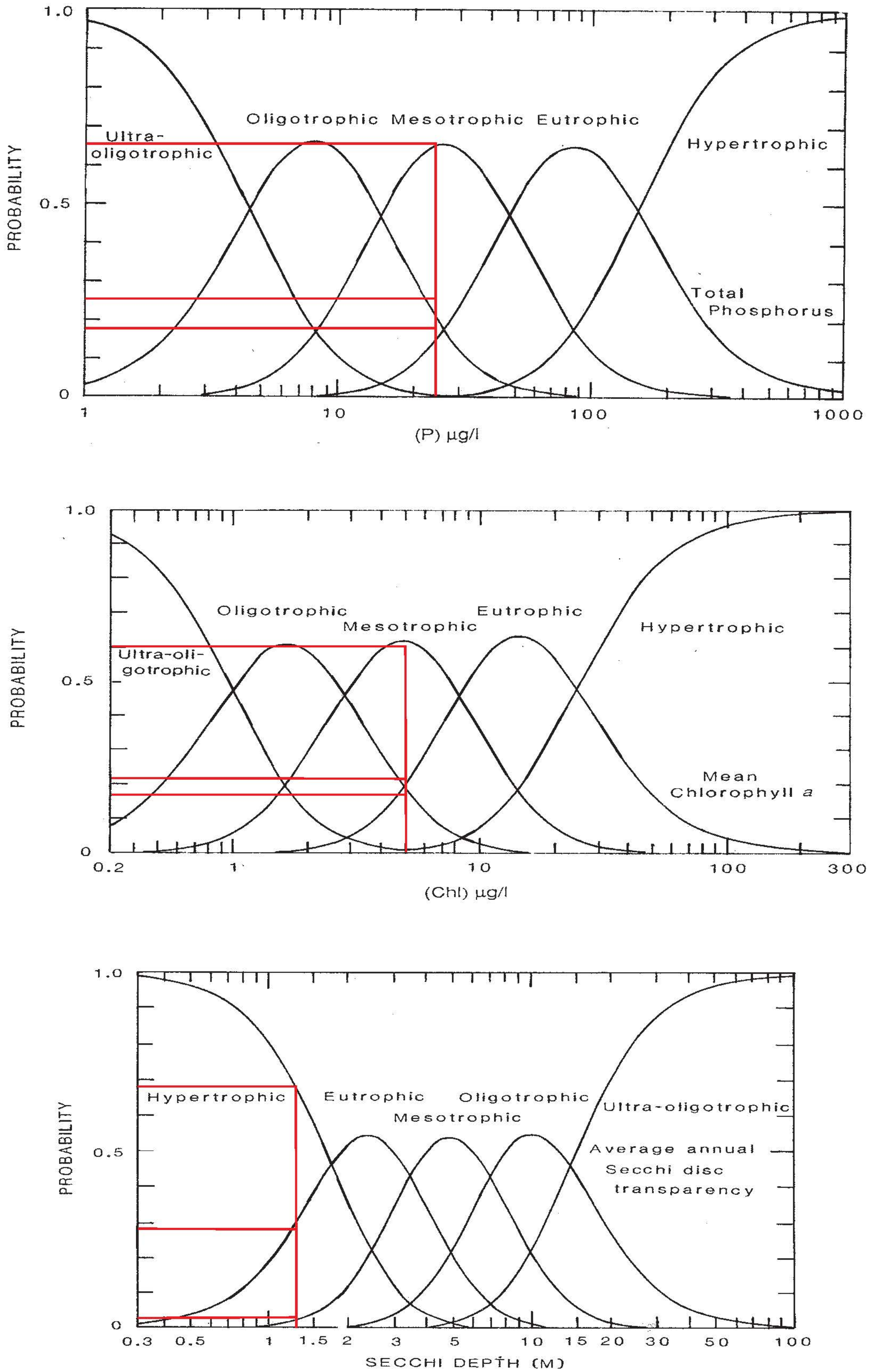
greater humic acid content—brown water color—present in Wisconsin lakes, and has been adopted by the Wisconsin Department of Natural Resources for use in lake management investigations.

Vollenweider Trophic State Classification

Using the Vollenweider trophic system and applying the data in Table 9, Nagawicka Lake would be classified as having a 65 percent probability of being mesotrophic based upon phosphorus levels, as shown in Figure 8. The Lake would have less than a 25 percent probability of being either eutrophic or oligotrophic based upon mean annual phosphorus concentrations. Based upon chlorophyll-a levels, the Lake would be classified as having a 62 percent probability of being mesotrophic, with less than a 30 percent probability of being eutrophic or hypertrophic. Based upon Secchi-disk readings, the Lake would be classified as having a 68 percent probability of being hypertrophic, with less than a 30 percent probability of being eutrophic or mesotrophic, as shown in

Figure 8

TROPHIC STATE CLASSIFICATION OF NAGAWICKA LAKE BASED UPON THE VOLLENWEIDER MODEL



Source: S.-O. Ryding and W. Rast, <u>*The Control of Eutrophication of Lakes and Reservoirs,*</u> *Vol. 1 1989; Wisconsin Department of Natural Resources; and SEWRPC.*

Figure 5. While these indicators result in slightly differing lake trophic state classifications, it may be concluded that Nagawicka Lake should be classified as a meso-eutrophic lake, or a lake with acceptable water quality for most uses.

Trophic State Index

The Trophic State Index (TSI) assigns a numerical trophic condition rating based on Secchi-disk transparency, and total phosphorus and chlorophyll-a concentrations. The original Trophic State Index developed by Carlson has been modified for Wisconsin lakes by the Wisconsin Department of Natural Resources using data on 184 lakes throughout the State.[17] The Wisconsin Trophic State Index (WTSI) ratings for Nagawicka Lake are shown in Figure 6 as a function of sampling date. Based on the Wisconsin Trophic State Index rating of between 38 and 54, Nagawicka Lake may be classified as mesotrophic. Figure 6 clearly shows an improvement in lake trophic status between the 1970s and 1980s, with the WTSI decreasing from between 50 and 70 to between 42 and 51. This improvement in water quality is likely to be, in part, the result of the construction of the Dela-Hart sewerage system and diversion of treated wastewater treatment plant effluent to a discharge point downstream of Nagawicka Lake. Nonetheless, slightly increased WTSI values in recent years may indicate some cause for concern during this period.

SUMMARY

Nagawicka Lake represents a typical hard-water, alkaline lake that is considered to have relatively good water quality, especially since the implementation of public sewage treatment measures during 1980. Physical and chemical parameters measured during the study period indicated that the water quality was within the “poor” to “good” range, depending upon the parameters considered. Total phosphorus levels were found to be generally at the level considered to cause nuisance algal and macrophytic growths. Summer stratification was commonly observed in Nagawicka Lake. Nevertheless, the surface waters of the Lake remained well oxygenated and supported a healthy fish population. Winterkill was not a problem in Nagawicka Lake because of the substantial volume of the Lake that provided adequate oxygenated water volume for the support of fish throughout the winter. Internal releases of phosphorus from the bottom sediments were not considered to be a problem in Nagawicka Lake.

There were no significant point sources of pollutants in the Nagawicka Lake watershed. Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. In 1995, the total annual phosphorus load to Nagawicka Lake was estimated to be 13,110 pounds. Runoff from the rural lands contributed the largest amount of phosphorus, about 72 percent of the total phosphorus load, with the runoff from urban land contributing about 27 percent of the total phosphorus load. In addition, onsite sewage disposal system loadings in the drainage basin and direct precipitation onto the Lake surface contributed relatively minor amounts of phosphorus to the Lake. The Bark River constituted the primary source of phosphorus to the Lake.

Approximately 67 percent, or 8,600 pounds, of the total phosphorus loading is estimated to remain in the Lake by conversion to biomass or through sedimentation, resulting in a net transfer of 4,200 pounds of phosphorus downstream.

Based on the Vollenweider phosphorus loading model and the Wisconsin Trophic State Index ratings calculated from Nagawicka Lake data, Nagawicka Lake may be classified as a meso-eutrophic lake.

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[17] *R.A. Lillie, S. Graham, and P. Rasmussen, op. cit.*

Chapter V

AQUATIC BIOTA AND ECOLOGICALLY VALUABLE AREAS

INTRODUCTION

Nagawicka Lake is an important element of the natural resource base of the City of Delafield. The Lake, its biota, and the adjacent park and residential lands combine to contribute to the quality of life in the area. When located in urban settings, resource features such as lakes and wetlands are typically subject to extensive recreational use and high levels of pollutant discharges, common forms of stress to aquatic systems, and this may result in the deterioration of these natural resource features. For this reason, the formulation of sound management strategies must be based on a thorough knowledge of the pertinent characteristics of the individual resource features, as well as of the urban development in the area concerned. Accordingly, this chapter provides information concerning the natural resource features of the Nagawicka Lake watershed, including data on primary environmental corridors, wetlands, aquatic macrophytes, fish, and wildlife. Recreational activities relating to the use of these natural resource features are described in Chapter VI.

AQUATIC PLANTS

Aquatic plants include larger plants, or macrophytes, and microscopic algae, or phytoplankton. These plant communities form an integral part of the aquatic food web, converting inorganic nutrients present in the water and sediments into organic compounds which are directly available as food for other aquatic organisms. In this process, known as photosynthesis, plants utilize energy from sunlight and release oxygen required by other aquatic life forms.

Aquatic Macrophytes

Aquatic macrophytes play an important role in the ecology of Southeastern Wisconsin lakes. They can be either beneficial or a nuisance, depending on their distribution and abundance, and the activities taking place on the waterbody. Macrophytes are usually an asset because they provide food and habitat for fish and other aquatic life, produce oxygen, and may remove nutrients and pollutants from the water that could otherwise cause algal blooms or other problems. Aquatic macrophytes become a nuisance when their presence reaches densities that interfere with swimming and boating and the normal functioning of a lake ecosystem. Many factors, including lake configuration, depth, water clarity, nutrient availability, bottom substrate, wave action, and type of fish populations present, determine the distribution and abundance of aquatic macrophytes in a lake. Some nonnative plant species, lacking natural controls, may be especially favored by the habitats available in this Region and can exhibit explosive growths to the detriment not only of lake users, but also of indigenous aquatic life and native plant species.

To document the types and relative abundances of aquatic macrophytes in Nagawicka Lake, an aquatic plant survey was conducted by staff of the Southeastern Wisconsin Regional Planning Commission during June 1997. The survey of aquatic plant communities in Nagawicka Lake was conducted in association with the City of Delafield Lake Welfare Committee. This survey was used to update and refine the aquatic plant survey conducted by Aron & Associates in 1993.[1] The aquatic plant survey was completed to obtain a general overview of species composition. A species list, compiled from the results of this aquatic plant survey, is set forth in Table 17. Principal plant species are illustrated in Appendix B.

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[1]*Aron & Associates,* Nagawicka Lake Plant Management Plan*, August 1993.*

Table 17

AQUATIC PLANT SPECIES OBSERVED IN NAGAWICKA LAKE AND THEIR ECOLOGICAL SIGNIFICANCE

Aquatic Plant Species Present	Ecological Significance[a]
Ceratophyllum demersum (coontail)	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris (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 wildfowl eat foliage; sparingly eaten by muskrats and moose
Najas flexilis (bushy pondweed)	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Nuphar sp. (yellow water lily)	Leaves, stems, and flowers are eaten by deer; roots eaten by beavers and porcupines; seeds eaten by wildfowl; leaves provide harbor to insects, in addition to shade and shelter for fish
Nymphaea sp. (white water lily)	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrats; roots eaten by beaver, deer, moose, and porcupine
Potamogeton amplifolius (large-leaf pondweed)	Provides support for insects and produces good food supply for fish and ducks
Potamogeton crispus (curly-leaf pondweed)	Provides food, shelter, and shade for some fish and food 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 (white-stemmed 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 (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 June 1997 survey, 12 species of submergent plants were identified in Nagawicka Lake. Species that interfere with the recreational and aesthetic use of the Lake, such as *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Potamogeton crispus*, were all found to be present in the Lake. Plant growth occurred throughout most of the Lake where the depth was less than 15 feet, with the exception of the southeastern and southwestern shores where growth was sparse probably due to the sudden change in depth. Musk grass (*Chara* spp.), wild celery (*Vallisneria americana*), and native milfoil appeared to be the dominant species in many areas of the main basin. Healthy populations of pondweeds (*Potamogeton* spp.) appeared to be scattered throughout the Lake, and were most commonly found at depths of between five and 10 feet. Eurasian water milfoil, *Myriophyllum* *spicatum*, was scattered throughout the Lake, but largely confined to areas of the Lake with depths of between 10 and 15 feet. The distribution of these plant communities is shown on Map 19. In general, Nagawicka Lake supports a healthy and diverse aquatic macrophyte community.

Phytoplankton

Phytoplankton, or algae, are small, generally microscopic plants that are found in all lakes and streams. They occur in a wide variety of forms, in single cells or colonies, and can be either attached or free floating. Phytoplankton abundance varies seasonally with fluctuations in solar irradiance, turbulence due to prevailing winds, and nutrient availability. In lakes with high nutrient levels, heavy growths of phytoplankton, or algal blooms, may occur. Algal blooms have been occasionally perceived as a problem in Nagawicka Lake. Filamentous algal species in particular are known to occur within the Lake, and the Lake has been subjected to algicide treatments to control nuisance levels of phytoplankton growth. While algal samples have been collected as part of the Wisconsin Department of Natural Resources Long-Term Trends Monitoring Program, these samples are awaiting analysis, and the identification and quantification of those algae present within the Lake have not yet been included as part of the reported Wisconsin Department of Natural Resources studies.

Aquatic Plant Management

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Thus, while previous interventions were likely, the first recorded efforts to manage the aquatic plants in Nagawicka Lake took place in 1950. Aquatic plant management activities in Nagawicka Lake can be categorized as macrophyte harvesting, chemical macrophyte control, and chemical algal control.

Perceived excessive macrophyte growths on Nagawicka Lake have historically resulted in application of a chemical control program. Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Chemical herbicides are known to have been applied to Nagawicka Lake from at least 1950 through 1992, as set forth in Table 18.

In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison area, and, by the 1930s, sodium arsenite was widely used throughout the State for aquatic plant control. No other chemicals were applied in significant amounts to control macrophytes until recent years, when a number of organic chemical herbicides came into general use. The amounts of sodium arsenite applied to Nagawicka Lake, and years of application during the period 1950 through 1967, are listed on Table 18; the total amount of sodium arsenite applied over this 17-year period being about 87,214 pounds.

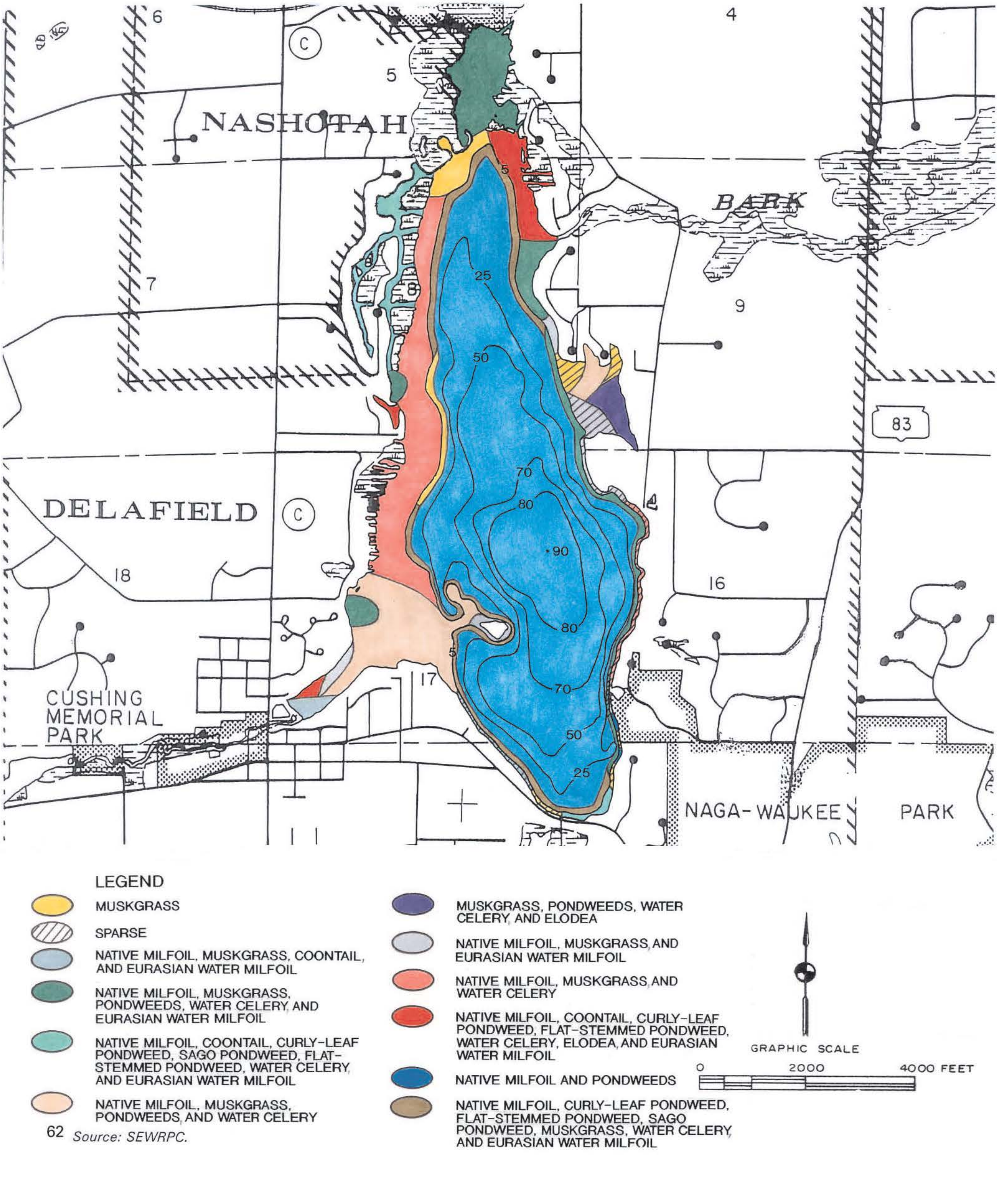
Sodium arsenite was typically sprayed onto the surface of Nagawicka Lake within an area of up to 200 feet from the shoreline. Treatment typically occurred between mid-June and mid-July. The amount of sodium arsenite used was calculated to result in a concentration of about 10 milligrams per liter (mg/l) sodium arsenite (about five mg/l arsenic) in the treated lake water. The sodium arsenite typically remained in the water column for less than 120 days. Although the arsenic residue was naturally converted from a highly toxic form to a less toxic and less biologically active form, much of the arsenic residue was deposited in the lake sediments.

When it became apparent that arsenic was accumulating in the sediments of treated lakes, the use of sodium arsenite was discontinued in the State in 1969. The applications and accumulations of arsenic were found to present potential health hazards to both humans and aquatic life. Notwithstanding, the concentrations of arsenic within the lake sediments of Nagawicka Lake are within draft sediment quality criteria limits set forth by the Wisconsin Department of Natural Resources, and shown in Table 13 in Chapter IV, and are not considered to pose a hazard.

As shown in Table 18, the aquatic herbicides Diquat, Aquathol, and 2,4-D have also been applied to Nagawicka Lake to control aquatic macrophyte growth. Diquat and Aquathol are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many

Map 19

AQUATIC PLANT COMMUNITY DISTRIBUTION IN NAGAWICKA LAKE: 1997



Source: SEWRPC.

Table 18

HISTORIC CHEMICAL CONTROLS ON NAGAWICKA LAKE: 1950-1994

	Macrophyte Control				Algal Control	
Year[a]	Sodium Arsenite (pounds)	Diquat (gallons)	Aquathol K (gallons)	2,4-D (pounds)	Copper Sulfate (pounds)	Cutrine-Plus (gallons)
1950	300	0.00	0.0	0.00	20	0.00
1951	200	0.00	0.0	0.00	15	0.00
1952	0	0.00	0.0	0.00	0	0.00
1953	200	0.00	0.0	0.00	0	0.00
1954	2,560	0.00	0.0	0.00	0	0.00
1955	2,980	0.00	0.0	0.00	0	0.00
1956	2,760	0.00	0.0	0.00	0	0.00
1957	3,216	0.00	0.0	0.00	0	0.00
1958	5,216	0.00	0.0	0.00	0	0.00
1959	2,860	0.00	0.0	0.00	200	0.00
1960	2,100	0.00	0.0	0.00	250	0.00
1961	6,520	0.00	0.0	0.00	300	0.00
1962	5,130	0.00	0.0	0.00	400	0.00
1963	12,240	0.00	0.0	0.00	1,400	0.00
1964	11,340	0.00	0.0	0.00	2,200	0.00
1965	11,700	0.00	0.0	0.00	1,400	0.00
1966	9,702	0.00	0.0	0.00	1,440	0.00
1967	8,190	0.00	0.0	0.00	1,150	0.00
1969	0	0.00	0.0	0.00	405	0.00
1970	0	0.00	0.0	0.00	1,930	0.00
1980	0	0.00	6.0	0.00	0	9.00
1982	0	17.00	15.0	0.00	0	20.00
1985	0	10.00	20.5	3.00	0	33.00
1986	0	19.00	21.5	9.00	0	38.50
1987	0	17.25	22.5	0.00	0	21.75
1988	0	0.00	0.0	20.00	0	38.00
1989	0	0.00	3.0	31.25	350	2.25
1991	0	0.00	0.0	8.25	0	0.75
1992	0	1.75	0.0	7.00	0	1.75
Total	87,214	65.00	88.5	78.50	11,460	165.00

[a]*During years not included, no chemical controls were used.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Aquathol primarily kills pondweeds, but does not control such nuisance species as Eurasian water milfoil (*Myriophyllum spicatum*). The herbicide 2,4-D is a systemic herbicide which is absorbed by the leaves and translocated to other parts of the plant; it is more selective than the other herbicides listed above and is generally used to control Eurasian water milfoil. However, it will also kill species such as water lilies (*Nymphaea* sp. and *Nuphar* sp.). The present restrictions on water use after application of these herbicides are given in Table 19.

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to Nagawicka Lake. As shown in Table 19, copper sulfate and Cutrine Plus have been applied to Nagawicka Lake, on occasion. Like arsenic, copper, the active ingredient in many algicides, including Cutrine Plus, may accumulate in the bottom sediments. Excessive levels of copper may be toxic to fish and benthic organisms, but,

Table 19

PRESENT RESTRICTIONS ON WATER USES AFTER APPLICATION OF AQUATIC HERBICIDES[a]

Use	Days after Application			
	Cutrine-Plus	Diquat	Hydrothol and Aquathol	2,4-D
Drinking	0	14	7-14	- -[b]
Fishing	0	14	3	0
Swimming	0	1	- -	0
Irrigation	0	14	7-14	- -[b]

[a]*The U.S. Environmental Protection Agency has indicated that, if these restrictions are observed, pesticide residues in water, irrigated crops, or fish will not pose an unacceptable risk to humans and other organisms using or living in the treatment zone.*

[b]*2,4-D products are not to be applied to waters used for irrigation, animal consumption, drinking, or domestic uses, such as cooking and watering vegetation.*

Source: Wisconsin Department of Natural Resources.

generally, have not been found to be harmful to humans.[2] Restrictions on water uses after application of Cutrine Plus are also given in Table 19.

AQUATIC ANIMALS

Aquatic animals include microscopic zooplankton; benthic, or bottom-dwelling invertebrates; fish and reptiles; amphibians; mammals; and waterfowl that inhabit the Lake and its shorelands. These make up the primary and secondary consumers of the food web.

Zooplankton

Zooplankton are minute, free-floating animals inhabiting the same environment as phytoplankton. Zooplankton are primary consumers in the aquatic food chain, feeding to a large extent on such phytoplankton as green algae and diatoms. The zooplankton, in turn, are preyed upon by fish, particularly the larvae and fry of bluegills, pumpkinseeds, sunfish, and largemouth bass. While the zooplankton population is an indicator of the trophic status of a lake and of the diversity of aquatic habitat, and zooplankton were sampled as part of the Wisconsin Department of Natural Resources Long-Term Trend Monitoring Program, no information on the species composition or relative abundance is currently available for Nagawicka Lake. However, given the composition and condition of the fish community in Nagawicka Lake, it may be assumed that the zooplankton population is sufficiently robust and diverse to support a relatively healthy fishery.

Fish of Nagawicka Lake

Nagawicka Lake supports a relatively large and diverse fish community. Studies conducted by the Wisconsin Department of Natural Resources during the 1980s indicated that 30 species of fish have been captured in the

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[2]*Jeffrey A. Thornton and Walter Rast, "The Use of Copper and Copper Compounds as Algicides," in H. Wayne Richardson,* Handbook of Copper Compounds and Applications, *Marcel Dekker, New York, 1997, pp. 123-142.*

Lake,[3] as shown on Table 20. The pugnose shiner, a State Threatened Species, has also been reported from Nagawicka Lake.

Important predator fish in Nagawicka Lake include walleyed pike, northern pike, smallmouth bass, and largemouth bass. Largemouth bass are considered to be common, while the rest are considered to be present. These species are carnivorous, feeding primarily on other fish, crayfish, and frogs. These species are among the largest and most prized game fish sought by Nagawicka Lake anglers. A wide range of panfish are also present in the Lake, as shown in Table 20. "Panfish" is a common term applied to a broad group of smaller fish with a relatively short and usually broad shape makes them a perfect size for the frying pan. Panfish species known to exist in Nagawicka Lake include bluegills, pumpkinseeds, green sunfish, and black crappies.

The habitats of panfish vary widely among the different species, but their cropping of the plentiful supply of insects and plants, coupled with prolific breeding rates, leads to large populations with a rapid turnover. Some lakes within Southeastern Wisconsin have stunted, or slow-growing, panfish populations because their numbers are not controlled by predator fishes. Panfish frequently feed on the fry of predator fish and, if the panfish population is overabundant, they may quickly deplete the predator fry population. Figure 9 illustrates the importance of a balanced predator-prey relationship, using walleyed pike and perch as an example.

"Rough fish" is a broad term applied to species, such as carp, that do not readily bite on hook and line, but feed on game fish, destroy habitat needed by more desirable species, and are commonly considered in Southeastern Wisconsin as undesirable for human consumption. Rough fish species which have been found in Nagawicka Lake include carp, lake chubsucker, and bowfin.

Nagawicka Lake is currently passively managed for the production of bluegills, largemouth bass, and northern pike, which regulates the harvest of fishes from the Lake under current state fishing regulations. The 1998-99 regulations governing the harvest of fishes from the waters of the State are summarized in Table 21.

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the Nagawicka Lake study, it is possible, by polling naturalists and wildlife managers familiar with the area, to complete a list of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed in the Nagawicka Lake area; associating these lists with the historic and remaining habitat areas in the Nagawicka Lake area as inventoried; and projecting the appropriate amphibian, reptile, bird, and mammal species into the Nagawicka Lake area. The net result of the application of this technique is a listing of those species which were probably once present in the drainage area; those species which may be expected to still be present under currently prevailing conditions; and those species which may be expected to be lost or gained as a result of urbanization within the area.

Given the rural nature of all but the immediate shoreland area of Nagawicka Lake, many animals and numbers of waterfowl commonly inhabit areas of the watershed, especially in the still undeveloped areas southwest of the Lake and upstream of the Lake. A variety of mammals, ranging in size from large animals like the northern white-tailed deer to small animals like the pygmy shrew, are found in the Nagawicka Lake area. Mink, muskrat, beaver, white-tailed deer, red and grey fox, grey and fox squirrel, and cottontail rabbits are mammals reported to frequent the area. Table 22 lists 36 mammals whose ranges are known to extend into the area.

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[3]*Wisconsin Department of Natural Resources Fish Management Report No. 131,* Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County*, Summer 1982, February 1987.*

Table 20

SPECIES OF FISH IDENTIFIED DURING NAGAWICKA LAKE FISH SURVEYS[a]

Common Name	Family Name	Scientific Name	Relative Abundance
Largemouth Bass	Centrarchidae	Micropterus salmoides	Common
Smallmouth Bass	Centrarchidae	Micropterus dolomieui	Present
White Bass	Centrarchidae	Morone chrysops	Common
Grass Pickerel	Esocidae	Esox americanus vermiculatus	Common
Yellow Bullhead	Ictaluridae	Ictalurus natalis	Common
Black Bullhead	Ictaluridae	Ictalurus melas	Common
Brown Bullhead	Ictaluridae	Ictalurus nebulosus	Common
Northern Pike	Esocidae	Esox lucius	Abundant
Bluegill	Centrarchidae	Lepomis macrochirus	Abundant
Pumpkinseed	Centrarchidae	Lepomis gibbosus	Common
Walleyed Pike	Percidae	Stizostedion vitreum vitreum	Present
Yellow Perch	Percidae	Perca flavesens	Abundant
White Sucker	Catostomidae	Catostomus commersoni	Common
Bluntnose Minnow	Cyprinidae	Pimephales notatus	Common
Fathead Minnow	Cyprinidae	Pimephales promelas	Present
Brook Silverside	Atherinidae	Labidesthes sicculus	Common
Johnny Darter	Percidae	Etheostoma nigrum	Present
Rainbow Darter	Percidae	Etheostoma caeruleum	Present
Iowa Darter	Percidae	Etheostoma exile	Present
Tadpole Madtom	Ictaluridae	Notorus gyrinus	Present
Mimic Shiner	Cyprinidae	Notropis volucellus	Present
Warmouth	Centrarchidae	Lepomis gulosus	Common
Golden Shiner	Cyprinidae	Notemigonus crysoleucas	Present
Blacknose Shiner	Cyprinidae	Notropis heterolepis	Present
Emerald Shiner	Cyprinidae	Notropis atherinoides	Present
Green Sunfish	Centrarchidae	Lepomis cyanellus	Common
Black Crappie	Centrarchidae	Pomoxis nigromaculatus	Common
Bowfin	Amiidae	Amia calva	Present
Lake Chubsucker	Catostomidae	Erimyzon sucetta	Common
Carp	Cyprinidae	Cyprinus carpio	Common

[a]Based on miscellaneous data contained in Wisconsin Department of Natural Resources, Eagle Headquarters, files.

Source: Wisconsin Department of Natural Resources and SEWRPC.

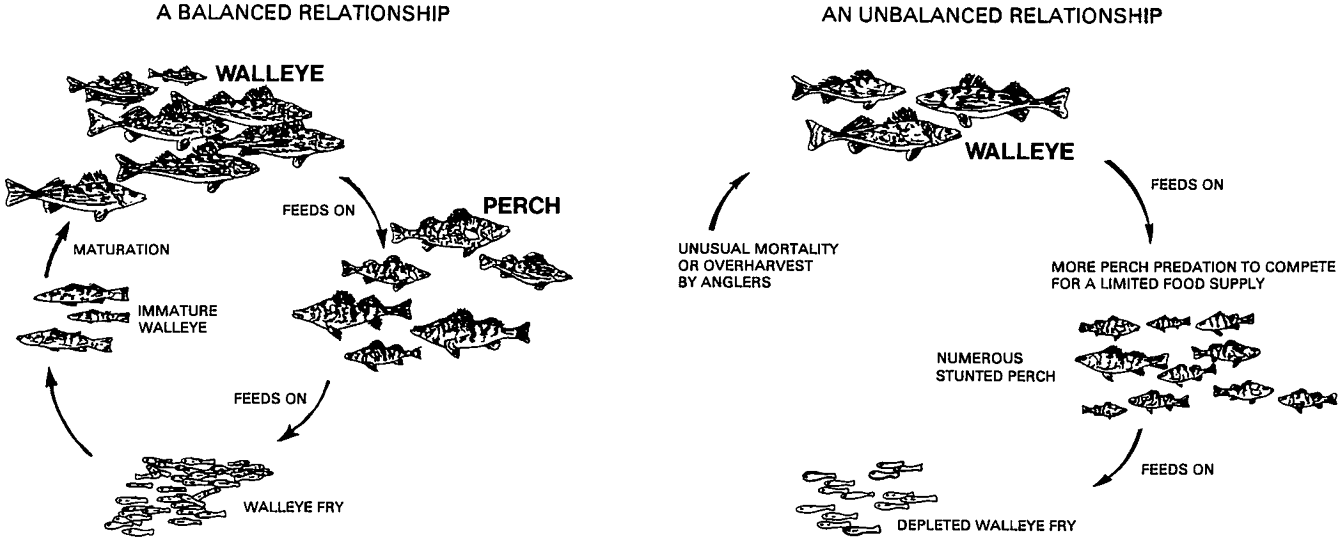
A large number of birds, ranging in size from large game birds to small songbirds, are found in the Nagawicka Lake area. Table 23 lists those birds that normally occur in the drainage area. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Nagawicka Lake drainage area supports a significant population of waterfowl, including mallard and teal. Larger numbers move through the drainage area during migrations when most of the regional species may also be present.

Mallards, wood duck, and blue-winged teal are the most numerous waterfowl and are known to nest in the area. Many game birds, songbirds, waders, and raptors also reside or visit the Lake and its environs. Sandhill cranes and loons are notable migratory visitors.

Because of the mixture of lowland and upland woodlots, wetlands, and agricultural lands still present in the area, along with the favorable summer climate, the area supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, whippoorwills, woodpeckers, nuthatches, and flycatchers, as well as several other species, serve as major insect predators. In addition to their ecological roles,

Figure 9

THE PREDATOR-PREY RELATIONSHIP



Source: Wisconsin Department of Natural Resources.

birds such as robins, red-winged blackbirds, orioles, cardinals, kingfishers, and mourning doves serve as subjects for bird watchers and photographers. Threatened species resident in the vicinity of Nagawicka Lake include the Cerulean and Kentucky warblers and the Arcadian flycatcher. The worm-eating warbler is an endangered species resident in the vicinity of the Lake.

Amphibians and reptiles are vital components of the ecosystem in an environmental unit like the Nagawicka Lake drainage area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Nagawicka Lake area. Table 24 lists the 14 amphibian and 16 reptile species normally expected to be present in the Nagawicka Lake area under present conditions and identifies those species most sensitive to urbanization. Blanding's turtle, a threatened species, is resident in the Kettle area of Nagawicka Lake.

Most amphibians and reptiles have definite habitat requirements which are adversely affected by advancing urban development, as well as by certain agricultural land management practices. The major detrimental factors affecting the maintenance of amphibians in a changing environment is the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

The complete spectrum of wildlife species originally native to Waukesha County has, along with its habitat, undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of extensive urban areas. Successive cultural uses and attendant management practices, both rural and urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In agricultural areas, these cultural management practices include draining land by ditching and tiling and the expanding use of fertilizers, herbicides, and pesticides. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

Table 21

WISCONSIN STATE FISHING REGULATIONS: 1998-1999

Species	Open Season	Daily Limit	Minimum Size
Largemouth and Smallmouth Bass	May 2 - March 1	Five in total	14 inches
Bluegill, Pumpkinseed (sunfish), Crappie, and Yellow Perch	Open all year	25 in total	None
Bullheads and Rough fish	Open all year	None	None
Northern Pike	May 2 - March 1	Two	26 inches
Walleyed Pike and Sauger (includes hybrids)	May 2 - March 1	Five in total	15 inches

Source: Wisconsin Department of Natural Resources Publication No. PUBL-FH301 97 REV, Guide to Wisconsin Hook and Line Fishing Regulations 1998-99, January 1997, and SEWRPC.

WILDLIFE HABITAT AND RESOURCES

Wildlife habitat areas remaining in the Region were inventoried by the Regional Planning Commission in 1985 in cooperation with the Wisconsin Department of Natural Resources. The five major criteria used to determine the value of these wildlife habitat areas are listed below:

1. Diversity
   An area must maintain a high, but balanced, diversity of species for a temperate climate, balanced in such a way that the proper predatory-prey (consumer-food) relationships can occur. In addition, a reproductive interdependence must exist.

2. Territorial Requirements
   The maintenance of proper spatial relationships among species, allowing for a certain minimum population level, can occur only if the territorial requirements of each major species within a particular habitat are met.

3. Vegetative Composition and Structure
   The composition and structure of vegetation must be such that the required levels for nesting, travel routes, concealment, and protection from weather are met for each of the major species.

4. Location with Respect to Other Wildlife Habitat Areas
   It is very desirable that a wildlife habitat maintain proximity to other wildlife habitat areas.

5. Disturbance
   Minimum levels of disturbance from human activities are necessary, other than those activities of a wildlife management nature.

On the basis of these five criteria, the wildlife habitat areas in the Nagawicka Lake drainage area were categorized as either Class I, High-Value; Class II, Medium-Value; or Class III, Good-Value, habitat areas. Class I wildlife habitat areas contain a good diversity of wildlife, are adequate in size to meet all of the habitat requirements for the species concerned, are generally located in proximity to other wildlife habitat areas, and meet all five criteria listed above. Class II wildlife habitat areas generally fail to meet one of the five criteria in the preceding list for a high-value wildlife habitat. However, they do retain a good plant and animal diversity. Class III wildlife habitat areas are remnant in nature in that they generally fail to meet two or more of the five criteria for a high-value

Table 22

MAMMALS OF THE NAGAWICKA LAKE AREA

Didelphidae
Virginia Opossum
Soricidae
Cinereous Shrew
Short-Tailed Shrew
Little Short-Tailed (least) Shrew
Vespertilionidae
Little Brown Bat
Silver-Haired Bat
Big Brown Bat
Red Bat
Hoary Bat
Leporidae
Mearns's Cottontail Rabbit
Sciuridae
Southern Woodchuck
Striped Ground Squirrel (gopher)
Ohio Chipmunk
Minnesota Grey Squirrel
Western Fox Squirrel
Minnesota Red Squirrel
Southern Flying Squirrel
Castoridae
American Beaver
Cricetidae
Woodland Deer Mouse
Prairie Deer Mouse
Northern White-Footed Mouse
Meadow Vole
Common Muskrat
Muridae
Norway Rat (introduced)
House Mouse (introduced)
Zapodidae
Hudsonian Meadow Jumping Mouse
Canidae
Northeastern Coyote
Eastern Red Fox
Gray Fox
Procyonidae
Upper Mississippi Valley Raccoon
Mustelidae
Least Weasel
Bang's Short-Tailed Weasel
Long-Tailed Weasel
Mink
American Badger (occasional visitor)
Northern Plains Skunk
Otter (occasional visitor)
Cervidae
White-Tailed Deer

Source: H. T. Jackson, Mammals of Wisconsin, 1961, Wisconsin Department of Natural Resources, and SEWRPC.

wildlife habitat, but may, nevertheless, be important if located in proximity to medium- or high-value habitat areas if they provide corridors linking wildlife habitat areas of higher value or if they provide the only available range in an area.

As shown on Map 20, about 962 acres, or about 20 percent of the drainage area directly tributary to Nagawicka Lake, were classified in the 1985 inventory as wildlife habitat. Of this, about 462 acres, or about 10 percent of the drainage area, were classified as Class I habitat; 255 acres, or 5 percent, were classified as Class II habitat; and 244 acres, or 5 percent, were classified as Class III habitat. About 7,885 acres, or about 27 percent of the total drainage area tributary to Nagawicka Lake, were classified in the 1985 inventory as wildlife habitat, as shown on Map 21. About 3,300 acres, or about 11 percent of the drainage area, were classified as Class I habitat; 2,700 acres, or 9 percent, were classified as Class II habitat; and 1,860 acres, or 6 percent, were classified as Class III habitat.

WETLANDS

Wetlands are defined by the Regional Planning Commission as, "areas that have a predominance of hydric soils and that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions." This definition, which is also used by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency, is essentially the same as the definition used by the U.S. Natural Resource Conservation Service.[4]

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[4]*Lands designated as prior converted cropland, that is, lands that were cleared, drained, filled, or otherwise manipulated to make them capable of supporting a commodity crop prior to December 23, 1985, may meet the criteria of the U.S. Natural Resource Conservation Service wetland definition, but they would not be regulated under Federal wetland programs. If such lands are not cropped, managed, or maintained for agricultural production, for five consecutive years, and in that time the land reverts back to wetland, the land would then be subject to Federal wetland regulations.*

Table 23

BIRDS KNOWN OR LIKELY TO OCCUR IN THE NAGAWICKA LAKE AREA

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Podicipedidae			
Pied-Billed Grebe	X	- -	X
Ardeidae			
American Bittern	X	- -	X
Least Bittern	X	- -	X
Great Blue Heron	X	- -	X
Green-Backed Heron	X	- -	X
Great Egret	- -	- -	X
Gruidae			
Sandhill Crane	X	- -	X
Anatidae			
Tundra Swan	- -	- -	X
Canada Goose	X	- -	X
Wood Duck	X	- -	X
Canvasback	X	- -	X
Green-Winged Teal	- -	- -	X
American Black Duck	- -	X	X
Mallard	X	X	X
Gadwall	- -	- -	X
Northern Pintail	- -	- -	X
Blue-Winged Teal	X	- -	X
Northern Shoveler	- -	- -	X
American Widgeon	- -	- -	X
Redhead	- -	- -	X
Ring-Necked Duck	- -	- -	X
Lesser Scaup	- -	- -	X
Common Goldeneye	- -	- -	X
Bufflehead	- -	- -	X
Mute Swan	X	X	X
Red-Breasted Merganser	- -	- -	X
Hooded Merganser	R	- -	X
Common Merganser	- -	- -	X
Cathartidae			
Turkey Vulture	- -	- -	X
Accipitridae			
Northern Goshawk	- -	R	X
Sharp-Shinned Hawk	X	- -	X
Cooper's Hawk	X	X	X
Northern Harrier	- -	R	X
Broad-Winged Hawk	- -	- -	X
Red-Tailed Hawk	X	X	X
Rough-Legged Hawk	- -	- -	X
Bald Eagle	- -	- -	X
Osprey	- -	- -	X
American Kestrel	X	X	X
Phasianidae			
Ring-Necked Pheasant (introduced)	X	X	NA
Ruffed Grouse	R	R	- -
Wild Turkey	X	X	- -

Table 23 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Rallidae			
Virginia Rail	X	- -	X
Sora	X	- -	X
American Coot	X	- -	X
Charadriidae			
Semipalmated Plover	- -	- -	X
Killdeer	X	- -	X
Scolopacidae			
Greater Yellowlegs	- -	- -	X
Lesser Yellowlegs	- -	- -	X
Solitary Sandpiper	X	- -	X
Spotted Sandpiper	P	- -	X
Upland Sandpiper	P	- -	P
Semipalmated Sandpiper	- -	- -	P
Pectoral Sandpiper	- -	- -	X
Common Snipe	X	- -	X
American Woodcock	X	- -	X
Wilson's Phalarope	- -	- -	X
Dunlin	- -	- -	P
Gaviidae			
Northern Common Loon	- -	- -	X
Laridae			
Ring-Billed Gull	- -	- -	X
Herring Gull	- -	- -	X
Forster's Tern	R	- -	P(E)
Black Tern	X	- -	X
Columbidae			
Rock Dove[a]	X	X	NA
Mourning Dove	X	X	X
Cuculidae			
Black-Billed Cuckoo	P	- -	X
Yellow-Billed Cuckoo	P	- -	X
Strigidae			
Eastern Screech Owl	X	X	NA
Great Horned Owl	X	X	NA
Snowy Owl	- -	- -	R
Barred Owl	X	X	NA
Long-Eared Owl	- -	R	R
Short-Eared Owl	- -	- -	R
Northern Saw-Whet Owl	- -	- -	X
Caprimulgidae			
Common Nighthawk	X	- -	X
Whippoorwill	- -	- -	X
Apodidae			
Chimney Swift	X	- -	X
Trochilidae			
Ruby-Throated Hummingbird	X	- -	X
Alcedinidae			
Belted Kingfisher	X	- -	X
Picidae			
Red-Bellied Woodpecker	X	X	X
Red-Headed Woodpecker	X	- -	X

Table 23 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Picidae (continued)			
Yellow-Bellied Sapsucker	- -	- -	X
Downy Woodpecker	X	X	NA
Hairy Woodpecker	X	X	NA
Northern Flicker	X	R	X
Pileated Woodpecker	X	X	X
Tyrannidae			
Olive-Sided Flycatcher	- -	- -	X
Eastern Wood-Peewee	X	- -	X
Yellow-Bellied Flycatcher	- -	- -	X
Willow Flycatcher	X	- -	X
Least Flycatcher	X	- -	X
Eastern Phoebe	X	- -	X
Great Crested Flycatcher	X	- -	X
Eastern Kingbird	X	- -	X
Alaudidae			
Horned Lark	X	X	X
Hirundinidae			
Purple Martin	X	- -	X
Tree Swallow	X	- -	X
Northern Rough-Winged Swallow	X	- -	X
Bank Swallow	X	- -	X
Cliff Swallow	X	- -	X
Barn Swallow	X	- -	X
Corvidae			
Blue Jay	X	X	X
American Crow	X	X	X
Paridae			
Tufted Titmouse	X	- -	X
Black-Capped Chickadee	X	X	X
Sittidae			
Red-Breasted Nuthatch	X	X	X
White-Breasted Nuthatch	X	X	NA
Certhiidae			
Brown Creeper	X	X	X
Troglodytidae			
Carolina Wren	- -	- -	R
House Wren	X	- -	X
Winter Wren	- -	- -	X
Sedge Wren	X	- -	X
Marsh Wren	X	- -	X
Muscicapidae			
Golden-Crowned Kinglet	X	X	X
Ruby-Crowned Kinglet	- -	- -	X
Blue-Gray Gnatcatcher	X	- -	X
Eastern Bluebird	X	- -	X
Veery	X	- -	X
Gray-Cheeked Thrush	- -	- -	X
Swainson's Thrush	- -	- -	X
Hermit Thrush	- -	- -	X
Wood Thrush	X	- -	X
American Robin	X	- -	X

Table 23 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Mimidae			
Gray Catbird	X	- -	X
Brown Thrasher	X	- -	X
Motacillidae			
Water Pipit	- -	- -	X
Bombycillidae			
Bohemian Waxwing	- -	R	- -
Cedar Waxwing	X	X	X
Lanniidae			
Northern Shrike	- -	R	X
Sturnidae			
European Starling[a]	X	X	X
Vireonidae			
Solitary Vireo	- -	- -	X
Yellow-Throated Vireo	X	- -	X
Warbling Vireo	X	- -	X
Red-Eyed Vireo	X	- -	X
Philadelphia Vireo	- -	- -	X
Emberizidae			
Prothonotary Warbler	R	- -	X
Blue-Winged Warbler[b]	X	- -	X
Golden-Winged Warbler	X	- -	X
Tennessee Warbler	P	- -	X
Orange-Crowned Warbler	P	- -	X
Nashville Warbler	P	- -	X
Northern Parula	- -	- -	X
Yellow Warbler	X	- -	X
Chestnut-Sided Warbler	P	- -	X
Magnolia Warbler	P	- -	X
Cape May Warbler	P	- -	X
Black-Throated Blue Warbler	P	- -	X
Yellow-Rumped Warbler	P	- -	X
Black-Throated Green Warbler	P	- -	X
Cerulean Warbler	P	- -	X
Blackburnian Warbler	P	- -	X
Palm Warbler	P	- -	X
Bay-Breasted Warbler	P	- -	X
Blackpoll Warbler	P	- -	X
Black-and-White Warbler	P	- -	X
American Redstart	X	- -	X
Ovenbird	X	- -	X
Northern Waterthrush	- -	- -	X
Connecticut Warbler	P	- -	X
Mourning Warbler	P	- -	X
Common Yellowthroat	X	- -	X
Wilson's Warbler	P	- -	X
Kentucky Warbler	P	- -	X
Canada Warbler	P	- -	X
Hooded Warbler	P	- -	X
Scarlet Tanager	X	- -	X
Northern Cardinal	X	X	NA
Rose-Breasted Grosbeak	X	- -	X
Indigo Bunting	X	- -	X
Dickcissel	- -	- -	R

Table 23 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Emberizidae (continued)			
Rufous-Sided Towhee	X	- -	X
American Tree Sparrow	- -	X	X
Chipping Sparrow	X	- -	X
Clay-Colored Sparrow	- -	- -	X
Field Sparrow	X	- -	X
Vesper Sparrow	P	- -	X
Savannah Sparrow	X	- -	X
Grasshopper Sparrow	X	- -	X
Henslow's Sparrow	P	- -	X
Fox Sparrow	X	- -	X
Song Sparrow	X	X	X
Lincoln's Sparrow	- -	- -	X
Swamp Sparrow	X	R	X
White-Throated Sparrow	- -	R	X
White-Crowned Sparrow	- -	- -	X
Dark-Eyed Junco	- -	X	X
Lapland Longspur	- -	R	X
Snow Bunting	- -	R	X
Boblink	X	- -	X
Red-Winged Blackbird	X	- -	X
Eastern Meadowlark	X	- -	X
Western Meadowlark	R	- -	X
Rusty Blackbird	- -	R	X
Common Grackle	X	- -	X
Brown-Headed Cowbird	X	- -	X
Orchard Oriole	R	- -	R
Northern Oriole	X	- -	X
Purple Finch	- -	X	X
Common Redpoll	- -	X	X
Pine Siskin	- -	X	X
American Goldfinch	X	X	X
House Finch (introduced)	X	- -	X
Evening Grosbeak	- -	X	X
Ploceidae			
House Sparrow[a]	X	X	NA

NOTE: Breeding: Nesting species
Wintering: Present January through February
Migrant: Spring and/or fall transient

NA - not applicable
X - present, not rare
R - rare
(E) - endangered species in Wisconsin
? - seasonal status uncertain
P - possibly present

[a]*Alien, or nonnative, bird species.*

[b]*Includes the Brewster's Warbler hybrid variant.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 24

AMPHIBIANS AND REPTILES OF THE NAGAWICKA LAKE AREA

Scientific (family) and Common Name	Species Reduced or Dispersed with Full Area Urbanization	Species Lost with Full Area Urbanization
Amphibians		
Proteidae		
Mudpuppy	X	- -
Ambystomatidae		
Blue-Spotted Salamander	- -	X
Eastern Tiger Salamander	X	- -
Salamandridae		
Central Newt	X	- -
Bufonidae		
American Toad	X	- -
Hylidae		
Western Chorus Frog	X	- -
Blanchard's Cricket Frog[a,b]	X	- -
Northern Spring Peeper	- -	X
Eastern Gray Tree Frog	- -	X
Ranidae		
Bull Frog	- -	X
Green Frog	X	- -
Northern Leopard Frog	- -	X
Wood Frog	- -	X
Reptiles		
Chelydridae		
Common Snapping Turtle	X	- -
Kinosternidae		
Musk Turtle (stinkpot)	X	- -
Emydidae		
Western Painted Turtle	X	- -
Midland Painted Turtle	X	- -
Blanding's Turtle[c]	- -	X
Trionychidea		
Eastern Spiny Softshell	X	- -
Colubridae		
Northern Water Snake	X	- -
Queen Snake[b,d]	- -	X
Northern Brown Snake	X	- -
Northern Red-Bellied Snake	X	- -
Eastern Garter Snake	X	- -
Chicago Garter Snake	X	- -
Butler's Garter Snake[c]	X	- -
Eastern Hognose Snake	- -	X
Eastern Smooth Green Snake	- -	X
Eastern Milk Snake	- -	X

[a]*Likely to be extirpated from the watershed.*

[b]*Identified as endangered in Wisconsin.*

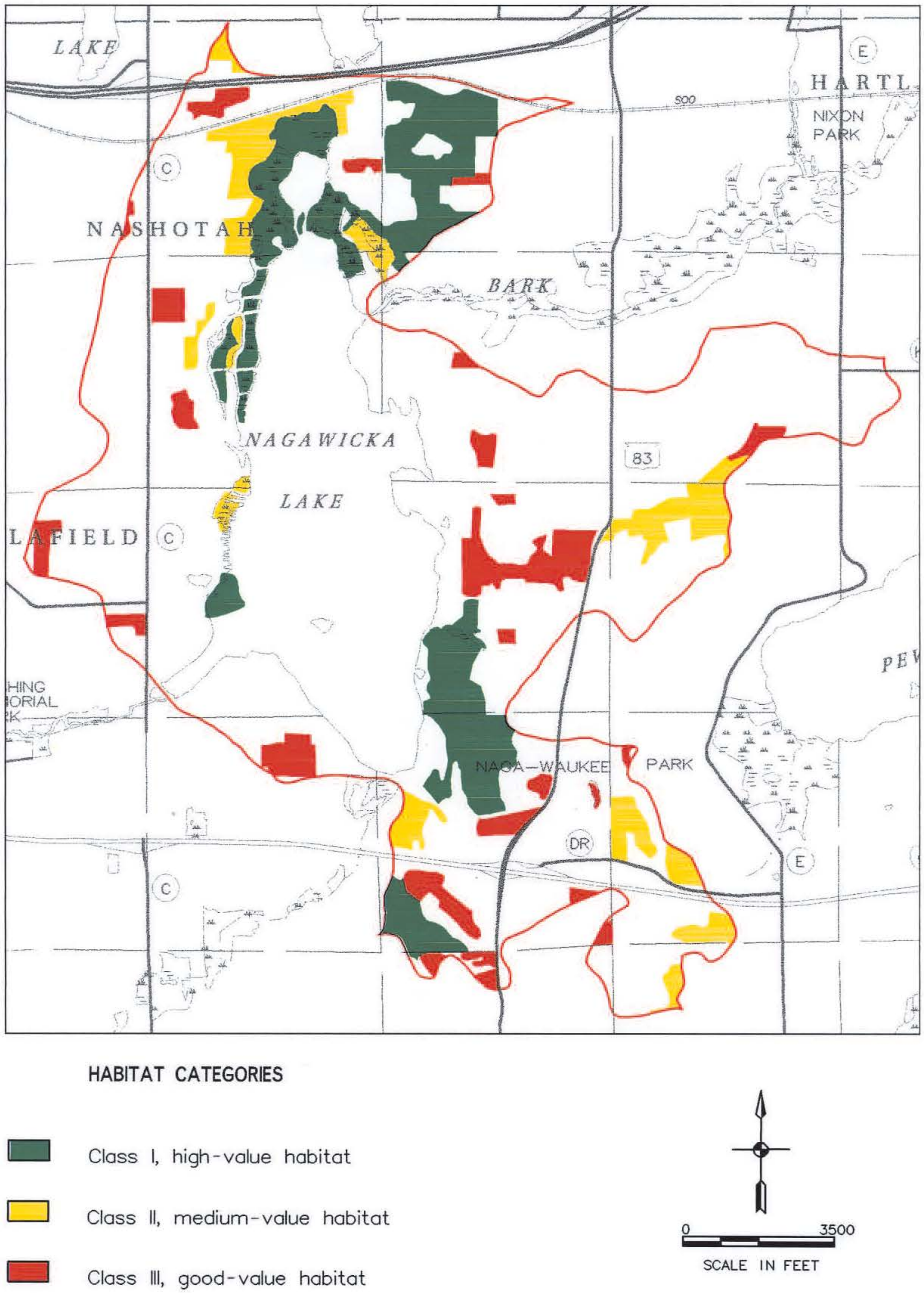
[c]*Identified as threatened in Wisconsin.*

[d]*Unverified sighting.*

Source: Wisconsin Department of Natural Resources, Kettle Moraine State Forest, Lapham Peak Unit, The Wisconsin Herpetological Atlas, and SEWRPC.

Map 20

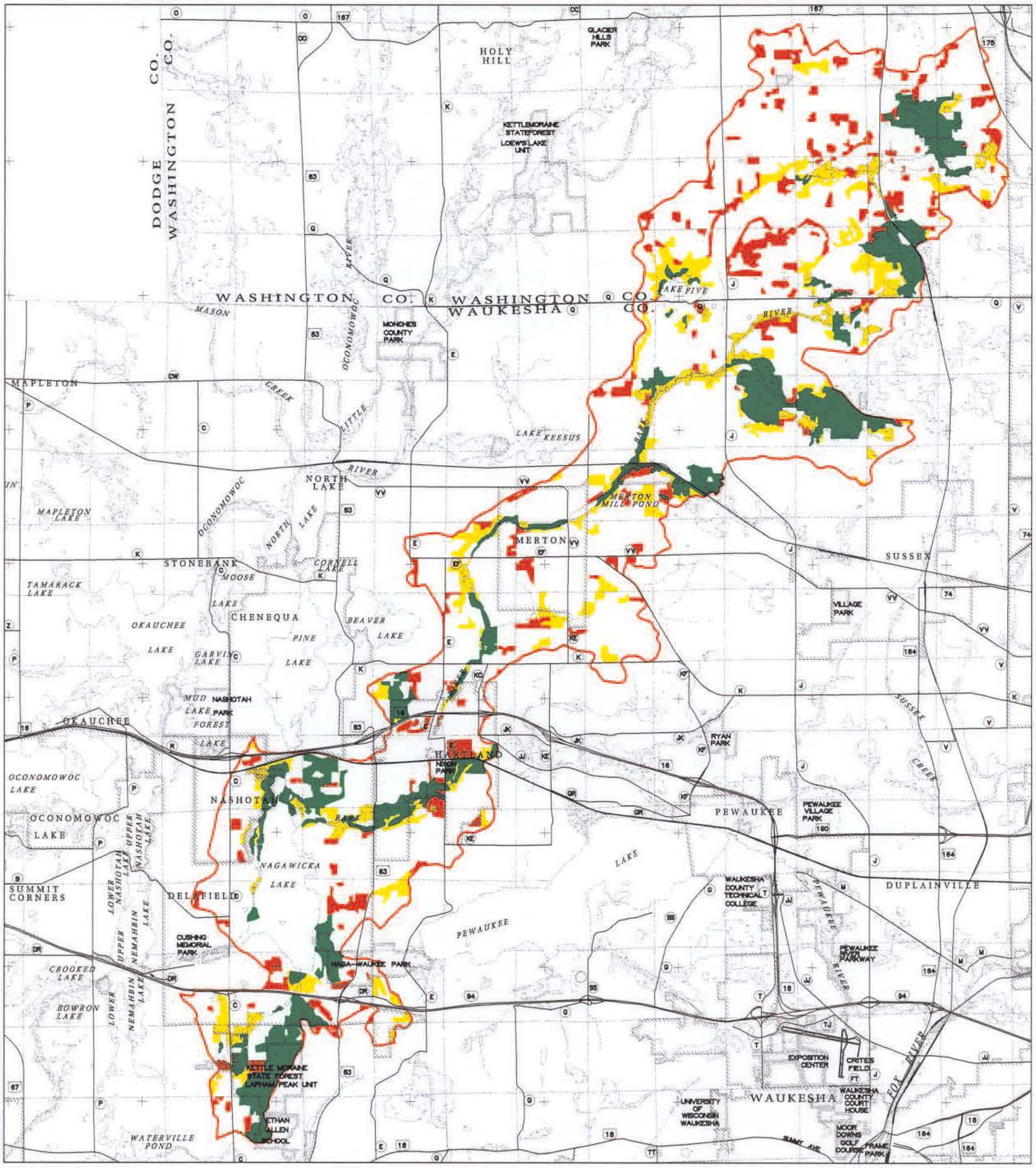
WILDLIFE HABITAT AREAS WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1985



Source: SEWRPC.

Map 21

WILDLIFE HABITAT AREAS WITHIN THE TOTAL TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1985



HABITAT CATEGORIES

Class I, high-value habitat

Class II, medium-value habitat

Class III, good-value habitat

0 1 2
Scale in miles

Source: SEWRPC.

Another definition, which is applied by the State of Wisconsin Department of Natural Resources and which is set forth in Chapter 23 of the *Wisconsin Statutes*, defines a wetland as "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which has soils indicative of wet conditions." In practice, the Department definition differs from the Regional Planning Commission definition in that the Department considers very poorly drained, poorly drained, and some of the somewhat poorly drained soils as wetland soils meeting the Department "wet condition" criterion. The Commission definition only considers the very poorly drained and poorly drained soils as meeting the "hydric soil" criterion. Thus, the State definition as actually applied is more inclusive than the Federal and Commission definitions in that the Department may include some soils that do not show hydric field characteristics as wet soils capable of supporting wetland vegetation, a condition which may occur in some floodlands.[5]

As a practical matter, experience has shown that application of the Wisconsin Department of Natural Resources, the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, and the Regional Planning Commission definitions, produce reasonably consistent wetland identifications and delineations in the majority of situations within the Southeastern Wisconsin Region. That consistency is due in large part to the provision in the Federal wetland delineation manual which allows for the application of professional judgement in cases where satisfaction of the three criteria for wetland identification is unclear.

Wetlands in Southeastern Wisconsin are classified predominantly as deep marsh, shallow marsh, southern sedge meadow, fresh (wet) meadow, shrub carr, alder thickets, low prairie, fens, bogs, southern wet- and wet-mesic hardwood forest, and conifer swamp. Wetlands form an important part of the landscape in and adjacent to Nagawicka Lake in that they perform an important set of natural functions that make them ecologically and environmentally invaluable resources. Wetlands affect the quality of water by acting as a filter or a buffer zone allowing silt and sediments to settle out. They also influence the quantity of water by providing water during periods of drought and holding it back during periods of flood. When located along shorelines of lakes and streams, wetlands help protect those shorelines from erosion. Wetlands also may serve as groundwater discharge and recharge areas in addition to being important resources for overall ecological health and diversity by providing essential breeding and feeding grounds, shelter, and escape cover for many forms of fish and wildlife.

Wetlands are poorly suited to urban use. This is due to the high soil compressibility and instability, high water table, low load-bearing capacity, and high shrink-swell potential of wetland soils, and, in some cases, to the potential for flooding. In addition, metal conduits placed in some types of wetland soils may be subject to rapid corrosion. These constraints, if ignored, may result in flooding, wet basements and excessive operation of sump pumps, unstable foundations, failing pavements, broken sewer and water lines, and excessive infiltration of clear water into sanitary sewerage systems. In addition, there are significant onsite preparation and maintenance costs associated with the development of wetlands, particularly as they relate to roads, foundations, and public utilities.

The Regional Planning Commission maintains an inventory of wetlands within the Region which is updated every five years. As shown on Map 22, in 1990, wetlands covered about 140 acres, or 3 percent, of the drainage area directly tributary to Nagawicka Lake. There were about 2,800 acres of wetlands in the total drainage area tributary to Nagawicka Lake. The amount and distribution of wetlands in the area should remain relatively constant if the recommendations contained in the adopted regional land use plan are followed.

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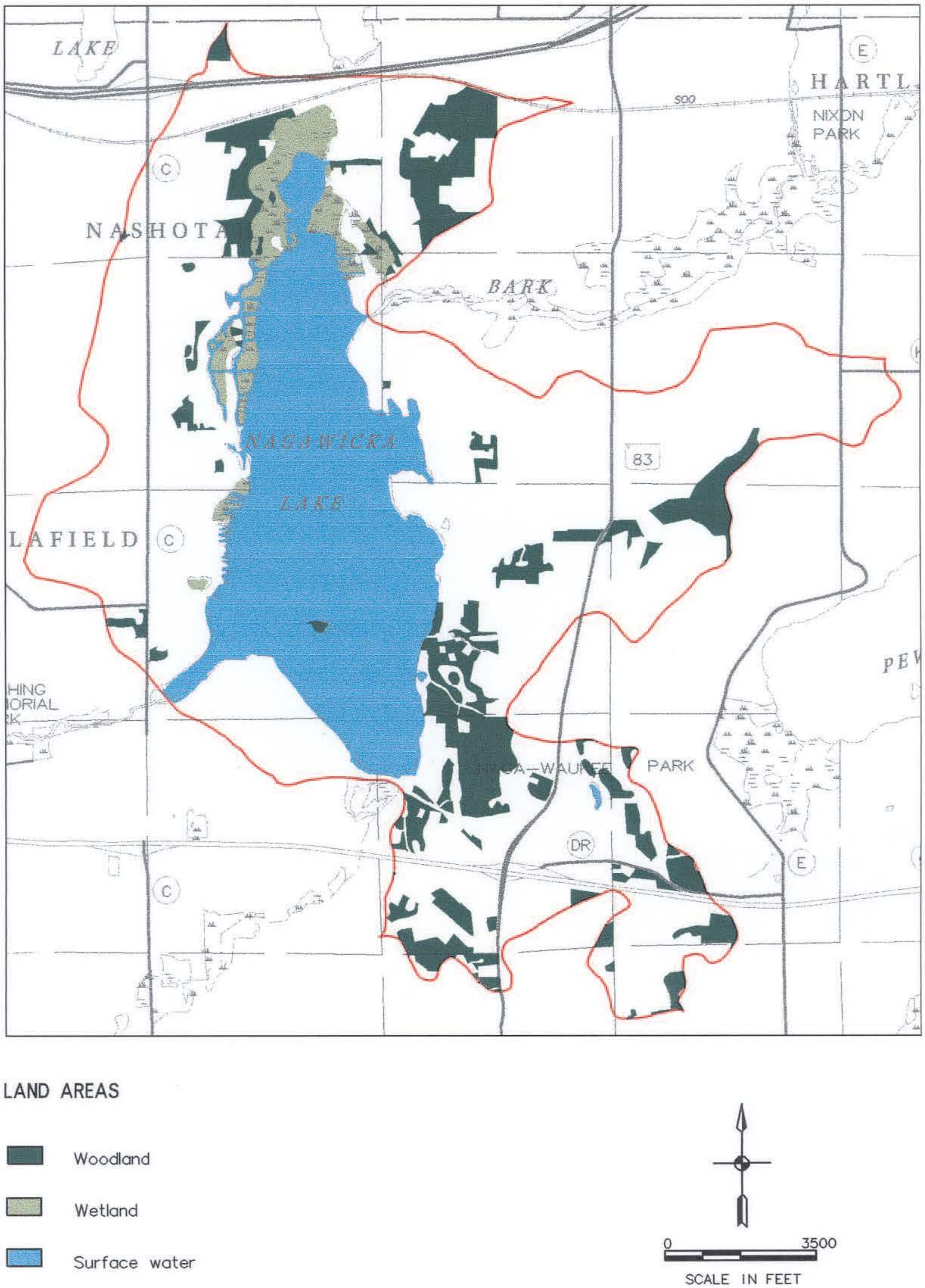
[5]*Although prior converted cropland is not subject to Federal wetland regulations unless cropping ceases for five consecutive years and the land reverts to a wetland condition, the State may consider prior converted cropland to be subject to State wetland regulations if the land meets the criteria set forth in the State wetland definition before it has not been cropped for five consecutive years.*

Map 22

WOODLANDS AND WETLANDS WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1990



Source: SEWRPC.

WOODLANDS

Woodlands are defined by the Regional Planning Commission as those areas containing a minimum of 17 trees per acre with a diameter of at least four inches at breast height (4.5 feet above the ground).[6] The woodlands are classified as dry, dry-mesic, mesic, wet-mesic, wet hardwood, and conifer swamp forests; the last three are also considered wetlands. The Regional Planning Commission also maintains an inventory of woodlands within the Region which is updated every five years. In the drainage area directly tributary to Nagawicka Lake, shown on Map 22, approximately 535 acres of woodland were inventoried in 1990. These woodlands covered about 11 percent of the drainage area. About 3,000 acres of woodlands were present in the total drainage area tributary to Nagawicka Lake.

The major tree species include the black willow (*Salix nigra*), cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), silver maple (*Acer saccharinum*), American elm (*Ulmus americana*), basswood (*Tilia americana)*, northern red oak (*Quercus rubra*), and shagbark hickory (*Carya ovata*). Some isolated stands of tamarack (*Larix laricina*) also exist in the drainage area, together with such other upland species as the white oak (*Quercus alba*), burr oak (*Quercus macrocarpa*), black cherry (*Prunus serotina*), and sugar maple (*Acer saccharum*).

The amount and distribution of woodlands in the area should also remain relatively stable if the recommendations contained in the Waukesha County development and regional land use plans are followed. If, however, urban development is allowed to continue within the watershed much of the remaining woodland cover may be expected to be lost.

ENVIRONMENTAL CORRIDORS

One of the most important tasks undertaken by the Regional Planning Commission in its work program has been the identification and delineation of those areas of the Region having concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, as such, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base per se, are closely related, to or centered on, that base and, therefore, are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

In Southeastern Wisconsin, the delineation of these 12 natural resource and natural resource-related elements on maps results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the aforementioned important resource and resource-related elements and are, by definition, at least 400 acres in size, two miles in length, and 200 feet in width. The primary environmental corridors identified in the Nagawicka Lake drainage area are contiguous with environmental corridors and isolated natural areas lying within the Bark River watershed, and, consequently, meet these size and natural resource element criteria.

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[6]*SEWRPC* Technical Record*, Vol. 4, No. 2, March 1981*.

It is important to note here that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of one element of the total environment may lead to a chain reaction of deterioration and destruction. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas in interconnected lake and stream ecosystems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater which serves as a source of domestic, municipal, and industrial water supplies and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation, and in more rapid runoff and increased flooding, as well as in the destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the Nagawicka Lake direct drainage area thus becomes apparent and critical.

Primary environmental corridors were first identified within the Region in 1963 as part of the original regional land use planning effort of the Commission and were subsequently refined under the Commission watershed studies and regional park and open space planning programs. The primary environmental corridors in Southeastern Wisconsin generally lie along major stream valleys and around major Lakes and contain almost all the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all the major bodies of surface water and related undeveloped floodlands and shorelands.

Primary Environmental Corridors

Primary environmental corridors in the Nagawicka Lake drainage area are shown on Map 23. About 1,625 acres, or 34 percent, of the drainage area directly tributary to the Lake were identified as primary environmental corridor. An additional 80 acres, or 2 percent of the drainage area, were identified as isolated natural features located within the drainage area. In the total drainage area tributary to Nagawicka Lake, about 6,500 acres, or 22 percent of the drainage area, were identified as primary environmental corridors; 285 acres, or about 1 percent of the drainage area, were identified as secondary environmental corridors; and, about 610 acres, or 2 percent of the drainage area, were identified as isolated natural features.

Environmental corridors are subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors not only tends to destroy the very resources and related amenities sought by the development, but also tends to create severe environmental and developmental problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems. The preservation of as yet undeveloped corridors is one of the major ways in which the water quality can be protected and perhaps improved at relatively little additional cost to the taxpayers of the area.

In the Nagawicka Lake drainage area, the river banks and lakeshores located within the environmental corridors should be candidates for immediate protection through proper zoning or through public ownership. Of the areas not already publicly owned, the remaining areas of natural shoreline, and riparian wetland areas, are perhaps the most sensitive areas in need of greatest protection. In this regard, the regional natural areas and critical species habitat protection and management plan recommends public acquisition of specific lands.[7] Within the drainage area directly tributary to Nagawicka Lake, extension of the Wisconsin Department of Natural Resources Nagawicka Lake Bog and Oak Woods project area and acquisition of the Bark River School Sedge Meadow by

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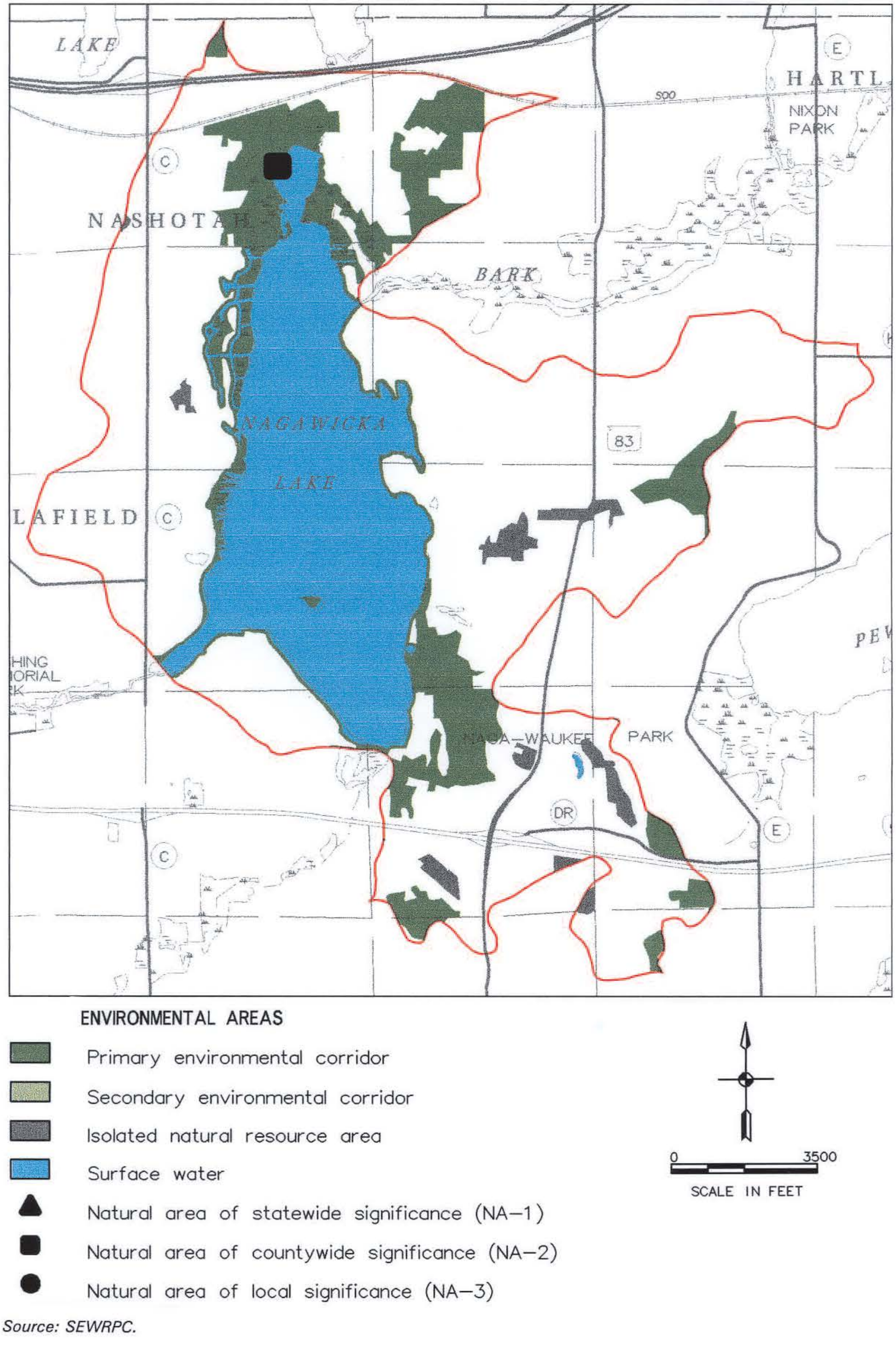
[7]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

Map 23

ENVIRONMENTAL CORRIDORS AND NATURAL AREAS WITHIN THE DIRECT TRIBUTARY DRAINAGE AREA TO NAGAWICKA LAKE: 1990



Source: SEWRPC.

Waukesha County, totaling 92 acres, is specifically recommended. Within the total tributary drainage area to the Lake, extension of public ownership of the Thousand Oaks Tamarack relict site by the Town of Lisbon and the Lisbon Low Woods by Waukesha County, totaling an additional 274 acres, is recommended. In addition to these sites recommended for public acquisition for environmental protection purposes, the acquisition of several additional sites by private conservation organizations, including The Nature Conservancy, is recommended. These sites include the Sussex Swamp, totaling 147 acres, in the Town of Lisbon, Waukesha County, and the Amy Belle Lake Lowlands, Colgate Shrub-Carr, and Lake Five Woods, totaling 227 acres, in the Town of Richfield, Washington County.

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Chapter VI

CURRENT WATER USES AND WATER USE OBJECTIVES

INTRODUCTION

Nearly all major lakes in the Southeastern Wisconsin Region serve multiple purposes, ranging from recreation to receiving waters for stormwater runoff. Recreational uses range from noncontact, passive recreation, such as picnicking and walking along the shoreline, to full-contact, active recreation, such as swimming and waterskiing. Water use objectives and supporting water quality standards have been adopted by the Southeastern Wisconsin Regional Planning Commission as set forth in the adopted regional water quality management plan[1] for all major lakes and streams in the Region. The current water uses, as well as the water use objectives and supporting water quality standards for Nagawicka Lake, are discussed in this chapter.

RECREATIONAL USE

Existing Recreational Use and Facilities

Nagawicka Lake provides an ideal setting for the provision of parks and open space sites and facilities. There is a publicly owned open space and lake access site along the Nagawicka Lake shoreline, the Nagawaukee County Park. This site includes a public recreational boating access site, a golf course, picnicking areas, hiking and cross-country skiing trails, and public swimming beach. A City of Delafield public park, Fireman's Park, and a public boat launching site at Bleeker Street also exists around the lakeshore. Privately owned sites with boat access and mooring facilities include the Nagawicka Shores Condominium marina, and Nagawicka Yacht Club. These sites are shown on Map 24. Existing recreational facilities in the vicinity of Nagawicka Lake, including surrounding park areas situated off the lakeshore, are also shown on Map 24.

The county-owned lake-access site is on the southeastern shore of Nagawicka Lake, providing a boat-launching area and swimming area. The city-owned lake-access site is on the southwestern shore of Nagawicka Lake, providing a boat-launching area and service area for the City's aquatic plant harvester. The Nagawicka Lake Bog and Oak Wood State Natural Area, adjoining the northern shoreline of Nagawicka Lake, is a portion of a 156-acre reserve comprising a tamarack bog. This bog contains relict plant species, such as pitcher plant, sundew, bogbean, moccasin-flower orchid, and starflower.

Water-based outdoor recreational activities on Nagawicka Lake include boating, fishing, swimming, and other active and passive recreational pursuits. Because of its size, Nagawicka Lake receives a significant amount of powerboat usage. Boat surveys conducted on June 26 and July 19, 1997, indicated that a total of 54 and 121 watercraft of various types—fishing, pleasure, skiing, and sailing vessels and personal watercraft—were in use on the Lake on weekdays and weekend days, respectively, as set forth in Table 25. In addition, more than 1,050 boats were moored on the Lake or stored on shore. Most of the watercraft not in use were fishing boats, about 300 craft; pontoon boats, about 250 craft; and power boats, about 150 craft, with lesser numbers of sailboats, about 115 craft; paddle boats, about 100 craft; canoes, about 75 craft; and personal watercraft ("jetskis"), about 70 craft.

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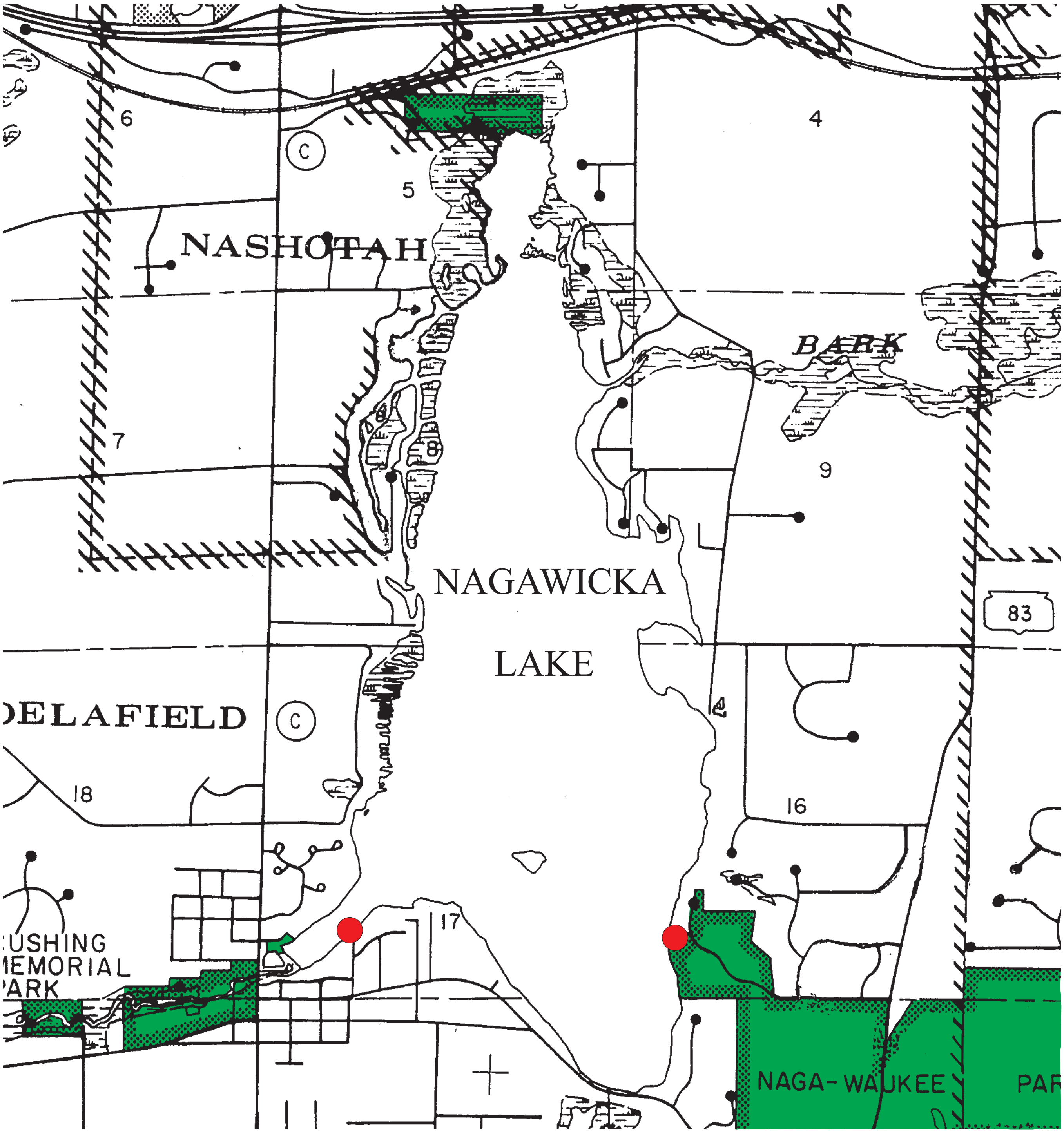
[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume One,* Inventory Findings, *September 1978; Volume Two,* Alternative Plans, *February 1979; and Volume Three,* Recommended Plan, *June 1979. See also SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

Map 24

PARKS AND BOAT ACCESS SITES ON NAGAWICKA LAKE: 1998



LEGEND

PUBLIC BOATING ACCESS

PUBLIC PARKS AND RECREATIONAL AREAS

Source: SEWRPC.

Table 25

RECREATIONAL USE SURVEY ON NAGAWICKA LAKE: 1997

Date and Time	Weekday Boating Activity (number of watercraft in use)					Other (nonboating uses)[a]	Total
	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing		
June 26, 1998							
11:00-11:30 a.m.	11	4	- -	9	- -	37	61
4:00-4:30 p.m.	6	17	3	- -	4	48	78
Total	17	21	3	9	4	85	139
Mean	9	11	2	5	2	43	70

Date and Time	Weekend Boating Activity (number of watercraft in use)					Other (nonboating uses)[a]	Total
	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing		
July 19, 1997							
10:45-11:30 a.m.	17	14	11	- -	14	8	64
1:00-4:00 p.m.	19	29	15	2	- -	196	261
Total	36	43	26	2	14	204	325
Mean	18	21	13	1	7	102	161

[a]*Nonboating uses include persons fishing from shore, picnicking, walking, swimming, and sight-seeing.*

Source: SEWRPC.

Seasonal community and private events and activities take advantage of the aesthetic qualities of the Lake. Ice fishing, cross-country skiing, and snowmobiling are popular winter pastimes on Nagawicka Lake.

It is important to note that the provision of park and open space sites within the drainage area tributary to Nagawicka Lake should be guided, to a large extent, by the recommendations contained in the Waukesha County development plan.[2] The purpose of that plan, in part, is to guide the preservation, acquisition, and development of land for park, outdoor recreation, and related open space purposes and to protect and enhance the underlying and sustaining natural resource base of the City and Village. With respect to the Nagawicka Lake drainage area, including the lands along the Bark River and the shoreline of Nagawicka Lake, the plan recommends the maintenance of existing park and open space sites in the area, and the development of a portion of the Bark River Parkway linking the Lake with other regional trail systems. In addition, the plan recommends that the undeveloped lands in the primary environmental corridor drainage area tributary to Nagawicka Lake be retained and maintained as natural open space.

Wisconsin Department of Natural Resources Recreational Rating

A recreational rating technique has been developed by the Wisconsin Department of Natural Resources to characterize the recreational value of inland lakes. As shown in Table 26, Nagawicka Lake received 63 out of the

[2]*SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996; see also SEWRPC Community Assistance Planning Report No. 137,* A Park and Open Space Plan for Waukesha County, *December 1989.*

Table 26

WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECREATIONAL RATING OF NAGAWICKA LAKE

Space: Total Area917 acres			Total Shore Length7.0 miles		
Ratio of Total Area to Total Shore Length0.20					
Quality (18 maximum points for each item)					
Fish:					
X 9	High production	__ 6	Medium production	__ 3	Low production
__ 9	No problems	X 6	Modest problems, such as infrequent winterkill, small rough fish problems	__ 3	Frequent and overbearing problems, such as winterkill, carp, excessive fertility
Swimming:					
X 6	Extensive sand or gravel substrate (75 percent or more)	__ 4	Moderate sand or gravel substrate (25 to 50 percent)	__ 2	Minor sand or gravel substrate (less than 25 percent)
X 6	Clean water	__ 4	Moderately clean water	__ 2	Turbid or darkly stained water
__ 6	No algae or weed problems	X 4	Moderate algae or weed problems	__ 2	Frequent or severe algae or weed problems
Boating:					
X 6	Adequate water depths (75 percent of basin more than five feet deep)	__ 4	Marginally adequate water depths (50 to 75 percent of basin more than five feet deep)	__ 2	Inadequate depths (less than 50 percent of basin more than five feet deep)
X 6	Adequate size for extended boating (more than 1,000 acres)	__ 4	Adequate size for some boating (200 to 1,000 acres)	__ 2	Limit of boating challenge and space (less than 200 acres)
__ 6	Good water quality	X 4	Some inhibiting factors, such as weedy bays, algae blooms, etc.	__ 2	Overwhelming inhibiting factors, such as weed beds throughout
Aesthetics:					
X 6	Existence of 25 percent or more wild shore	4	Less than 25 percent wild shore	__ 2	No wild shore
X 6	Varied landscape	__ 4	Moderately varied	__ 2	Unvaried landscape
__ 6	Few nuisances, such as excessive algae carp, etc.	X 4	Moderate nuisance conditions	__ 2	High nuisance condition
Total Quality Rating: 63 out of a possible 72					

Source: Wisconsin Department of Natural Resources and SEWRPC.

possible 72 points, indicating that moderately diverse recreational opportunities are provided by the Lake. Favorable features include the boating and angling opportunities provided. In contrast, unfavorable features include extensive aquatic macrophyte growths in portions of the Lake. In general, Nagawicka Lake provides good opportunities for a variety of outdoor recreational activities, particularly boating, fishing, and aesthetic enjoyment.

Recreational Use Conclusions

The scope of uses engaged in on Nagawicka Lake is sufficiently broad to be consistent with the recommended use objectives of full recreational use and the support of a healthy warmwater sport fishery, as set forth in the regional water quality management plan.

WATER USE OBJECTIVES

The regional water quality management plan recommended the adoption of full recreational and warmwater sport fisheries objectives for Nagawicka Lake. The findings of the inventories of the natural resource base, set forth in Chapters III through V indicate that the use of the Lake and the resources of the area are generally supportive of such objectives, although it is expected that remedial measures will be required if the Lake is to fully meet the objectives.

The recommended warmwater sport fishery objective is supported in Nagawicka Lake by a sport fishery based largely on largemouth bass and panfish. These fishes have traditionally been sought after in Nagawicka Lake.

WATER QUALITY STANDARDS

The water quality standards supporting the warmwater fishery and full recreation use objectives as established for planning purposes in the regional water quality management plan, are set forth in Table 27. These standards are similar to those set forth in Chapters NR 102 and 104 of the *Wisconsin Administrative Code*, but were refined for planning purposes in terms of their application. Standards are recommended for temperature, pH, dissolved oxygen, fecal coliforms, and total phosphorus. These standards apply to the epilimnion of the lakes and to streams. The total phosphorus standard applies to spring turnover concentrations measured in the surface waters. Such contaminants as oil, debris, scum; or odor, taste, and color-producing substances; and toxins are not permitted in concentrations harmful to the aquatic life as set forth in Chapters NR 102 of the *Wisconsin Administrative Code*.

The adoption of these standards is intended to specify conditions in the waterways concerned that mitigated against excessive macrophyte and algal growths and promoted all forms of recreational use, including angling, in these waters.

Table 27

RECOMMENDED WATER QUALITY STANDARDS TO SUPPORT
RECREATIONAL AND WARMWATER FISH AND AQUATIC LIFE USE

Water Quality Parameter	Water Quality Standard
Maximum Temperature	89EF[a,b]
pH Range	6.0-9.0 standard units
Minimum Dissolved Oxygen	5.0 mg/l[b]
Maximum Fecal Coliform	200/400 MFFCC/100 ml[c]
Maximum Total Residual Chlorine	0.01 mg/l
Maximum Un-ionized Ammonia Nitrogen	0.02 mg/l
Maximum Total Phosphorus	0.02 mg/l[d]
Other	- -[e,f]

[a]*There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 3EF for lakes.*

[b]*Dissolved oxygen and temperature standards apply to the epilimnion of stratified lakes and to the unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inland lakes. Trends in the period of anaerobic conditions in the hypolimnion of stratified inland lakes should be considered important to the maintenance of water quality, however.*

[c]*The membrane filter fecal coliform count per 100 milliliters (MFFCC/100 ml) shall not exceed a monthly geometric mean of 200 per 100 ml based on not less than five samples per month, nor a level of 400 per 100 ml in more than 10 percent of all samples during any month.*

[d]*This standard for lakes applies only to total phosphorus concentrations measured during spring when maximum mixing is underway.*

[e]*All waters shall meet the following minimum standards at all times and under all flow conditions: Substances that will cause objectionable deposits on the shore or in the bed of any body of water shall not be present in such amounts as to interfere with public rights in waters of the State. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the State. Materials producing color, odor, taste, or unsightliness shall not be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[f]*Unauthorized concentrations of substances are not permitted that alone or in combination with other material present are toxic to fish or other aquatic life. Standards for toxic substances are set forth in Chapter NR 105 of the Wisconsin Administrative Code.*

Source: SEWRPC.

Chapter VII

SUMMARY

This lake and watershed inventory was cooperatively prepared by the Southeastern Wisconsin Regional Planning Commission, the City of Delafield Lake Welfare Committee, and the Wisconsin Department of Natural Resources. The planning effort incorporated the results of the Wisconsin Department of Natural Resources Long-Term Trends water quality sampling program commenced in 1986 and aquatic plant and recreational use inventories conducted by the Regional Planning Commission staff in 1997. In addition, supplemental water quality data, and inventories of existing and future recommended land use patterns within the watershed of the Lake, the physiography and natural resource base of the watershed, recreational uses of the Lake, and the existing management practices in the watershed were compiled by Commission staff, and analyzed.

The primary objectives of this inventory are: 1) to contribute to the overall conservation and wise use of Nagawicka Lake through the compilation of information on the physical characteristics and natural resources of the Lake and its watershed; 2) to identify and document the water-based recreational experiences of residents and visitors to the Lake; and 3) to quantify the severity of nuisance resulting from recurring excessive aquatic macrophyte growth and impacts of sediments in portions of the Lake basin. The objectives of this inventory are set within the longer-term objective of improving water quality, water-based recreation, and aesthetic value of the Lake, and to enhance its resource value. This inventory should serve as a component of a lake management plan that will guide management actions relative to Nagawicka Lake over time and in such a way as to contribute to achieving the lake management objectives established for the Lake in a technically sound manner. Lake protection and rehabilitation measures to meet these objectives will be developed within the framework of a comprehensive lake management plan to be prepared during Phase II of this planning program. This planning program is summarized in the project description appended hereto as Appendix A.

Nagawicka Lake, a 917-acre drainage lake on the Bark River, a tributary of the Rock River, is located upstream of the Nemahbin Lakes and downstream of Bark Lake, within the City of Delafield and Village of Nashotah, in Waukesha County. The Lake level is controlled by two outlet structures and a mill race located on the southwestern shore of the Lake. The outlet structures have variable discharge elevations which maintain a mean depth of 36 feet in the Lake. The Lake’s total tributary drainage area is about 45 square miles in areal extent.

Nagawicka Lake is a deep water, dimictic, meso-eutrophic waterbody with water quality varying from poor to good, depending upon the indicator considered, and a relatively slow through-flow of water. These characteristics contribute to increasing concerns regarding water quality and recreational use potentials of Nagawicka Lake.

INVENTORY AND ANALYSIS FINDINGS

Land Use

- As of 1990, approximately 22,500 acres, or about 78 percent, of the total tributary drainage area were still in rural land uses, with the dominant rural land use being agricultural uses, comprising 12,800 acres, or 44 percent of the total drainage area tributary to the Lake. The remaining rural land uses—wetlands, woodlands, and open lands—constituted about 9,700 acres, or 34 percent of the total drainage area.

- As of 1990, approximately 6,250 acres, or 22 percent of the tributary drainage area, were in urban land uses, with the dominant urban land use being residential uses, comprising 5,000 acres, or 17 percent of the total drainage area tributary to the Lake. Commercial, industrial, recreational, and other urban land uses comprised about 1,250 acres, or about 4 percent of the total drainage area tributary to the Lake.

- The Waukesha County development plan and regional land use plan forecast about 4,700 acres of additional urban development within the total tributary drainage basin. About 4,000 acres of this new urban development is expected to be in residential uses. Thus, a significant portion of the rural lands outside of the environmental corridors, environmentally sensitive areas, and prime agricultural lands would be in residential and other urban use under full buildout conditions, particularly in that portion of the drainage basin directly tributary to the Lake.

- Sanitary and household wastewaters from that portion of the drainage area directly tributary to the Lake are treated and disposed of through a public sanitary sewerage system operated by the City of Delafield and Village of Nashotah, and connected to the Delafield-Hartland Water Pollution Control Commission (Dela-Hart) sewerage system for treatment purposes. In addition, the Village of Hartland, within the upstream tributary drainage area, is served by a public sanitary sewer system which is also connected to the Dela-Hart sewerage system. Wastewaters from elsewhere in the tributary drainage area are generally disposed of through the use of onsite sewage disposal systems.

Water Budget

- It is estimated that an average of about 29,000 acre-feet of water enters Nagawicka Lake per year. Of this total, about 26,000 acre-feet of water, or about 90 percent, was contributed by inflow from the Bark River and other surface and groundwater sources; and about 3,000 acre-feet, or 10 percent, was contributed by direct precipitation onto the lake surface.

- Of the total water output from Nagawicka Lake of about 29,000 acre-feet, approximately 26,700 acre-feet, or about 90 percent, was discharged via the Bark River and groundwater outflows, and about 2,300 acre-feet, or about 10 percent, evaporated from the surface of the lake.

Water Quality

- Water quality data collected during the 1972 through 1997 study period indicated that Nagawicka Lake has water quality which was characterized as ranging from poor to good compared to other lakes in Southeastern Wisconsin, based upon the primary water quality indicators, total phosphorus and chlorophyll-a concentrations and Secchi-disk transparency.

- Temperature and dissolved oxygen profiles indicate that complete mixing of Nagawicka Lake is seasonally restricted by thermal stratification which occurs during summer and winter.

- In Nagawicka Lake, the mean concentration of total phosphorus in the spring was about 0.02 milligram per liter (mg/l), which is at the Commission-recommended water quality threshold for recreational use and the maintenance of warmwater fish and aquatic life. This standard recommend that total phosphorus concentrations not exceed 0.02 mg/l during the spring turnover.

- Based on these data, Nagawicka Lake is classified as meso-eutrophic, a term describing a moderately fertile lake ecosystem that is typical of lakes in Southeastern Wisconsin.

Pollutant Loadings

- The total phosphorus load to Nagawicka Lake was calculated to be approximately 13,000 pounds using the Wisconsin Department of Natural Resources WILMS model. Of this total, 99 percent is estimated to be contributed from the land surface, and about 1 percent from direct precipitation onto the lake surface and onsite sewage disposal systems in the total drainage area tributary to the Lake. Of this mass, about 1,580 pounds of phosphorus was transported out of Nagawicka Lake by the Bark River.

Sediment Quality

- In Nagawicka Lake, the sediment nitrate-nitrogen concentration was about one milligram per kilogram (mg/kg); nitrite-nitrogen was about 0.4 mg/kg; and ammonia-nitrogen ranged from 111 mg/kg to 147 mg/kg. Sediment total nitrogen concentrations ranged from 1,530 mg/kg to 3,570 mg/kg.

- Sediment arsenic concentrations, possibly in part the result of historic aquatic plant management activities which applied about 87,200 pounds of sodium arsenite to the Lake between 1950 and 1963, ranged from 0.7 mg/kg to 2.1 mg/kg. Sediment copper concentrations, also possibly in part the result of historic aquatic plant management activities, ranged from six to 11 mg/kg.

- These concentrations exceeded the recommended lowest effect level (LEL) guideline concentrations established by the Wisconsin Department of Natural Resources as indicative of contaminated sediments only in the case of ammonia-nitrogen; the concentrations of the other elements were less than the LEL guideline concentrations for contaminated sediments.

Natural Resource Base

- As of 1990, wetlands covered about 2,700 acres, or about 9 percent, of the total drainage area tributary to the Lake. Woodlands covered an additional 2,900 acres, or about 10 percent of the total drainage area tributary to the Lake.

- Approximately 7,900 acres, or about 27 percent, of the total drainage area tributary to Nagawicka Lake were identified as wildlife habitat: about 3,300 acres as Class I habitat, 2,700 acres as Class II habitat, and 1,900 acres as Class III habitat.

- Primary environmental corridor lands covered about 5,200 acres, or about 18 percent, of the total drainage area tributary to Nagawicka Lake. About 285 acres of the land classified as secondary environmental corridor and about 600 acres of the land classified as isolated natural areas were also identified in the drainage basin. These corridor areas include almost all the remaining high-value woodlands, wetlands, and wildlife habitat areas in and around Nagawicka Lake, including those critical species habitats and natural areas determined to have local, regional or Statewide significance.

Public Access

- In 1990, there were two public access site on Nagawicka Lake, two privately owned boating access sites, and a Waukesha County park situated on the lakeshore.

- In 1997, more than 1,050 watercraft were observed by Commission staff to be present in and around Nagawicka Lake. Of these, between 24 and 30 were in active use during the week and between 56 and 65 during the weekend.

- In a recreational rating technique developed by the Wisconsin Department of Natural Resources to characterize the recreational value of inland lakes, Nagawicka Lake received 63 out of the possible 72 points, indicating that relatively diverse recreational opportunities are provided by the Lake.

Nagawicka Lake is a valuable natural resource in the Southeastern Wisconsin Region. Nevertheless, the delicate, complex relationship between the water quality conditions in Nagawicka Lake and the land uses within its tributary drainage area is likely to be subject to ongoing pressures as demands for water-based recreation in the lake, and for residential development within its watershed, resulting from increases in population, income, leisure time, and individual mobility forecast for the Region, continue to grow into the foreseeable future. To provide the water quality protection needed to maintain conditions in Nagawicka Lake conducive to meeting such pressures, it will be necessary to adopt and administer an effective program of lake management including water quality, recreational use, aquatic plant, and watershed land management plans. This inventory forms an integral part of those plans.

In this regard, a comprehensive lake management plan, consistent with previously adopted comprehensive land use and water quality plans for the Southeastern Wisconsin Region,[1] is to be prepared as Phase II of the current planning program. Related stormwater and flood management plans for portions of the drainage area will also be considered in the planning process.

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[1]*SEWRPC Planning Report No. 40,* A Regional Land Use Plan for Southeastern Wisconsin—2010, *January 1992; SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Three,* Recommended Plan, *June 1979; and as refined in SEWRPC Memorandum Report No. 93, A* Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

APPENDICES

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Appendix A

PROPOSED WISCONSIN LAKE MANAGEMENT PLANNING GRANT PLANNING PROGRAM FOR NAGAWICKA LAKE, WAUKESHA COUNTY

PROJECT DESCRIPTION

INTRODUCTION

Nagawicka Lake is a 917-acre lake situated in the City of Delafield, Waukesha County. The Nagawicka Lake community has a long history of efforts by the residents to protect and improve the Lake's water quality. In addition to civic groups, such as the Nagawicka Lake Improvement Association, the City of Delafield Lake Committee has been formed to deal with issues surrounding water quality, lake uses, and landowner concerns, and provide advice to the Delafield City Council. This Committee, and through the Committee the City of Delafield, is being requested to consider and address lake-related, citizen concerns with increasing frequency. Further, as demands for lake property are steadily rising and nonresidential land is subsequently being subdivided and developed, Nagawicka Lake residents have become increasingly concerned about present and future impacts on the Lake and its ecosystem. Because of the widespread nature of these concerns, the City of Delafield has resolved that a comprehensive lake management plan be prepared for Nagawicka Lake.

Currently, the lake organizations participate in ongoing water quality monitoring programs, including the Wisconsin Department of Natural Resources (WDNR) sponsored Self-Help Monitoring program. Nagawicka Lake also is included in the WDNR Long-Term Trend Monitoring Program.[1] Previous studies related to lake water quality and lake use have included a recent aquatic plant survey and management plan prepared by Aron & Associates,[2] a WDNR fisheries creel survey,[3] and a quantification of the contaminant loadings to the Lake, as an intermediate body of water upstream of Upper Nemahbin Lake, by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) in 1995.[4] The data collected through these programs, as well as any necessary additional data such as those data on lake bottom sediments gathered pursuant to several completed or proposed dredging projects in the Lake, will be used in completing the proposed planning program effort: the formulation of a comprehensive lake management plan for Nagawicka Lake. This plan will serve as an effective basis for future lake management decisions affecting Nagawicka Lake.

The proposed program of study, set forth below, is designed as the second of a two-stage process of data gathering and analysis, and data synthesis and plan preparation. The format adopted below follows directly the format of Part II, Project Description of the Chapter NR 190 Lake Management Planning Grant program application, WDNR form 3200-86 Rev.10-95, and is appended thereto.

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[1]*Wisconsin Department of Natural Resources Report,* Nagawicka Lake, Waukesha County, Long Term Trend Lake: 1986*, 1986; Wisconsin Department of Natural Resources Report,* Nagawicka Lake, Waukesha County, Long Term Trend Lake: 1987*, 1987.*

[2]*Aron & Associates,* Nagawicka Lake Plant Management Plan*, August 1993.*

[3]*Wisconsin Department of Natural Resources Fish Management Report No. 131,* Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County, Summer 1982*, February 1987.*

[4]*SEWRPC Memorandum Report No. 101,* Upper Nemahbin Lake Watershed Inventory Findings, Waukesha County, Wisconsin*, May 1995.*

PROJECT DESCRIPTION

A. Reason for the Proposed Project

Nagawicka Lake is a heavily used, recreational lake situated within easy reach of the metropolitan areas of Milwaukee and Waukesha. The Lake is a popular destination for weekend recreational users from this conurbation, and is also a popular year-round residential area. As demands for lake property are steadily rising, and nonresidential land in the vicinity of the Lake is subsequently being subdivided and developed, Nagawicka Lake residents have become increasingly concerned about present and future impacts to the Lake and its ecosystem. The concerns raised have related to impacts such as decreased water clarity and accumulation of silt; loss of riparian wetlands; increased growth of aquatic plants; contamination of the lake waters by nonpoint source pollutants; user-related aesthetic degradation, such as shoreland modifications and in-fill development; and, surface water use conflicts. In order to better control these impacts, and provide for the continued recreational and residential use of the Lake, the lake users and residents have expressed a clear desire for the development of a lake management plan covering Nagawicka Lake and its watershed. To this end, the City of Delafield established a citizen-based Lake Committee to, among other things, consider the need for lake management planning, and made provision for the initiation of a lake management planning program in the City's 1997 budget. Lake management planning grant funds are therefore requested under this grant application to define the issues of concern and develop and evaluate a full range of remedial options leading to a comprehensive lake management plan for the Lake.

B. Project Goals

The overall goal of the proposed planning project is to produce a comprehensive lake management plan for Nagawicka Lake. The objectives of the planning project are:

1. To refine the description of existing conditions in the Nagawicka Lake watershed including identification and quantification of potential point and nonpoint sources of pollution, nutrient and contaminant inputs, and nutrient and contaminant balances;

2. To identify the extent of any existing and potential future water quality problems likely to be experienced in the Lake, including an assessment of the Lake's water quality using physical-chemical monitoring data being collected as part of ongoing water quality monitoring programs and estimates of changes in these conditions in the future;

3. To assess the degree and intensity of recreational water use in and around Nagawicka Lake, including the impacts of sediments and aquatic plants on the Lake ecosystem and Lake use; and

4. To formulate appropriate management actions, public information and education strategies, ordinances, and other possible responses to the identified problems.

Accomplishment of these goals will result in the production of a comprehensive lake management plan for the Lake and its watershed consistent with the objectives of Chapter NR 190, *Wisconsin Administrative Code*, and is part of an ongoing program of lake-related management actions being undertaken by the City of Delafield.

C. Project Description

Background

The proposed planning project for Nagawicka Lake is designed as part of a phased program of lake-related information gathering, evaluation, and lake management actions being undertaken by the City of Delafield in cooperation with other governmental and nongovernmental organizations and agencies. Several lake-related studies have been completed by these organizations pursuant to the first three planning program objectives set forth above. These studies have included an aquatic plant survey and a number of water quality studies completed with the assistance of the WDNR. In addition, the Nagawicka Lake Improvement Association is participating in the WDNR Self-Help Monitoring Program. Based on the information generated through these current and completed studies, funding is being requested for the development of a comprehensive lake management plan in order to maintain and improve the ecosystem.

The Phase I planning program was designed to conduct an assessment of the magnitude of the current and potential future lake management problems pursuant to project goals 1 through 3 as set forth above. The proposed Phase II planning program is designed to propose appropriate remedial measures pursuant to project goal 4 as set forth above.

Phase I Planning Program

Funding is requested for the conduct of planning studies relating to the overall lake management and planning program set forth above. Three elements were included in the Phase I program which formed the inventory and analysis stage of a two stage planning project consisting of six elements. The three elements of the Phase I program, enumerated below as Tasks 1 though 3, were completed during this Phase I planning program.

1. Compilation and Synthesis of Existing Water Quality and Quantity Data: This task will result in the collection, collation, evaluation, and synthesis of the data gathered during the various studies that have been completed on Nagawicka Lake, including the various reports generated by the DNR from data gathered during their Long-term Trend Monitoring Program, and data gathered by SEWRPC pursuant to the preparation of SEWRPC Planning Report No. 30, *A Regional Water Quality Management Plan for Southeastern Wisconsin—2000*, Volume Two, *Alternative Plans*, published in February 1979 and its current update, SEWRPC Memorandum Report No. 93, *A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, published in March 1995.

2. Water Quality Evaluation: Generally, field studies will be conducted to verify and refine various information obtained through the synthesis of studies outlined above. In addition, field inspections and site specific investigations will update and complete the limnological data base—including the lake's aquatic plant inventories—insofar as is necessary to identify existing and potential water quality problems manifested in Nagawicka Lake, to propose solutions to the water quality problems facing the Lake, and develop detailed planning recommendations to control and manage water quality, in-lake biological responses and recreational demands within the Lake. Field verification will also assist in identifying environmentally sensitive areas within the lake and watershed. These latter areas will be identified using protocols established by the Southeastern Wisconsin Regional Planning Commission for determining environmental corridors.

   Specifically, these field investigations will comprise:

   (1) Water quality studies of Nagawicka Lake that will continue during the currency of this planning program under the WDNR Self-help Monitoring and Long-Term Trends Monitoring Programs—These studies will be continued by the lake organizations and WDNR and will be used in this planning study;

   (2) Aquatic plant inventory of Nagawicka Lake—Inventory data collected by Aron & Associates pursuant to the preparation of an aquatic plant management plan for Nagawicka Lake, and additional data gathered by the WDNR pursuant to the Long-Term Trends Monitoring Program, will be reviewed and supplemented by SEWRPC staff to refine the WDNR sensitive area determinations and the aquatic plant management plan as necessary during this study;

   (3) Recreational use surveys of Nagawicka Lake—These surveys will be undertaken by SEWRPC staff and will quantify the types of uses made of the Lake, the frequency and duration of such uses and the relative demand for the various types of uses, including the recording of the portion of the Lake used for such activities, the area needed and the time required to perform such activities;

(4) Shoreline condition surveys of Nagawicka Lake—This survey will be undertaken by SEWRPC staff and will assess the degree of shoreline protection and relative stability;

(5) Refinement of the environmental corridors in the Nagawicka Lake watershed—A reconnaissance will be undertaken by SEWRPC staff to confirm inventory information on the state of the watershed; this reconnaissance will be undertaken with a view to assessing the extent of the watershed protection needs, and the relative environmental sensitivity of the Nagawicka Lake watershed.

3. Assessment of recreational use and recreational use demands on Nagawicka Lake: Based on the foregoing analyses and inventories, an assessment of the present and forecast future recreational use of Nagawicka Lake will be made. Such an assessment will guide the formulation of appropriate planning responses to the situation pertaining at Nagawicka Lake and take note of the legitimate demands of the lake residents for access to water-based recreational opportunities and maintenance of residential ambience, as determined by field investigations conducted under task (2). This assessment will also take due cognizance of the unique and valuable ecological features of this system, including the presence and maintenance of the bog in the northern portion of Nagawicka Lake.

Proposed Phase II Planning Program

Funding is now being requested for the conduct of planning studies relating to the overall lake management and planning program set forth above. Three elements are included in the proposed program for which grant funding is requested in terms of the Phase II grant application. The three elements for which funding is requested form the data synthesis and plan preparation stage of a two stage planning project consisting of six elements. The three elements of the proposed Phase II program, enumerated below as Tasks 4 though 6, will be completed during the Phase II planning program.

4. Determination of alternative in-lake water quality management actions: All of aforementioned data gathered during the Phase I planning program, together with the results of the data synthesis, field studies and recreational use surveys, will be used to formulate appropriate lake management actions specifically suited to the current and forecast conditions prevailing at Nagawicka Lake. The proposed assessment of alternative lake management actions will include:

(1) Review and analysis of reports and findings generated by previous studies—This review could include specific field investigations aimed at validating model forecasts generated during previous studies to ensure the continued validity of the order of magnitude estimates of the extent of the problems and remedial efforts required to stabilize or rehabilitate Nagawicka Lake recently developed by the Southeastern Wisconsin Regional Planning Commission and others.

(2) Identification of the range of possible management options that could be applied to Nagawicka Lake, with varying levels and degrees of intervention—The management options identified will include consideration of potential development, present and potential water quality and water pollution, desired water uses, public concerns, and varying degrees of the maintenance of plant and animal communities within the Nagawicka Lake watershed.

(3) Determination of the technical feasibility of the options once a comprehensive list of possible management options has been identified.

(4) Evaluation of feasible options to determine their cost, effectiveness and impact period following their implementation but preceding any anticipated beneficial result.

(5) Selection of those options that have the best chance of being successful in meeting the desired use goals set by the community for further consideration by the City of Delafield Lake Committee and community.

(6) Formulation of the most effective and acceptable options into a strategy for the management of Nagawicka Lake that is agreeable to community members, local decision-makers, and other interested parties.

5. Identification of future community information needs: The proposed planning program will recognize the importance of an informed and aware citizenry within the Nagawicka Lake area of the City of Delafield and Village of Nashotah. To this end, at least two public information meetings are proposed for the grant period. The purpose of these meetings will be to inform the Nagawicka Lake residents of the nature of the proposed planning program, its conduct and anticipated outcomes, and to convey to the Nagawicka Lake residents the findings of the lake management planning studies. It is expected that these meetings will be interactive—the concerns voiced by the lake residents will be used to guide the abovementioned planning studies. In this regard, these meetings are also expected to identify information needs within the Nagawicka Lake community. In response to these needs, appropriate educational materials, to be obtained from UWEX and other state agencies, will be identified and, where stocks exist, distributed to lake residents.

6. Development of recommended in-lake water quality management actions: The results of these analyses and recommendations will be presented as a SEWRPC Community Assistance Planning Report or similar document detailing the recommended lake protection measures necessary to protect and maintain the water quality and quantity of, and recreational and residential opportunities afforded by, Nagawicka Lake.

As public involvement and the providing of information to the public is regarded as a significant component of the Lake Management Planning Project Grant Program, the City of Delafield Lake Committee aims to utilize press releases, newsletter articles, mailings, and presentations to inform area residents on specific lake-related topics and current plans and projects. If needed, targeted educational efforts on individual topics will be recommended. Such programming continues to be a component of the regular public meetings of the lake organizations serving the Nagawicka Lake community.

Contractor

The City of Delafield will contract with the Southeastern Wisconsin Regional Planning Commission to develop a comprehensive lake management plan for Nagawicka Lake.

Products to be Produced

The products to be produced with grant-assisted funding under the proposed planning program will be, at the conclusion of the Phase I planning program, an SEWRPC Memorandum Report or similar document setting forth the inventory findings and analysis, and, at the conclusion of the Phase II planning program, an SEWRPC Community Assistance Planning Report or similar document setting forth the alternative and recommended management plans. These reports will constitute a comprehensive lake management plan for Nagawicka Lake consistent with the objectives of Chapter NR 190 of the *Wisconsin Administrative Code*.

D. Project Duration

In order to fully make use of the available studies and to collect any additional data that might be needed, it is anticipated that the duration of the planning program will be approximately two years: June 1997 to June 30, 1999. The Phase I planning studies will be undertaken during the period June 1997 through June 30, 1998. The Phase II planning studies will be undertaken during the period June 1998 through June 30, 1999. The request for grant funding of Phase II planning program activities will be submitted to the WDNR pursuant to the Chapter NR 190 Lake Management Planning Grant Program requirements no later than August 1, 1998. The proposed timetable is shown below:

Task	Agency	1997		1998				1999	
		3rd Quarter	4th Quarter	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter	2nd Quarter
PHASE I		■	■						
1. Data Review, Analysis and Report Preparation	SEWRPC	■	■						
2. Water Quality Evaluation	SEWRPC		■	■	■				
3. Recreational Use Assessment	SEWRPC			■	■	■	■		
Submission of Phase II Planning Grant Request	City and SEWRPC					■	■		
PHASE II						■	■		
4. Development of Options "Short List"	SEWRPC and City					■	■		
5. Community Information Needs Assessment	SEWRPC and City						■	■	
6. Lake Management Plan Preparation	SEWRPC and City							■	■

E. Project Costs

Funding is requested to cover the cost of phased completion of the comprehensive management plan. The anticipated cost of the Phase I planning project is $12,000. Of this, $3,000 is the local share to be paid by the City of Delafield, and $9,000 is the state allocation in terms of the WDNR Lake Management Planning Grant Program. The anticipated cost of the Phase II planning project is $10,000. Of this, $2,500 is the local share to be paid by the City of Delafield, and $7,500 is the state allocation in terms of the WDNR Lake Management Planning Grant Program. A breakdown of estimated costs is as follows:

		Phase I	Phase II
1.	Laboratory Analysis	$ 0	$ 0
2.	Other Services (SEWRPC)	$11,500	$ 8,000
3.	Printing of Final Report	$ 0	$ 1,500
4.	Other Supplies	$ 400	$ 400
5.	Miscellaneous	$ 100	$ 100
	Total Expense	$12,000	$10,000
	State Share Requested	$ 9,000	$ 7,500
	Local Share Provided	$ 3,000	$ 2,500

F. Distribution of the Final Reports/Lake Management Plan

The City of Delafield will lodge copies of the completed report and lake management plan with the Public Library, Waukesha County, Wisconsin Department of Natural Resources, and other interested parties. Copies of the plan may be sent to the riparian residents in the form of a separate mailer. The City of Delafield Lake Committee will hold an informational meeting during each Phase of the planning program to inform interested persons of the studies and lake management plan recommendations.

G. Official Management Resolution

The Resolution of the City of Delafield Common Council, together with letters of support for this planning grant application from the Village of Nashotah and the Waukesha County Land Conservation Committee, are submitted in respect of this Phase II grant application.

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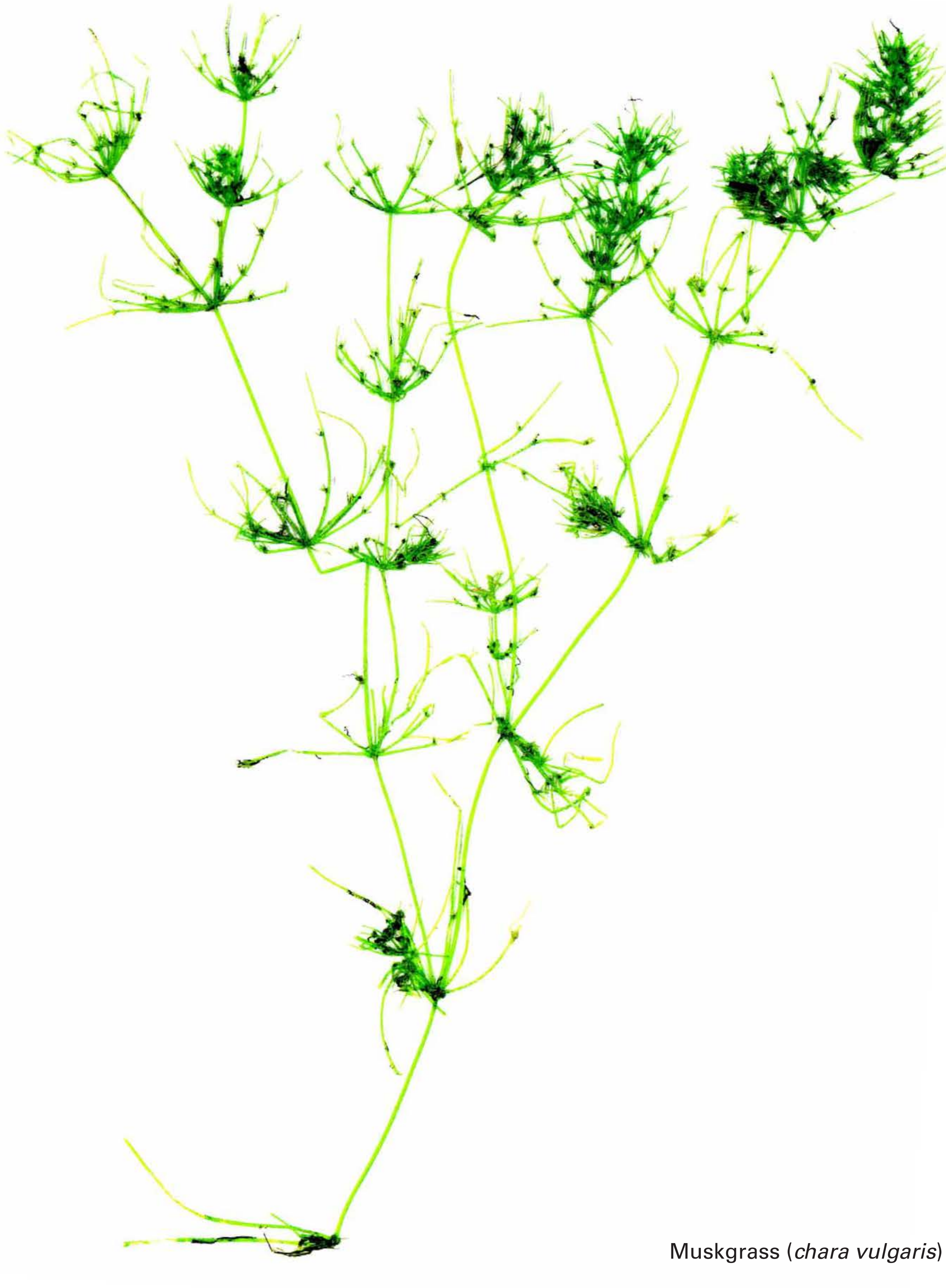
Appendix B

ILLUSTRATIONS OF COMMON AQUATIC PLANTS IN NAGAWICKA LAKE

Coontail (*ceratophyllum demersum*)

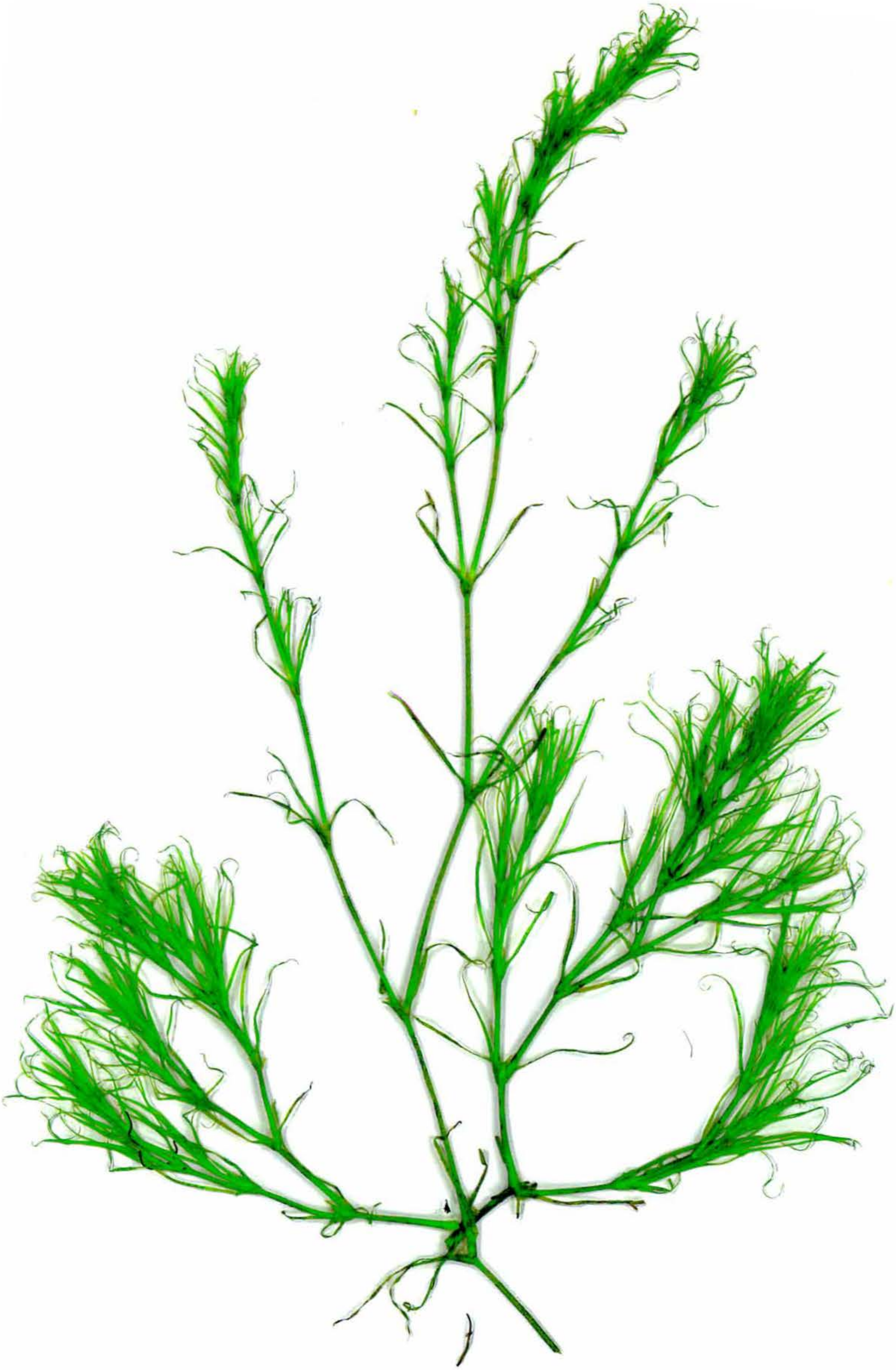


Muskgrass (*chara vulgaris*)

Waterweed (*elodea canadensis*)

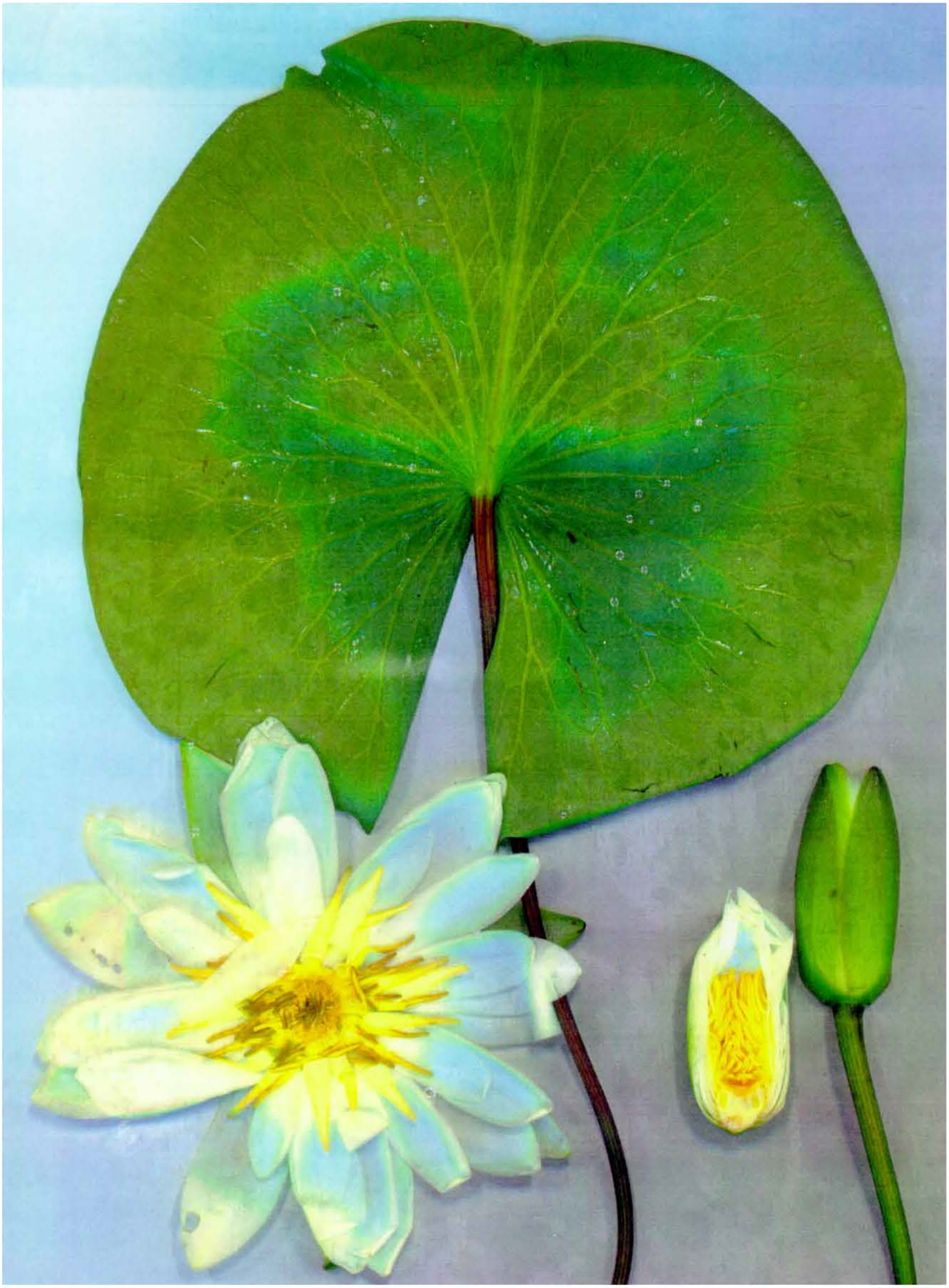
Eurasian Water Milfoil (*myriophyllum spicatum*)

Native Water Milfoil (*myriophyllum* sp.)



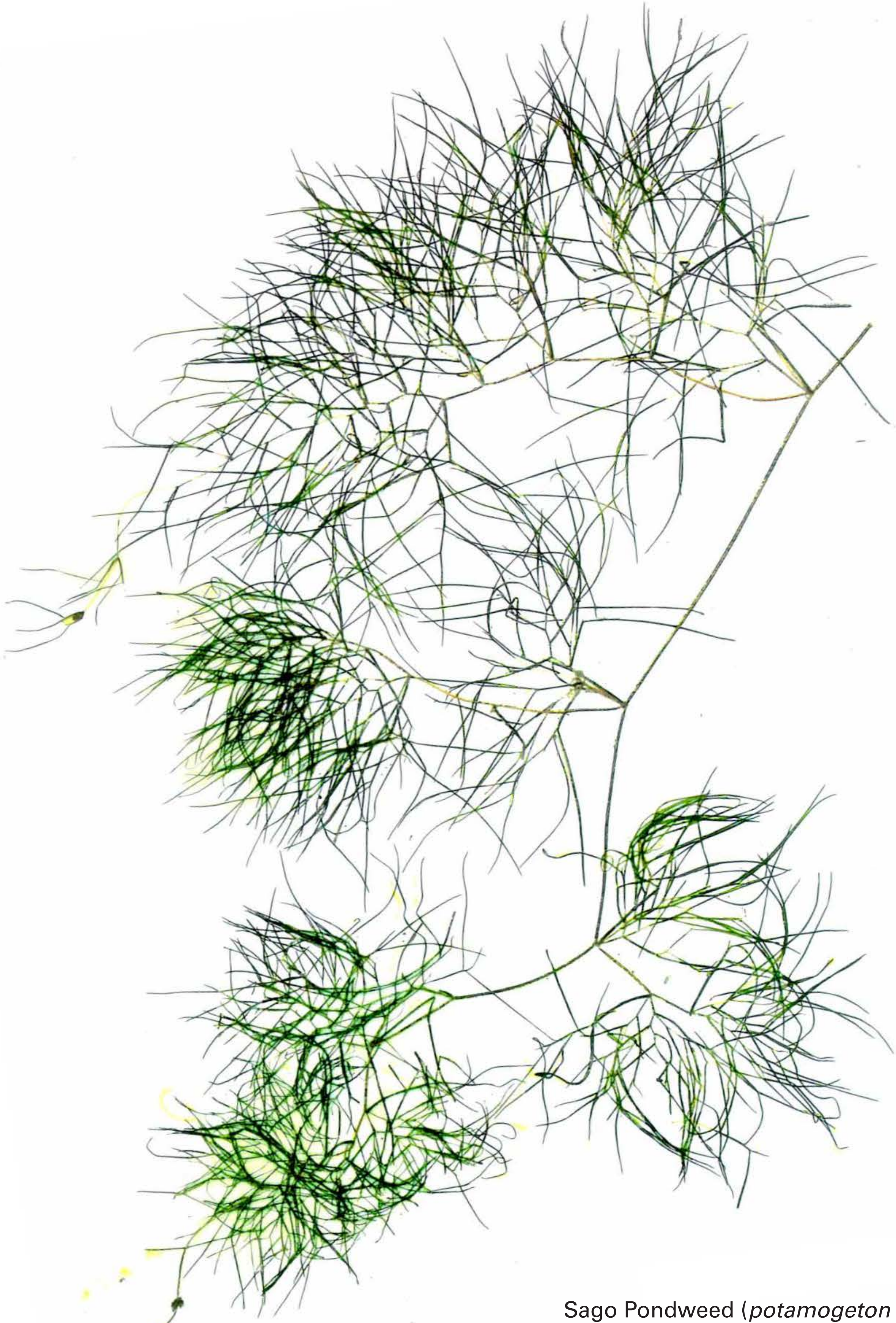
Bushy Pondweed (*najas flexilis*)

Yellow Water Lily (*nuphar variegatum*)



White Water Lily (*nymphaea odorata*)

Curly-Leaf Pondweed (*potamogeton crispus*)



Sago Pondweed (*potamogeton pectinatus*)

Flat-Stem Pondweed (*potamogeton zosteriformis*)

Eel Grass / Wild Celery (*valisneria americana*)