MEMORANDUM REPORT NO. 137

A WATER QUALITY PROTECTION AND STORMWATER MANAGEMENT PLAN FOR BIG CEDAR LAKE WASHINGTON COUNTY WISCONSIN

volume one

INVENTORY FINDINGS, WATER QUALITY ANALYSES, AND RECOMMENDED MANAGEMENT MEASURES

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Big Cedar Lake Protection and Rehabilitation District

Cedar Lakes Conservancy Foundation

Southeastern Wisconsin Regional Planning Commission

Washington County Land Conservation Department

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Volume One

INVENTORY FINDINGS, WATER QUALITY ANALYSES, AND RECOMMENDED MANAGEMENT MEASURES

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In cooperation with the

Washington County Land Conservation Department
Big Cedar Lake Protection and Rehabilitation District
Cedar Lakes Conservation Foundation

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Chapter I

INTRODUCTION

BACKGROUND AND PURPOSE OF STUDY

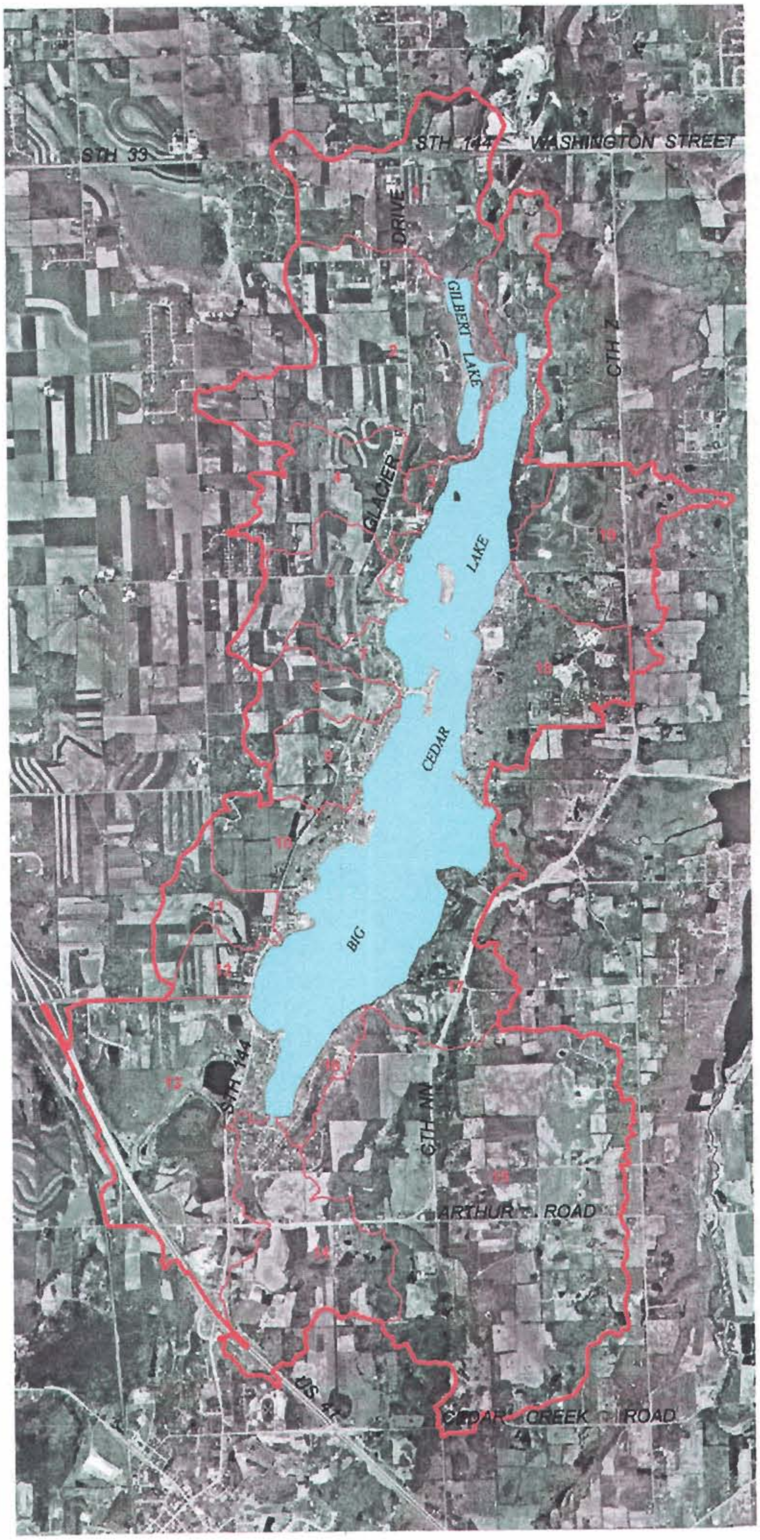
Big Cedar Lake, located in the Towns of Polk and West Bend, Washington County, Wisconsin, is not only the largest Lake in Washington County, but also a valuable resource offering a variety of recreational and related opportunities to the resident community and its visitors. The Lake and its tributary drainage area are shown on Map 1. Located in close proximity to the City of West Bend, and within a convenient distance of the greater Milwaukee metropolitan area, the Lake is an integral part of the resource base of the Southeastern Wisconsin Region, and the focal point of a lake-oriented community. Seeking to protect this resource, improve the usability of the Lake, and prevent deterioration of the natural assets and recreational potential of Big Cedar Lake, the community formed a lake protection and rehabilitation district around the Lake during 1974 under the provisions of Chapter 33, *Wisconsin Statutes*. Prior to that date, a Town sanitary district created around the Lake during 1939 undertook lake management activities on Big Cedar Lake. Since its formation, the Big Cedar Lake Protection and Rehabilitation District has undertaken a lake-oriented program of community involvement, education, monitoring, and management, in association with Washington County and the Towns of Polk and West Bend. In addition to these conventional lake and watershed management programs, the District has pursued an active program of pollution control activities, including the installation of agricultural management practices to control erosion and nutrient losses from several farming operations in the Lake drainage area; the construction of sediment retention basins and conduct of wetland restoration activities; and the acquisition of an important conservation area in association with the Cedar Lakes Conservation Foundation.

This report is the first volume of a report setting forth a water quality protection plan for Big Cedar Lake, and is part of the ongoing commitment of the Big Cedar Lake Protection and Rehabilitation District, the Towns of Polk and West Bend, and Washington County to sound planning with respect to this Lake. This plan was prepared during 1999 by the Southeastern Wisconsin Regional Planning Commission, in cooperation with the Big Cedar Lake Protection and Rehabilitation District and the Washington County Department of Land Conservation. The plan synthesizes information gathered on the Lake by the U.S. Geological Survey, the Wisconsin Department of Natural Resources, and the Big Cedar Lake Protection and Rehabilitation District. The planning program was funded through grants awarded to the Cedar Lakes Conservation Foundation, supplemented by funds provided by the Foundation and the Big Cedar Lake Protection and Rehabilitation District.

This plan is intended to form an integral part of any future, comprehensive lake management plan for Big Cedar Lake. The scope of this report is limited to a consideration of those measures which can be determined to be effective in the protection of lake water quality, based upon available data. The companion volume will provide alternative and recommended measures for controlling pollutant loadings to the Lake from stormwater runoff in three selected subbasin areas tributary to Big Cedar Lake.

Map 1

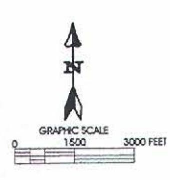
SUBBASIN BOUNDARIES IN THE DRAINAGE AREA OF BIG CEDAR LAKE



LEGEND

SUBBASIN BOUNDARY AND IDENTIFICATION NUMBER

DRAINAGE AREA OF BIG CEDAR LAKE



Source: SEWRPC.

The lake protection and water quality management goals and objectives for Big Cedar Lake were developed in consultation with the Big Cedar Protection and Rehabilitation District. The goals and objectives are:

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

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

3. To effectively maintain, and, if practicable, enhance, the water quality of Big Cedar Lake so as to better facilitate the conduct of water-related recreation, improve the aesthetic value of the resource to the community, and enhance the resource value of the waterbody.

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

FORMAT OF PLAN PRESENTATION

The recommendations set forth in Volume One of this water quality protection and stormwater management plan for Big Cedar Lake address the current status and initial recommendations for the maintenance and improvement of water quality within Big Cedar Lake. Volume Two of the plan addresses specific measures to minimize stormwater-borne nutrient and other pollutant loadings to the Lake from land use activities in three selected subbasin areas draining to the Lake. The current volume and its companion, together, will address the sources and in-lake impacts of nonpoint source pollution to Big Cedar Lake. In addition, the approach developed for assessing, quantifying, and managing stormwater-borne contaminants set forth for the selected subbasin areas in Volume Two will provide a template for future stormwater management planning in the other subbasin areas draining to Big Cedar Lake.

Following this introductory chapter, the findings and recommendations for water quality protection of Big Cedar Lake are presented in four additional chapters that comprise Volume One. Chapter II, "Inventory Findings," presents pertinent data on land use, the natural resources base, and local plans and zoning within the drainage area tributary to Big Cedar Lake insofar as these elements of the drainage area affect and impact the water quality of the Lake, and related data on water quality, contaminant loadings, and biotic responses to these loadings within the Lake basin. Chapter III, "Lake Water Quality Problems and Issues," presents specific issues relating to the protection and rehabilitation of water quality of Big Cedar Lake. Chapter IV, "Alternative and Recommended Lake Water Quality Protection Measures," describes alternative water quality management measures for the Lake consistent with the need to address the identified water quality problems and issues, and sets forth recommended measures to protect and rehabilitate Lake water quality. Chapter V provides an overview of the study findings and recommendations in a concluding summary.

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

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Chapter II

INVENTORY FINDINGS

INTRODUCTION

Big Cedar Lake is located immediately southwest of the City of West Bend in the Towns of Polk and West Bend, Washington County (see Map 1). The Lake, situated at the headwaters of the Cedar Creek—a tributary to the Milwaukee River—is a drained lake, having a clearly defined outlet, but lacking a definite inlet, except for the navigational channel linking Gilbert Lake with Big Cedar Lake. The primary sources of inflow to Big Cedar Lake are runoff from those lands directly tributary to Big Cedar Lake, groundwater inflows, and tributary flows into Big Cedar Lake from Gilbert Lake. Additional water is provided to Big Cedar Lake through direct precipitation onto the Lake surface. Outflow from Big Cedar Lake is through Cedar Creek, which flows into Little Cedar Lake, and, ultimately, into the Milwaukee River. Little Cedar Lake, a 246-acre lake, is located about 1.7 miles downstream of the outlet of Big Cedar Lake on Cedar Creek.

Big Cedar Lake is a 932-acre waterbody,[1] the hydrographical characteristics of which are set forth in Table 1. The Lake is elongate in aspect, having two large basins. Gilbert Lake, a 44-acre drained lake located immediately northwest of Big Cedar Lake, is connected to the northernmost basin of Big Cedar Lake by a narrow channel, as shown on Map 2. The waterbody has a maximum depth of about 105 feet, a mean depth of 34 feet, and a volume of almost 32,000 acre-feet, as shown in Table 1. The bathymetry of the Lake is shown on Map 3.

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[1] *Wisconsin Conservation Department,* Surface Water Resources of Washington County, *published in 1963, documents the surface area of Big Cedar Lake as 1,004 acres in areal extent. This area was refined to 932 acres in subsequent publications: See Wisconsin Department of Natural Resources Lake Use Report No. ML-1,* Big Cedar Lake, Washington County, Wisconsin, *published in 1972, and Wisconsin Department of Natural Resources Publication No. PUB-FH-800 99REV,* Wisconsin Lakes, *published in 1999. The area of 932 acres also is reported in the adopted regional water quality management plan and related planning reports: SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000*; Volume Two,* Alternative Plans, *February 1979; SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995; SEWRPC Memorandum Report No. 139, Draft,* Surface Water Resources of Washington County, Wisconsin: Lake and Stream Classification Project: 2000, *December 2000; and Wisconsin Department of Natural Resources Publication No. PUBL-WR-366 93,* Nonpoint Source Control Plan for the Cedar Creek Priority Watershed Project, *August 1993. Recent measurements of the lake surface area generated from the Commission's Geographic Information System data base are consistent with a surface area of about 932 acres.*

Table 1

HYDROLOGY AND MORPHOLOGY CHARACTERISTICS OF BIG CEDAR LAKE

Parameter	Measurements
Size (total	
Surface Area	932 acres
Total Drainage Area	6,641 acres
Volume	31,983 acre-feet
Residence Time[a]	5.52 years
Shape	
Maximum Length of Lake	3.8 miles
Length of Shoreline	11.0 miles
Maximum Width of Lake	0.64 miles
Shoreline Development Factor	2.57
Depth	
Percentage of Lake Area	
Less than Three Feet	7 percent
Three to 20 Feet	46 percent
Greater than 20 Feet	47 percent
Mean Depth	34 feet
Maximum Depth	105 feet

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

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

Source: Wisconsin Department of Natural Resources and SEWRPC.

The drainage area tributary to Big Cedar Lake, situated within the Village of Slinger and the Towns of Addison, Barton, Polk and West Bend in Washington County, is approximately 5,710 acres in areal extent, as shown on Map 4. The lands immediately surrounding the Lake have been urbanized over time, as shown on Map 5, although the balance of the drainage area remains primarily in agricultural and other open land usage, including natural areas—wetlands, woodlands, and other open natural areas—as shown on Map 6. Lake-oriented urban residential lands are the principal urban features of the riparian portion of the drainage area tributary to Big Cedar Lake.

The earliest, definitive data on water quality conditions in Big Cedar Lake were collected by the Wisconsin Department of Natural Resources (WDNR) in the early 1970s.[2] Data collected during that monitoring effort indicated that Big Cedar Lake had relatively good water quality and that there was little evidence of excessive fertilization. Nevertheless, the data were interpreted as showing a possible trend toward enrichment. For this reason, these early studies were supplemented by environmental investigations conducted by CDM Limnetics from February 1976 through January 1977,[3] and by Aqua-Tech Incorporated from March 1977 through November 1977.[4] These supplemental studies included the compilation of data on surface and ground water inflows, water quality, and biological responses within the Lake and its drainage area. Based upon these data, the Wisconsin Department of Natural Resources developed a set of recommended management measures during 1978 for the protection of the Lake's water quality.[5] These measures included both urban and rural pollution control

[2]*Wisconsin Department of Natural Resources, Lake Use Report No. ML-1,* Big Cedar Lake, Washington County, Wisconsin, *1972.*

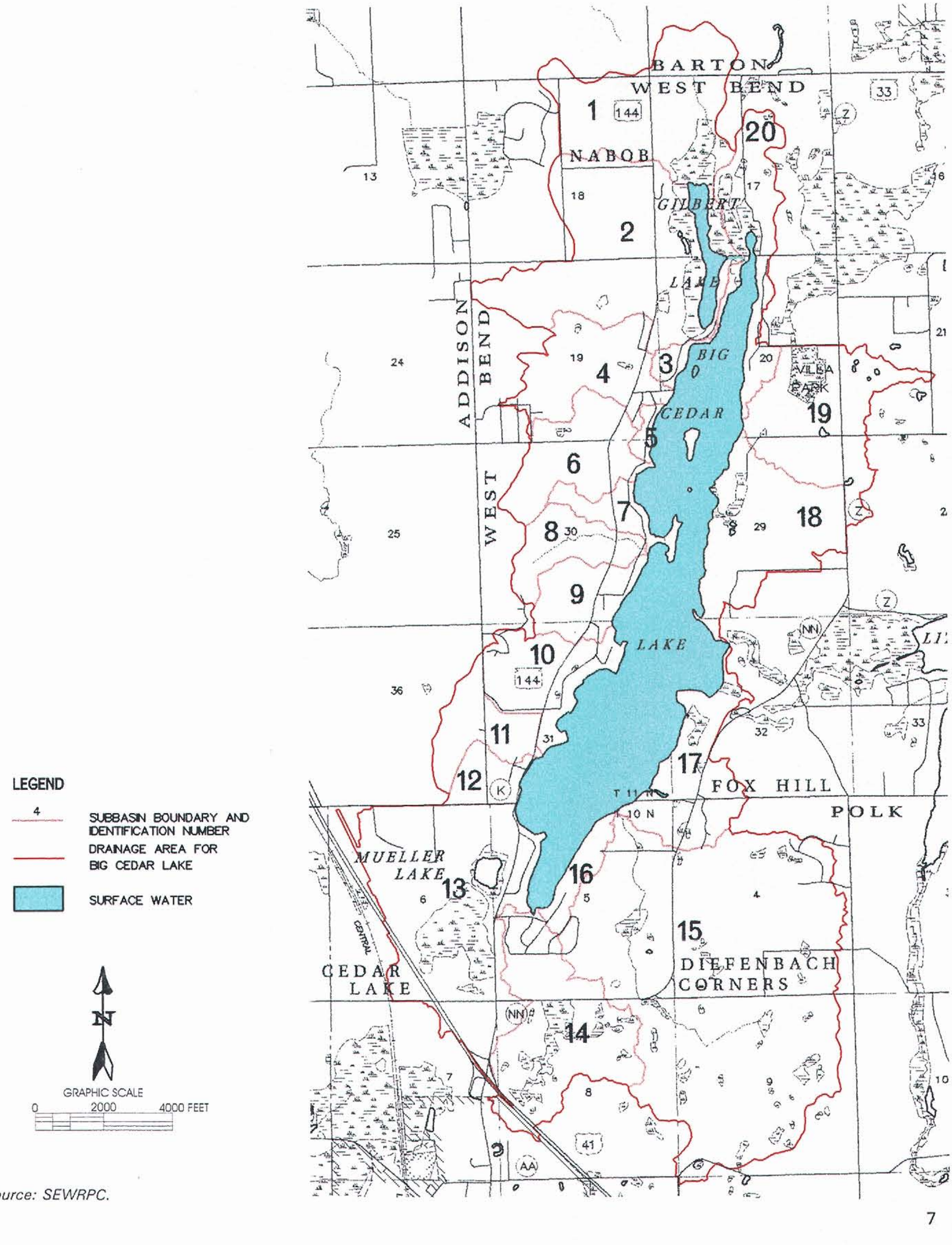
[3]*CDM Limnetics,* An Environmental Study of Big Cedar Lake and the Hydrological and Water Quality Characteristics of its Associated Watershed for the Inland Lake Protection and Rehabilitation District of Big Cedar Lake, Washington County, Wisconsin, *March 1977.*

[4]*Aqua-Tech, Incorporated,* A Water Quality Assessment of the Surface Water Runoff Discharging Into Big Cedar Lake, Washington County, Wisconsin for the Months of March, April and May, 1977; June and July, 1977; and October, November, and December, 1977 As Part of the Continuing Inland Lake Feasibility Study, *January 1978.*

[5]*Wisconsin Department of Natural Resources, Office of Inland Lake Renewal,* Big Cedar Lake, Washington County, Management Alternatives, *1978.*

Map 2

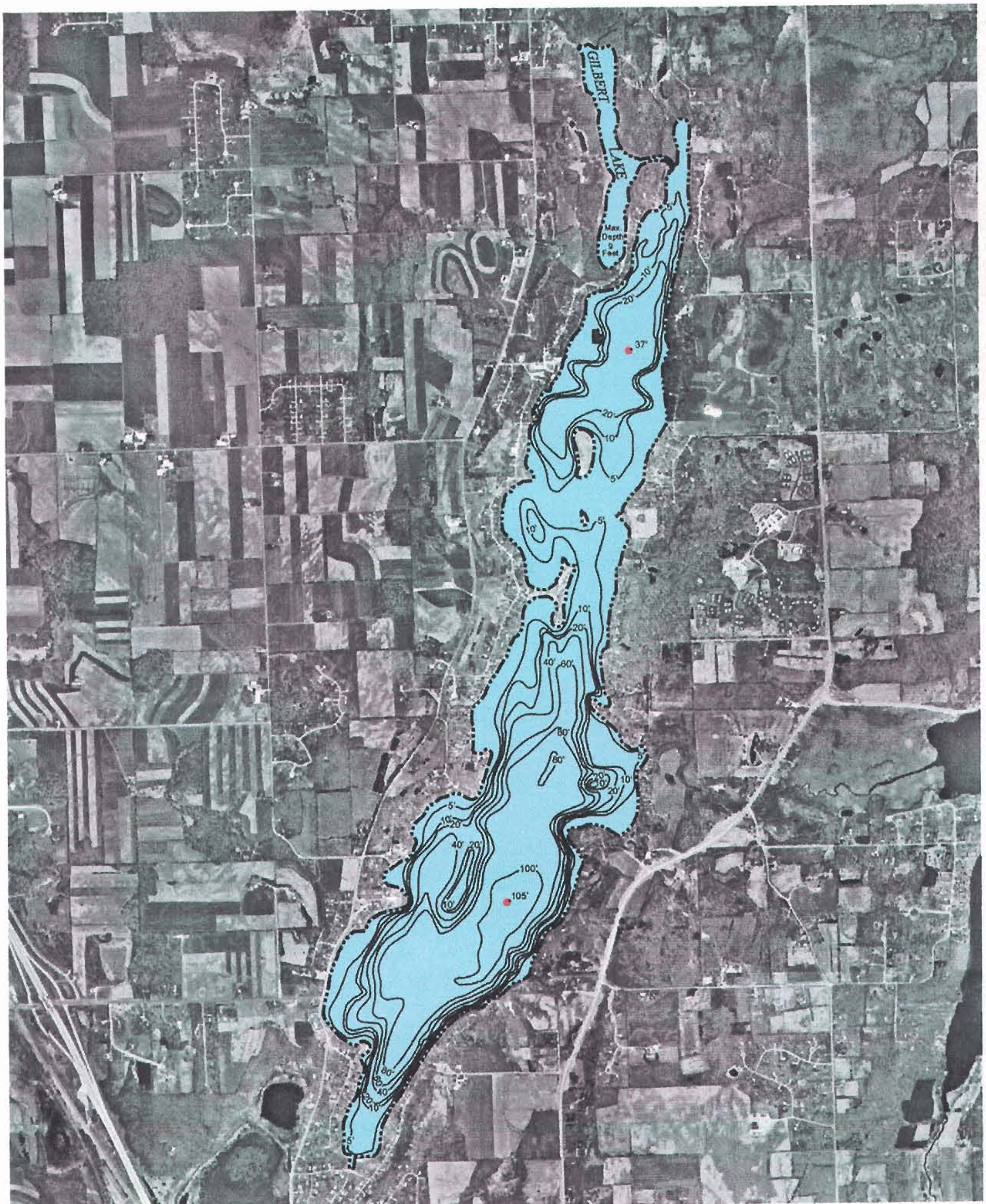
DRAINAGE AREAS CONTRIBUTING RUNOFF TO BIG CEDAR LAKE, INCLUDING HYDROLOGIC SUBBASINS



Source: SEWRPC.

Map 3

BATHYMETRIC MAP OF BIG CEDAR LAKE AND LOCATION OF MONITORING STATIONS



—20'— WATER DEPTH CONTOUR IN FEET

● LOCATION OF SAMPLING SITE

N

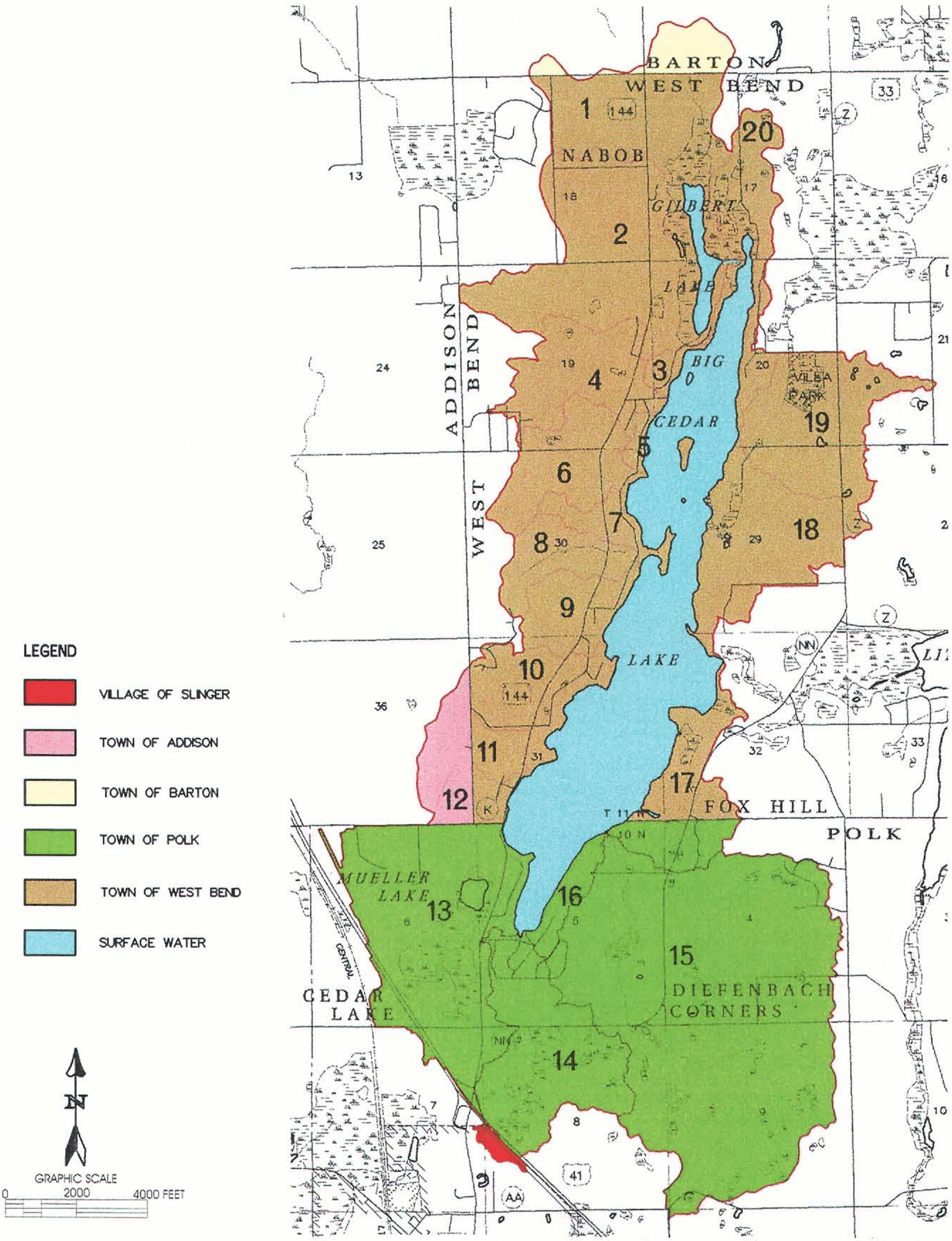
GRAPHIC SCALE

0 1500 3000 FEET

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 4

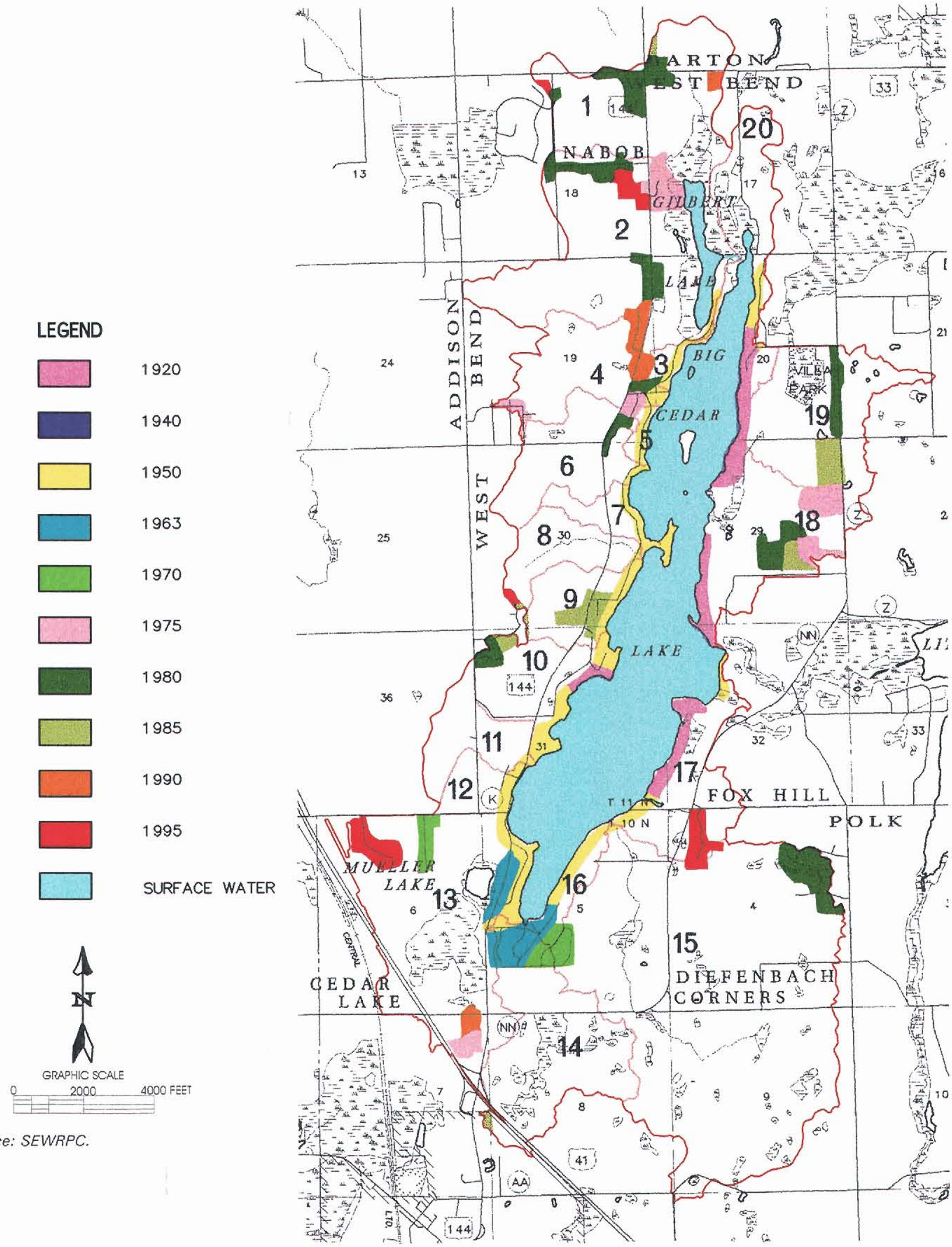
CIVIL DIVISION BOUNDARIES WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



Source: SEWRPC.

Map 5

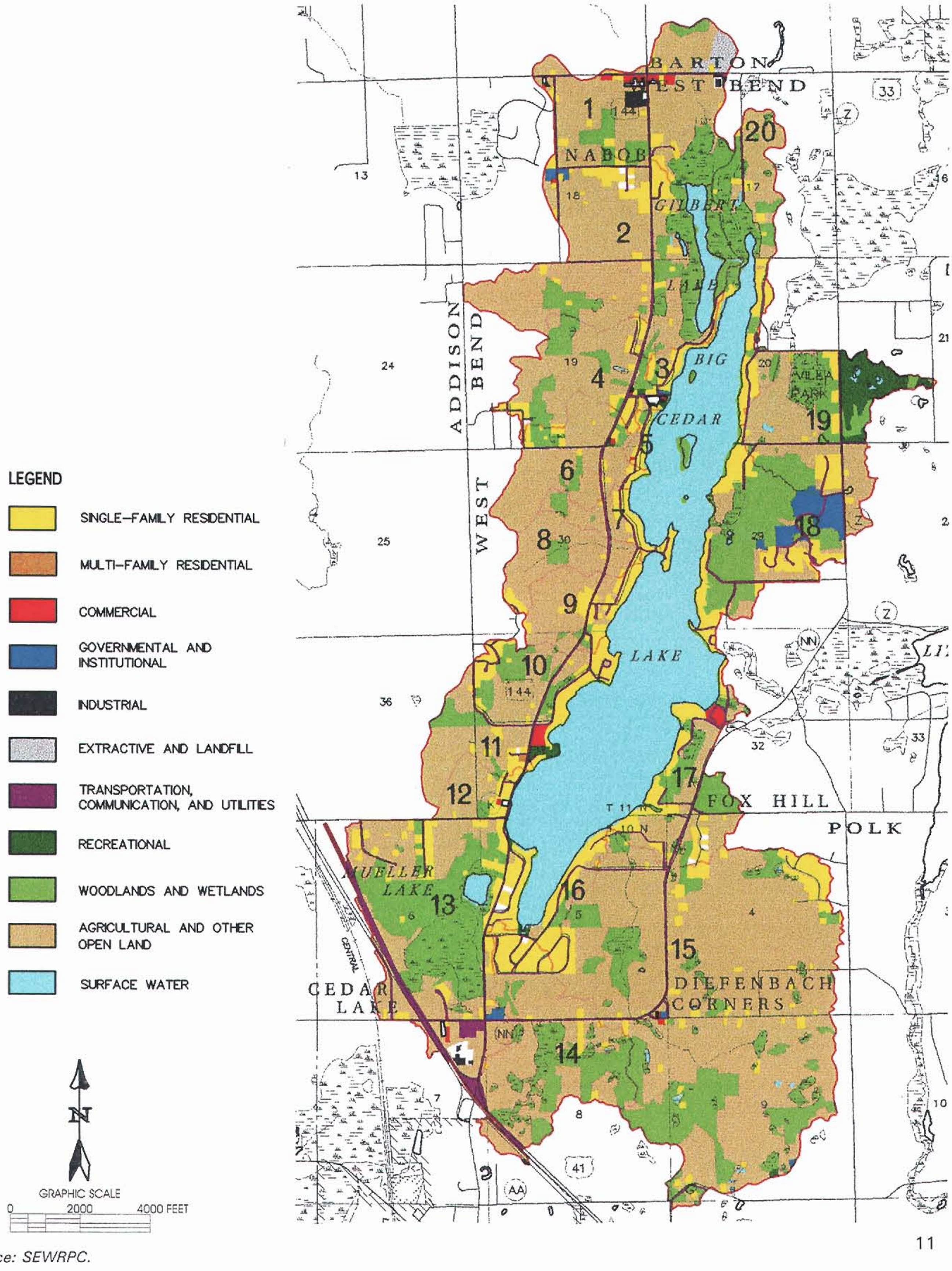
HISTORIC URBAN GROWTH WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



Source: SEWRPC.

Map 6

EXISTING LAND USES WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE: 1995



Source: SEWRPC.

measures.[6] In 1979, the Southeastern Wisconsin Regional Planning Commission completed a regional water quality management plan for Southeastern Wisconsin.[7] That plan contained specific recommendations for reduction in nonpoint source pollutants from both rural and urban lands tributary to Big Cedar Lake which were needed to achieve the adopted water use objectives for the Lake. That plan recommended a reduction of about 25 percent in both the rural and urban nonpoint sources, plus streambank erosion control, construction site erosion control, and onsite sewage disposal system management be achieved in the drainage area tributary to Big Cedar Lake. Subsequently, a nonpoint source pollution abatement priority watershed program[8] was prepared in 1994 by the Wisconsin Department of Natural Resources and its partners. The Cedar Creek priority watershed project established nonpoint source pollutant loading reduction goals of 30 percent for sediment and nutrients. Additional reduction goals were established for urban stormwater pollutants. The nonpoint source pollutant recommendations set forth in these plans have been partially implemented by the Big Cedar Lake Protection and Rehabilitation District in cooperation with Washington County and the WDNR during the intervening period.

Notwithstanding, the residents of the Big Cedar Lake area continued to express concerns about trends in water quality conditions, and, in 1980, the Big Cedar Lake Management District initiated a citizen-based, water clarity monitoring program under the auspices of the WDNR Self-Help Monitoring program. This program was expanded in 1986 when Big Cedar Lake was selected as a Long-Term Trend monitoring lake by the WDNR. Sampling of both the northern and southern basins of the Lake, under the auspices of this monitoring program, commenced in 1987 and was continued through 1998. The two sampling sites are shown on Map 3. In addition, from 1985 through 1990, the Big Cedar Lake Management District, in cooperation with the U.S. Geological Survey, continued to monitor water clarity, and the U.S. Geological Survey installed and maintained a Lake level gauge at the Lake.[9] In March 1999, following the conclusion of the WDNR Long-Term Trend monitoring program, the Big Cedar Lake Management District again contracted with the U.S. Geological Survey for the conduct an intensive water quality monitoring program for Big Cedar Lake. Both the 1999 monitoring program and the WDNR Long-Term Trends monitoring program 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 continue to be collected.

EXISTING WATER QUALITY CONDITIONS

The data collection program on Big Cedar Lake can be categorized into decadal periods, beginning in the 1970s with the early lake water quality monitoring programs, and continuing into the 1980s. The most recent data was gathered during the late 1980s and throughout the 1990s. For purposes of assessing the current lake water quality

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[6]*Urban pollution control measures were recommended to include limitation of sediment transport to the Lake, control of runoff from urban development to pre-development levels, use of settling basins and grassed waterways to minimize nutrient transport to the Lake, and location of onsite sewage disposal systems at least 100 feet from the ordinary high water mark of the Lake. Rural pollution control measures were recommended to include proper management of barnyards and manure storage facilities. In-lake pollution control measures were recommended to include aquatic plant harvesting.*

[7]*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.*

[8]*Wisconsin Department of Natural Resources,* Nonpoint Source Control Plan for the Cedar Creek Priority Watershed Project, *August 1993.*

[9]*U.S. Geological Survey Water-Data Report No. WI-85-1 (and following years, published annually),* Water Resources Data, Wisconsin: Water Year 1985, *August 1986 through May 1991.*

conditions on Big Cedar Lake, generally, the more recent data available are 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 from the main basin of the Lake once per season during the 1987 through 1998 monitoring period, except during summer when samples were taken from the main basin on a monthly basis. Two sites within the Big Cedar Lake basin were sampled. The primary sampling stations were located at the deepest points in northern and southern basins of the Lake, as shown on Map 3. These findings are summarized in Tables 2 and 3, and Figures 1 and 2. More detailed information on these water quality data, including locations and procedures, may be found in reports published by the WDNR and U.S. Geological Survey.

Thermal Stratification

Thermal and dissolved oxygen profiles for Big Cedar Lake for the period 1994 through 1997 are shown in Figures 1 and 2 for the two basins sampled. Surface water temperatures in the Lake ranged from approximately 34°F during the winter to approximately 79°F during the summer. Complete mixing of the Lake was restricted by thermal stratification during the summer and by ice cover in the winter.

Thermal stratification is the result of differential heating of lake water and the resulting water temperature-density relationships. Water is unique among liquids because it reaches its maximum density, or weight per unit of volume, at about 39°F. The development of thermal stratification begins in early summer, reaches its maximum in the late summer, and disappears in the fall, as illustrated diagrammatically in Figure 3. 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, heavier bottom water, as shown in Figures 1 and 2, for the months of June, July and August. This "barrier" is marked by a sharp temperature gradient known as the thermocline and is characterized by about a 2°F 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 has a major impact on both the chemical and biological activity in a lake, as will be discussed further in this report.

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. This action, which follows summer stratification, is known as "fall turnover."

When the water temperature drops to the point of maximum water density, about 39°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 Big Cedar Lake, ice cover typically exists from December until early April. Winter stratification occurs 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 Figures 1 and 2, for the month of April. After spring turnover, the water at the surface again warms and becomes lighter, causing it to float above the colder, deeper water. Wind and

Table 2

SEASONAL WATER QUALITY CONDITIONS FOR THE NORTHERN BASIN OF BIG CEDAR LAKE: 1987-1998

	Fall (mid-September to mid-December)		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
Parameter[a]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Physical Properties								
Alkalinity, as $CaCO_3$								
Range	--	--	--	--	197.0-204.0	196.0-204.0	--	--
Mean	--	--	--	--	200.1	199.6	--	--
Standard Deviation	--	--	--	--	2.1	2.7	--	--
Number of Samples	--	--	--	--	10	9	--	--
Color								
Range	--	--	--	--	10.0-15.0	10.0-15.0	--	--
Mean	--	--	--	--	11.5	10.6	--	--
Standard Deviation	--	--	--	--	2.4	1.7	--	--
Number of Samples	--	--	--	--	10	9	--	--
Dissolved Oxygen								
Range	--	--	7.7-17.2	0.4-6.7	7.7-14.0	0.4-13.8	7.8-14.0	0.0-8.2
Mean	--	--	12.5	2.2	11.5	9.9	9.0	0.6
Standard Deviation	--	--	2.9	2.1	1.5	3.6	1.3	1.6
Number of Samples	--	--	8	7	11	10	30	28
Hardness, as $CaCO_3$								
Range	--	--	--	--	220.0-240.0	220.0-240.0	--	--
Mean	--	--	--	--	233.8	234.3	--	--
Standard Deviation	--	--	--	--	7.4	7.9	--	--
Number of Samples	--	--	--	--	8	7	--	--
pH (units)								
Range	--	--	7.1-8.4	6.9-8.2	7.3-8.6	7.3-8.6	6.7-8.8	6.7-8.2
Mean	--	--	7.8	7.4	8.2	8.2	8.3	7.6
Standard Deviation	--	--	0.4	0.4	0.4	0.3	0.4	0.4
Number of Samples	--	--	8	8	11	10	30	29
Secchi Depth (feet)								
Range	--	--	7.9-17.4	--	5.2-8.2	--	4.6-23.0	--
Mean	--	--	12.2	--	7.0	--	9.6	--
Standard Deviation	--	--	3.7	--	0.9	--	4.7	--
Number of Samples	--	--	8	--	11	--	29	--
Dissolved Solids at 180°C								
Range	--	--	--	--	276.0-328.0	276.0-326.0	--	--
Mean	--	--	--	--	296.7	296.8	--	--
Standard Deviation	--	--	--	--	17.6	18.8	--	--
Number of Samples	--	--	--	--	6	5	--	--
Specific Conductance (μS/cm)								
Range	--	--	296.0-810.0	397.0-900.0	285.0-505.0	350.0-506.0	345.0-500.0	400.0-589.0
Mean	--	--	424.7	541.7	427.5	441.9	435.9	482.4
Standard Deviation	--	--	199.5	195.2	71.3	59.1	44.7	47.1
Number of Samples	--	--	6	6	11	10	25	23
Temperature (°F)								
Range	--	--	32.5-37.6	33.4-40.3	36.1-66.2	36.1-50.9	57.2-82.4	44.6-63.5
Mean	--	--	34.4	37.7	48.6	45.0	73.8	52.8
Standard Deviation	--	--	1.7	2.1	7.7	4.4	5.9	3.8
Number of Samples	--	--	8	8	11	10	30	29
Turbidity (NTU)								
Range	--	--	--	--	1.2-2.3	1.5-3.3	--	--
Mean	--	--	--	--	1.5	1.9	--	--
Standard Deviation	--	--	--	--	0.3	0.6	--	--
Number of Samples	--	--	--	--	10	9	--	--
Metals/Salts								
Dissolved Calcium								
Range	--	--	--	--	38.0-42.0	38.0-43.0	--	--
Mean	--	--	--	--	40.0	40.3	--	--
Standard Deviation	--	--	--	--	1.2	1.5	--	--
Number of Samples	--	--	--	--	10	9	--	--
Dissolved Chloride								
Range	--	--	--	--	35.0-36.1	35.9-36.0	--	--
Mean	--	--	--	--	35.6	36.0	--	--
Standard Deviation	--	--	--	--	0.8	0.1	--	--
Number of Samples	--	--	--	--	2	2	--	--
Dissolved Fluoride								
Range	--	--	--	--	--	--	--	--
Mean	--	--	--	--	--	--	--	--
Standard Deviation	--	--	--	--	--	--	--	--
Number of Samples	--	--	--	--	--	--	--	--

Table 2 (continued)

Parameter[a]	Fall (mid-September to mid-December)		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Metals/Salts (continued)								
Dissolved Iron (μg/l)								
Range	- -	- -	- -	- -	0.0-0.1	0.0-0.1	- -	- -
Mean	- -	- -	- -	- -	0.0	0.0	- -	- -
Standard Deviation	- -	- -	- -	- -	0.0	0.0	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Magnesium								
Range	- -	- -	- -	- -	30.0-34.0	29.0-34.0	- -	- -
Mean	- -	- -	- -	- -	32.3	32.1	- -	- -
Standard Deviation	- -	- -	- -	- -	1.1	1.4	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Manganese (μg/l)								
Range	- -	- -	- -	- -	4.0-40.0	5.0-40.0	- -	- -
Mean	- -	- -	- -	- -	26.3	25.2	- -	- -
Standard Deviation	- -	- -	- -	- -	17.7	17.5	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Potassium								
Range	- -	- -	- -	- -	1.3-1.9	1.5-2.0	- -	- -
Mean	- -	- -	- -	- -	1.7	1.7	- -	- -
Standard Deviation	- -	- -	- -	- -	0.2	0.1	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Silica								
Range	- -	- -	- -	- -	0.5-1.6	0.5-2.3	- -	- -
Mean	- -	- -	- -	- -	1.1	1.2	- -	- -
Standard Deviation	- -	- -	- -	- -	0.4	0.5	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Sodium								
Range	- -	- -	- -	- -	11.0-17.0	11.0-17.0	- -	- -
Mean	- -	- -	- -	- -	14.4	14.6	- -	- -
Standard Deviation	- -	- -	- -	- -	1.9	1.9	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Sulfate SO_4								
Range	- -	- -	- -	- -	5.0-22.0	5.0-22.0	- -	- -
Mean	- -	- -	- -	- -	17.8	18.6	- -	- -
Standard Deviation	- -	- -	- -	- -	5.4	5.7	- -	- -
Number of Samples	- -	- -	- -	- -	9	8	- -	- -
Nutrients								
Dissolved Nitrogen, Ammonia								
Range	- -	- -	- -	- -	0.005-0.048	0.016-0.223	- -	- -
Mean	- -	- -	- -	- -	0.020	0.048	- -	- -
Standard Deviation	- -	- -	- -	- -	0.012	0.062	- -	- -
Number of Samples	- -	- -	- -	- -	11	10	- -	- -
Dissolved Nitrogen, NO +NO								
Range	- -	- -	- -	- -	0.007-0.0276	0.080-0.300	- -	- -
Mean	- -	- -	- -	- -	0.168	0.180	- -	- -
Standard Deviation	- -	- -	- -	- -	0.077	0.072	- -	- -
Number of Samples	- -	- -	- -	- -	11	10	- -	- -
Total Nitrogen, Organic								
Range	- -	- -	- -	- -	0.400-0.640	0.300-1.000	- -	- -
Mean	- -	- -	- -	- -	0.524	0.529	- -	- -
Standard Deviation	- -	- -	- -	- -	0.084	0.195	- -	- -
Number of Samples	- -	- -	- -	- -	10	9	- -	- -
Dissolved Orthophosphorus								
Range	- -	- -	- -	- -	0.002-0.033	0.002-0.009	- -	- -
Mean	- -	- -	- -	- -	0.007	0.004	- -	- -
Standard Deviation	- -	- -	- -	- -	0.009	0.002	- -	- -
Number of Samples	- -	- -	- -	- -	11	10	- -	- -
Total Phosphorus								
Range	0.011-0.014	0.010-0.017	0.007-0.021	0.005-0.016	0.009-0.020	0.014-0.057	0.007-0.042	0.011-0.109
Mean	0.012	0.014	0.0120	0.010	0.014	0.022	0.014	0.047
Standard Deviation	0.001	0.004	0.005	0.003	0.004	0.013	0.006	0.018
Number of Samples	3	3	10	8	11	10	35	34
Biological								
Chlorophyll-*a* (μg/l)								
Range	- -	- -	0.5-11.0	- -	5.3-18.0	4.3-4.3	1.3-10.0	- -
Mean	- -	- -	5.1	- -	10.1	4.3	5.1	- -
Standard Deviation	- -	- -	4.1	- -	3.8	0.0	1.8	- -
Number of Samples	- -	- -	7	- -	11	1	33	- -

[a] *Milligrams per liter unless otherwise indicated.*

[b] *Depth of sample approximately 1.5 feet.*

[c] *Depth of sample greater than 30 feet.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 3

SEASONAL WATER QUALITY CONDITIONS FOR THE SOUTHERN BASIN OF BIG CEDAR LAKE: 1971-1998

Parameter[a]	Fall (mid-September to mid-December		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Physical Properties								
Alkalinity, as $CaCO_3$								
Range	172.0-188.0	180.0-208.0	169.0-194.0	162.0-206.0	179.0-206.0	180.0-208.0	156.0-188.0	180.0-212.0
Mean	181.9	191.9	182.6	189.8	191.8	194.3	170.7	194.6
Standard Deviation	5.4	10.8	12.2	17.6	7.4	8.3	10.2	8.5
Number of Samples	10	10	5	5	21	21	10	10
Color								
Range	--	--	--	--	5.0-10.0	5.0-15.0	5.0-5.0	--
Mean	--	--	--	--	8.5	9.5	5.0	--
Standard Deviation	--	--	--	--	2.4	2.8	0.0	--
Number of Samples	--	--	--	--	30	10	2	--
Dissolved Oxygen								
Range	7.8-13.4	0.0-10.3	10.0-15.7	0.0-10.7	8.6-15.4	0.2-14.8	7.8-13.1	0.0-5.2
Mean	9.8	4.4	12.3	6.0	12.5	7.4	9.0	0.6
Standard Deviation	1.5	4.4	1.9	4.1	1.4	4.4	0.9	1.2
Number of Samples	10	10	6	6	30	29	40	40
Hardness, as $CaCO_3$								
Range	200.0-200.0	220.0-220.0	227.0-227.0	243.0-243.0	220.0-240.0	220.0-240.0	204.0-212.0	215.0-245.0
Mean	200.0	220.0	227.0	243.0	230.0	230.0	208.7	228.3
Standard Deviation	0.0	0.0	0.0	0.0	5.8	6.3	4.2	15.3
Number of Samples	1	1	1	1	7	6	3	3
pH (units)								
Range	7.8-8.4	7.4-8.1	7.9-8.3	7.9-8.3	7.6-8.7	7.4-8.6	7.2-8.9	7.0-8.1
Mean	8.1	7.9	8.1	8.1	8.1	8.0	8.4	7.5
Standard Deviation	0.2	0.2	0.1	0.2	0.3	0.3	0.3	0.3
Number of Samples	10	10	6	6	30	30	40	40
Secchi Depth (feet)								
Range	4.3-14.0	--	3.5-17.1	--	4.0-26.2	--	5.2-26.2	--
Mean	9.0	--	9.1	--	12.5	--	11.6	--
Standard Deviation	3.3	--	5.3	--	6.1	--	4.7	--
Number of Samples	9	--	5	--	29	--	39	--
Dissolved Solids at 180°C								
Range	--	--	--	--	274.0-322.0	276.0-324.0	--	--
Mean	--	--	--	--	294.3	293.3	--	--
Standard Deviation	--	--	--	--	18.0	18.0	--	--
Number of Samples	--	--	--	--	7	6.0	--	--
Specific Conductance (μS/cm)								
Range	340.0-568.0	350.0-626.0	320.0-440.0	310.0-427.0	275.0-511.0	285.0-530.0	176.0-512.0	398.0-580.0
Mean	401.0	416.7	376.8	395.8	390.7	405.3	423.3	477.2
Standard Deviation	67.8	81.7	53.3	48.3	67.7	72.4	65.7	47.8
Number of Samples	9	9	5	5	26	24	32	32
Temperature (°F)								
Range	39.2-52.7	40.7-45.0	32.5-36.5	35.8-39.2	32.0-74.0	32.9-45.0	59.4-80.6	34.0-46.4
Mean	45.5	42.8	34.4	37.5	41.6	39.4	74.0	42.2
Standard Deviation	4.3	1.6	1.5	1.5	9.9	2.7	4.5	2.2
Number of Samples	10	10	6	6	30	29	40	40
Turbidity (NTU)								
Range	0.4-2.5	1.1-15.0	2.6-3.1	1.1-2.5	0.5-4.3	0.7-14.0	0.2-6.0	0.5-4.0
Mean	1.5	4.9	2.8	1.9	1.4	2.2	2.0	2.0
Standard Deviation	0.6	5.1	0.3	0.7	0.9	3.0	1.9	1.3
Number of Samples	7	6	3	3	19	18	7	5
Metals/Salts								
Dissolved Calcium								
Range	29.0-64.0	32.0-60.0	26.0-38.0	26.0-43.0	25.0-68.0	18.0-115.0	19.0-42.0	25.0-73.0
Mean	38.7	39.1	33.0	36.5	40.0	43.9	29.5	42.8
Standard Deviation	11.1	8.9	5.1	7.6	10.4	21.4	6.1	12.7
Number of Samples	9	9	4	4	21	20	10	10
Dissolved Chloride								
Range	8.0-26.0	9.0-24.0	11.0-27.0	13.0-18.0	10.0-37.1	11.0-37.3	8.0-17.0	6.0-17.0
Mean	14.3	13.9	17.0	15.0	17.7	18.0	13.9	12.9
Standard Deviation	5.0	4.4	7.0	2.2	9.1	8.9	3.6	3.9
Number of Samples	10	10	4	4	13	13	7	7
Dissolved Fluoride								
Range	--	--	--	--	--	--	--	--
Mean	--	--	--	--	--	--	--	--
Standard Deviation	--	--	--	--	--	--	--	--
Number of Samples	--	--	--	--	--	--	--	--

Table 3 (continued)

Parameter[a]	Fall (mid-September to mid-December)		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Metals/Salts (continued)								
Dissolved Iron (μg/l)								
Range	0.050-0.560	0.050-.500	0.090-0.730	0.080-0.700	0.020-0.080	0.020-0.110	0.050-0.350	0.050-0.390
Mean	0.176	0.164	0.410	0.390	0.053	0.055	0.160	0.173
Standard Deviation	0.215	0.189	0.453	0.438	0.019	0.023	0.165	0.188
Number of Samples	5	5	2	2	12	11	3	3
Dissolved Magnesium								
Range	30.0-47.0	23.6-54.0	27.0-38.0	33.0-39.0	29.0-84.0	16.0-55.0	26.0-52.0	19.0-50.0
Mean	39.9	38.0	32.5	35.3	38.1	33.9	37.1	34.4
Standard Deviation	5.1	8.6	4.5	2.9	12.1	8.5	8.0	8.2
Number of Samples	9	9	4	4	21	20	10	10
Dissolved Manganese (μg/l)								
Range	0.020-40.000	0.020-120.0	0.040-0.040	0.020-0.490	0.020-40.0	0.020-40.0	0.020-0.060	0.020-0.0110
Mean	8.040	24.068	0.040	0.255	19.9	16.6	0.033	0.053
Standard Deviation	17.866	53.628	0.0	0.332	19.5	18.8	0.023	0.049
Number of Samples	5	5	2	2	13	11	3	3
Dissolved Potassium								
Range	1.1-4.7	0.6-3.9	0.7-8.4	0.7-6.9	0.8-4.6	1.0-5.3	0.7-2.6	1.3-2.5
Mean	2.3	2.0	3.8	3.2	2.0	2.0	1.8	1.9
Standard Deviation	1.1	1.0	4.0	3.3	0.9	1.1	0.7	0.5
Number of Samples	9	9	3	3	21	20	7	7
Dissolved Silica								
Range	2.4-2.4	3.6-3.6	- -	- -	0.2-1.5	0.2-1.8	- -	- -
Mean	2.4	3.6	- -	- -	0.7	0.9	- -	- -
Standard Deviation	0.0	0.0	- -	- -	0.4	0.5	- -	- -
Number of Samples	1	1	- -	- -	10	10	- -	- -
Dissolved Sodium								
Range	5.0-12.0	5.0-11.0	8.0-13.0	8.0-12.0	4.0-18.0	0.6-39.0	5.1-15.0	5.1-10.0
Mean	8.1	8.0	11.3	9.3	10.7	11.8	9.1	7.8
Standard Deviation	2.6	2.4	2.9	2.3	4.8	8.0	3.3	2.1
Number of Samples	9	9	3	3	21	20	7	7
Dissolved Sulfate SO_4								
Range	11.0-21.0	9.0-20.0	11.0-20.0	12.0-21.0	8.0-22.0	5.0-22.0	11.0-23.0	12.0-20.0
Mean	16.1	15.5	16.3	17.3	17.1	17.0	17.2	16.0
Standard Deviation	4.5	4.4	4.7	4.7	4.3	5.3	4.6	3.2
Number of Samples	8	8	3	3	16	17	5	5
Nutrients								
Dissolved Nitrogen, Ammonia								
Range	0.020-0.110	0.030-1.100	0.020-0.170	0.020-0.640	0.0-0.180	0.018-1.870	0.020-0.150	0.070-1.530
Mean	0.049	0.357	0.060	0.182	0.037	0.208	0.064	0.661
Standard Deviation	0.025	0.412	0.062	0.260	0.038	0.415	0.047	0.598
Number of Samples	10	10	5	5	22	22	10	10
Dissolved Nitrogen, NO_2+NO_3								
Range	0.023-0.362	0.030-0.206	0.042-0.347	0.062-0.500	0.002-0.400	0.016-0.484	0.0-0.154	0.107-0.983
Mean	0.099	0.094	0.207	0.231	0.177	0.198	0.048	0.257
Standard Deviation	0.098	0.059	0.127	0.179	0.098	0.107	0.046	0.311
Number of Samples	10	10	5	5	22	22	10	10
Total Nitrogen, Organic								
Range	0.400-2.120	0.430-1.930	0.400-1.220	0.500-1.470	0.400-0.910	0.300-2.750	0.390-0.979	0.400-2.930
Mean	0.796	1.013	0.705	0.754	0.585	0.803	0.582	1,434
Standard Deviation	0.519	0.504	0.312	0.407	0.135	0.574	0.206	0.787
Number of Samples	9	9	5	5	20	21	9	9
Dissolved Orthophosphorus								
Range	0.005-0.190	0.050-0.314	0.006-0.195	0.049-0.269	0.002-0.143	0.002-0.237	0.006-0.183	0.007-0.376
Mean	0.083	0.114	0.088	0.11	0.043	0.061	0.062	0.140
Standard Deviation	0.043	0.086	0.080	0.106	0.048	0.074	0.059	0.124
Number of Samples	10	10	4	4	23	23	11	11
Total Phosphorus								
Range	0.015-0.190	0.056-0.350	0.013-0.140	0.009-0.210	0.009-0.190	0.006-0.260	0.006-0.200	0.013-0.450
Mean	0.106	0.147	0.069	0.090	0.049	0.068	0.027	0.115
Standard Deviation	0.055	0.010	0.055	0.075	0.051	0.078	0.041	0.101
Number of Samples	10	10	5	5	29	30	40	40
Biological								
Chlorophyll-*a* (μg/l)								
Range	3.2-5.0	- -	5.0-5.0	- -	0.4-11.0	- -	0.9-8.0	- -
Mean	4.1	- -	5.0	- -	4.9	- -	3.5	- -
Standard Deviation	1.3	- -	0.0	- -	3.0	- -	1.5	- -
Number of Samples	2	- -	1	- -	19	- -	34	- -

[a]*Milligrams per liter unless otherwise indicated.*

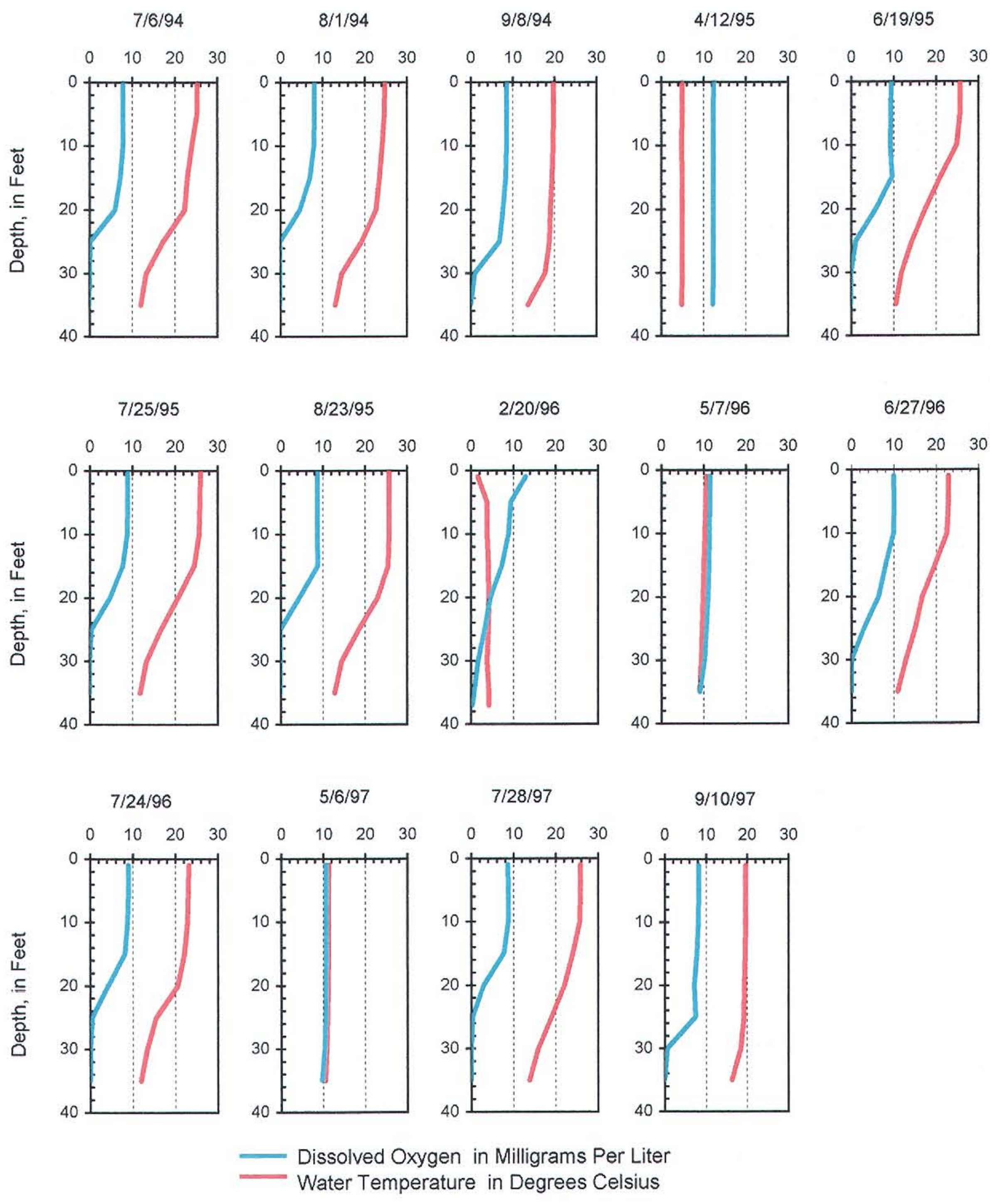
[b]*Depth of sample approximately 1.5 feet.*

[c]*Depth of sample greater than 70 feet.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 1

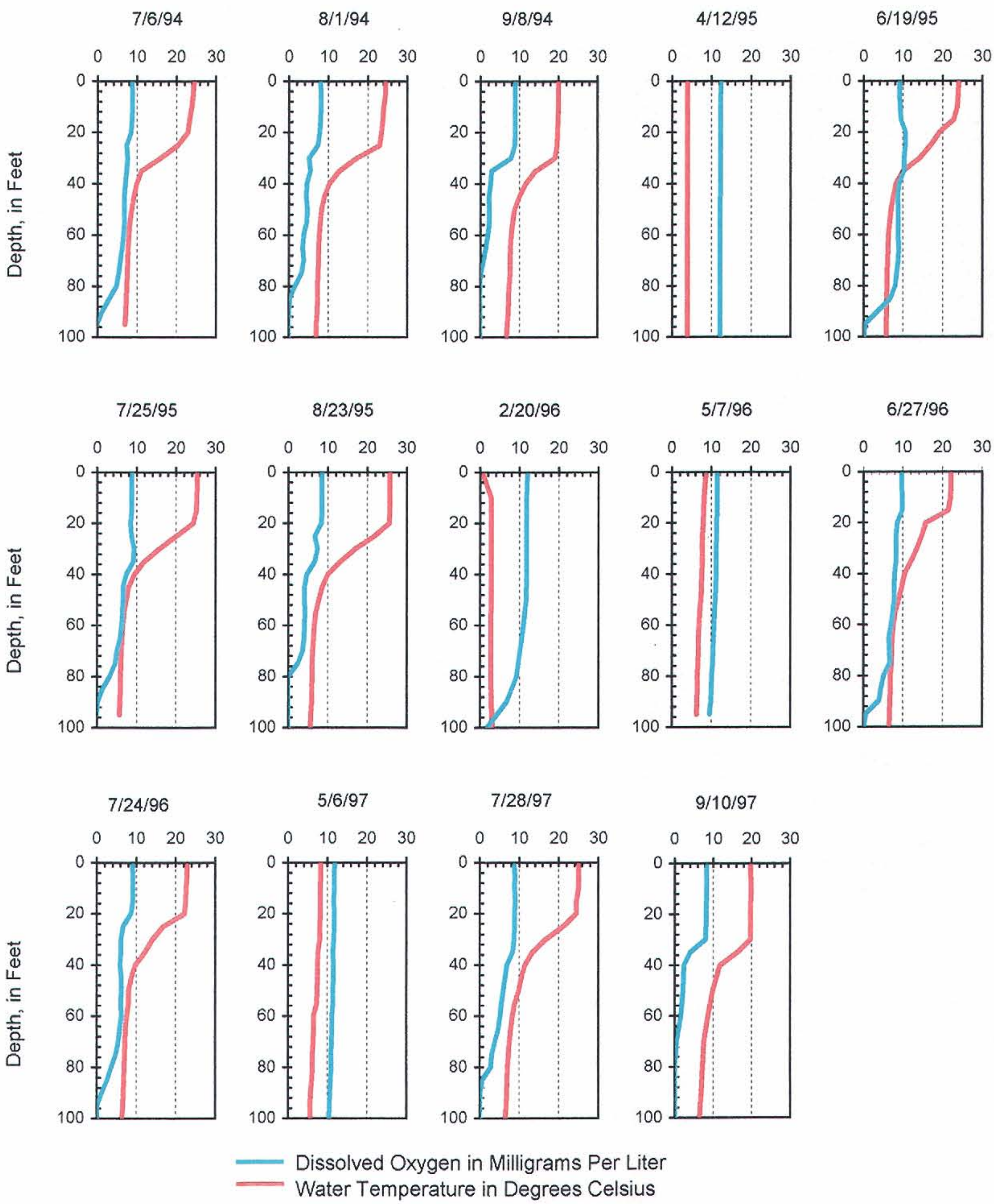
TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR THE NORTHERN BASIN OF BIG CEDAR LAKE: 1994-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 2

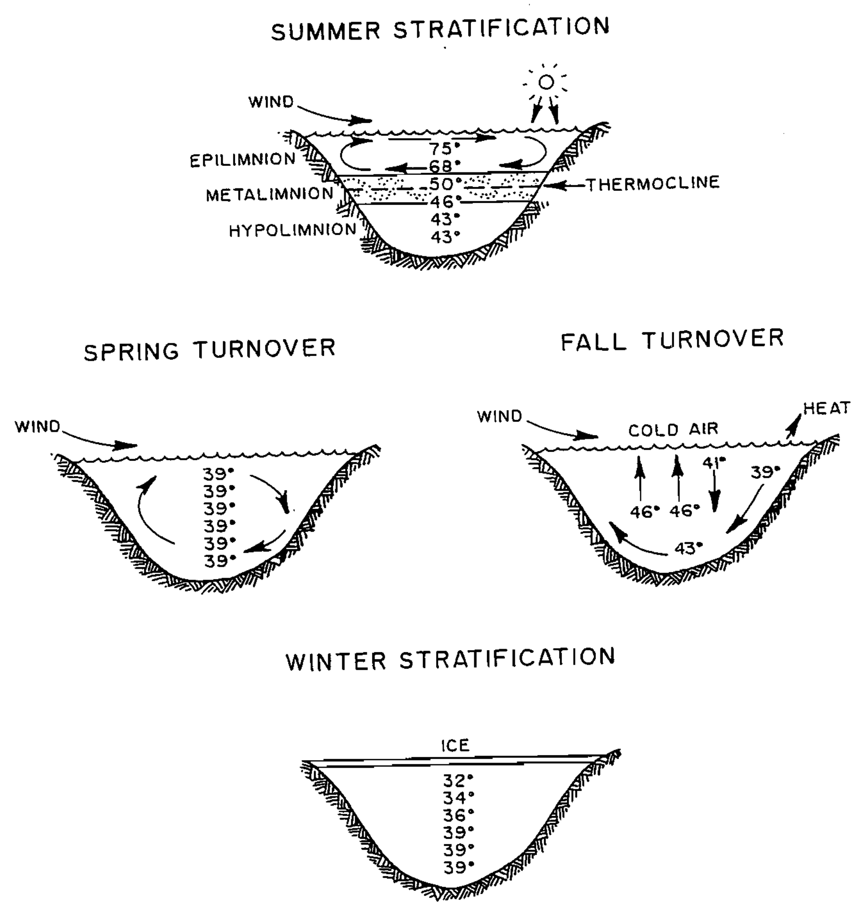
TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR THE SOUTHERN BASIN OF BIG CEDAR LAKE: 1994-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 3

THERMAL STRATIFICATION OF LAKES



Source: University of Wisconsin-Extension and SEWRPC.

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 3.

Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake ecosystem. As shown in Figures 1 and 2, dissolved oxygen levels were generally higher at the surface of Big Cedar Lake, where there was an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant 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.

The hypolimnion of Big Cedar Lake becomes anoxic during summer stratification. During monitoring period, dissolved oxygen concentrations at the bottom of the Lake fell to near zero by mid- to late-June, as shown in Figures 1 and 2 for the months of June, July, August, and September. During most years studied, at depths of between approximately 35 feet and 75 feet, oxygen concentrations were at or below the recommended concentration of five milligrams per liter (mg/l).

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 as shown in Figures 1 and 2 for the month of February. Under these conditions, anoxia can contribute to winter-kill of fish, although none were reported in Big Cedar Lake during the study period. At the end of winter, dissolved oxygen concentrations in the bottom waters of the lake are restored during the period of spring turnover, which generally occurs between March and May in most years.

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 concentrations exist. This migration, when combined with temperature, can select against some fish species that prefer the cooler water temperatures that generally prevail in the lower portions of the lakes. In Big Cedar Lake, there is some evidence set forth in the aforereferenced WDNR Lake Use Report No. ML-1 that cisco have been subjected to frequent summer-kills as a result of deoxygenation of the cooler water habitat in which they occur. In addition, when there is insufficient oxygen at depth, these fish can be 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. Some evidence of internal loading in Big Cedar Lake is observed in terms of the elevated specific conductance levels reported in the hypolimnion of the Lake during summer stratification set forth in Figures 4 and 5.

Specific Conductance

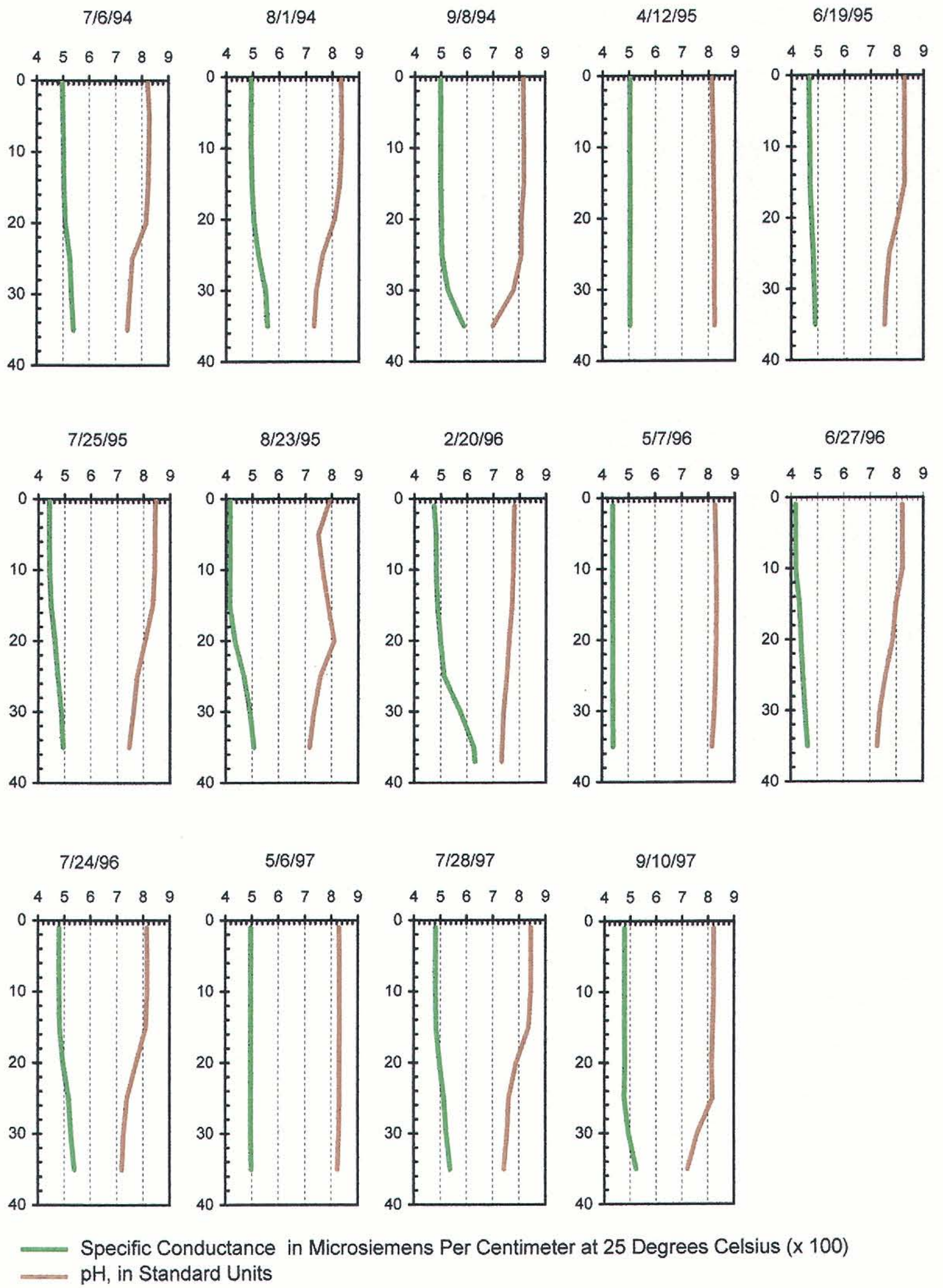
Specific conductance is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. As shown in Tables 2 and 3, the specific conductance of Big Cedar Lake during spring of 1994 through 1997 ranged from 441 to 506 microSiemens per centimeter (μS/cm) at 25°C in the northern basin of the Lake, and from 434 to 504 μS/cm at 25°C in the southern basin of the Lake. These values are within the normal range for lakes in Southeastern Wisconsin.[10]

During periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion. This phenomenon, as noted above, is referred to as "internal loading." Surface to bottom conductivity gradients were observed during the summer, when specific conductance increases with depth from between 475 and 479 μS/cm at the surface to between 492 and 538 μS/cm

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

Figure 4

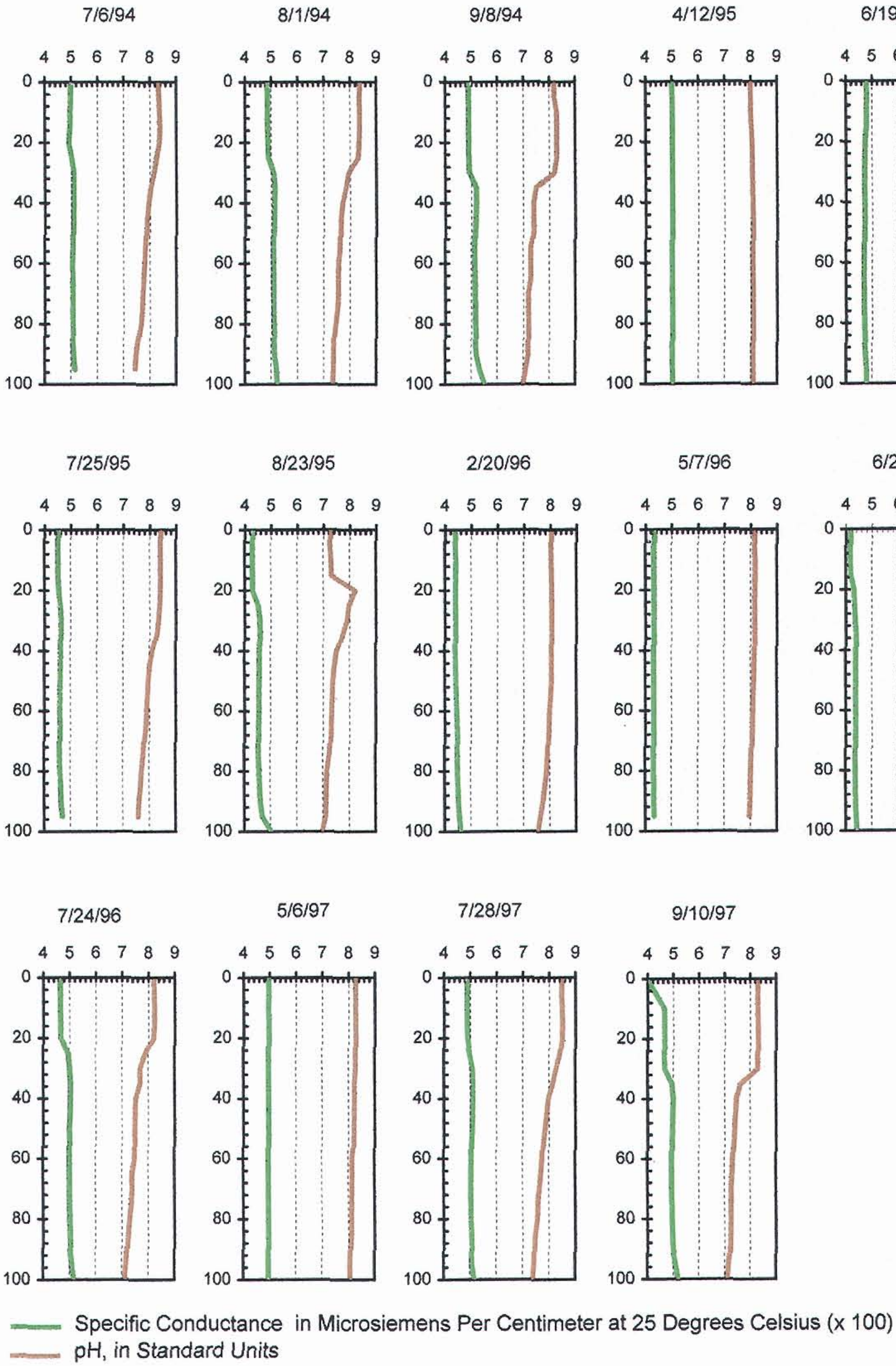
SPECIFIC CONDUCTANCE AND pH PROFILES FOR THE NORTHERN BASIN OF BIG CEDAR LAKE: 1994-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 5

SPECIFIC CONDUCTANCE AND pH PROFILES FOR THE SOUTHERN BASIN OF BIG CEDAR LAKE: 1994-1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

at about 35 feet in depth in the northern Lake basin, and from between 418 and 500 μS/cm at the surface to between 443 and 553 μS/cm at about 100 feet in depth in the southern Lake basin. During winter, surface to bottom conductivity gradients were also observed, as shown in Figures 4 and 5 for the month of February 1996. In the northern basin, specific conductance increased from about 475 μS/cm to about 630 μS/cm at 35 feet in depth; in the southern basin, specific conductance increased from about 440 μS/cm to about 460 μS/cm at about 100 feet in depth.

Hydrogen Ion Concentration (pH) and Alkalinity

The pH of the water 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, while a pH below 7 indicates acidic water. In Big Cedar Lake, the pH was found to range between 7.0 and 8.5 standard units, as shown in Tables 2 and 3. Since the pH does not fluctuate below 7.0 standard units, the Lake is not considered to be susceptible to the harmful effects of acidic deposition. Likewise, since the pH does not exceed 8.5 standard units, the Lake is not considered to be subject to significant pH modification of the surface waters as a consequence of excessive algal growth. Nevertheless, a surface to bottom pH gradient does develop during periods of stratification, with the surface waters of the Lake being more alkaline than the bottom waters, as shown in Figures 4 and 5. Such a gradient is consistent with, and the result of, the chemical processes that take place in the hypolimnion of the Lake during periods of deoxygenation. This phenomenon, and the range of pH values, observed in Big Cedar Lake is typical of lakes in the Southeastern Wisconsin Region.[11]

The capacity of a lake to absorb and neutralize acids is referred to as alkalinity, which is an index of the buffering capacity of a lake. 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 calcium carbonate ($CaCO_3$). Applying these measures to the study lake, Big Cedar Lake may be classified as a hard-water alkaline lake. During the spring of 1980 through 1994, alkalinity ranged from 172 mg/l to 284 mg/l, while hardness ranged from 200 mg/l to 320 mg/l. These values were within the normal range of lakes in Southeastern Wisconsin.[12]

Chloride

Chloride concentrations in Big Cedar Lake have been measured on several occasions between 1967 and 1998. During this period, chloride concentrations were reported to have increased over four-fold from about eight mg/l to about 38 mg/l. The most important anthropogenic source of chlorides is believed to be the salts used on streets and highways for winter snow and ice control. Water softener salts also form a potentially significant anthropogenic source of chloride to inland waters. While the concentrations measured in Big Cedar Lake are within the normal range of lakes in Southeastern Wisconsin,[13] the significant increase in chloride concentration throughout the Region is a trend, shown in Figure 6, that bears further monitoring and investigation.

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, or because of high concentrations of

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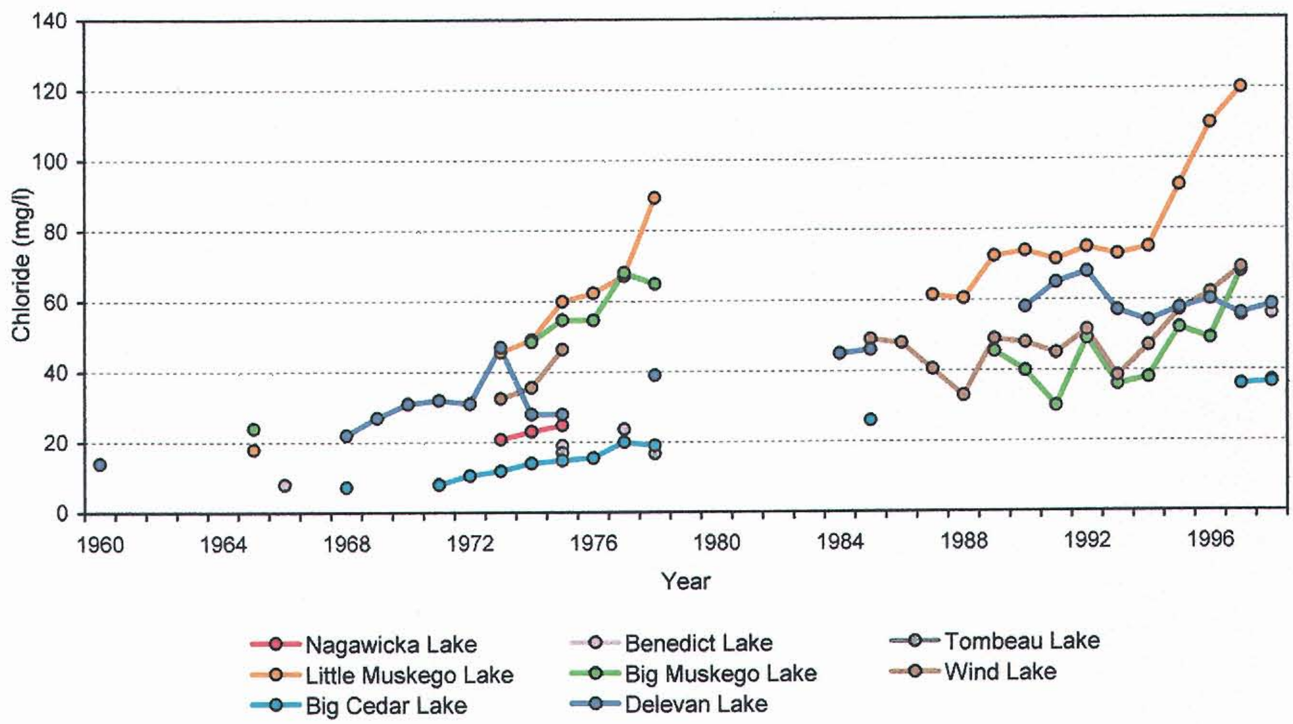
[11]Ibid.

[12]Ibid.

[13]Ibid.

Figure 6

CHLORIDE CONCENTRATION TRENDS FOR ASSORTED LAKES IN SOUTHEASTERN WISCONSIN: 1960-1998



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

inorganic materials such as silt. 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 sediment and nutrient loadings. These same factors make Secchi-disk readings vary from year to year as well. Secchi-disk readings for Big Cedar Lake ranged from 4.6 feet to 19.7 feet in the northern basin of the Lake, and from 5.2 feet to 26.2 feet in the southern basin of the Lake, during the period September 1980 through August 1998, as set forth in Tables 2 and 3. As shown in Figure 7, these values indicate fair to excellent water quality compared to other lakes in Southeastern Wisconsin.[14]

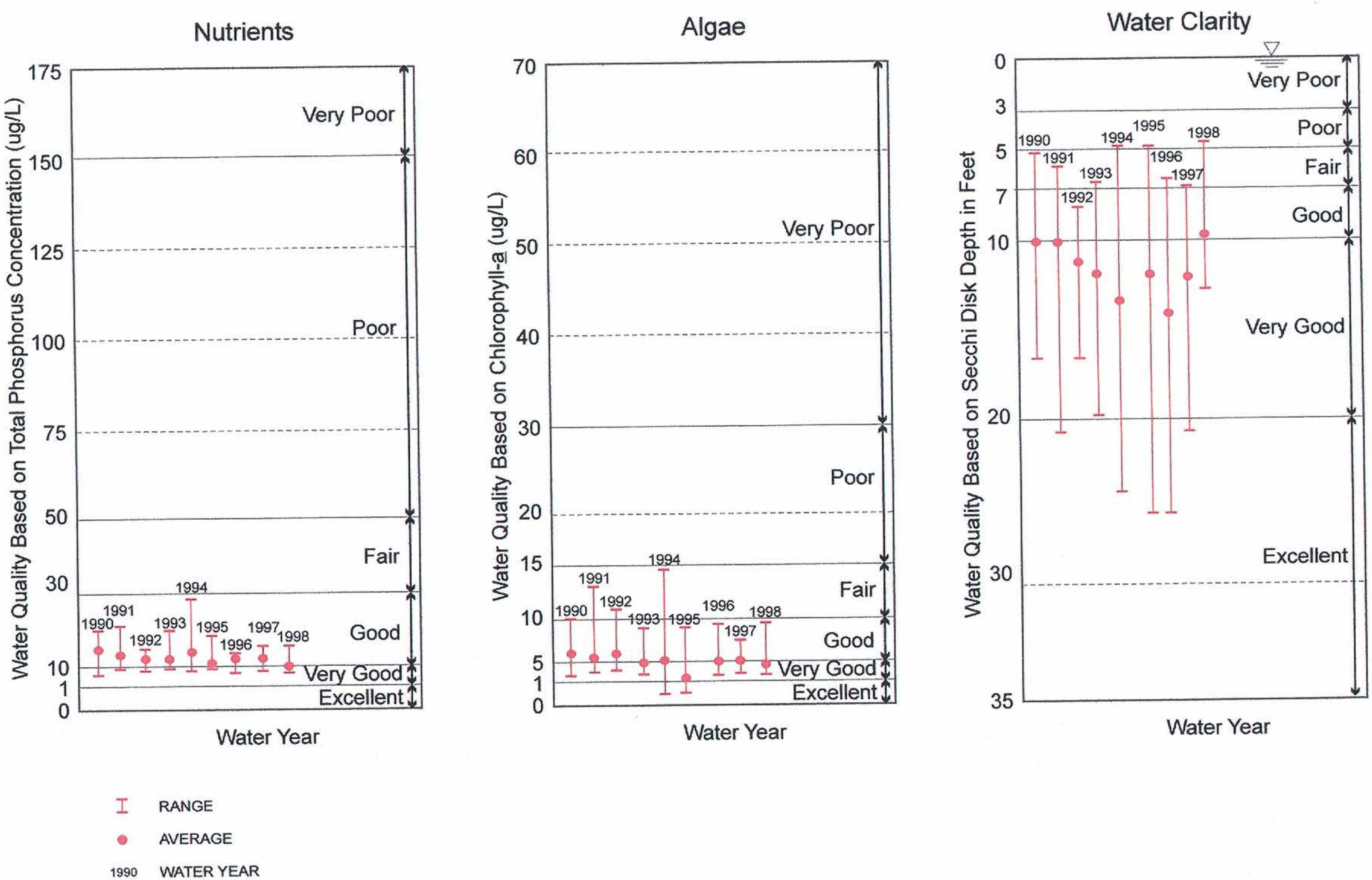
Chlorophyll-*a*

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 Big Cedar Lake ranged from a low of 0.5 micrograms per liter (μg/l) in March 1994, to a high of 14.4 μg/l in April 1994 in the

[14]Ibid.

Figure 7

PRIMARY WATER QUALITY INDICATORS FOR BIG CEDAR LAKE:1990-1998



Source: Wisconsin Department of Natural Resources and SEWRPC.

northern basin of the Lake, and to a high of 8.6 μg/l in April 1994 in the southern basin of the Lake, as set forth in Tables 2 and 3. These values were within the range of chlorophyll-*a* concentrations recorded in other lakes in the Region[15] and indicate fair to excellent water quality, as illustrated in Figure 7.

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 that 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 nutrient.[16] As shown in Table 4, the nitrogen-to-phosphorus ratios in samples collected from Big Cedar Lake during the period from 1985 through 1994 were always greater than 20 to 1. 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 Big Cedar 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 Big Cedar Lake were generally found to be less than 0.02 mg/l, as shown in Tables 2 and 3. Throughout the study period, total phosphorus in the surface waters of Big Cedar Lake ranged from 0.006 mg/l to 0.069 mg/l in the northern Lake basin, and from 0.007 mg/l to 0.055 mg/l in the southern basin of the Lake, indicating fair to very good water quality, as illustrated in Figure 7. Total phosphorus concentrations were found to be higher in the bottom waters, ranging from 0.009 mg/l to 0.230 mg/l, as shown in Tables 2 and 3.

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.

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[15]Ibid.

[16]*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.*

Table 4

NITROGEN-PHOSPHORUS RATIOS FOR BIG CEDAR LAKE: 1972-1998

	North Basin			South Basin		
Date	Nitrogen	Phosphorus	N:P Ratio	Nitrogen	Phosphorus	N:P Ratio
May 10, 1972	--	--	--	0.77	0.190	4.1
May 11, 1973	--	--	--	0.68	0.120	5.7
June 15, 1973	--	--	--	0.65	0.100	6.5
April 8, 1974	--	--	--	0.56	0.110	5.1
April 23, 1975	--	--	--	0.91	0.090	10.1
April 8, 1976	--	--	--	0.59	0.100	5.9
April 19, 1977	--	--	--	0.43	0.070	6.1
April 21, 1978	--	--	--	0.69	0.060	11.5
April 9, 1987	--	--	--	0.50	0.017	29.4
April 13, 1988	0.40	0.015	26.7	--	--	--
April 26, 1989	0.60	0.017	35.3	0.60	0.021	28.6
April 18, 1991	0.60	0.020	30.0	0.50	0.012	41.7
April 15, 1992	0.50	0.010	50.0	0.50	0.015	33.3
May 11, 1993	0.50	0.010	50.0	0.60	0.012	50.0
April 20, 1994	0.40	0.009	44.4	0.40	0.013	30.8
April 12, 1995	0.50	0.019	26.3	--	--	--
May 7, 1996	0.60	0.014	42.9	0.50	0.013	38.5
May 6, 1997	0.50	0.013	38.5	0.40	0.012	33.3
April 1, 1998	0.64	0.009	71.1	0.43	0.013	33.1

Source: Wisconsin Department of Natural Resources and SEWRPC.

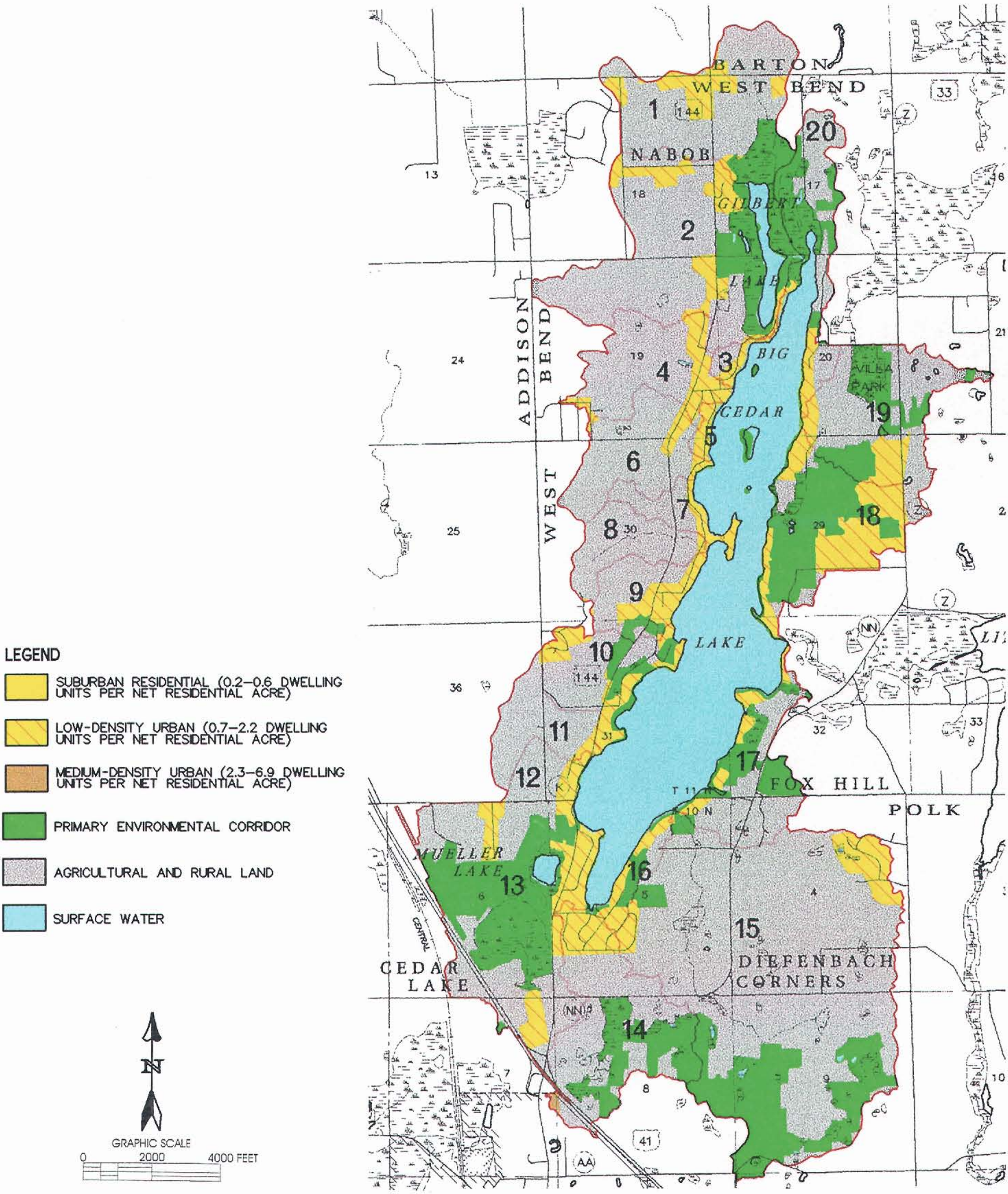
The 1980 through 1994 data indicated that there was little internal loading of phosphorus from the bottom sediments of Big Cedar Lake. As shown in Tables 2 and 3, the dissolved phosphorus concentrations in the bottom waters were relatively low, ranging from 0.005 mg/l to 0.103 mg/l for samples collected during the summer, when such releases of phosphorus are most likely to occur. Thus, the contribution of phosphorus from the bottom waters of Big Cedar Lake may be considered negligible in terms of the total phosphorus load.

POLLUTION LOADINGS AND SOURCES

Currently, there are no known point source discharges of pollutants to Big Cedar Lake or to the surface waters tributary to Big Cedar Lake. Nonpoint sources of water pollution include urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities; and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems from within the approximately 10.4 square mile drainage area tributary to Big Cedar Lake. With the exception of onsite sewage disposal systems and streambank and lakeshore erosion, all of these nonpoint sources of pollution are associated with discrete categories of land usage. Land usage in the drainage area directly tributary to Big Cedar Lake is illustrated on Maps 6 and 7 for existing 1995 and the planned year 2020 land uses in the drainage area, respectively. Land usage is tabulated for existing land use conditions in Table 5. Under year 2020 conditions, only limited additional conversion of rural land to urban land uses within the drainage area tributary to Big Cedar Lake is envisioned in the regional land use

Map 7

PLANNED LAND USES WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE: 2020



Source: SEWRPC.

Table 5

LAND USE WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE BY SUBBASIN: 1995

Land Use Category	Subbasin																			
	CL-1	CL-2	CL-3	CL-4	CL-5	CL-6	CL-7	CL-8	CL-9	CL-10	CL-11	CL-12	CL-13	CL-14	CL-15	CL-16	CL-17	CL-18	CL-19	CL-20
Urban Land Uses (acres)																				
Residential	22.1	56.6	17.6	30.2	9.1	17.6	21.9	8.1	32.5	51.6	13.0	13.1	84.0	43.7	88.8	29.4	50.6	68.8	30.5	36.9
Commercial	7.0	0.3	- -	0.7	0.3	0.5	- -	- -	- -	4.9	- -	0.6	1.0	- -	1.0	- -	4.4	- -	- -	- -
Industrial	26.8	- -	- -	0.3	- -	- -	- -	- -	- -	- -	- -	- -	2.3	- -	- -	- -	- -	- -	- -	- -
Utilities and Transportation	20.2	27.2	2.1	15.3	2.3	8.7	6.2	3.5	8.3	17.4	4.5	6.0	83.4	20.4	20.5	4.9	18.0	57.3	20.0	8.3
Recreational	0.4	0.1	0.1	0.9	- -	0.6	- -	- -	- -	5.1	0.1	- -	0.7	1.1	1.1	0.1	- -	0.2	52.3	- -
Land Under Development	- -	3.1	- -	0.4	- -	0.1	- -	- -	- -	- -	0.5	- -	2.7	0.7	0.1	- -	2.2	0.5	- -	- -
Rural Land Uses (acres)																				
Agricultural	206.9	296.4	- -	120.0	- -	136.6	20.5	86.3	45.1	54.9	88.4	46.4	75.7	129.8	767.9	6.5	41.3	0.2	101.9	36.6
Pasture	8.0	29.6	5.6	8.5	4.3	19.7	11.4	16.9	34.6	12.8	4.3	0.8	29.6	35.1	131.5	2.0	14.7	16.9	5.5	9.3
Wetland	33.0	63.4	2.6	0.9	- -	1.6	0.3	- -	- -	0.4	- -	- -	101.6	44.3	45.5	- -	13.0	12.9	29.3	33.2
Woodland	38.7	52.2	4.5	45.9	1.6	18.8	5.9	10.1	4.8	37.4	19.3	4.5	129.4	73.8	104.0	5.8	45.3	133.5	61.3	34.8
Water	- -	5.6	3.6	1.1	1.7	0.3	3.5	- -	0.4	0.4	- -	0.2	14.9	0.7	5.0	3.9	5.1	1.5	3.8	3.4
Vacant Land	15.9	21.8	- -	1.8	0.1	- -	0.8	0.5	4.8	3.4	- -	- -	102.0	31.1	226.7	5.5	27.3	22.6	23.2	29.3
Total	379.2	561.3	36.0	226.0	19.3	204.5	70.6	125.4	130.5	188.2	129.9	71.6	627.2	380.7	1,391.9	58.1	221.9	314.5	327.9	191.8

Source: SEWRPC.

plan,[17] as shown by comparison of Maps 6 and 7. However, infilling of existing platted lots and limited additional low-density, single-family residential development within the tributary drainage area and in the vicinity of the Lake is expected to occur. In this regard, it should be noted that the Town of West Bend recently completed a land use plan that envisions the conversion of much of the remaining agricultural lands within the Town to large-lot, low-density, single-family residential usage within the planning period.

Pollutant loads to a lake are generated by various natural processes and human activities that take place in the drainage area tributary to a lake. These loads are transported to the lake through the atmosphere, across the land surface, and by way of inflowing streams. Pollutants transported by the atmosphere are deposited onto the surface of the lake as dry fallout and direct precipitation. Pollutants transported across the land surface enter the lake as direct runoff and, indirectly, as groundwater inflows, including drainage from onsite wastewater treatment systems. Pollutants transported by streams enter a lake as surface water inflows. In drained lakes, like Big Cedar Lake, pollutant loadings transported across the land surface directly tributary to a lake, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities, comprise the principal route by which contaminants enter a waterbody.[18] For this reason, the discussion that follows is based upon nonpoint source pollutant loadings to Big Cedar Lake.

The nonpoint source pollutant loads to Big Cedar Lake were estimated on the basis of land use inventory data and unit area load coefficients determined for Southeastern Wisconsin.[19] Phosphorus loads were calculated using the Wisconsin Lake Model Spreadsheet program (WILMS), created by the Wisconsin Department of Natural Resources.[20]

To validate the estimated pollutant loading estimates to Big Cedar Lake, Commission staff applied the estimated phosphorus load in the Vollenweider-type OECD phosphorus budget model to estimate an in-lake total phosphorus concentration.[21] This calculation resulted in an estimated annual average phosphorus concentration that was compared to the observed whole-lake phosphorus concentration in the Lake. Agreement between the estimated and observed values would suggest that the estimated contaminant loads are a reasonable estimate of the loads entering Big Cedar Lake, and that other pollutant sources, including internal loading, to Big Cedar Lake, are relatively small compared to the loading from external sources. Likewise, similar comparisons were made using chlorophyll-*a* concentrations estimated from the Vollenweider-type model and observed in-lake concentrations.

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

[18]*Sven-Olof Ryding and Walter Rast,* The Control of Eutrophication of Lakes and Reservoirs, *Unesco Man and the Biosphere Series, Volume 1, Parthenon Press, Carnforth, 1989; Jeffrey A. Thornton, Walter Rast, Marjorie M. Holland, Geza Jolankai, and Sven-Olof Ryding,* The Assessment and Control of Nonpoint Source Pollution of Aquatic Ecosystems, *Unesco Man and the Biosphere Series, Volume 23, Parthenon Press, Carnforth, 1999.*

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

[20]*Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-96 REV,* Wisconsin Lake Model Spreadsheet Version 2.0 User's Manual, *June 1994.*

[21]*Organization for Economic Cooperation and Development,* Eutrophication of Waters: Monitoring, Assessment and Control, *Paris, 1982.*

Of the controllable pollutant sources, the most significant sources under existing land use conditions vary with the particular pollutant of concern. Measures for the control of contaminants from these various sources can be effected through a variety of measures as set forth in Chapter IV.

Phosphorus Loads

In order to estimate the amount of pollution contributed by nonpoint sources to Big Cedar Lake, annual loading budgets for phosphorus and sediment were developed for the watershed under the study using the unit area load model. The results of that model were compared to analyses prepared by the Commission staff utilizing the Wisconsin Lake Model Spreadsheet version 2.00. The resulting estimated phosphorus budget for Big Cedar Lake, is shown in Table 6. A total annual phosphorus loading of about 2,340 pounds is estimated to be contributed to Big Cedar Lake. Of this total, it is estimated that about 1,690 pounds per year, or 72 percent of the total loading, was contributed by runoff from rural land; and about 400 pounds per year, or 17 percent, was contributed by runoff from urban land. The remaining phosphorus loading was contributed by direct precipitation onto the Lake surface. Phosphorus release from the Lake bottom sediments, internal loading, may also contribute additional phosphorus loadings to the Lake. However, this loading was assumed to be negligible given the good agreement between predicted and observed phosphorus concentrations in Big Cedar Lake. As noted above, agreement between the estimated and observed values suggests that the estimated contaminant loads are a reasonable representation of the loads entering Big Cedar Lake, and indicates that other pollutant sources, including internal loading, to Big Cedar Lake, are relatively small compared to the loading from external sources.

As of 1995, the entire drainage area tributary to Big Cedar Lake was served by onsite sewage disposal systems. Approximately 900 onsite sewage disposal systems exist in the riparian land area surrounding Big Cedar Lake. 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, which, in turn, may discharge to Big Cedar Lake.

With the exception of holding tank systems, 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. 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.

The residential development surrounding Big Cedar Lake is located in areas covered by poorly to moderately well-drained soils, as shown on Map 8. For the most part, these soils are not clearly defined with regard to the criteria for conventional onsite sewage disposal systems under Chapter Comm 83 of the *Wisconsin Administrative Code*, shown graphically on Map 9. Thus, in much of this area, the site suitability for onsite systems must be determined on a site-specific basis. The suitability of the soils for conventional onsite sewage disposal is influenced, in part, by soil characteristics and the occurrence of some steeply sloped lands surrounding Big Cedar Lake, as shown on Maps 8 and 10. Use of alternative onsite sewage disposal systems significantly increases the land area suitable for residential development using onsite sewage disposal systems, as set forth on Map 11. Notwithstanding, the good agreement between predicted and observed in-lake phosphorus concentrations, the former having been forecast on the basis of land usage, suggests that onsite sewage disposal systems are not expected to be a major contributor of phosphorus loading on a Lakewide basis. None-the-less, there is a need to monitor such systems which, if not properly functioning, can cause localized Lake problems and, potentially, groundwater impacts.

Table 6

PHOSPHORUS LOADINGS TO BIG CEDAR LAKE BY SUBBASIN: 1995

Land Use Category	Subbasin																			
	CL-1	CL-2	CL-3	CL-4	CL-5	CL-6	CL-7	CL-8	CL-9	CL-10	CL-11	CL-12	CL-13	CL-14	CL-15	CL-16	CL-17	CL-18	CL-19	CL-20
Urban Loadings (pounds of phosphorus per year)																				
Residential	4.9	12.6	4.0	6.7	2.0	4.0	4.9	1.8	7.3	11.6	2.9	2.9	18.7	13.8	20.0	6.6	11.3	15.4	6.8	8.2
Commercial and Industrial	31.5	16.0	1.2	9.4	1.5	5.3	3.6	2.1	4.8	12.9	2.6	3.9	50.2	16.8	12.4	2.9	13.0	33.3	11.6	4.8
Rural Loadings (pounds of phosphorus per year)																				
Agricultural	138.7	200.4	- -	80.3	- -	91.3	13.7	57.8	30.2	36.7	59.4	31.1	52.3	124.6	514.2	4.4	29.1	0.5	68.1	24.5
Pasture	2.7	6.3	0.8	1.5	0.6	2.4	1.6	2.0	5.1	2.8	0.3	- -	17.0	12.1	29.5	0.8	5.5	5.3	10.6	5.2
Wetland	1.5	3.2	0.1	- -	- -	0.1	0.1	- -	- -	- -	- -	- -	4.6	2.8	1.8	- -	0.6	0.6	1.3	1.5
Woodland	1.6	2.2	0.2	1.8	0.1	0.7	0.2	0.4	0.2	1.5	0.8	0.2	5.2	4.2	8.8	0.2	1.8	5.3	2.5	1.4
Water	- -	1.5	1.0	0.3	0.5	0.1	0.9	- -	0.1	0.1	- -	0.1	4.0	0.4	1.2	1.1	1.4	0.4	1.0	0.9
Total[a]	181.0	242.0	7.2	100.0	4.6	104.0	25.0	64.1	47.7	65.6	66.1	38.1	152.0	175.0	589.0	15.9	62.7	60.7	102.0	46.5

[a] *Total excludes phosphorus loadings to Big Cedar Lake through direct precipitation onto the lake surface, which amounts to about 250 pounds.*

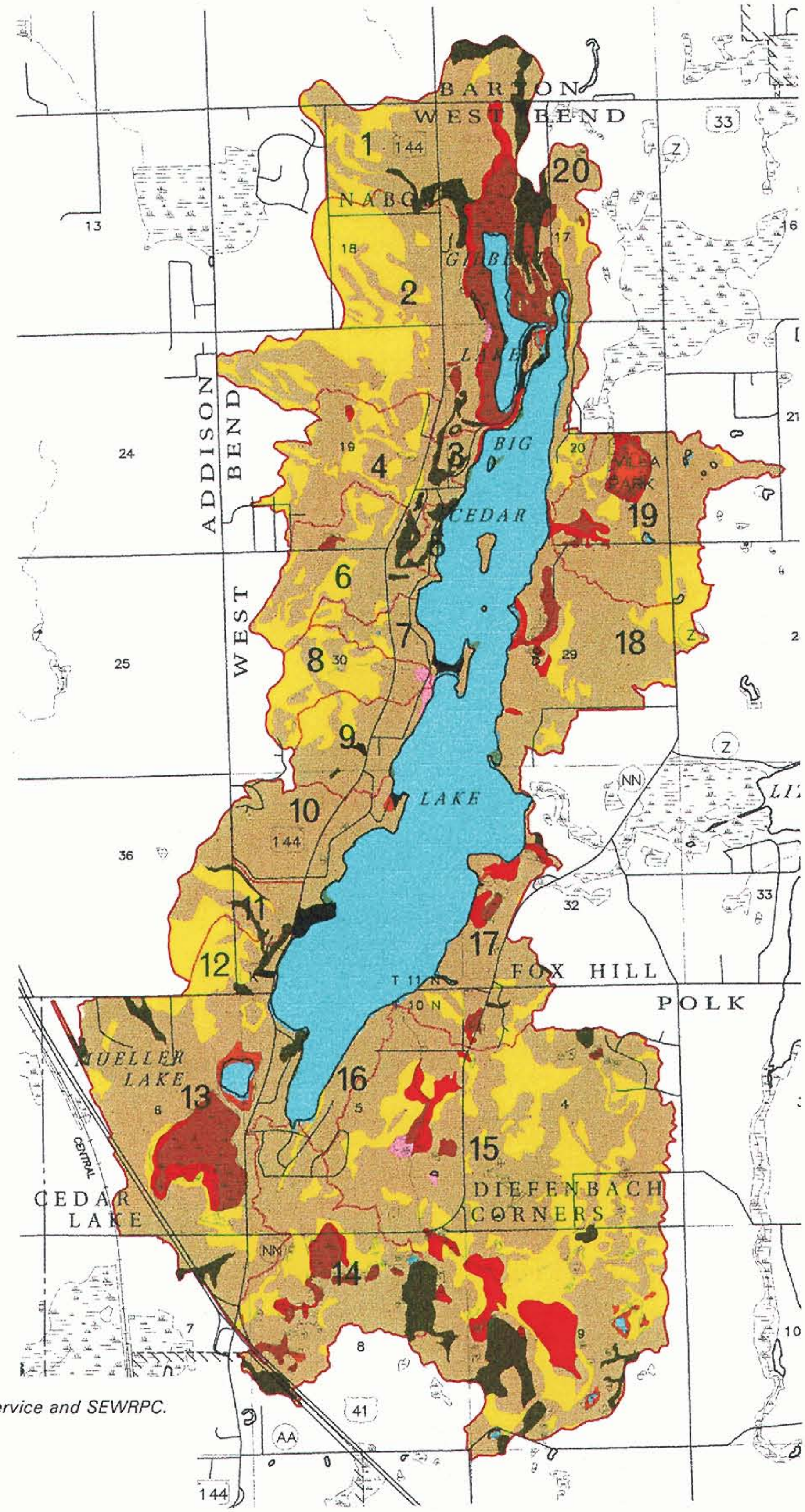
Source: SEWRPC.

Map 8

HYDROLOGIC SOIL GROUPS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE

HYDROLOGIC SOIL CATAGORIES

- GROUP A: WELL-DRAINED SOILS
- GROUP A/B: WELL-DRAINED SOILS/ MODERATELY DRAINED SOILS [1]
- GROUP A/D: WELL-DRAINED SOILS/ VERY POORLY DRAINED SOILS [2]
- GROUP B: MODERATELY DRAINED SOILS
- GROUP B/D: MODERATELY DRAINED SOILS/ VERY POORLY DRAINED SOILS [3]
- GROUP C: POORLY DRAINED SOILS
- GROUP C/D: POORLY DRAINED SOILS/ VERY POORLY DRAINED SOILS [4]
- GROUP D: VERY POORLY DRAINED SOILS
- HYDROLOGIC SOIL TYPE NOT DETERMINED
- SURFACE WATER

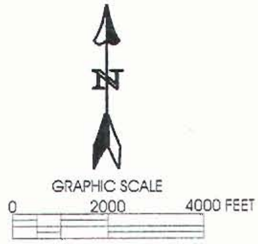


1 Well-drained soil if water table is lowered through provision of a drainage system. Moderately drained soil if water table is not lowered.

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 if water table is not lowered.

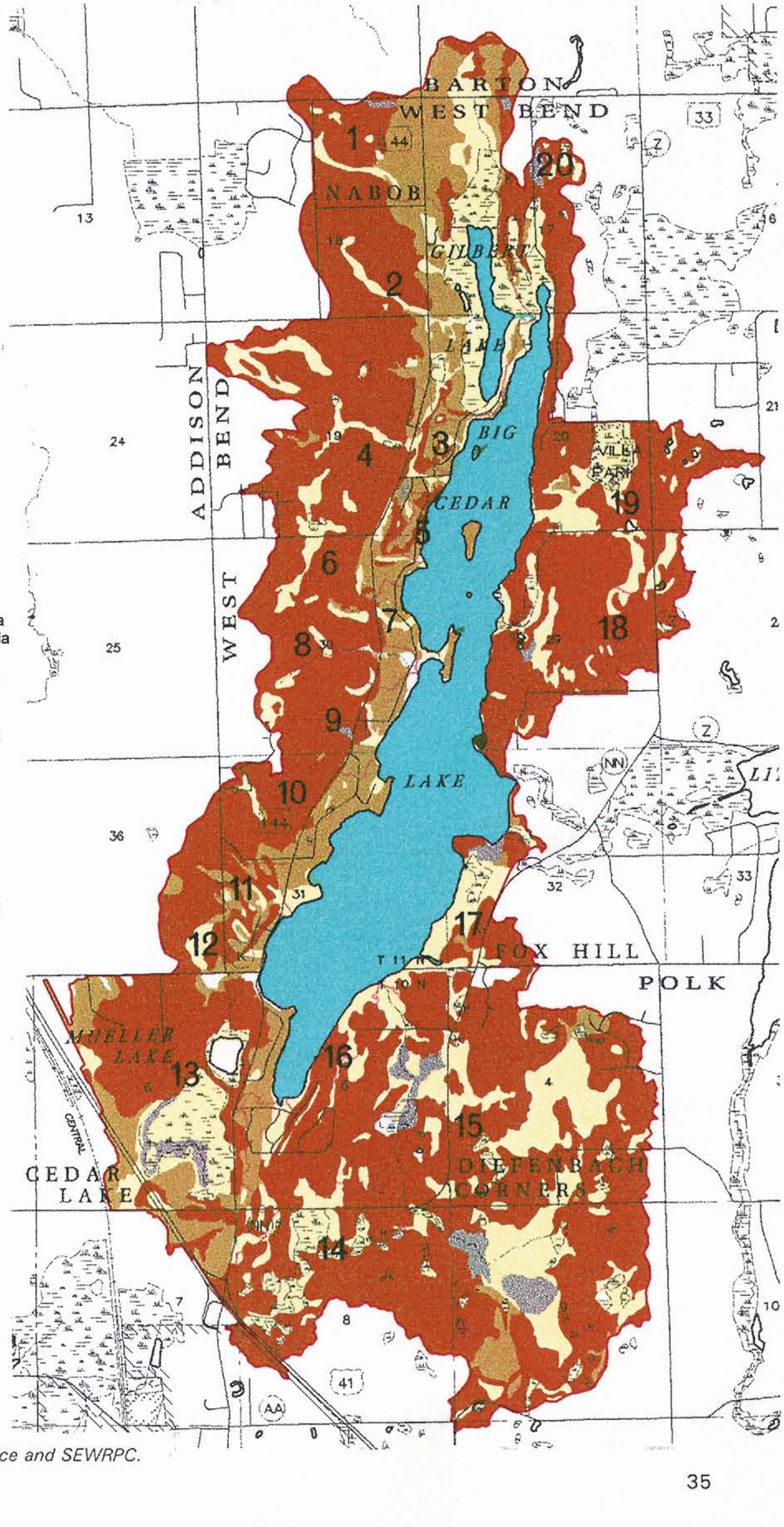
4 Poorly drained soil if water table is lowered through provision of a drainage system. Very poorly drained soil if water table is not lowered.



Source: U.S. Natural Resources Conservation Service and SEWRPC.

Map 9

SUITABILITY OF SOILS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE FOR CONVENTIONAL ONSITE SEWAGE DISPOSAL SYSTEMS UNDER CURRENT ADMINISTRATIVE RULES



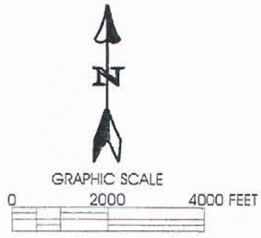
UNSUITABLE: Areas covered by soils which have a high probability of not meeting the June 2000 criteria of Chapter Comm. 83 of the *Wisconsin Administrative Code* governing conventional onsite sewage disposal systems

UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the June 2000 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 June 2000 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

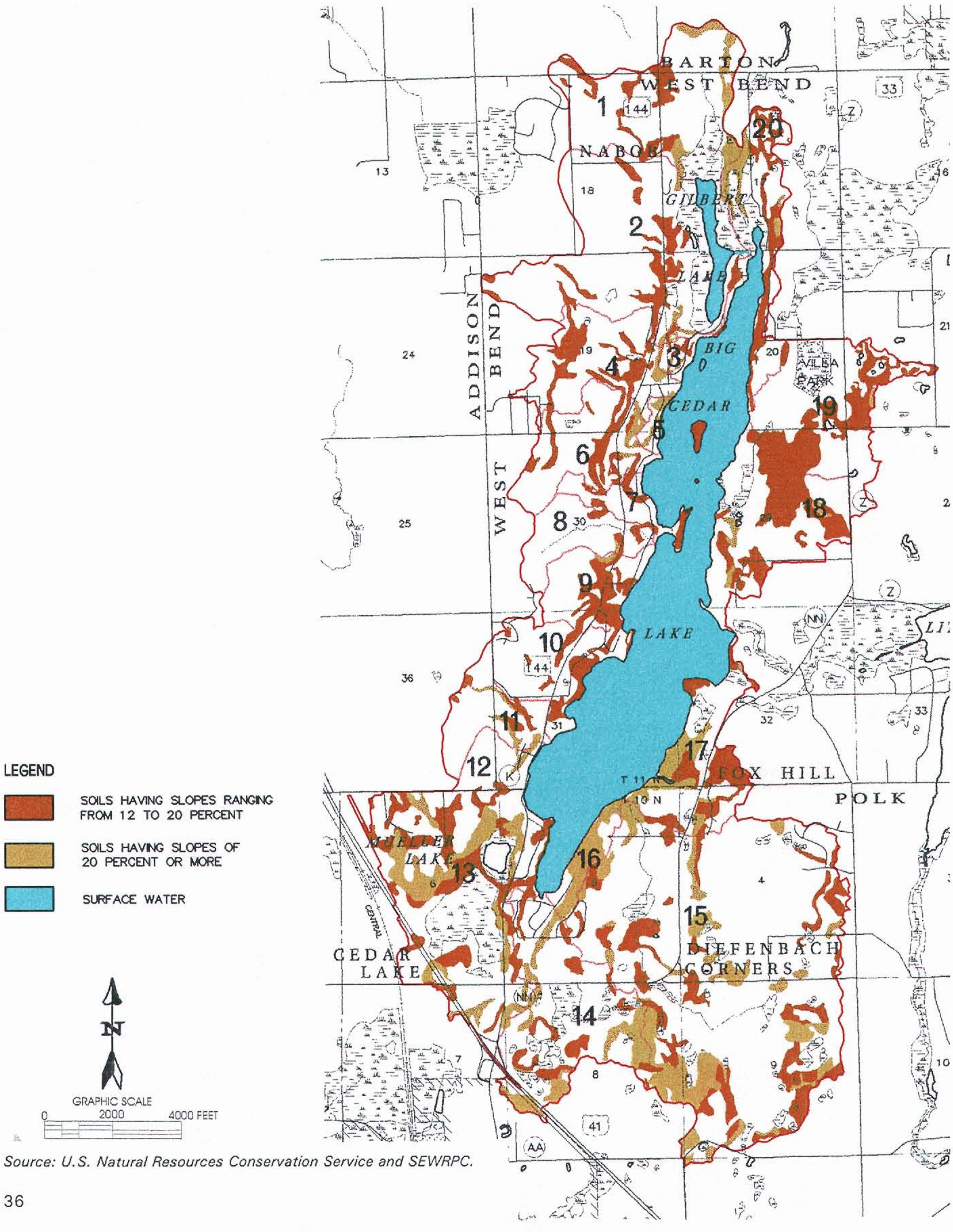
SURFACE WATER



Source: U.S. Natural Resources Conservation Service and SEWRPC.

Map 10

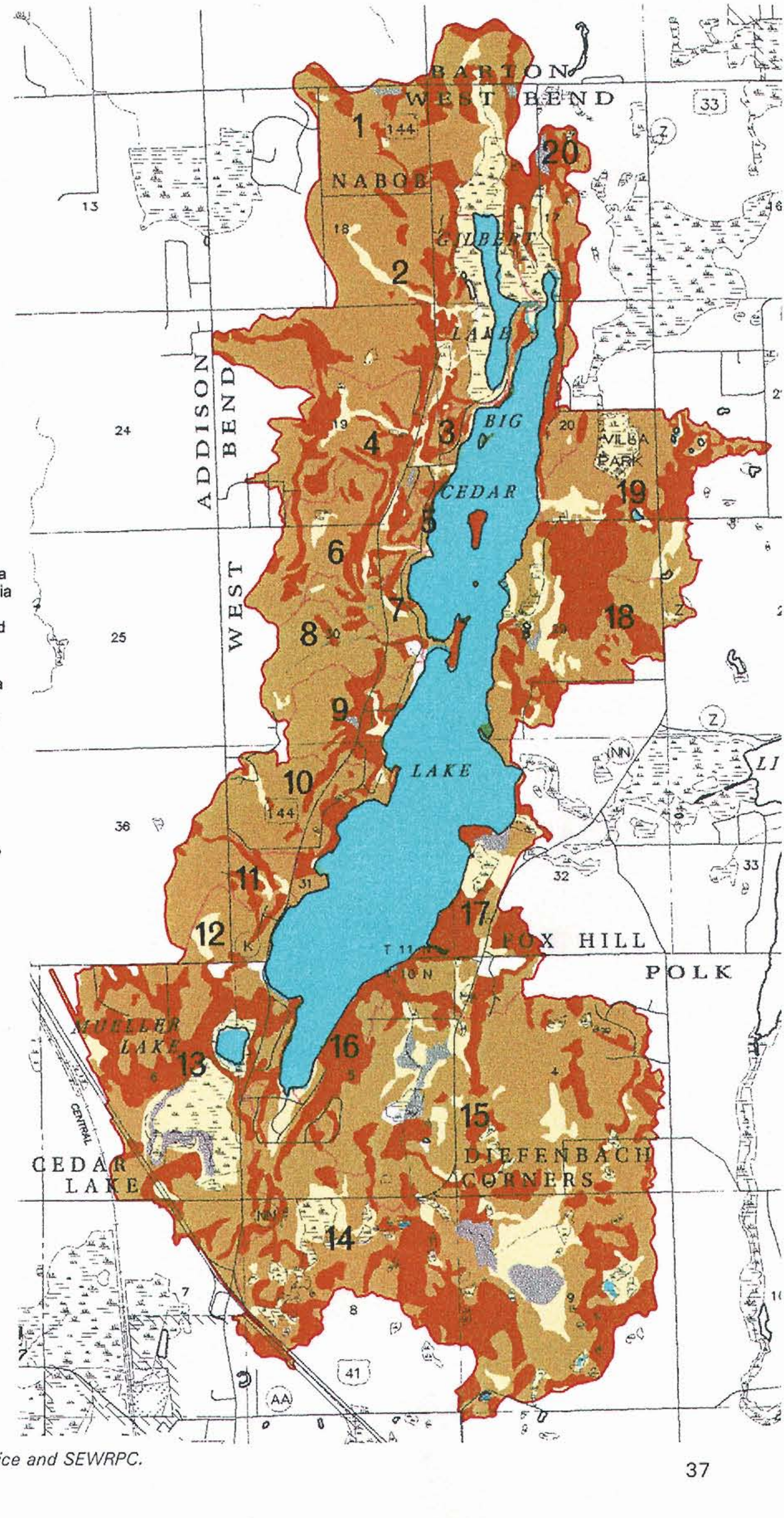
PHYSIOGRAPHIC FEATURES OF THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



Source: U.S. Natural Resources Conservation Service and SEWRPC.

Map 11

SUITABILITY OF SOILS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE FOR ALTERNATIVE ONSITE SEWAGE DISPOSAL SYSTEMS UNDER CURRENT ADMINISTRATIVE RULES



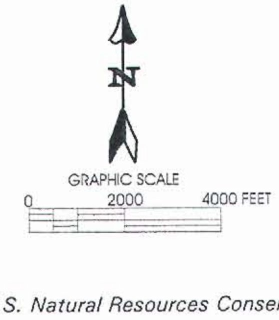
UNSUITABLE: Areas covered by soils which have a high probability of not meeting the June 2000 criteria of Chapter Comm. 83 of the *Wisconsin Administrative Code* governing conventional mound sewage disposal systems

UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the June 2000 criteria of Chapter Comm. 83 of the *Wisconsin Administrative Code* governing conventional mound sewage disposal systems so that no classification can be assigned

SUITABLE: Areas covered by soils having a high probability of meeting the June 2000 criteria of Chapter Comm. 83 of the *Wisconsin Administrative Code* governing conventional mound sewage disposal systems

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

SURFACE WATER



Source: U.S. Natural Resources Conservation Service and SEWRPC.

A local facilities planning program[22] conducted in 1989 for the then existing Big Cedar Lake Sanitary District, in collaboration with the Little Cedar Lake Sanitary District and Silver Lake Sanitary District, concluded that replacement of a significant number of the existing onsite sewage disposal systems serving the urban development surrounding the Lake would be limited by lot size and land slope, suggesting that, in the long term, onsite sewage disposal systems in some areas would have to be replaced with holding tanks over a 20-year period. The study indicated that about 20 properties, or 4 percent of the onsite sewage disposal systems, were served by holding tank systems at that time. The local facilities planning program concluded that the condition and operation of the onsite sewage disposal systems serving residential developments around Big Cedar Lake continue to be monitored for potential failures. In this regard, it should be noted that, although 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 may 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. In this regard, the availability of alternative types of onsite sewage disposal systems for replacement of existing systems, as is currently being considered under proposed revisions to Chapter Comm 83 of the *Wisconsin Administrative Code*, may provide options for some residents other than holding tanks should their existing systems fail.

Approximately 76 percent of the total phosphorus loading to the Lake, or about 1,780 pounds, is estimated to be used by the biomass within the Lake or deposited in the lake sediments,[23] resulting in a net downstream transport of about 560 pounds of phosphorus, or 24 percent of the total phosphorus loading to the Lake. The phosphorus mass retained in the Lake is typically reduced by the Big Cedar Lake Management District aquatic plant harvesting program, which removes phosphorus from the Lake[24] as a component of the aquatic plant biomass.

Sediment Loads

Bottom sediment conditions have an important effect on the condition of a lake. As the sediment is deposited, valuable benthic habitats are buried, macrophyte-prone substrates are increased, fish spawning areas are covered, and aesthetic nuisances develop. Sediment particles also act as transport mechanisms for other substances, such as phosphorus, nitrogen, organic materials, pesticides, and heavy metals which may enter the water column of a lake through biogeochemical processes such as those previously described above.

The annual sediment load to Big Cedar Lake was estimated to be about 670 tons, as set forth in Table 7. About 590 tons per year, or 88 percent of the total sediment load, was estimated to be contributed by runoff from rural land, and approximately 90 tons per year, or 12 percent of the total sediment load, was estimated to be contributed by runoff from urban land. A further mass of sediment, totaling approximately 95 tons, was deposited directly onto the Lake surface in the forms of wet and dry fall out. Sediment transport out of Big Cedar Lake was estimated to be about 105 tons after accounting for in-lake retention of sediments in Big Cedar Lake.[25]

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[22]*Ruekert & Mielke, Inc.,* Tri-Lakes Area Sanitary Study, *November 1989.*

[23]*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.*

[24]*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.*

[25]*Using the method of Larsen and Mercier,* op. cit.

Table 7

SEDIMENT AND HEAVY METAL LOADINGS TO BIG CEDAR LAKE BY SUBBASIN: 1995

Subbasin	Sediment (pounds per year)	Copper (pounds per year)	Zinc (pounds per year)	Cadmium (pounds per year)
CL-1	125,174	8.9	53.5	0.34
CL-2	155,939	2.2	8.4	0.00
CL-3	5,005	1.4	2.5	0.00
CL-4	62,363	1.8	5.7	0.01
CL-5	3,429	1.3	1.7	0.00
CL-6	72,761	1.5	3.2	0.01
CL-7	17,292	1.4	3.1	0.00
CL-8	47,325	1.2	1.1	0.00
CL-9	39,332	1.7	4.6	0.00
CL-10	40,002	3.1	14.5	0.05
CL-11	43,357	1.3	1.8	0.00
CL-12	23,132	1.4	2.7	0.01
CL-13	64,948	3.4	16.7	0.03
CL-14	79,974	1.9	6.1	0.00
CL-15	418,307	3.0	13.9	0.01
CL-16	7,621	1.6	4.1	0.00
CL-17	36,304	3.0	13.6	0.04
CL-18	16,388	2.4	9.6	0.00
CL-19	54,095	1.6	4.3	0.00
CL-20	25,593	1.7	5.2	0.00
Total[a]	1,338,341	45.8	176.3	0.49

[a] *These loadings do not include the contribution to Big Cedar Lake from direct precipitation and dry fallout.*

Source: SEWRPC.

Heavy Metal Loads

Urbanization brings with it increased use of metals and other materials that contribute pollutants to aquatic systems.[26] Table 7 sets forth the estimated loadings of copper, zinc, and cadmium likely to be contributed to Big Cedar Lake from urban development surrounding the Lake. On an annual basis, it is estimated that about 46 pounds of copper, 175 pounds of zinc, and 0.5 pound of cadmium enter Big Cedar Lake. The majority of these metals become associated with sediment particles[27] and are likely to be encapsulated into the bottom sediments of the Lake. Measurements of zinc concentrations in the epilimnion and hypolimnion of Big Cedar Lake, reported to

[26] *Thornton, et al.*, op. cit.

[27] *Werner Stumm and James J. Morgan,* Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters, *Wiley-Interscience, New York, 1970.*

be below the limits of detection during 1997, would suggest that the occurrence of these metals in the Big Cedar Lake system pose little threat to the integrity of the aquatic ecosystem.[28]

RATING OF TROPHIC CONDITION

As a means of summarizing or synthesizing the water quality condition of a waterbody, 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 State, 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[29] and the Wisconsin Trophic State Index (WTSI) classification system are presented.[30] The WTSI is a refinement of the Carlson Trophic State Index (TSI),[31] designed to account for the 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.

Trophic State Classification

Using the Vollenweider trophic system and applying the data in Tables 2 and 3, Big Cedar Lake would be classified as being mesotrophic. Based upon phosphorus levels, as shown in Figure 8, Big Cedar Lake would have about a 60 percent probability of being oligotrophic; based upon chlorophyll-*a* levels, the Lake would have about

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[28]*Frits van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia, Second Edition, *Lewis Publishers, Boca Raton, 1990; zinc concentrations should not exceed 180 μg/l in freshwater systems for the protection of freshwater aquatic life.*

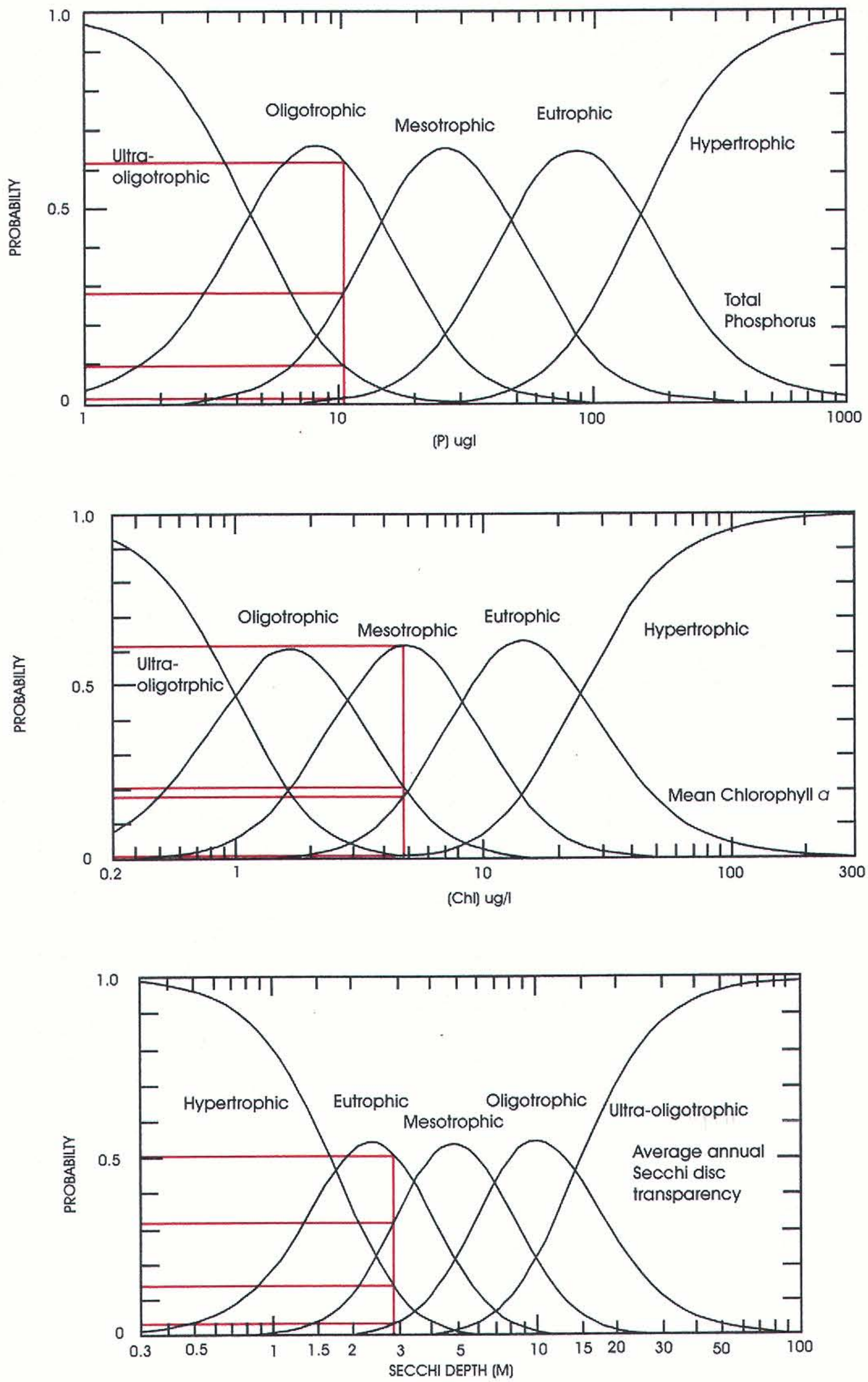
[29]*H. Olem and G. Flock,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *U.S. Environmental Protection Agency Report EPA-440/4-90-006, Office of Water (WH-553), Washington, D.C., August 1990.*

[30]*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.*

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

Figure 8

TROPHIC STATE CLASSIFICATION OF BIG CEDAR LAKE BASED UPON THE VOLLENWEIDER MODEL



Source: S.-O. Ryding and W. Rast, The Control of Eutrophication of Lakes and Reservoirs, *Volume 1, 1989; and SEWRPC.*

a 60 percent probability of being mesotrophic; and based upon Secchi-disk readings, the Lake would have about a 50 percent probability of being eutrophic, as shown in Figure 8. In terms of both phosphorus concentration and Secchi-disk transparency, the Lake would have about a 30 percent probability of being classified as mesotrophic. Thus, while these indicators result in widely varying lake trophic state classifications, it may be concluded that Big Cedar Lake should be classified as a mesotrophic lake, or a lake with acceptable water quality for most uses.

Trophic State Index

The Trophic State Index 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.[32] The Trophic State Index ratings for Big Cedar Lake are shown in Figure 9 as a function of sampling date. Based on the Wisconsin Trophic State Index rating of about 46, Big Cedar Lake may also be classified as mesotrophic.

AQUATIC BIOTA

As mentioned above, the trophic state of a lake is a measure of the potential biological productivity of the waterbody. The greater the level of enrichment, or the higher the trophic level of a waterbody, the greater the biological productivity. As lakes increase in trophic status, however, the quality and diversity of that biological productivity is likely to decline, with fewer species being present in greater numbers. Often these species that occur with greater frequency and at greater densities are those that are perceived as interfering with human use of the waterbody, and many lack significant environmental value as habitat or food sources.

Aquatic plants, including the larger plants or macrophytes, and microscopic algae or phytoplankton, 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, including fishes. In this process, known as photosynthesis, plants utilize energy from sunlight and release oxygen required by other aquatic life forms.

Aquatic Plants

Aquatic plants 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. Algae, when present in lakes as balanced populations, provide an important food source to both fishes and zooplankton, which in turn form a food source for fishes. Both algae and 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 plants 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.

Phytoplankton 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. The biomass or amount of algae in a lake is typically determined as the concentration of chlorophyll-*a* in the water column of a lake. Algal blooms, as

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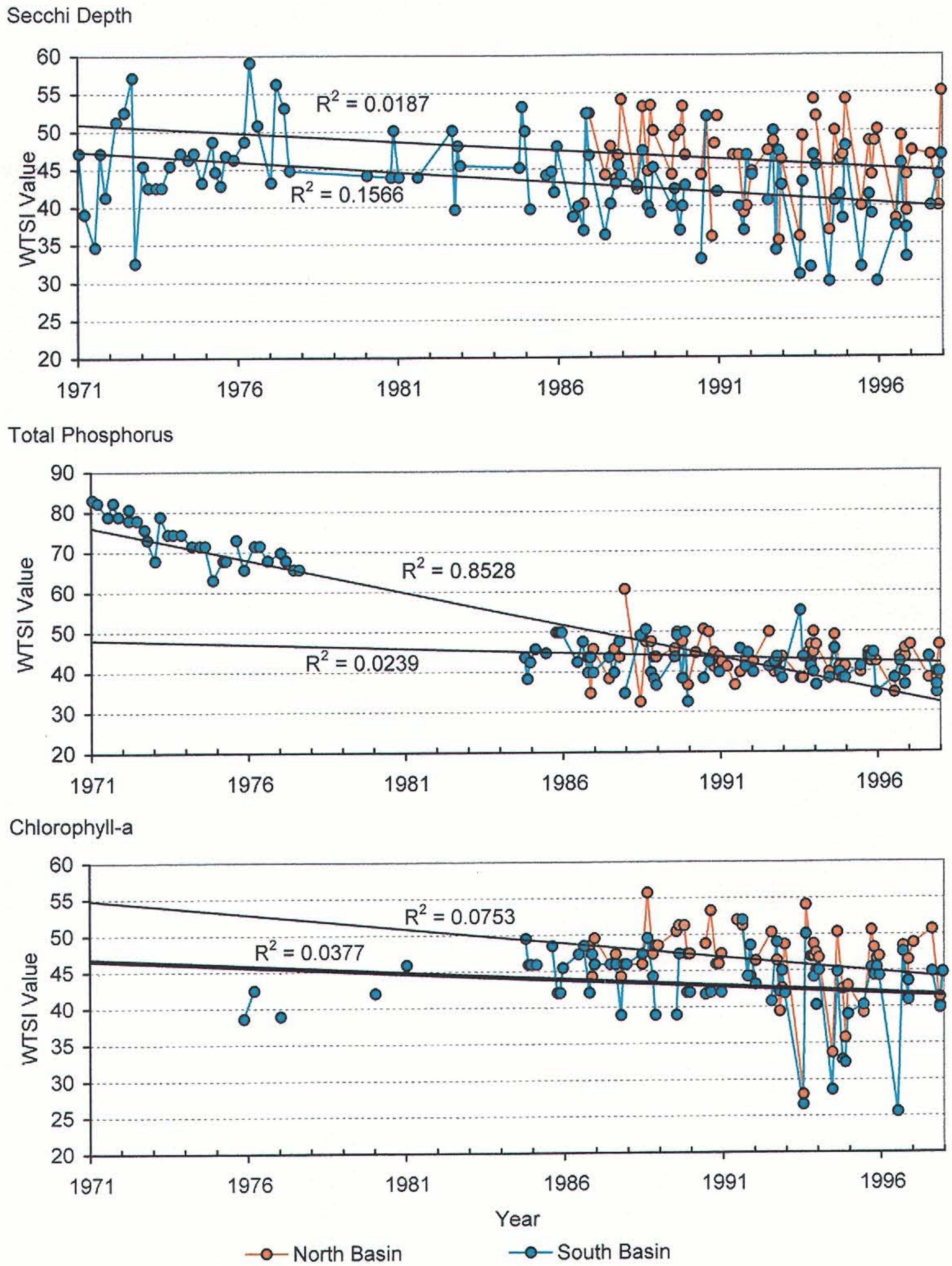
[32]*R.A. Lillie, S. Graham, and P. Rasmussen,* op. cit.

Figure 9

TROPHIC STATE INDEX FOR THE NORTHERN AND SOUTHERN BASINS OF BIG CEDAR LAKE: 1971-1998



Source: Wisconsin Department of Natural Resources and SEWRPC.

indicated by chlorophyll-*a* concentrations in excess of 20 micrograms per liter, have not been perceived as a major problem on Big Cedar Lake, as suggested by the data set forth in Tables 2 and 3.

In contrast, aquatic macrophyte growths in Big Cedar Lake have been viewed as a concern requiring intervention for many years, aquatic plant management being an important function of the then Big Cedar Lake Sanitary District, the precursor agency to the Big Cedar Lake Management District. An aquatic plant survey was conducted by staff of the WDNR during their sensitive area assessment conducted in July 1993. A species list, compiled from the results of this survey, is set forth in Table 8. Ten species of plants were identified in Big Cedar Lake, many of which were common to abundant. Species that interfere with the recreational and aesthetic use of the Lake, such as Eurasian water milfoil (*Myriophyllum spicatum*) and certain pondweeds (*Potamogeton* spp.) were found to be present in the Lake.

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Therefore, while previous interventions were likely, the first recorded efforts to manage the aquatic plants in Big Cedar Lake took place in 1951. Aquatic plant management activities in Big Cedar Lake can be categorized as macrophyte harvesting and chemical macrophyte control. Under the present macrophyte control program, the Big Cedar Lake Management District harvests macrophytes to improve navigation and enhance swimming opportunities. No State permits are currently required to mechanically harvest vegetation in lakes, although the harvested plant material must be removed from the water.

Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Chemical herbicides are known to have been applied to Big Cedar Lake from at least 1951 through 1987, after which the practice was discontinued.

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. Almost 180,000 pounds of sodium arsenite, the third highest mass after those applied to Pewaukee and Okauchee lakes, were applied to Big Cedar Lake during the period 1951 through 1963, as listed in Table 9. This arsenic was naturally converted from a highly toxic form to a less toxic and less biologically active form, with much of the arsenic residue being deposited in the lake sediments. Arsenic concentrations measured in the epilimnion, metalimnion, and hypolimnion of the Lake during 1985 would suggest that this element remains in close association with the lake bottom sediments and poses little threat to the integrity of the aquatic ecosystem.[33]

The aquatic herbicide 2,4-D has also been applied to Big Cedar Lake to control aquatic macrophyte growth. The herbicide 2,4-D is a systemic herbicide that 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.). Between 1985 and 1987, 42 pounds and 8 gallons of 2,4-D were applied to the Lake to control macrophyte growth.

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. Few data on these populations are available. However, Big Cedar Lake is known for its fishing, and, in 1963, the Lake was managed for largemouth and smallmouth bass, northern pike,

[33]*Frits van der Leeden, Fred L. Troise, and David Keith Todd,* The Water Encyclopedia, Second Edition, *Lewis Publishers, Boca Raton, 1990; arsenic concentrations should not exceed 72 µg/l in freshwater systems for the protection of freshwater aquatic life.*

Table 8

AQUATIC PLANT SPECIES PRESENT IN BIG CEDAR LAKE AND THEIR POSITIVE ECOLOGICAL SIGNIFICANCE

Species	Positive Ecological Significance[a]
Chara sp. (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
Myriophyllum spicatum (Eurasian water milfoil)	None known
Najas flexilis (bushy pondweed)	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Nuphar variegatum (yellow water lily)[b]	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 tuberosa (white water lily)[b]	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 spp. (pondweeds)	Provides food and cover for fish
Potamogeton amplifolius (large-leaf pondweed)	Provides food and shelter for fish; supports insects eaten by fish; and provides food for ducks
Potamogeton pectinatus (Sago pondweed)	This plant is the most important pondweed for ducks; provides food and shelter for fish; leaves eaten by bluegills; softens water and removing lime and carbon dioxide and depositing marl
Potamogeton richardsonii (clasping-leaf pondweed)	Provides good food and cover for fish and supports insects eaten by fish
Utricularia sp. (bladderwort)	Provides food and cover for fish

[a]*Norman C. Fassett,* A Manual of Aquatic Plants, *University of Wisconsin Press, 1985.*

[b]*Emergent and floating-leaved aquatic plants.*

Source: SEWRPC.

panfish, and cisco.[34] Yellow perch, bluegill, and black crappie were the most abundant species of panfishes in the Lake at that time. The WDNR reports that a sturgeon was caught in the Lake in 1961, and a fantail darter was reported from the Lake in 1900.[35] During 1954 and 1955, trout were stocked in the Lake on an experimental basis, but an inadequate harvest and lack of suitable public access resulted in the discontinuation of the stocking program in subsequent years. Aquatic plant growth and stunted panfish populations were identified as major use problems in 1963, although the Lake's morphometry was determined to reduce their impact. Further fish surveys were conducted during 1974 and 1978. In 1974, the Lake was reported to be populated by walleye, white sucker, rock and largemouth bass, common carp, pumpkinseed, crappie, northern pike, johnny and Iowa darter, pugnose

[34]*Wisconsin Conservation Department,* Surface Water Resources of Washington County, *1963.*

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

Table 9

LAKES RECEIVING THE LARGEST AMOUNTS OF SODIUM ARSENITE AND COPPER SULFATE IN WISCONSIN FOR AQUATIC MACROPHYTE CONTROL: 1950-1969

Lake	County	Pounds of Herbicide
Sodium Arsenite		
Pewaukee	Waukesha	312,908
Okauchee	Waukesha	181,580
Big Cedar	Washington	179,164
Pine	Waukesha	129,877
Fowler	Waukesha	87,456[a]
Total	- -	890,445[b]
Copper Sulfate		
Waubesa	Dane	256,174
Kegonsa	Dane	217,154
Chetek Chain	Barron	139,025
Pewaukee	Waukesha	125,454
Nepco	Wood	103,750
Wapogasset	Polk	102,740
Half Moon	Eau Claire	93,135
Delavan	Walworth	81,113
Monona	Dane	48,100
Menomin	Dunn	40,700
Okauchee	Waukesha	36,983
Little St. Germain	Vilas	28,400
Big Cedar	Washington	21,440
Mirror	Sauk	19,505
Geneva	Walworth	18,915
Delton	Sauk	18,650
Bear Trap	Polk	18,600
Pine	Waukesha	17,434
Whitewater	Walworth	14,970
Big Butternut	Polk	14,050
Total	- -	1,416,292[c]

[a] *Includes applications of sodium arsenite to the Oconomowoc River near Fowler Lake.*

[b] *This amount of sodium arsenite constitutes 41 percent of the total amount of sodium arsenite applied to a total of 167 lakes and streams in Wisconsin from 1950 through 1969.*

[c] *This amount of copper sulfate constitutes 89 percent of the total amount of copper sulfate applied to a total of 130 lakes and streams in Wisconsin from 1950 through 1969.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

shiner, bluntnose minnow, green sunfish, bluegill, and yellow perch. In 1978, blackchin, blacknose, golden and mimic shiner; green sunfish; bluegill; yellow perch; pumpkinseed; johnny darter; banded killifish; largemouth bass; and bluntnose minnow were reported from the Lake. In 1995, the WDNR reported largemouth bass to be abundant, northern pike and panfish to be common, and walleye to be present.[36]

[36] *Wisconsin Department of Natural Resources Publication PUBL-FM-800 95REV,* Wisconsin Lakes, *1995.*

TERRESTRIAL BIOTA AND NATURAL RESOURCE BASE

Other Wildlife

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 Big Cedar Lake drainage area is likely to support many species of birds, and a variety of mammals, ranging in size from large animals like the northern white-tailed deer to small animals like the pygmy shrew. The complete spectrum of wildlife species originally native to Washington County, along with their habitat, has 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. Those wildlife habitat areas remaining in the vicinity of Big Cedar Lake as of 1990 are shown on Map 12. The 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 used to identify valuable wildlife habitat, while retaining 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 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. For the most part, these habitat areas are coincident with the remaining wetlands and woodlands remaining in the drainage area tributary to Big Cedar Lake, as shown on Map 13.

Wetlands, Woodlands and Environmentally Valuable Lands

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,[37] and not inconsistent with that applied by the State of Wisconsin Department of Natural Resources and set forth in Chapter 23, *Wisconsin Statutes*. This latter definition, which 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," is more inclusive than the Federal and Commission definitions in that it may include some soils that do not show hydric field characteristics as wet soils

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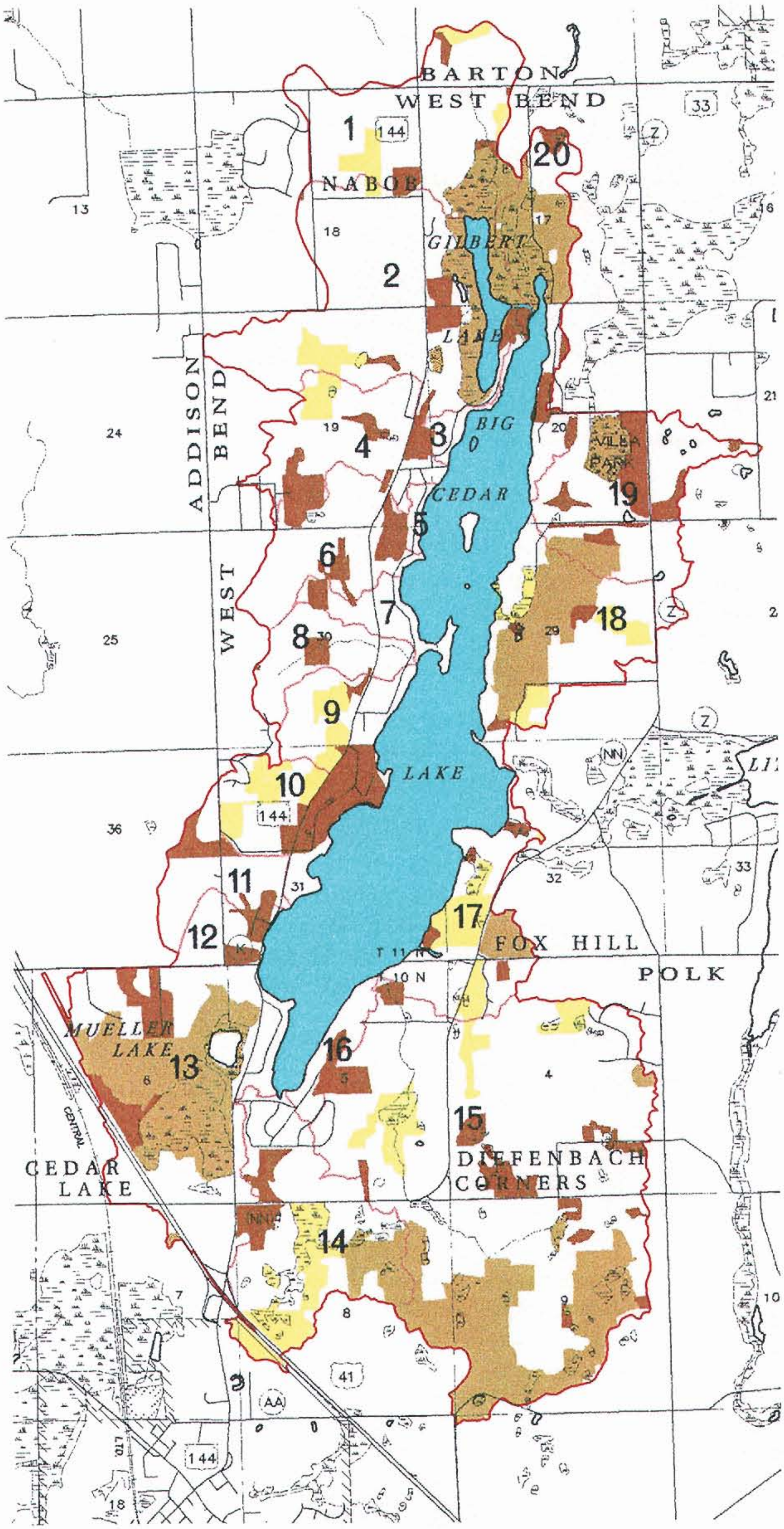
[37]*Lands designated as prior converted cropland, that is, lands that were cleared, drained, filled, or otherwise manipulated to make them capable of supporting a commodity crop prior to December 23, 1985, may meet the criteria of the U.S. Natural Resource Conservation Service wetland definition, but 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.*

Map 12

WILDLIFE HABITAT AREAS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



LEGEND

CLASS I WILDLIFE HABITAT AREA

CLASS II WILDLIFE HABITAT AREA

CLASS III WILDLIFE HABITAT AREA

SURFACE WATER

N

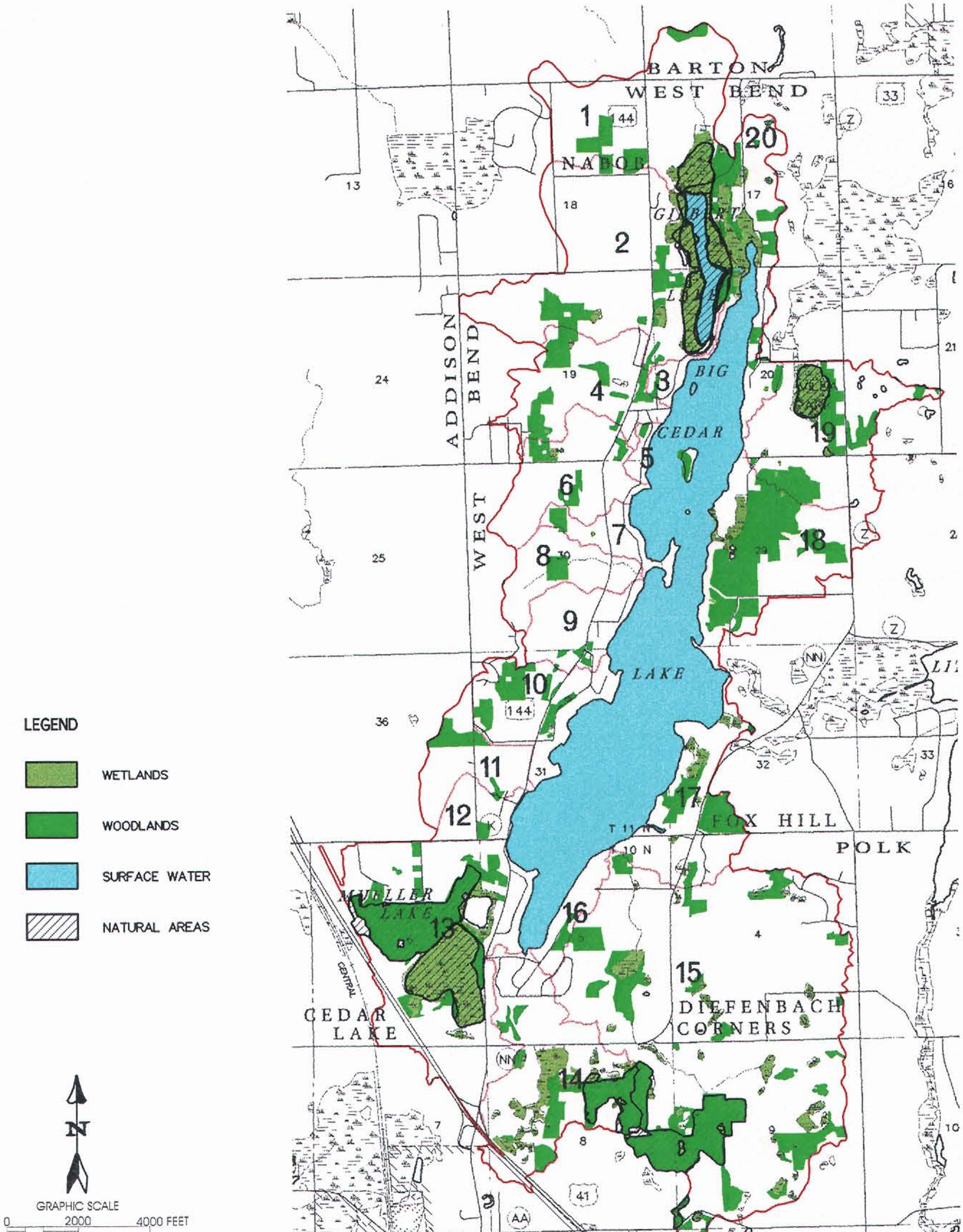
GRAPHIC SCALE

0 2000 4000 FEET

Source: SEWRPC.

Map 13

EXISTING WOODLANDS, WETLANDS, AND NATURAL AREAS
WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



Source: SEWRPC.

capable of supporting wetland vegetation, a condition which may occur in some floodlands.[38] Nevertheless, as a practical matter, experience has shown that all of these definitions produce reasonably consistent wetland identifications and delineations in the majority of situations within the Southeastern Wisconsin Region.

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).[39] The major tree species comprising woodlands in the drainage area tributary to Big Cedar Lake include aspen, black willow, green ash, American elm, hickory, tamarack, white birch, and willow.[40]

Both the amount and distribution of wetlands and woodlands in the drainage area tributary to Big Cedar Lake should remain relatively stable if the recommendations contained in the regional land use plan are followed. If, however, urban development is allowed to continue within the watershed much of the remaining woodland cover, at least, may be expected to be lost.

Because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of any single element of the total environment may lead to a chain reaction of deterioration and destruction: for example, the drainage of wetlands may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas, while the destruction of woodland cover may result in soil erosion and stream siltation, more rapid runoff and increased flooding, and 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. To protect and preserve the natural resources base of the Region, the Regional Planning Commission identified "environmental corridors" within the Region, beginning in 1963 as part of the original regional land use planning effort of the Commission. environmental corridors 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. The environmental corridors in the drainage area tributary to Big Cedar Lake are shown on Map 14.

SUMMARY

Big Cedar Lake represents a typical hard-water, alkaline lake that has not been subjected to high levels of pollution. Physical and chemical parameters measured during the late 1980s and early 1990s indicated that the water quality is within the "good" range, compared to other regional lakes. Total phosphorus levels were found to be generally below the level considered likely to result in severe nuisance algal and macrophyte growths. However, management of aquatic plants has been needed to provide for full recreational use of the Lake. Although both summer and winter stratification was observed in Big Cedar Lake, the Lake waters supported a healthy fish population. Winterkill was not a problem in Big Cedar Lake because dissolved oxygen levels were found to be adequate in sufficient volumes of water for the support of fish throughout the winter. Internal releases of phosphorus from the bottom sediments were not considered to be a problem in Big Cedar Lake.

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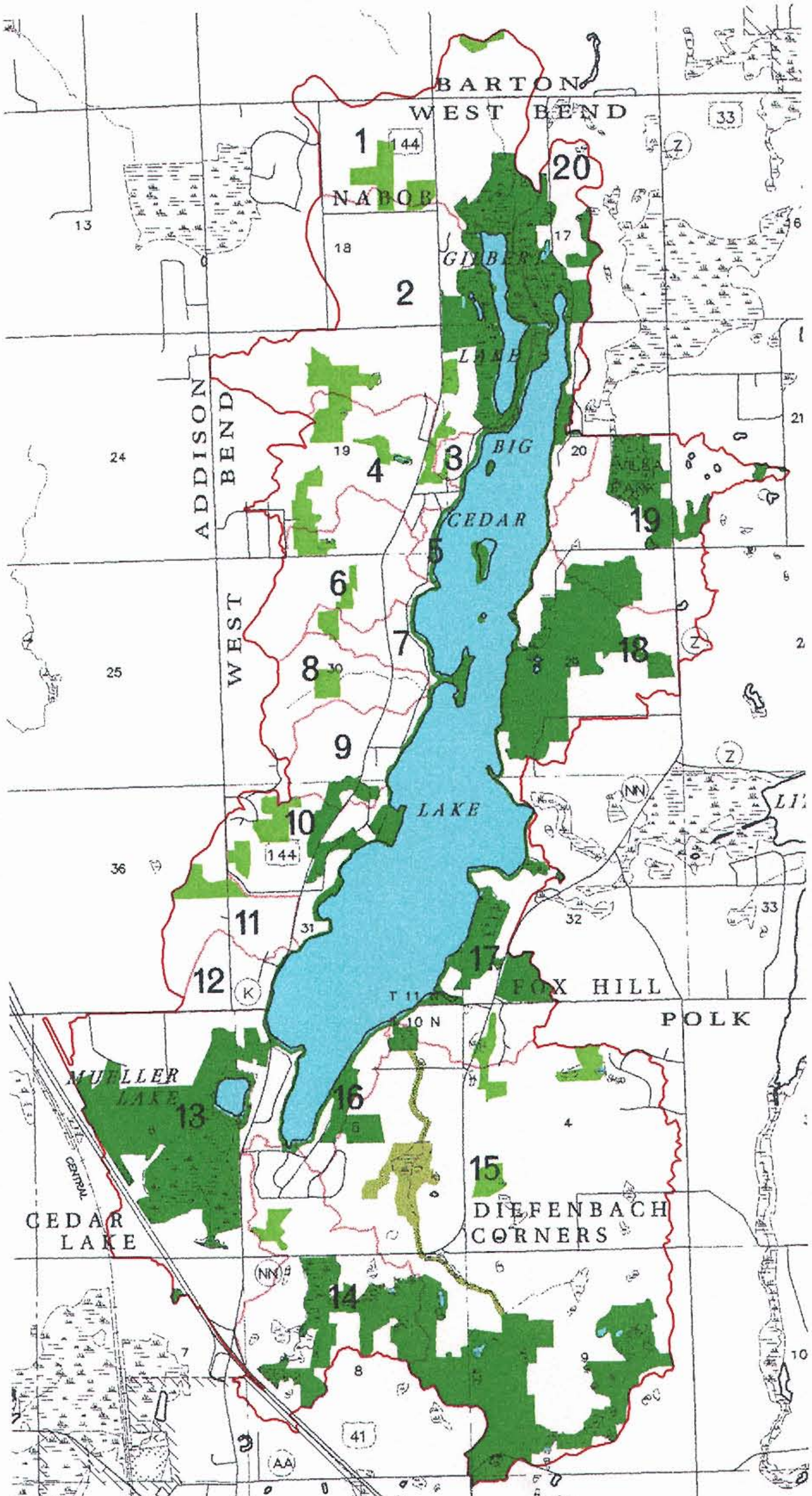
[38]*Although prior converted cropland is not subject to Federal wetland regulations unless cropping ceases for five consecutive years and the land reverts to a wetland condition, the State may consider prior converted cropland to be subject to State wetland regulations if the land meets the criteria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

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

[40]*See SEWRPC Memorandum Report No. 131,* Environmental Analysis of the Lands at the Headwaters of Gilbert Lake and Big Cedar Lake, *March 1999.*

Map 14

ENVIRONMENTALLY VALUABLE AREAS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



LEGEND

- PRIMARY ENVIRONMENTAL CORRIDOR
- SECONDARY ENVIRONMENTAL CORRIDOR
- ISOLATED NATURAL RESOURCE AREA
- SURFACE WATER

N

GRAPHIC SCALE

0 2000 4000 FEET

Source: SEWRPC.

There were no known point sources of pollutants in the Big Cedar Lake watershed. Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. Sediment, heavy metals, and phosphorus loadings from the watershed were estimated. The total annual phosphorus load to Big Cedar Lake, based upon 1995 land use data, was estimated to be about 2,340 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 17 percent of the total phosphorus load. Onsite sewage disposal systems and precipitation contributed the balance, but their influence on Lake water quality was considered to not be significant on a Lakewide basis. However, surveillance and management of onsite sewage disposal systems is important to avoid localized problems. Approximately 76 percent, or about 1,780 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 about 560 pounds of phosphorus downstream.

Based on the Vollenweider phosphorus loading model and the Trophic State Index ratings calculated from Big Cedar Lake data, Big Cedar Lake may be classified as a mesotrophic lake. The biological response of the Lake ecosystem to the external phosphorus loading is consistent with this state, aquatic plant growth being considered to be somewhat excessive during the summer months. However, the Lake supported a diverse fishery, and sustained a robust terrestrial ecosystem within the drainage area tributary to the Lake.

Chapter III

LAKE WATER QUALITY PROBLEMS AND ISSUES

INTRODUCTION

Although the water quality of Big Cedar Lake is relatively high and the Lake is capable of supporting a wide variety of water uses, there are three issues related to water quality that should be addressed in this lake water quality protection plan. These issues of concern include the potential changes in ecologically valuable areas and aquatic plants, nonpoint source pollution from land use activities, and in-lake water quality.

ECOLOGICALLY VALUABLE AREAS AND AQUATIC PLANTS

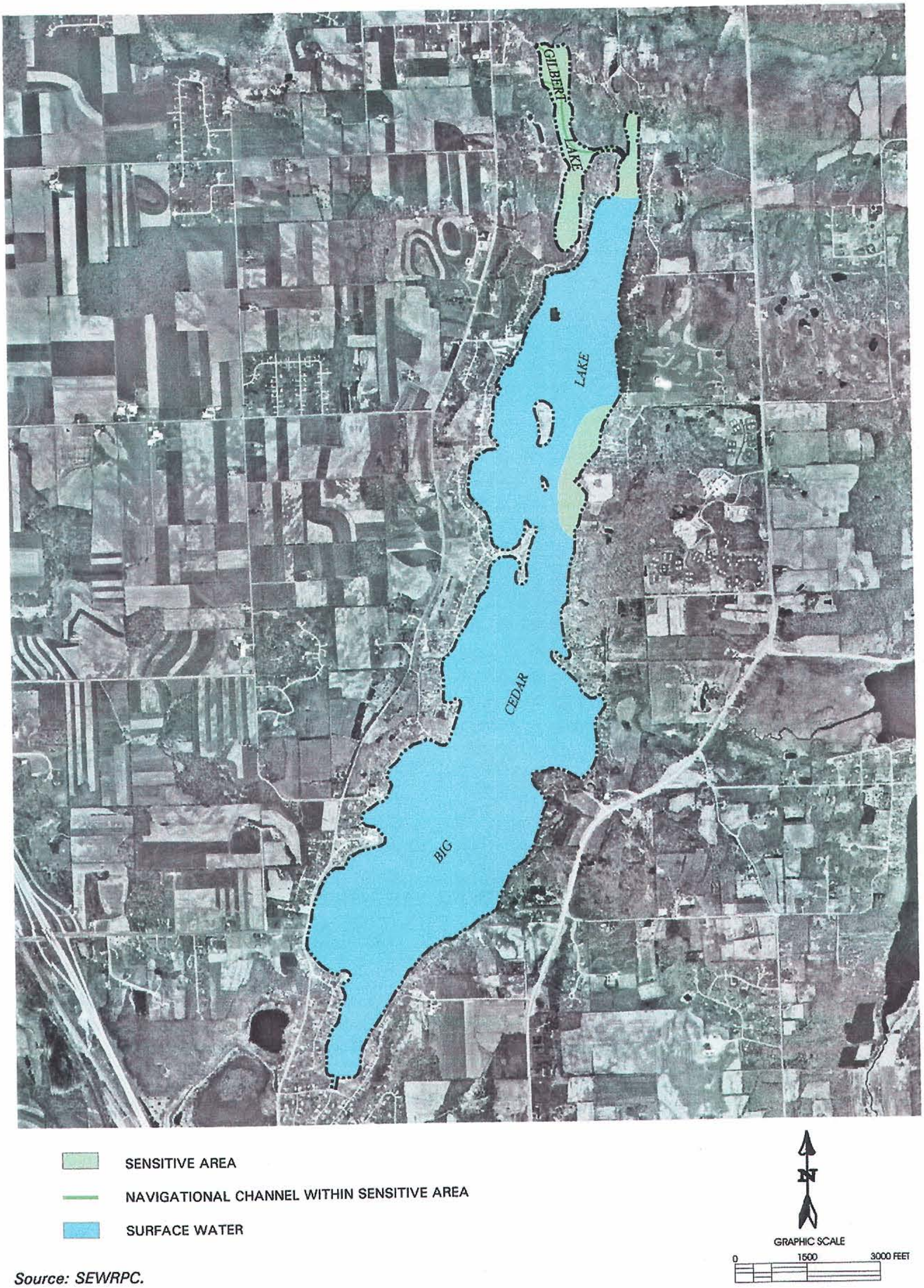
The ecologically valuable areas within the drainage area tributary to Big Cedar Lake, as documented in Chapter II, include wetlands and woodlands, and wildlife habitat. Most of these areas are included in the land designated as primary environmental corridors. Critical sites within the Lake include prime fish spawning habitat, macrophyte beds—especially those containing a diverse native flora—and the shoreline areas supporting the more productive aquatic habitat, primarily the eastern and southern shorelines. These areas have been designated as sensitive areas by the Wisconsin Department of Natural Resources (WDNR) during an assessment completed during July 1993. Protection of these areas, shown on Map 15, is an important issue which should be considered.

The presence of Eurasian water milfoil in limited areas of the Big Cedar Lake basin, and the presence of purple loosestrife in the wetlands adjoining Big Cedar Lake, represent another important issue which should be addressed. These plants often outcompete native aquatic plants, dominating the plant communities in lakes and wetlands in Southeastern Wisconsin to the detriment of fish and wildlife habitat and native species of plants. The dominance of Eurasian water milfoil and purple loosestrife in aquatic ecosystems in Southeastern Wisconsin degrades the natural resource base and commonly interferes with human recreational and aesthetic use of the natural resources.

As shown on Map 13, various wetland plant communities exist adjacent to Big Cedar Lake shores. These areas, along with the wetland areas adjacent to Gilbert Lake, provide important habitat for wildlife. The wetland area at the headwaters of Gilbert and Big Cedar Lakes, which is physically connected to the Lakes as shown on Map 16, provides valuable fish spawning habitat, especially during the early spring. In addition to providing habitat, this area also contributes to the scenic vistas that characterize the Big Cedar Lake watershed. Those wetlands situated between upland areas and the Lake also help to absorb runoff, and, by retaining sediments and nonpoint source pollutants, can help to protect Big Cedar Lake and downstream lakes, such as Little Cedar Lake, from degradation.

Map 15

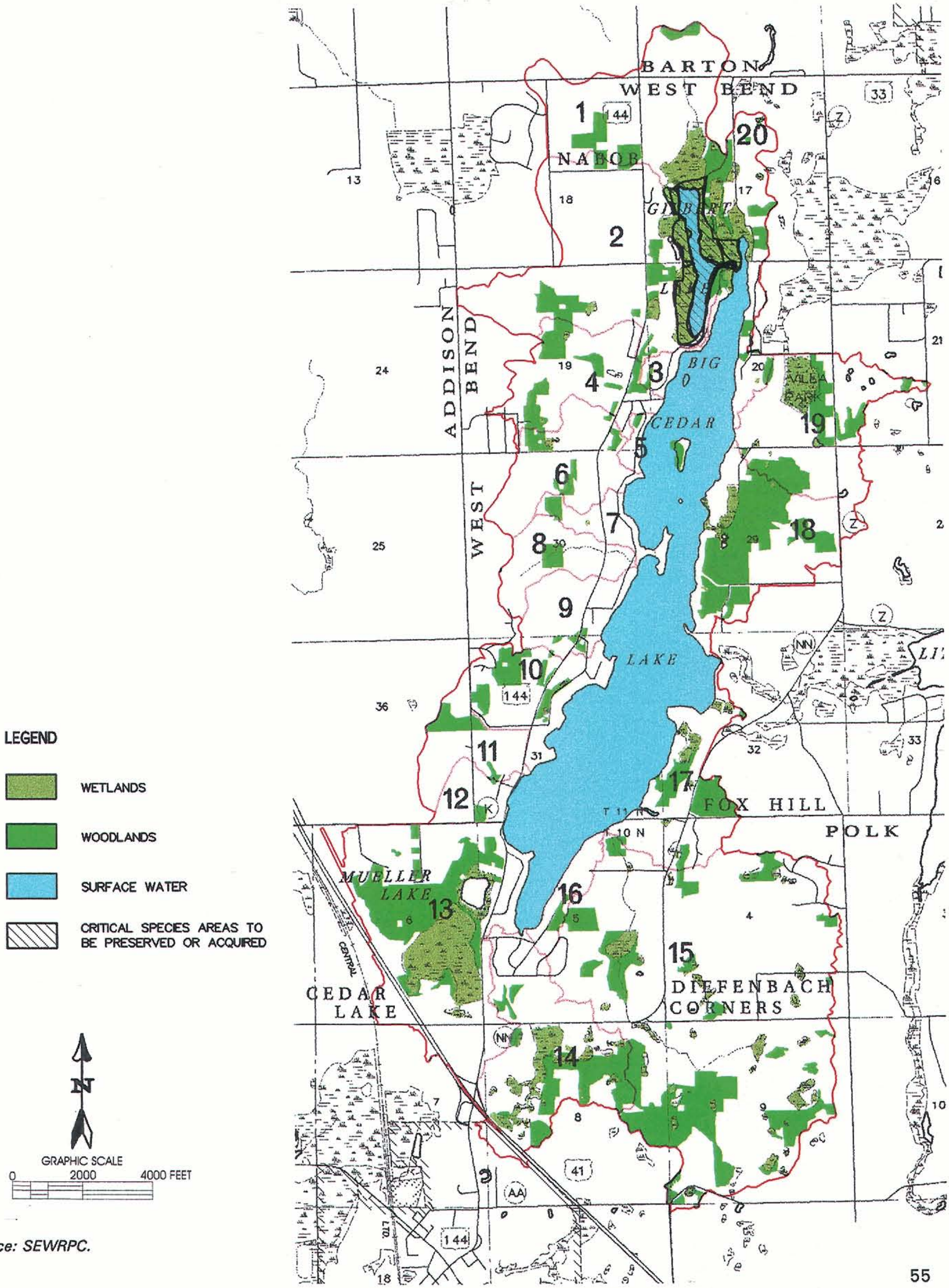
SENSITIVE AREAS IN BIG CEDAR LAKE



Source: SEWRPC.

Map 16

WETLANDS, WOODLANDS, AND CRITICAL SPECIES HABITATS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



Source: SEWRPC.

The environmental corridors in the Big Cedar Lake tributary drainage area, as shown on Map 14, contain almost all of the best remaining woodlands, wetlands, and wildlife habitat. The protection of these resources from additional intrusion by incompatible land uses which degrade and destroy the environmental values, and the preservation of the corridors in an essentially open and natural state, is an important issue to be considered.

NONPOINT SOURCE POLLUTION FROM LAND USE ACTIVITIES

Nonpoint source pollutants associated with new and existing urban development in the drainage area tributary to Big Cedar Lake represents a potentially significant threat to the Lake's water quality. The regional land use plan recommends that undeveloped lands within the drainage area tributary to Big Cedar Lake remain largely in rural use, as shown on Map 7. Specifically, the plan recommends that lands that have been identified as prime farmlands under the Washington County farmland preservation plan be retained in agricultural use, with development limited to one dwelling per 35 acres. Under the regional plan, the development of other lands, including nonprime farmland and upland primary environmental corridors, would be limited to rural residential development, that is, residential development at a density of no more than one dwelling unit per five acres, preferably in cluster-style.

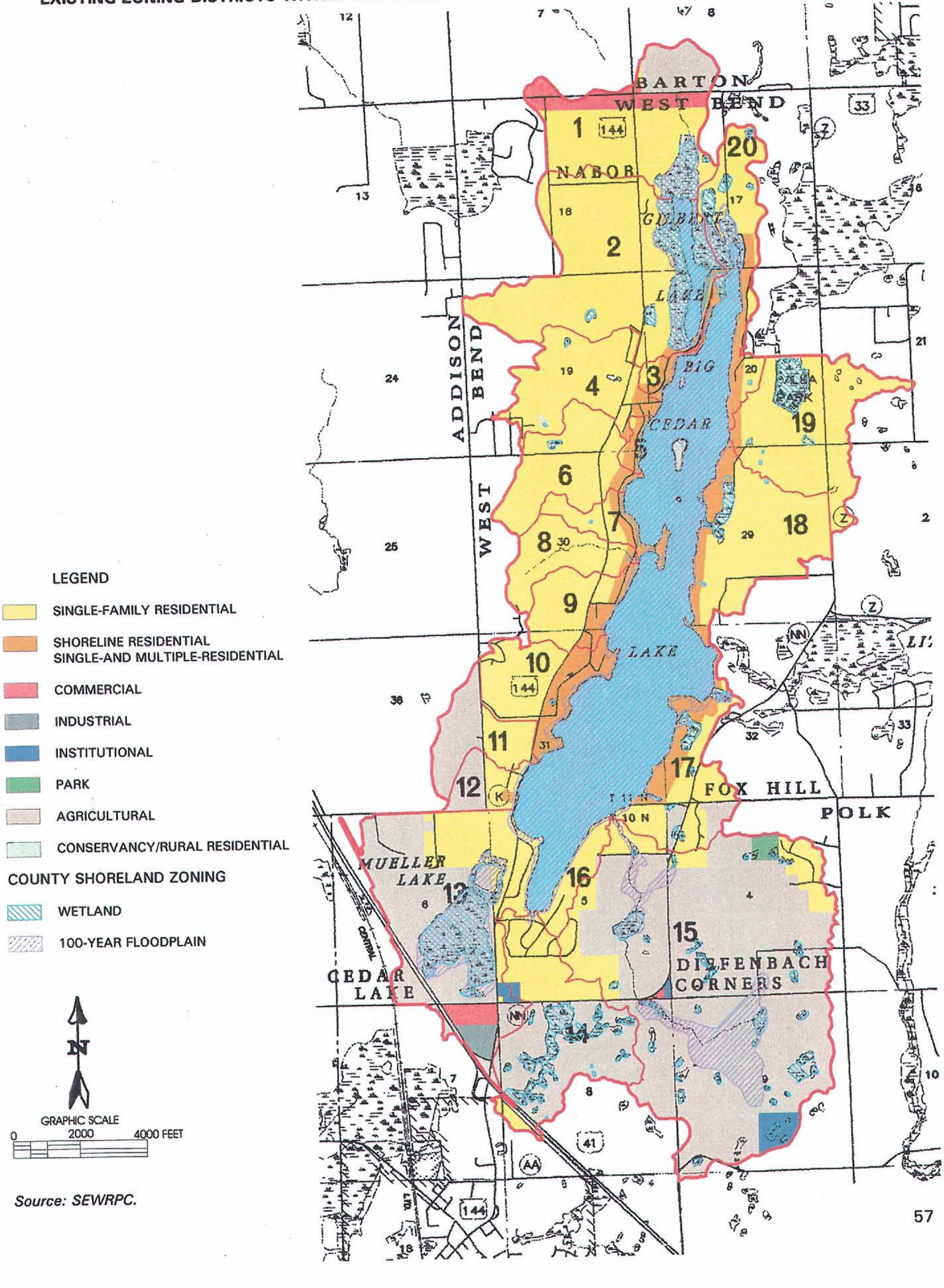
Existing zoning in the Big Cedar Lake drainage area is shown graphically on Map 17. Most of the undeveloped land in the drainage area is located in the Towns of Polk and West Bend. Existing zoning in the Town of Polk portion of the drainage area is consistent with the regional land use plan. Much of the area of the Town of West Bend within the Big Cedar Lake drainage area has been placed in the R-1R Rural Residential District of the Town of West Bend Zoning Ordinance. This district specifies a maximum density of three and one-half acres per dwelling unit, with wetlands, primary environmental corridors, and wildlife habitat areas excluded from the density calculation. When those areas are taken into account, the overall density could approach, or be less than, the regional plan recommended five-acre density. However, density bonuses intended to encourage clustered residential development, included in this zoning district, allow for higher overall densities. Depending on the subdivision design and the nature of the resource features preserved, the allowed density could be 50 percent greater than the five-acre density recommended in the regional plan. The prime agricultural land area within the western portion of the drainage area tributary to Big Cedar Lake in the Town of West Bend has not been placed in an exclusive agricultural zoning district as recommended in the regional land use plan.

In addition to the comprehensive zoning ordinances administered by the local authorities in the Big Cedar Lake drainage area, Washington County exercises special-purpose shoreland and floodland zoning in the direct drainage area tributary to Big Cedar Lake, as shown on Map 17. In 1986, the Washington County Shoreland and Floodland Protection Ordinance, adopted in 1975, was rewritten, separating the Floodplain Protection Ordinance from the Shoreland and Wetland Protection Ordinance. The County Shoreland and Floodland Protection Ordinance, adopted in 1975 pursuant to Chapter 30 of the *Wisconsin Statutes*, imposes special land use regulations on all unincorporated lands within 1,000 feet of the shoreline of a navigable lake, pond or flowage, and within 300 feet of the shoreline of a navigable river or stream, or to the landward side of the floodplain, whichever is greater. The change to this Ordinance, adopted in 1986, was made pursuant to Chapters 23 and 330 of the *Wisconsin Statutes* which required that counties regulate the use of all wetlands, five acres or larger, located within the shoreland area. Preliminary wetland maps for Washington County were prepared for the Wisconsin Department of Natural Resources by the Regional Planning Commission in 1963. In accordance with Chapter NR 115 of the *Wisconsin Administrative Code*, Washington County has updated its shoreland zoning regulations and attendant maps to regulate wetlands in the shoreland areas, and is presently further refining this Ordinance. It is anticipated that the refined Shoreland and Wetland Protection Ordinance will be adopted during the year 2000.

Based upon local zoning and current development trends, additional residential development is likely to occur in Subbasins 1 through 10 and 20, and portions of Subbasins 11 through 12 and 17 through 19, in the Town of West Bend; with some further residential development in portions of Subbasins 13 through 15 in the Town of Polk. All such new development has the potential to impact the nonpoint source pollutant loadings in the drainage area, both during and after construction. Because the primary pollutant loads to the Lake under current land use

Map 17

EXISTING ZONING DISTRICTS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE: 1990



Source: SEWRPC.

conditions are generated as nonpoint-source pollutants, as was noted in Chapter II, the control of nonpoint source pollution, especially from construction site erosion and stormwater runoff, remains an important issue to be considered.

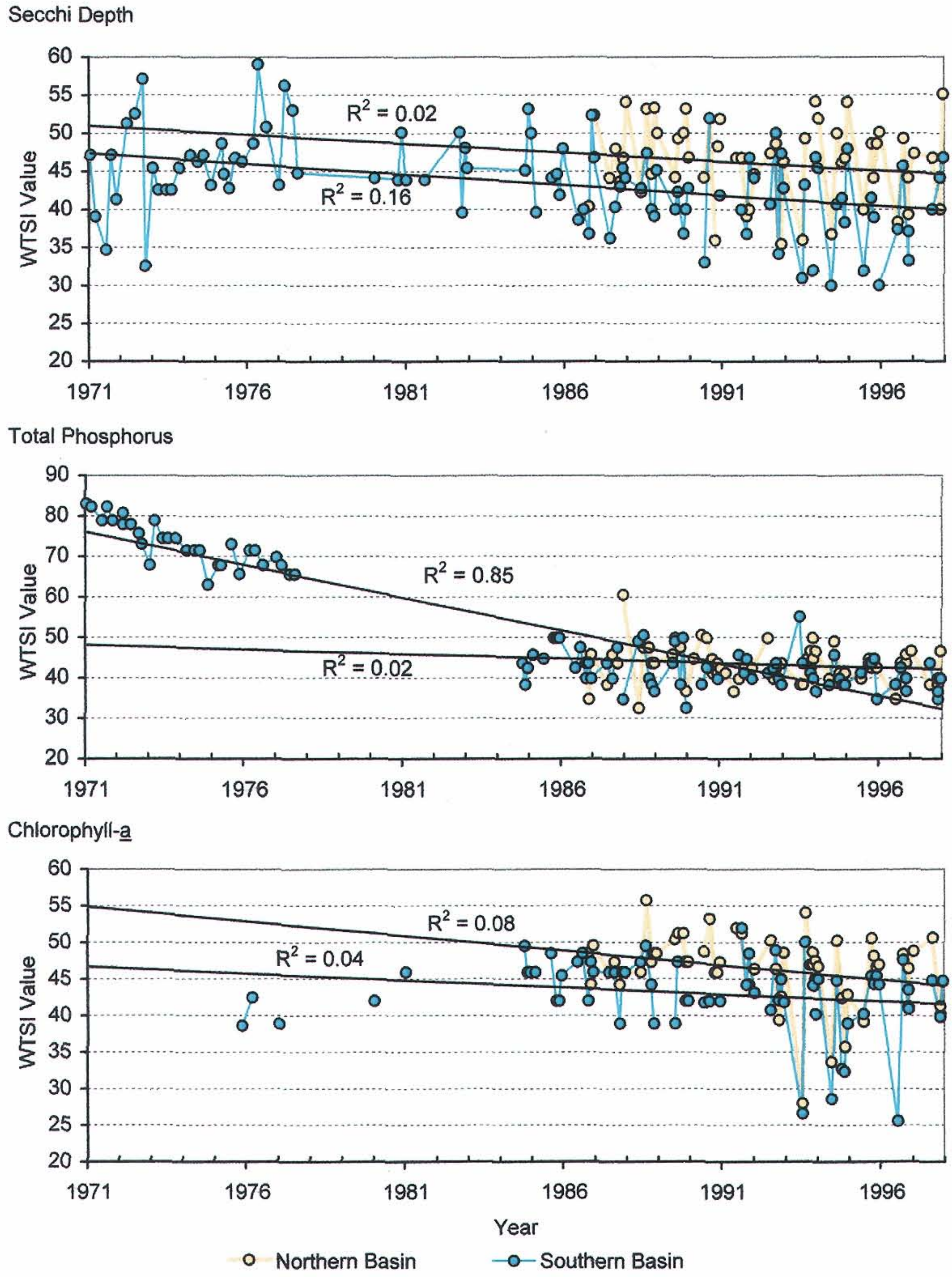
IN-LAKE WATER QUALITY

As of 1998, Big Cedar Lake can be considered as having relatively high water quality suitable for full contact recreational use and the support of a warm water sport fishery. As described in Chapter II, the Lake was well within the mesotrophic range, indicating that few severe water quality problems are expected. However, it has been demonstrated that some interventions, such as for aquatic plant management, are needed to meet the desired recreational use objectives of the Lake residents. This status is an improvement from the eutrophic state reported in previous water quality investigations. Figure 10 shows the trend toward improvement in water quality based upon the Wisconsin Trophic State Index (WTSI). Nevertheless, citizens within the Big Cedar Lake Protection and Rehabilitation District have expressed concerns regarding a perceived potential degradation in water quality in the Lake, principally related to the presence and accumulation of silt from stormwater runoff along the southern shores of the Lake. As Figure 10 shows, the concerns regarding water quality differences between the northern and southern basins of Big Cedar Lake may be justified. Based on the WTSI values set forth in Figure 10, it would appear that the shallower, northern basin has slightly lower water quality that the deeper southern basin. This may reflect the greater ability of the southern basin to assimilate pollutant loads or the propensity of the northern basin to support slightly higher levels of biotic production given its lesser depth, which would affect the physical behavior of the waters of the basin in response to external stimuli such as nutrient loading and wind mixing. Although, as described in Chapter II, most water quality indicators suggest an improvement in water quality, surface water quality, and the need to maintain and possible enhance that water quality, is considered to be an issue to be considered.

It should be noted that the one water quality indicator that has shown a definite decline in water quality is chloride concentration. These concentrations, as noted in Chapter II and shown in Figure 6, show a progressive and steep rise in concentration during the period of record, increasing from about 8 mg/l in the 1970s to over 24 mg/l in the 1980s. Much of this chloride may be assumed to be of anthropogenic origin, either from water softeners that usually add salts to the water used for domestic consumption and household purposes or from highway salting conducted to minimize ice-related traffic casualties during the winter months. For this reason, the increasing trend in chloride concentrations is an issue to be considered.

Figure 10

TROPHIC STATE INDEX FOR THE NORTHERN AND SOUTHERN BASINS OF BIG CEDAR LAKE: 1971-1998



Source: Wisconsin Department of Natural Resources and SEWRPC.

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Chapter IV

ALTERNATIVE AND RECOMMENDED LAKE PROTECTION MEASURES

INTRODUCTION

Chapter III described three issues of concern to be considered as part of this lake water quality protection plan. These issues are related to: 1) ecologically valuable areas and aquatic plants; 2) nonpoint source pollution from land use activities; and 3) in-lake water quality. Following a brief summary of the ongoing lake management program activities, alternatives and recommended measures to address each of these issues and concerns are described in this chapter. The alternatives and recommendations set forth herein are focused primarily on those measures which are applicable to the Big Cedar Lake Protection and Rehabilitation District and the Towns of Polk and West Bend. In addition, the alternatives and recommendations focus solely on the issue of water quality protection and management.

PAST AND PRESENT LAKE MANAGEMENT ACTIONS

The residents of Big Cedar Lake, in conjunction with the Towns of Polk and West Bend, have long recognized the importance of informed and timely action in the management of Big Cedar Lake. The initial action in this regard was the formation of the Big Cedar Lake Sanitary District in the late 1930s, and the conversion of that district into the Big Cedar Lake Protection and Rehabilitation District during the 1970s. The Sanitary District, and, more recently, the Lake Management District, provides the forum for many of the lake management activities of the Lake's residents. The District is currently enrolled in the water quality monitoring program conducted under the auspices of the Wisconsin Department of Natural Resources (WDNR) Self-Help Monitoring Program, and participated in the Long Term Trends or Ambient Lake Monitoring Program from its inception in 1986 to its conclusion in 1998. During 1999, this monitoring is being augmented by a U.S. Geological Survey water quality investigation. The Big Cedar Lake Protection and Rehabilitation District also has conducted studies of the aquatic plant communities in and around Big Cedar Lake. These studies are intended to be a component of a comprehensive lake management plan for Big Cedar Lake. Information gathered through sampling programs and studies is regularly reported to the community through public meetings of the Big Cedar Lake Protection and Rehabilitation District Commissioners, the annual meeting of the Big Cedar Lake Protection and Rehabilitation District electors, and the local media, as part of an ongoing citizen education and involvement program related to lake management activities.

The Cedar Creek subwatershed, including Big Cedar Lake, was included in the Cedar Creek priority watershed project planning area.[1] As noted in Chapter II, the District has worked toward the implementation of recommendations set forth in the Cedar Creek priority watershed plan as well as the recommendations set forth in the 1978 WDNR plan for the protection of the Lake's water quality,[2] and the 1979 regional water quality management plan[3] that contained specific recommendations relating to Big Cedar Lake. The plans recommended a phosphorus load reduction goal of about 30 percent of the then estimated current load from the drainage area directly tributary to Big Cedar Lake. The phosphorus loading reduction was recommended to be achieved primarily by rural agricultural management practices, including livestock waste controls and streambank protection measures.

In response to these recommendations, and in addition to the acquisition of data and information on the Lake ecosystem, the Big Cedar Lake Management District conducts an ongoing program of aquatic plant management within the Big Cedar Lake basin. In implementing the recommendations set forth in the applicable plans for the Cedar Creek watershed, the District also has undertaken various actions, in cooperation with State and local government agencies and in collaboration with the Cedar Lakes Conservation Foundation, that have resulted in the acquisition of critical lands within the drainage area tributary to Big Cedar Lake, and the implementation of management practices to control stormwater runoff from farm lands and other lands within the Big Cedar Lake drainage area. The District has also worked toward the restoration and conservation of wetlands and other critical habitat areas within the drainage basin. Over the 20-year period from 1974 through 1994, the Big Cedar Lake Protection and Rehabilitation District collaborated in the installation of manure management systems and alteration of cropping practices on five farms, the construction of waterway protection practices on two farms, the acquisition of a 100-acre upland and lowland site for conservation purposes, and the restoration of more than 15 acres of prairie and wetlands at three sites within the drainage area tributary to Big Cedar Lake. Through these practices and processes, the Big Cedar Lake Protection and Rehabilitation District has worked toward the implementation of recommendations set forth in the 1978 management plan prepared for the Lake by the WDNR, and subsequent recommendations set forth in the regional water quality management plan and Cedar Creek priority watershed plan.

PROTECTION OF ECOLOGICALLY VALUABLE AREAS AND AQUATIC PLANTS

Big Cedar Lake and its tributary drainage area contain ecologically valuable areas, including significant areas of diverse aquatic and wetland vegetation suitable for fish spawning and located within and immediately adjacent to the Lake. As described in Chapter III, the potential problems associated with ecologically valuable areas in and near Big Cedar Lake include the potential loss of wetlands and other important ecologically valuable areas due to urbanization or other encroachments; the degradation of wetlands and aquatic habitat due to the presence of invasive species, including purple loosestrife and Eurasian water milfoil; and disturbances associated with recreational boating.

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[1] *Wisconsin Department of Natural Resources Publication No. PUBL-WR-336-93,* Nonpoint Source Control Plan for the Cedar Creek Priority Watershed Project, *August 1993.*

[2] *Wisconsin Department of Natural Resources, Office of Inland Lake Renewal,* Big Cedar Lake, Washington County, Management Alternatives, *1978.*

[3] *SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000, *Volume Two,* Alternative Plans, *February 1979; see also SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

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

Land Management Measures
The recommended future condition land use plan for the drainage area tributary to Big Cedar Lake is set forth in the regional land use plan,[4] and in locally prepared land use plans. The regional land use plan, shown on Map 7, recommends the preservation of primary environmental corridor lands in essentially natural, open space use. The regional plan also recommends the preservation, to the extent practicable, of secondary environmental corridors and isolated natural resource areas. Most of the wetlands and other ecologically valuable lands adjacent to Big Cedar Lake and within the drainage area tributary to Big Cedar Lake are included within the environmental corridors and isolated natural resource areas. The plan recommends that such protection be afforded through appropriate conservancy zoning, and, in some cases, through public acquisition or easement arrangements, depending upon the location, type and character of the natural resource features to be preserved and protected. All lakes, rivers, streams, wetlands, and associated undeveloped floodlands and shorelands are recommended to be placed in lowland conservancy or floodplain protection districts. Upland environmental areas are recommended to be placed in upland resource conservancy districts which limit new development to rural density residential development, at no more than one dwelling unit per five acres. As noted in Chapter III, the existing local and County zoning in effect partially implements the recommendations regarding the preservation of environmental corridor lands.

The existing general zoning for the lands in the vicinity of Big Cedar Lake and in the tributary drainage area to Big Cedar Lake is largely, but not fully, consistent with the recommended future land use pattern set forth in the regional land use plan. In the Town of West Bend, land use zoning for the drainage area tributary to Big Cedar Lake generally provides for conservancy zoning of the wetland portions of the environmental corridors and isolated natural areas. The upland portions of the corridors, and the remainder of the drainage area excluding the immediate Lake shoreline area, is included within an R1-R zoning district. The R1-R rural residential zoning district provides for large-lot, single-family residential development on three and one-half acre net density lots, excluding wetlands, environmental corridors and wildlife habitat areas, as well as residential development at somewhat higher densities when cluster development techniques are employed. In the Lake shoreline area, the Town zoning provides for an R1-S shoreline residential district that includes existing shoreland development and that is intended to accommodate existing residential and related uses. In the Town of Polk, the wetlands and specific upland areas within the environmental corridors are included within wetland-floodland conservancy and upland conservancy overlay districts, respectively. In addition, an agricultural zoning district which allows for a rural density development at a five-acre minimum residential lot size has been adopted for the entire Town. Zoning within the drainage area tributary to Big Cedar Lake in the Towns of Addison and Barton is largely consistent with that set forth in the adopted regional land use plan.

Shoreland zoning within the Towns is provided through the Washington County zoning ordinance that imposes special land use regulations on, and regulates the use of all wetlands of five acres or larger located within, shoreland areas of unincorporated areas, as shown on Map 17. The shoreland zone is defined as the area within 300 feet of a navigable stream and 1,000 feet of a navigable lake, or to the landward side of the floodplain and related wetlands.

The existing zoning regulations adopted by the municipalities within the drainage area tributary to Big Cedar Lake have been reviewed and adjusted by most municipalities at various times during the 1990s. The regulations are intended to ensure that development occurs in an orderly manner and generally includes the preservation of

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

the wetland portions, and some of the upland portions, of environmental corridor lands. The zoning ordinances generally recognize that there is likely to be continuing demand for residential development in the drainage area and accommodate this demand by providing for development on five-acre lots in some areas—Town of Polk—and on three and one-half acre lots in other areas—Town of West Bend. The latter excludes consideration of wetlands, environmental corridors, and wildlife habitat. The Town of West Bend zoning ordinance also provides for a density bonus intended to encourage clustering of residential development. In cluster designs, dwellings are concentrated on a portion of the site concerned, while the balance of the site is retained in agricultural or other open space use, thereby maintaining the overall desired density. Nevertheless, should urban development not proposed or envisioned under the regional and/or local land use plans threaten to destroy or degrade natural resources located within the environmental corridors, appropriate public or private agencies should consider acquisition of such lands for resource and open space preservation purposes.

The potential for encroachment onto, or degradation of, critical properties by proposed or planned future urban development within the drainage area tributary to Big Cedar Lake represents a potentially deleterious situation impacting the natural resource base of the drainage area. Minimization of such impacts can be facilitated through the outright purchase or acquisition of conservation easements on critical lands. Public acquisition is a means of protecting these lands from encroachment or further degradation, and a means of facilitating their rehabilitation and restoration. Public acquisition is possible through the Chapters NR 50/51 of the Wisconsin Administrative Code, the Stewardship Grant Program, and Chapter NR 191, the Lake Protection Grant Program. Outright purchase, or the purchase of conservation easements, are both possible options that have been previously exercised by the Big Cedar Lake Protection and Rehabilitation District and Cedar Lakes Conservation Foundation. Lands proposed for purchase must be appraised using standard governmental land acquisition procedures as established by the Wisconsin Department of Natural Resources, and must be subject to a land management plan setting forth the processes and procedures for their long-term maintenance and development. The Chapter NR 191 grant program provides State cost-share funding for the purchase up to a maximum State share of $200,000 at up to a 75 percent State cost-share. The Chapter NR 50/51 grant program provides State cost-share funding up to a maximum State share of $100,000 at up to a 50 percent cost-share. Pursuant to the adopted regional natural areas and critical species habitat protection and management plan, the Gilbert Lake Tamarack Swamp, Hacker Road Bog, Big Cedar Lake Bog, Slinger Upland Woods, and Mueller Woods are recommended for acquisition or extension of public ownership of lands currently owned by State, County, and local governments.

In-Lake Management Measures

Various potential in-lake management actions may be considered for purposes of control of aquatic plants. These actions include harvesting, chemical treatment, lake drawdown, and lake bottom covering. Because the current aquatic plant problems on Big Cedar Lake, as described in Chapters II and III, are limited in nature, the only in-lake measure generally considered applicable is aquatic plant harvesting. In addition, manual harvesting of selected nuisance species such as Eurasian water milfoil and purple loosestrife, and limited chemical treatments of these two species in situations where extensive infestations occur, is considered applicable in an aquatic plant management program designed to protect and restore native aquatic plant flora throughout the drainage area tributary to the Lake.

Further, to limit the spread of invasive plant species, the promulgation of more stringent controls on the use of powered water craft in those portions of Big Cedar Lake where Eurasian water milfoil infestations occur could be considered as a means of preventing the further colonization and proliferation of that rooted macrophyte. These milfoil control areas would include the shore zones and the northern embayment adjacent to Gilbert Lake that have been designated as sensitive areas by the WDNR and shown on Map 15. Controls on boat traffic could be put in place using demarcated boat exclusion zones to limit motorized boat traffic in specific areas of the Lake to necessary boating traffic only. Necessary boat traffic could be considered as being limited to ingress and egress from piers, and the legitimate response to emergency situations. Boat exclusion areas, if created, must be designated by approved regulatory markers. In addition, placement of regulatory markers must conform to Section NR 5.09 of the Wisconsin Administrative Code, and all restrictions placed on the use of the waters of the State must be predicated upon the protection of public health, safety, or welfare. Boating ordinances, enacted in conformity with State law, must be clearly posted at public landings in accordance with the requirements of Section 30.77(4) of the *Wisconsin Statutes*.

Regulatory markers, or buoyage, has the advantage of being visible to recreational boaters but can be expensive to obtain, install and maintain. Nevertheless, affected areas can be clearly demarcated. Two general options exist regarding the use of buoyage: the establishment of regulated areas using regulatory buoys, such as slow-no-wake or exclusionary areas, or the enhancement of public awareness using informational buoys. Establishment of additional slow-no-wake areas within Big Cedar Lake, outside of the 100-feet and 200-feet slow-no-wake shoreland zone, will require amendment of the Town boating ordinances of the Towns of Polk and West Bend. Only regulatory markers are enforceable.

Buoys placed within the waters of the State of Wisconsin are subject to the requirements set forth in Chapter 30, *Wisconsin Statutes*. Such buoys are white in color, cylindrical in shape, seven or more inches in diameter, and extend 36 or more inches above the water line. Regulatory buoys include buoys used to demarcate restricted areas, prohibit boating or types of boating activities in specific areas, and control the movements of watercraft. Buoys used to demarcate regulated areas display their instructions in black lettering. Prohibition buoys display an orange diamond with an orange cross inside. Control buoys display an orange circle. Local authorities having jurisdiction over the waters involved may place danger buoys or informational buoys without an ordinance, although a Wisconsin Department of Natural Resources permit is required. Informational buoys are similar in construction to the regulatory buoys, but contain an orange square on the white background. Informational buoys are not enforceable.

Citizen Information and Education

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

Recommended Protection Measures

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

1. The Big Cedar Lake Protection and Rehabilitation District, through its existing boating ordinance and amendment thereof, should undertake the following boating regulation measures:

   a. Place signage and notices at the public access sites to alert lake users to applicable Lake ordinances as set forth in Section 30.77(4) of the *Wisconsin Statutes*, and monitor the level of compliance achieved.

   b. Demarcate the ecologically sensitive areas located on the northeast shoreline with regulatory buoys and signs to help enforce the recommended restrictions set forth in a. above, and shown on Map 15, to restrict motorized boat traffic.

   c. Demarcate the aquatic macrophyte beds containing *Myriophyllum spicatum* (Eurasian water milfoil) with regulatory buoyage to limit motorized boat traffic and diminish proliferation of this plant to other areas of the Lake.

2. The Big Cedar Lake Protection and Rehabilitation District and the Towns of Polk and West Bend should support the preservation of the environmental corridor lands in the drainage area riparian to Big Cedar Lake in essentially natural, open-space uses, primarily through public land use controls. Such preservation also should be promoted through the enforcement of existing regulations intended to protect such natural resources. At present, current municipal zoning protects the wetland and riparian portions of the environmental corridor lands in conservancy districts or conservancy overlay districts. In addition, Washington County implements shoreland zoning to protect wetlands and floodplain areas within the statutory shoreland zone surrounding Big Cedar Lake. It is recommended that these zoning codes be periodically reviewed to ensure that the environmental corridor lands are adequately protected in conservancy zoning districts to the extent practical, and that measures be taken to protect upland areas as well as wetland areas, as recommended in the regional land use plan and Washington County park and open space plan.[5]

3. Where land use controls do not adequately protect wetland and other areas within environmental corridor lands, the Towns of Polk and West Bend and the Big Cedar Lake Protection and Rehabilitation District should consider acquisition of, or acquisition of conservation easements over, such areas. This would facilitate future management actions that may be necessary to ensure the functionality and habitat quality of these areas. Such management actions could include the control of purple loosestrife or other invasive plants which might degrade the habitat quality of the wetlands and protect critical species habitat areas as set forth in SEWRPC Planning Report No. 42, *A Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997. Public acquisition of such lands is also recommended in the aforereferenced Washington County park and open space plan, and meets the criteria for cost-shared acquisition under the Chapter NR 191 Lake Protection Grant program administered by the Wisconsin Department of Natural Resources. Monies granted in terms of this program provide up to 75 percent of the purchase price, or the cost of acquisition of a conservancy easement, subject to a cap of $200,000 on the State share per parcel. The parcels recommended for public acquisition or protection by easement and the recommended lead agency are summarized in Table 10 and shown on Map 18.

4. Where land use controls do not adequately protect upland areas within environmental corridors, the Towns of Polk and West Bend and the Big Cedar Lake Protection and Rehabilitation District should consider acquisition of, or acquisition of conservation easements over, critical upland areas. As with wetland areas, this would facilitate future management actions that may be necessary to ensure the functionality and habitat quality of the uplands. Such management actions could include the control of invasive plant species which might degrade the habitat quality of the woodlands and protect critical species habitat areas as set forth in SEWRPC Planning Report No. 42, *A Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997. Public acquisition of such lands is also recommended in the aforereferenced Washington County park and open space plan, and meets the criteria for cost-shared acquisition under the Chapter NR 50/51 Stewardship Grant program administered by the Wisconsin Department of Natural Resources. Monies granted in terms of this program provide up to 50 percent of the purchase price, or the cost of acquisition of a conservancy easement, subject to a cap of $100,000 on the State share per parcel. The parcels recommended for public acquisition or protection by easement and the recommended lead agency are summarized in Table 10 and shown on Map 18.

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[5] *SEWRPC Community Assistance Planning Report No. 136, 2nd Edition,* A Park and Open Space Plan for Washington County, *August 1997.*

Table 10

LANDS RECOMMENDED FOR ACQUISITION OR ACQUISITION OF CONSERVATION EASEMENTS IN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE

Number on Map 18	Name of Parcel	Area (acres)	Proposed Acquisition Agency	Plan in Which Acquisition is Recommended	Notes
1	Mueller Woods	93.0	Cedar Lakes Conservation Foundation and Big Cedar Lake District	Regional natural areas plan[a]	Four acres currently under protective ownership
2	Slinger Upland Woods	196.0	WDNR	Regional natural areas plan	- -
3	Big Cedar Lake Bog	89.0	Washington County	Regional natural areas plan	- -
4	Hacker Road Bog	25.0	WDNR	Regional natural areas plan	Parcel is currently owned by the WDNR
5	Gilbert Lake Tamarack Swamp	76.0	Cedar Lakes Conservation Foundation	Regional natural areas plan	54 acres currently under protective ownership
6	Gilbert Lake	10.0	Cedar Lakes Conservation Foundation	Regional natural areas plan	Additional lands recommended to be acquired for critical species protection purposes
7	Gilbert Lake	209.6	Cedar Lakes Conservation Foundation and Big Cedar Lake District	Gilbert and Big Cedar Lakes headwaters plan[b]	Additional lands recommended to be acquired over the long term for sensitive plant community protection purposes
8	Ice Age Trail Corridor	- -	WDNR, Washington County, Ice Age Trail Foundation, Inc.	Park and open space plan[c]	- -

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

[b]*SEWRPC Memorandum Report No. 131,* Environmental Analysis of the Lands at the Headwaters of Gilbert Lake and Big Cedar Lake, Washington County, Wisconsin, *March 1999.*

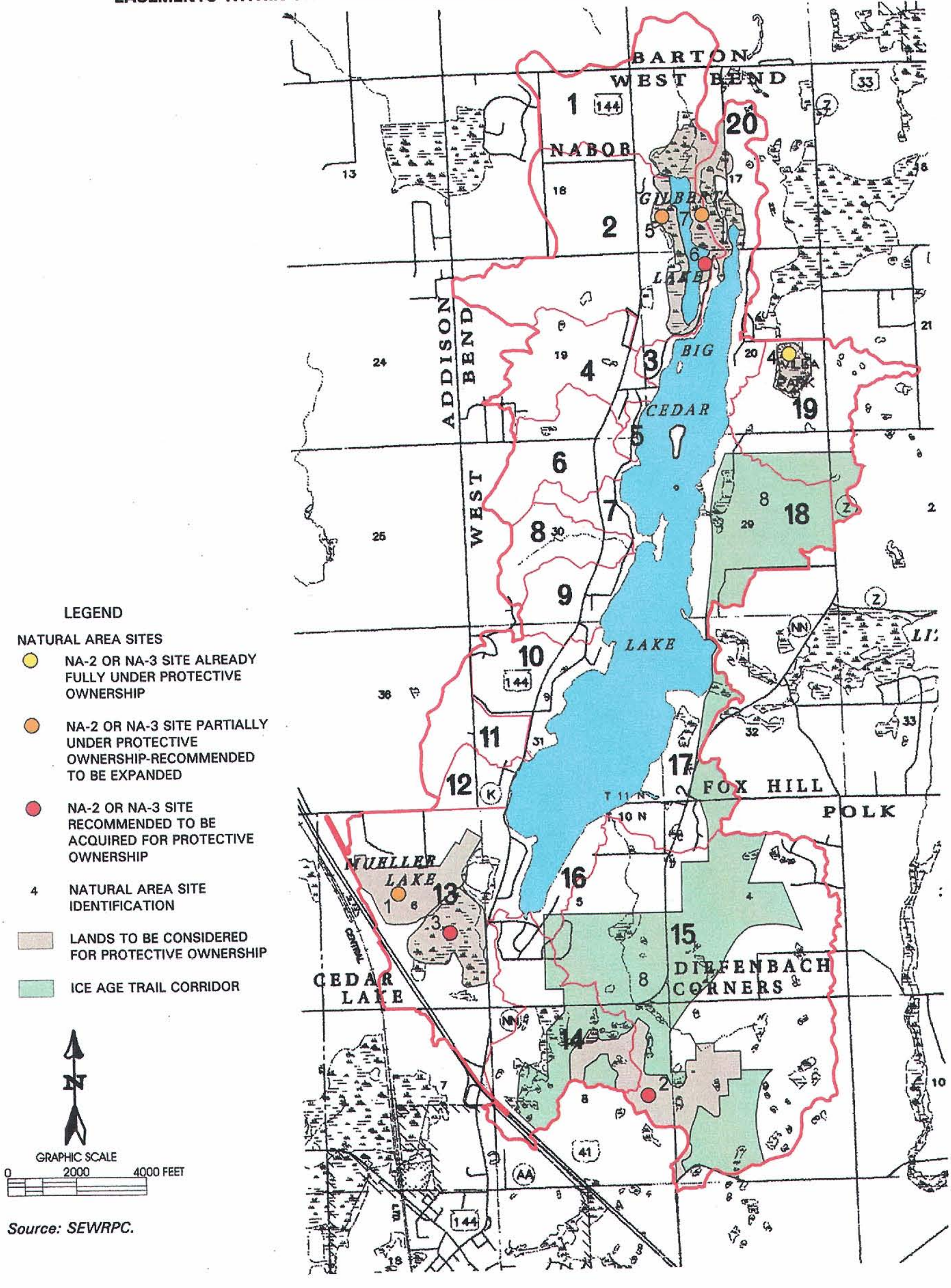
[c]*SEWRPC Community Assistance Planning Report No. 136, 2nd Edition,* A Park and Open Space Plan for Washington County, *August 1997.*

Source: SEWRPC.

5. The Big Cedar Lake Protection and Rehabilitation District and the Wisconsin Department of Natural Resources should work with private property owners to limit herbicide usage within ecologically valuable areas of Big Cedar Lake. The use of chemical herbicides should be limited to small areas for the control of purple loosestrife and Eurasian water milfoil in the Lake. Early spring treatment to control Eurasian water milfoil growth in the Lake has proven effective in other lakes in Southeastern Wisconsin and is recommended to be employed in conjunction with an ongoing aquatic plant harvesting program and implementation of limited further regulation of watercraft using the Lake, as set forth above. Early spring herbicide treatments result in a reduced biomass subject to decomposition and limits the accumulation of organic materials on the Lake bottom. Selected manual harvesting of these plant species is also recommended in areas where this level of control is appropriate to the abundance of plants. Such control measures encourage the resurgence of native plant species and enhance the value of the habitat areas within the Lake.

Map 18

LANDS RECOMMENDED FOR ACQUISITION OR ACQUISITION OF CONSERVATION EASEMENTS WITHIN THE DRAINAGE AREA TRIBUTARY TO BIG CEDAR LAKE



Source: SEWRPC.

6. The Towns of Polk and West Bend and the Big Cedar Lake Protection and Rehabilitation District, through a joint education and information program, should discourage human disturbances in ecologically valuable areas except as may be necessary to provide riparian residents with a reasonable level of access to the main body of the Lake, and limit boating and other water sports in the ecologically valuable areas, especially within the northern portions of the Lake. Lake residents and visitors should be made aware of the invasive nature of species such as purple loosestrife and Eurasian water milfoil, and be encouraged to participate in citizen-based control programs coordinated by the Wisconsin Department of Natural Resources and University of Wisconsin-Extension.

NONPOINT SOURCE POLLUTION CONTROLS

As described in Chapter II, the primary sources of pollutant loadings to Big Cedar Lake are nonpoint sources generated in the drainage area tributary to the Lake. The regional land use plan does not envision any significant increase in urban density residential lands in the drainage area tributary to Big Cedar Lake. However, rural density residential development and some urban density residential development is expected to occur in limited areas. As noted in Chapter III, this is of particular concern in the Town of West Bend where the current zoning regulations indicate a potential for additional rural residential development at densities of up to 50 percent greater than the five-acre rural density set forth in the regional land use plan. Such development or redevelopment as could occur has the potential to result in increased loadings of some pollutants associated with urban development and construction sites. The impacts of such development can be largely mitigated by the implementation of construction site and permanent stormwater management measures.

Array of Control Measures

Watershed management measures may be used to reduce nonpoint source pollutant loadings from such rural sources as runoff from cropland and pastureland; from such urban sources as runoff from residential, commercial, transportation, and recreational land uses; and from construction activities. The alternative, nonpoint source pollution control measures considered in this report are based upon the recommendations set forth in the regional water quality management plan,[6] the Washington County soil erosion control plan,[7] and information presented by the U.S. Environmental Protection Agency,[8] and the requirements of the Washington County erosion control and stormwater management ordinance.[9]

Both urban and rural nonpoint source pollution controls are considered viable to control nonpoint source pollution to Big Cedar Lake and its tributary drainage area.

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[6]*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.*

[7]*SEWRPC Community Assistance Planning Report No. 170,* Washington County Agricultural Soil Erosion Control Plan, *March 1989.*

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

[9]*Washington County Code, Chapter 17,* Erosion Control and Stormwater Management, *December 1997.*

Urban Nonpoint Source Controls
The regional water quality management plan recommends that the nonpoint source pollutant loadings from the urban areas tributary to Big Cedar Lake be reduced by about 25 percent in addition to reductions from urban construction erosion control, and streambank and shoreline erosion control measures. This recommendation was not further refined in the Priority Watershed Plan, although the plan did indicate stormwater conveyance as an issue of concern in the drainage area tributary to Big Cedar Lake.

Potentially applicable urban nonpoint source control measures include wet detention basins, grassed swales, and good urban "housekeeping" practices. Generally, the application of low-cost urban housekeeping practices may be expected to reduce nonpoint source loadings from urban lands by about 25 percent. Public education programs can be developed to encourage such good urban housekeeping practices, to promote the selection of building and construction materials which reduce the runoff contribution of metals and other toxic pollutants, and to promote the acceptance and understanding of the proposed pollution abatement measures and the importance of lake water quality protection. Urban housekeeping practices and source controls include restricted use of fertilizers and pesticides; improved pet waste and litter control; the substitution of plastic for galvanized steel and copper roofing materials and gutters; proper disposal of motor vehicle fluids; increased leaf collection; and reduced use of street deicing salt. Proper design and application of urban nonpoint source control measures such as grassed swales and detention basins requires the preparation of a detailed stormwater management system plan that addresses stormwater drainage problems and controls nonpoint sources of pollution.

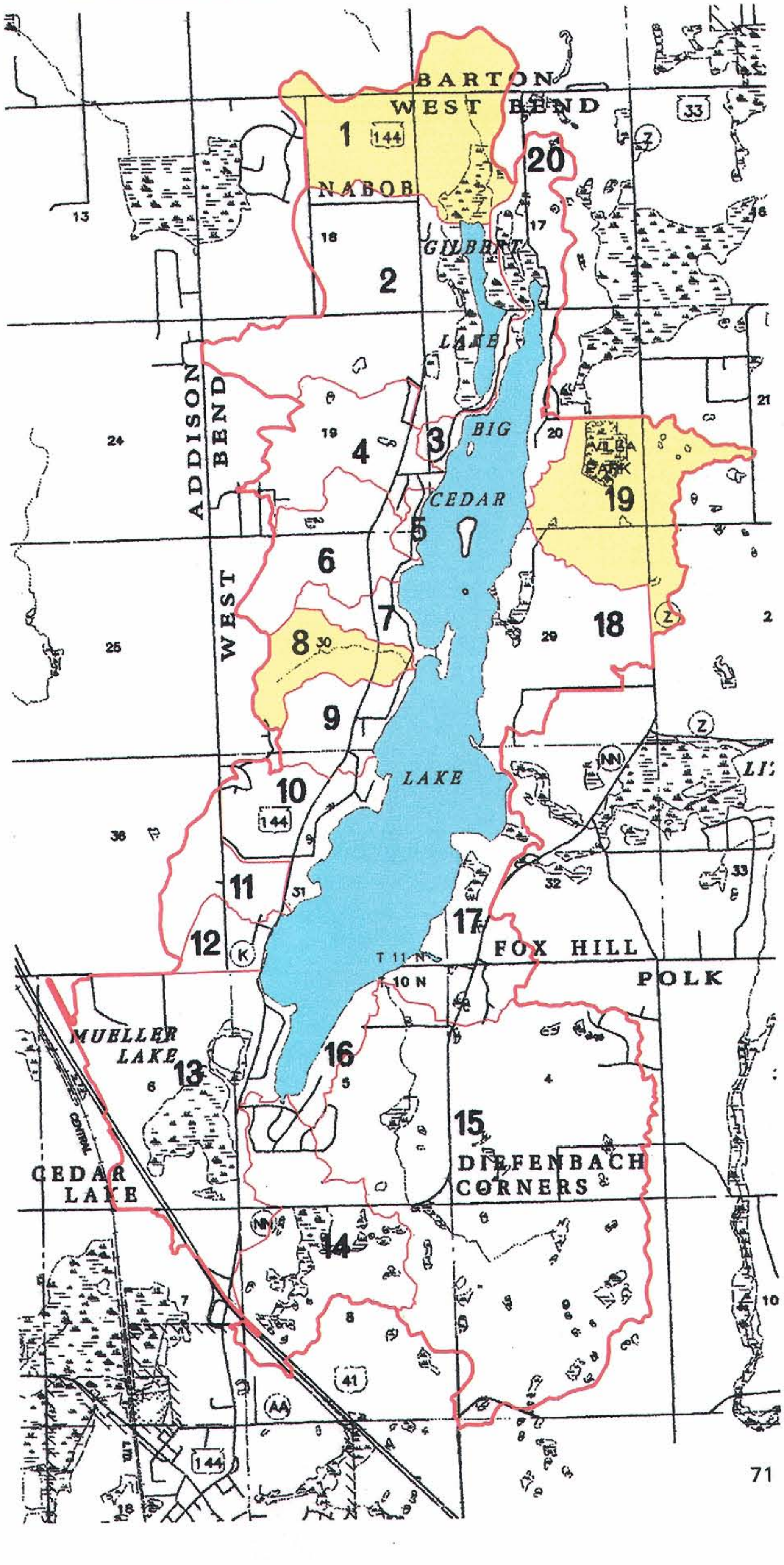
Based on preliminary analyses conducted in this planning effort relating to the sources and controllability of the pollutants contributed to Big Cedar Lake, completion and eventual implementation of stormwater management system plans for the 20 subbasins delineated within the tributary drainage area to Big Cedar Lake is recommended. In the first instance, detailed stormwater management plans should be prepared for those subbasins most likely to be impacted by proposed land development activities. Three such subbasins have been identified by Washington County Land Conservation Department staff as areas within which significant development is to be expected or known to be occurring as of 1999. The stormwater management plans developed for these subbasins, shown on Map 19, would serve as models for the plans recommended to be completed for the remaining seventeen subbasins.

Developing areas can generate significantly higher pollutant loadings than established areas of similar size. Developing areas include a wide array of activities, including individual site development within the existing urban area, and new land subdivision development. As previously noted, additional larger lot or clustered smaller lot residential development is planned for within the drainage area tributary to Big Cedar Lake. Because construction sites, especially, may be expected to produce suspended solids and phosphorus loadings at rates several times higher than established urban land uses, control of sediment loss from construction sites is recommended. Such controls are currently provided by measures set forth in the Washington County erosion control and stormwater management ordinance administered by the Washington County Land Conservation Department. The ordinance, with certain specific exemptions,[10] requires an erosion and runoff control permit for land disturbing activities that affect 4,000 square feet or more of land surface area, involve more than 400 cubic yards of material, or impact 100 linear feet or more of a drainageway. The ordinance also requires an erosion and

[10]*Exemptions are limited to agricultural cropping activities and the activities of State agencies regulated under State erosion control and stormwater management requirements, the construction of single- and two-family residential buildings regulated under the Uniform Dwelling Code, activities disturbing less than one acre of land surface within the shoreland/wetland/floodland zone regulated under County shoreland/floodplain/wetland zoning ordinances, County soil conservation and water pollution control projects, and road construction activities of the County and local municipalities within the County.*

Map 19

SUBBASINS WITHIN THE MANAGEMENT AREA TRIBUTARY TO BIG CEDAR LAKE IDENTIFIED FOR DETAILED STORMWATER MANAGEMENT PLANNING



STORMWATER MANAGEMENT PLANNING AREAS

GRAPHIC SCALE
0 2000 4000 FEET

Source: SEWRPC.

runoff control permit, with certain specific exemptions,[11] for land divisions wherein a tax parcel is divided into five or more lots of five or less acres each in areal extent within a common development plan, for road construction, and for the creation of 20,000 square feet or more of impervious surface. The controls required to be implemented under this ordinance to control erosion include temporary measures taken to reduce pollutant loadings from construction sites during stormwater runoff events as set forth in the construction site management handbook developed by the Wisconsin Department of Natural Resources.[12] Examples of control measures that could be considered for the control of construction site erosion include such revegetation practices as temporary seeding, mulching, and sodding and such runoff control measures as filter fabric fences, straw bale barriers, storm sewer inlet protection devices, diversion swales, sediment traps, and sedimentation basins. The ordinance also sets specific performance standards for stormwater management that include standards for maintenance of predevelopment peak flows, stormwater quality, protection of wetlands, protection of groundwater quality, flood routing and control, and maintenance of soil integrity within stormwater management practices. Further, the ordinance requires that the stormwater management measures be maintained by a responsible party, or by the County should the responsible party fail to maintain the practices.

In addition to the County ordinance, the Town of West Bend has adopted a construction site erosion control ordinance as sub-Section 11.10, Construction Site Erosion Control, of the Town zoning ordinance, which is administered and enforced by the Town in both the shoreland and nonshoreland areas of the unincorporated areas of the drainage area tributary to Big Cedar Lake. The provisions of this ordinance apply to all land disturbing activities in the Town that occur on platted lots within a subdivision plat; lots developed under a certified survey map; areas of 4,000 square feet or greater; works where fill and/or excavation volumes exceed 400 cubic yards; public streets, roads or highways; watercourses; and utilities. In addition, the soil erosion control and stormwater management provisions of the Washington County land division ordinance would apply to subdivisions of five lots or greater. The Towns of Addison and Polk, and the Village of Slinger, include the regulation of land disturbing activities within the general provisions set forth in Section 2.00 of their zoning ordinances.

In addition to the measures set forth above, nonpoint source pollution from urban areas can be minimized through sound land use planning and management. In this regard, the adoption of zoning practices requiring residential development on large lots in the Towns of Polk and West Bend, as described above, can facilitate urban nonpoint source pollution control by promoting cluster development and the maintenance of large areas of the drainage area tributary to Big Cedar Lake in essentially open space usage. Cluster development, as outlined in SEWRPC Planning Guide No. 7, *Rural Cluster Development Guide*, published in December 1996, can promote the installation of stormwater management practices within developing areas, and the preservation of open space.

Rural Nonpoint Source Controls

Upland erosion from agricultural and other rural lands is a contributor of sediment to streams and lakes in the tributary drainage area to Big Cedar Lake. Estimated phosphorus and sediment loadings from croplands, woodlots, pastures, and grasslands in the drainage area tributary to Big Cedar Lake were presented in Chapter II. These loadings are recommended to be reduced to the target level of agricultural erosion control of three tons per acre per year, identified in the Washington County agricultural soil erosion control plan as the tolerable levels that can be sustained without impairing productivity. Implementation of these recommendations is considered to be an important water quality management measure for Big Cedar Lake. The regional water quality management plan recommended that the nonpoint source pollutant loadings from the rural agricultural areas tributary to Big Cedar Lake be reduced by about 25 percent. This recommendation was slightly refined in the Priority Watershed Plan, which indicated that sediment loadings to Big Cedar Lake from agricultural lands be reduced by about 30 percent.

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[11]Ibid.

[12]*Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook, *latest edition April 1994.*

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

Recommended Control Measures

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

1. The Big Cedar Lake Protection and Rehabilitation District should support the application of good land use planning practices within the drainage area tributary to Big Cedar Lake, and encourage the adoption of the planning guidelines set forth in the adopted regional and local land use plans by the Towns, Village, and County.

2. Washington County and the Town of West Bend should strictly enforce the adopted construction site erosion control and stormwater management ordinances to reduce sediment and contaminant loadings from the urbanizing areas in the tributary drainage area to Big Cedar Lake, especially in those areas nearest to the Lake.

3. The Village of Slinger and the Towns of Addison and Polk should review their ordinance provisions governing construction site erosion control and water quality protection, and consider adoption of specific construction site erosion control and stormwater management ordinances based upon the County model ordinance.

4. The Big Cedar Lake Protection and Rehabilitation District, in conjunction with the Towns of Polk and West Bend, should assume the lead in continuing public educational and informational programming for the residents around and in the immediate vicinity of Big Cedar Lake, which encourages the institution of good urban housekeeping practices including, pesticide and fertilizer use management, improved pet waste and litter control, and yard waste management, as well as other lake management-related topics. It is recommended that informational programming related to nonpoint source pollution abatement and other lake management topics continue to be included at the annual meetings of the Big Cedar Lake Protection and Rehabilitation District.

5. Washington County should facilitate preparation and eventual implementation of stormwater management plans for each of the 20 subbasins delineated within the tributary drainage area to Big Cedar Lake is recommended. The three subbasins in which urban incipient development is expected or known to be occurring, shown on Map 19, are proposed to be used as model sites for such stormwater management planning during Phase II of this planning program.

6. The Village of Slinger, and the Towns of Addison, Barton, Polk and West Bend should adopt the rural cluster development guidelines within their local land use planning and zoning requirements to encourage development and implementation of stormwater management plans within developing residential and existing rural areas, consistent with the pollution reduction goals set forth in the adopted regional water quality management plan as refined in the priority watershed plan for the Cedar Creek watershed.

IN-LAKE WATER QUALITY MANAGEMENT

Big Cedar Lake is an high quality water resource located at the headwaters of Cedar Creek, and, as a mesotrophic waterbody, may be considered a relatively unpolluted lake in the context of Southeastern Wisconsin.[13] Further, the available water quality data, summarized in Chapter II, suggest that lake water quality conditions have generally improved since the initial water quality studies were undertaken in 1970s.

Protection of the surface water quality of Big Cedar Lake can be accomplished through the protection of ecologically valuable areas, and adoption of good housekeeping and stormwater management practices within the drainage area tributary to Big Cedar Lake. Continuation of public informational programming on the maintenance of onsite sewage disposal systems and yard and household waste management by the Big Cedar Lake Protection and Rehabilitation District is recommended. Specific assistance in, and educational materials relevant to, such programming is available from the University of Wisconsin-Extension. Informational programming on onsite sewage disposal systems should complement, and be complemented by, ongoing inspections of such systems by County staff as provided for in Chapter Comm 83 of the *Wisconsin Administrative Code.*

Continued participation in the Wisconsin Department of Natural Resources Self-Help and U.S. Geological Survey Trophic State Index (TSI) monitoring programs is also recommended as a means of assessing the health of Big Cedar Lake on a regular basis. These programs can provide an early warning of undesirable changes in lake water quality and aquatic species composition and initiate appropriate responses in a timely manner. Such data can supplement and be coordinated with data gathered by the Wisconsin Department of Natural Resources under the current surface water monitoring strategy developed to conduct monitoring activities and to perform basic assessments for each watershed in the Region on an approximately five- to seven-year rotating cycle.[14]

Finally, in cases where all land-based management measures have been implemented to the extent possible, consideration could be given to in-lake management measures, such as dredging, on a site-specific and case-by-case basis. Such in-lake management measures are likely to be limited in areal extent, and will be subject to regulatory oversight by the Wisconsin Department of Natural Resources. To the extent that such measures may be considered, detailed concept and implementation plans should be prepared.

AUXILIARY PLAN RECOMMENDATIONS

Public information, education, and involvement remains an important component of any lake management program. It is recommended that informational brochures and pamphlets, of interest to homeowners and supportive of the recommendations contained herein be provided to homeowners through direct distribution or targeted civic center outlets such as the appropriate Town Halls. Informational programming is recommended to be included as a regular part of the annual meeting of the electors of the Big Cedar Lake Protection and Rehabilitation District. This plan and its subsequent iterations should be made available for public inspection at the District's annual meetings.

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

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

Chapter V

SUMMARY

Big Cedar Lake, with a surface area of 932 acres, is the largest inland lake in Washington County. Situated immediately to the southwest of the City of West Bend in central Washington County, Big Cedar Lake has been a popular recreational and residential venue since the initial European settlement of the area in the mid-1800s.

Early concern regarding the quality of the Lake resulted in the creation of a Town Sanitary District serving this lake-focused community during the 1930s. This District undertook many of the early lake management measures on the Lake, and continued to provide solid waste management services and aquatic plant management measures for the Lake until the 1970s, when the sanitary district was converted to a public inland lake protection and rehabilitation district. Since the 1970s, the Big Cedar Lake Protection and Rehabilitation District has provided lake management services to the community in concert with other state and local government agencies.

Big Cedar Lake has been the subject of numerous lake management studies and surveys. The earliest definitive water quality data on the Lake were collected by the Wisconsin Department of Natural Resources (WDNR) in the early 1970s, and showed that the Lake was considered to be in relatively good condition, with little evidence of pollution or excessive fertilization. However, at that time, WDNR staff indicated that the water quality condition of the Lake could decline. This indication prompted a series of more detailed water quality studies of the Lake and its tributary drainage area during the late 1970s and early 1980s, which studies were continued through the late 1990s under the auspices of the WDNR Long Term Trends and Self-Help monitoring programs. This series of studies has created a data set on Big Cedar Lake water quality that spans a period of almost thirty years, providing a unique basis from which to assess the existing water quality condition of the Lake and current trends in water quality indicators.

Lake management planning activities associated with Big Cedar Lake also span a considerable period. The earliest plan recommendations were set forth by the WDNR in 1978, and focused on the control of enrichment and sediment transport in the Lake and its tributary drainage area. Recommendations addressed both agricultural activities in the drainage area and onsite sewage disposal system management. These recommendations were refined and elaborated in the adopted regional water quality management plan published in the following year. This plan likewise focused on the nonpoint sources of aquatic pollution arising from land use activities, targeting agricultural land uses within the drainage area tributary to the Lake. The recommendations were augmented and extended to cover the reduction in sediment loss from agricultural lands within the drainage area in the WDNR priority watershed plan for Cedar Creek, published in 1993.

As a result of the plan recommendations, the Big Cedar Lake Protection and Rehabilitation District, in collaboration with state and local governments and the Cedar Lakes Conservation Foundation, has implemented numerous lake and land management practices within the Lake and tributary drainage area. These measures have included the installation of manure management systems on farms within the drainage basin, the alteration of cropping practices to minimize soil loss within the watershed, the construction of stormwater detention and conveyance systems, the restoration of woodland, wetland and prairie ecosystems, and the acquisition of conservation lands.

This water quality protection plan for Big Cedar Lake was prepared by the Southeastern Wisconsin Regional Planning Commission in cooperation with the Big Cedar Lake Protection and Rehabilitation District, Cedar Lakes Conservation Foundation, and Washington County Land Conservation Department. Inventories and analyses were conducted of the existing and recommended future land use activities within the drainage area tributary to Big Cedar Lake, the associated pollutant loadings and sources, the natural resources base of the drainage area, and the management practices employed both on the Lake and in the drainage area. The primary management objectives of this effort were:

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

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

- To effectively maintain, and, if practicable, enhance the water quality of Big Cedar Lake so as to better facilitate the conduct of water-related recreation, improve the aesthetic value of the resource to the community, and enhance the resource value of the waterbody.

This plan is intended to provide the basis for achieving these objectives over time in a technically sound manner.

INVENTORY AND ANALYSIS FINDINGS

Water Quality

Water quality data collected during the period 1967 through 1998 indicate that the ranges of values for temperature, dissolved oxygen concentration, pH, specific conductance, chloride concentration, and nitrogen and phosphorus concentrations fall within the normal range for lakes in Southeastern Wisconsin.

Physical and chemical parameters measured during this period indicate that water quality is considered to be fair to excellent, based upon water clarity, phosphorus concentration, and chlorophyll-a concentration, compared with other lakes in Southeastern Wisconsin.

The water quality indicators suggest that the condition of the Lake has improved during the approximately thirty-year period of record, decreasing from an eutrophic state in the 1970s to a mesotrophic state in the 1990s. Chloride concentrations are an exception to this trend, increasing almost five-fold during the same period.

Water quality data collected in the northern and southern basins of Big Cedar Lake since the 1980s suggest that there are quantifiable differences in quality between the shallower northern basin and the deeper southern basin of the Lake. While these differences are more a matter of degree than differences of major significance, the shallower, northern basin tends to be warmer, more susceptible to intra-annual mixing, and of marginally lesser quality based upon water clarity, phosphorus concentrations and chlorophyll-a concentrations than the deeper and more stable southern basin. Such differences appear to be the result of the natural morphometry of the basins.

The biological quality of the Lake is high, although Eurasian water milfoil and purple loosestrife are both present in the Lake and its drainage area. Based upon the available data, the fishery is reported to be stable and balanced, with both predator fishes and forage fishes present in the system. However, the available fisheries data are from 1978, indicating a need for an updated survey to verify or refine this conclusion.

Pollutant Loadings
Almost 2,500 pounds of phosphorus are estimated to enter Big Cedar Lake annually. Of this mass, about 24 percent is transferred downstream through the outlet of the Lake to Cedar Creek and the downstream waterbodies. The majority of this load, about 1,600 pounds per year, originates from rural lands, with about 400 pounds per year originating from urban lands within the drainage area. The balance of about 500 pounds of phosphorus per year enters the Lake through direct deposition onto the Lake surface.

About 670 tons of sediment are estimated to enter Big Cedar Lake annually. Of this mass, it is estimated that 105 tons are transferred downstream through the outlet. The majority of this load, about 590 tons per year, originates from rural lands, with about 90 tons per year originating from urban lands within the drainage area. The balance of about 95 tons of sediment per year enters the Lake through fallout deposition onto the Lake surface.

About 46 pounds of copper, 175 pounds of zinc, and 0.5 pound of cadmium are estimated to enter Big Cedar Lake annually from urban lands within the drainage area.

Natural Resource Base
As of 1995, wetlands covered about 390 acres of the drainage area tributary to Big Cedar Lake, or about six percent of the tributary drainage area inclusive of the Lake surface. Woodlands covered a further approximately 960 acres of the drainage area, or about 15 percent of the tributary drainage area.

As of 1995, about 1,950 acres of the drainage area tributary to Big Cedar Lake were considered to be valuable wildlife habitat. Class I, high-value wildlife habitat comprised about 1,000 acres or about 15 percent of the drainage area tributary to Big Cedar Lake; Class II, moderate-value wildlife habitat comprised about 400 acres or about six percent of the drainage area tributary to Big Cedar Lake; and Class III, valuable wildlife habitat comprised about 550 acres or about eight percent of the drainage area tributary to Big Cedar Lake.

Environmental corridors, delineated by the Southeastern Wisconsin Regional Planning Commission covered about 1,700 acres. Primary environmental corridors comprised about 1,400 acres or about 20 percent of the drainage area tributary to Big Cedar Lake; secondary environmental corridors comprised about 50 acres or about one percent of the drainage area tributary to Big Cedar Lake; and isolated natural features comprised about 250 acres or about four percent of the drainage area tributary to Big Cedar Lake. These corridor areas and isolated natural areas include almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas in and around Big Cedar Lake.

Environmentally valuable area within Big Cedar Lake provide aquatic habitat used for shelter, spawning and feeding by aquatic animals and include shoreline and lake bottom areas adjacent to the northern riparian wetland area of Big Cedar Lake, including Gilbert Lake, and areas adjacent to the east central portion of Big Cedar Lake.

Land Use and Zoning
Urban land uses in 1995 occupied about 1,250 acres, or about 18 percent of the drainage area tributary to Big Cedar Lake. The dominant urban land use was residential, encompassing 745 acres, or about 60 percent of the area in urban use.

As of 1995, rural land uses occupied about 5,400 acres, or about 82 percent of the drainage area tributary to Big Cedar Lake, were still in rural land uses. About 2,700 acres, or about one-half of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface water, including the surface area of Big Cedar Lake, accounted for approximately 2,700 acres, or about 50 percent of the area in rural use.

Existing zoning within the Big Cedar Lake drainage area in the Town of Polk portion of the drainage area is consistent with the regional land use plan. In the Town of West Bend, the lands within the Big Cedar Lake drainage area have been placed into zoning districts that approach those recommended in the regional plan, although density bonuses intended to encourage clustered residential development may allow for higher overall densities. In addition, the prime agricultural land area within the western portion of the drainage area in the Town have not been placed in an exclusive agricultural zoning district as recommended in the regional land use plan.

In addition to the comprehensive zoning ordinances administered by the local authorities in the Big Cedar Lake drainage area, Washington County exercises special-purpose shoreland and floodland zoning in the direct drainage area tributary to Big Cedar Lake.

WATER QUALITY MANAGEMENT MEASURES

Alternative management techniques, including watershed and in-lake management measures, were evaluated based on effectiveness, cost, and technical feasibility. Those alternative measures determined to best protect and maintain water quality conditions within Big Cedar Lake in a manner consistent with the abovementioned objectives established for Big Cedar Lake are set forth in this recommended water quality protection plan for the Lake.

For the protection and maintenance of water quality conditions:

1. Protection of the surface water quality of Big Cedar Lake can be accomplished through the protection of ecologically valuable areas, and adoption of good housekeeping practices and other stormwater management measures within the drainage area tributary to Big Cedar Lake. In this regard, it is recommended that stormwater management plans be prepared for each of the 20 subbasins identified as draining to Big Cedar Lake. Plans for three such subbasins are proposed to be developed under the second phase of this planning program.

2. Continuation of public informational programming on the maintenance of onsite sewage disposal systems and yard and household waste management by the Big Cedar Lake Protection and Rehabilitation District is recommended, complemented by ongoing inspections of such systems by County staff as provided for in Chapter Comm 83 of the *Wisconsin Administrative Code*.

3. Continued participation in the Wisconsin Department of Natural Resources Self-Help and U.S. Geological Survey TSI monitoring programs is also recommended as a means of assessing the health of Big Cedar Lake on a regular basis.

4. Enforcement of the construction site erosion control and water quality protection ordinances adopted by the Town of West Bend and by Washington County to reduce sediment and contaminant loadings from the urbanizing areas in the tributary drainage area to Big Cedar Lake, especially in those areas nearest to the Lake.

5. Evaluation, as necessary, of in-lake management measures, such as dredging, is recommended on a site-specific, case-by-case basis in areas where all land-based management measures have been implemented, subject to applicable regulatory oversight, permitting, and detailed engineering design.

For the protection of the natural resources base:

1. Review and adoption of construction site erosion control and water quality protection ordinances by the Towns of Addison and Polk and by the Village of Slinger.

2. Conduct of public informational programming by the Big Cedar Lake Protection and Rehabilitation District, in conjunction with the Towns of Polk and West Bend, to encourage the institution of good urban housekeeping practices including, pesticide and fertilizer use management, improved pet waste and litter control, and yard waste management, as well as other lake management-related topics.

3. Preparation and eventual implementation of stormwater management plans for each of the 20 subbasins delineated within the tributary drainage area to Big Cedar Lake.

For the protection and enhancement of fish and other aquatic resources, including wildlife and woodland and wetland habitat:

1. Placement of signage and notices at the public access sites to alert lake users to applicable Lake ordinances as set forth in Section 30.77(4) of the *Wisconsin Statutes*, and monitoring the level of compliance achieved.

2. Demarcation of the ecologically sensitive areas located on the northeast shoreline with regulatory buoys and signs to help enforce the recommended restrictions on motorized boat traffic.

3. Demarcation of the aquatic macrophyte beds containing *Myriophyllum spicatum* (Eurasian water milfoil) with regulatory buoyage to restrict motorized boat traffic and diminish proliferation of this plant to other areas of the Lake.

4. Continuation of the aquatic plant harvesting program to facilitate public access to the Lake and utilization of its amenities.

5. Preservation of the environmental corridor lands and isolated natural resource features in the drainage area tributary to Big Cedar Lake in essentially natural, open-space uses, primarily through public land use controls administered at the municipal government level with support from Washington County.

6. Where environmental corridor lands are not considered to be adequately preserved through public land use controls, public acquisition of wetlands, woodlands, and upland areas within the drainage area tributary to the Lake, or acquisition of conservancy easements over such lands, should be considered in order to facilitate future management actions that may be necessary to ensure the habitat quality of these natural resource features and protect critical species habitat areas within the drainage area as set forth in adopted regional and sub-regional plans. Lands to be considered for acquisition include the Gilbert Lake Tamarack Swamp, Hacker Road Bog, Big Cedar Lake Bog, Slinger Upland Woods, and Mueller Woods.

7. Limitation of herbicide usage within ecologically valuable areas of Big Cedar Lake to small areas for the control of purple loosestrife and Eurasian water milfoil in the Lake. Selected manual harvesting of these plant species is also recommended in areas where this level of control is appropriate to the abundance of plants. Such control measures encourage the resurgence of native plant species and enhance the value of the habitat areas within the Lake.

8. Enhance public awareness through joint education and information programs, to discourage human disturbances in ecologically valuable areas except as may be necessary to provide riparian residents with a reasonable level of access to the main body of the Lake, and limit boating and other water sports in the ecologically valuable areas.

For public information and education:

1. Continuation of public information, education, and involvement as an important component of the District's lake management program, and provision of educational and informational materials to homeowners through direct distribution or targeted civic center outlets such as the Town Hall.

2. Continuation of public meetings convened by the Big Cedar Lake Protection and Rehabilitation District and Towns of Polk and West Bend at regular intervals, with informational issues being a regular part of such meetings. This plan and its subsequent iterations should be made available for public inspection at the District's annual meetings.

The recommended plan is based, in large part, upon existing and ongoing lake water quality management measures being employed by the Big Cedar Lake Protection and Rehabilitation District, Washington County, the riparian municipalities, and Cedar Lakes Conservation Foundation. The plan recommends an expansion of the stormwater management activities in the drainage area tributary to Big Cedar Lake. The Big Cedar Protection and Rehabilitation District, in association with the Cedar Lakes Conservation Foundation, is recommended to undertake primary responsibility for implementing this plan, with the assistance of the County and local municipalities, and other agencies and organizations as may be appropriate, including the WDNR and University of Wisconsin-Extension. This plan, which is consistent with previously adopted plans and programs, including the regional land use and water quality management plans, the Washington County park and open space and soil erosion control plans, and the priority watershed, nonpoint source pollution abatement plan for the Cedar Creek watershed, and provides an important element for the adoption and implementation of an effective program of lake water quality management for Big Cedar Lake.