COMMUNITY ASSISTANCE
PLANNING REPORT NO. 181
(2nd Edition)

A LAKE MANAGEMENT PLAN FOR OCONOMOWOC LAKE

WAUKESHA COUNTY WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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NUMBER 181, 2nd Edition

A LAKE MANAGEMENT PLAN FOR OCONOMOWOC LAKE

WAUKESHA COUNTY, WISCONSIN

Prepared by the

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Chapter I

INTRODUCTION

Oconomowoc Lake is an 804-acre[1] through-flow lake, situated within U.S. Public Land Survey Sections 1, 2, and 3, Township 7 North, Range 17 East, in the Village of Oconomowoc Lake, Waukesha County. The Lake is fed and drained by the Oconomowoc River, which drains to the Rock River and, ultimately, to the Mississippi River. The Lake offers a variety of water-based recreational opportunities and is the focus of the eponymous lake-oriented community, the Village of Oconomowoc Lake, surrounding the waterbody.

For many years, the Village of Oconomowoc Lake and its residents have undertaken a program of lake protection to maintain the high-quality, lake-oriented residential and recreational experiences available to Village residents and their visitors. To this end, Oconomowoc Lake has been the subject of various studies, including the preparation of lake-specific plan elements within the regional water quality management plan,[2] the Oconomowoc River nonpoint source pollution abatement plan,[3] and water quality management plan for Oconomowoc Lake that was completed by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) during 1990.[4] The regional water quality management plan identified surface water quality problems within the Rock River watershed; identified major sources of pollution; and provided recommendations for abating those sources over time to achieve specific water use objectives and attendant water quality standards that were refined in the lake-specific plan. These recommendations were later refined in the nonpoint source pollution abatement plan, again on a drainage area basis. The SEWRPC water quality management plan for Oconomowoc Lake focused on point

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[1]*In SEWRPC Planning Guide No. 5,* Floodland and Shoreland Development Guide, *1968, the area of Oconomowoc Lake was reported to be 767 acres, as measured from 1956 aerial photographs. Based on 1980 aerial photographs, the area of Oconomowoc Lake was estimated to be 804 acres. The differences in these measured areas may be attributed to the improved survey control available to accurately establish the scale of the latter, as opposed to the earlier, photographs; differences in the scales of the photographs; and some actual changes in lake water levels.*

[2]*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.*

[3]*Wisconsin Department of Natural Resources Publication No. PUBL WR-194-86,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *March 1986.*

[4]*SEWRPC Community Assistance Planning Report No. 181,* A Water Quality Management Plan for Oconomowoc Lake, Waukesha County, Wisconsin, *March 1990.*

and nonpoint source pollution controls within the area directly tributary to the Lake, including: review and modification of the zoning ordinances of the Village of Oconomowoc Lake; urban land management, including construction site erosion controls, wastewater management, and urban sourced-nonpoint pollution; and inlake measures designed to alleviate "excessive algae growth." Monitoring water quality and fish populations were additional recommendations set forth in the plan.

In 2004, the Village of Oconomowoc Lake requested the further assistance of SEWRPC in the conduct of the planning studies leading to the preparation of a refined lake management plan for Oconomowoc Lake. This plan represents part of the ongoing commitment of the Village of Oconomowoc Lake to sound planning with respect to the Lake and forms a logical complement to the lake management actions that have been implemented on and around the Lake. The current plan was prepared by SEWRPC in cooperation with the Village of Oconomowoc Lake, and it incorporates the data and analyses developed in the aforementioned lake management-related studies, as well as pertinent water quality and other data gathered by the U.S. Geological Survey, Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and private consultants working under contract to the Village. This report presents both land-based and in-lake measures for enhancing the water quality conditions, maintaining the lake ecosystem, and providing opportunities for the safe and enjoyable use of the Lake by residents and visitors to this community. More specifically, this report describes the physical, chemical, and biological characteristics of the Lake and pertinent related characteristics of the tributary area, as well as the feasibility of various tributary area and in-lake management measures which may be applied to achieving these goals.

The primary management objectives for Oconomowoc Lake include: 1) providing water quality suitable for the maintenance of fish and other aquatic life, 2) reducing the severity of existing nuisance problems resulting from excessive macrophyte and algae growth and the presence of invasive species which constrain or preclude intended water uses, and 3) improving opportunities for water-based recreational activities. The lake management plan herein presented should constitute a practical guide for the management of the water quality of Oconomowoc Lake and for the management of the land surfaces which drain directly to this important body of water. This plan conforms to the requirements of and standards set forth in the relevant *Wisconsin Administrative Codes.*[5]

The plan sets forth the inventory data used as the basis for reviewing the alternative lake management measures and developing the recommended management measures. The inventory data include an overview of the Lake and its tributary area, a review of the governance structures currently in place surrounding the Lake, a summary of water quality, a summary of the biology, and a review of the water use objectives established for the Oconomowoc Lake used to determine alternative and recommended plan elements for the management of the lake and its tributary area. A subset of these measures is recommended to address current and forecast future lake management issues relevant to Oconomowoc Lake.

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[5]*This plan has been prepared pursuant to the standards and requirements set forth in four chapters of the* Wisconsin Administrative Code: *Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 103, "Water Quality Standards for Wetlands;" Chapter NR 107, "Aquatic Plant Management;" and Chapter NR 109, "Aquatic Plants: Introduction, Manual Removal & Mechanical Control Regulations." The plan recommendations also are consistent with the requirements of the Chapter NR 198, "Aquatic Invasive Species Control Grants," and Chapter NR 7, "Recreational Boating Facilities Program."*

Chapter II

PHYSICAL DESCRIPTION

INTRODUCTION

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

WATERBODY CHARACTERISTICS

Oconomowoc Lake is located entirely within the Village of Oconomowoc Lake, as shown on Map 1. The Lake is a drainage, or through-flow, lake, having both a defined natural channel inflow and a defined outflow. Oconomowoc Lake has two distinct basins, oriented in approximately an east-west direction. The lake level is controlled artificially by a control structure located at the point of discharge from the Lake to the Oconomowoc River, and is influenced by the volume of water entering the Lake from the Okauchee Lake dam located to the north of Oconomowoc Lake on the Oconomowoc River. The Lake is the fourth lake in a chain of six major lakes located along the Oconomowoc River within the Southeastern Wisconsin Region.[1]

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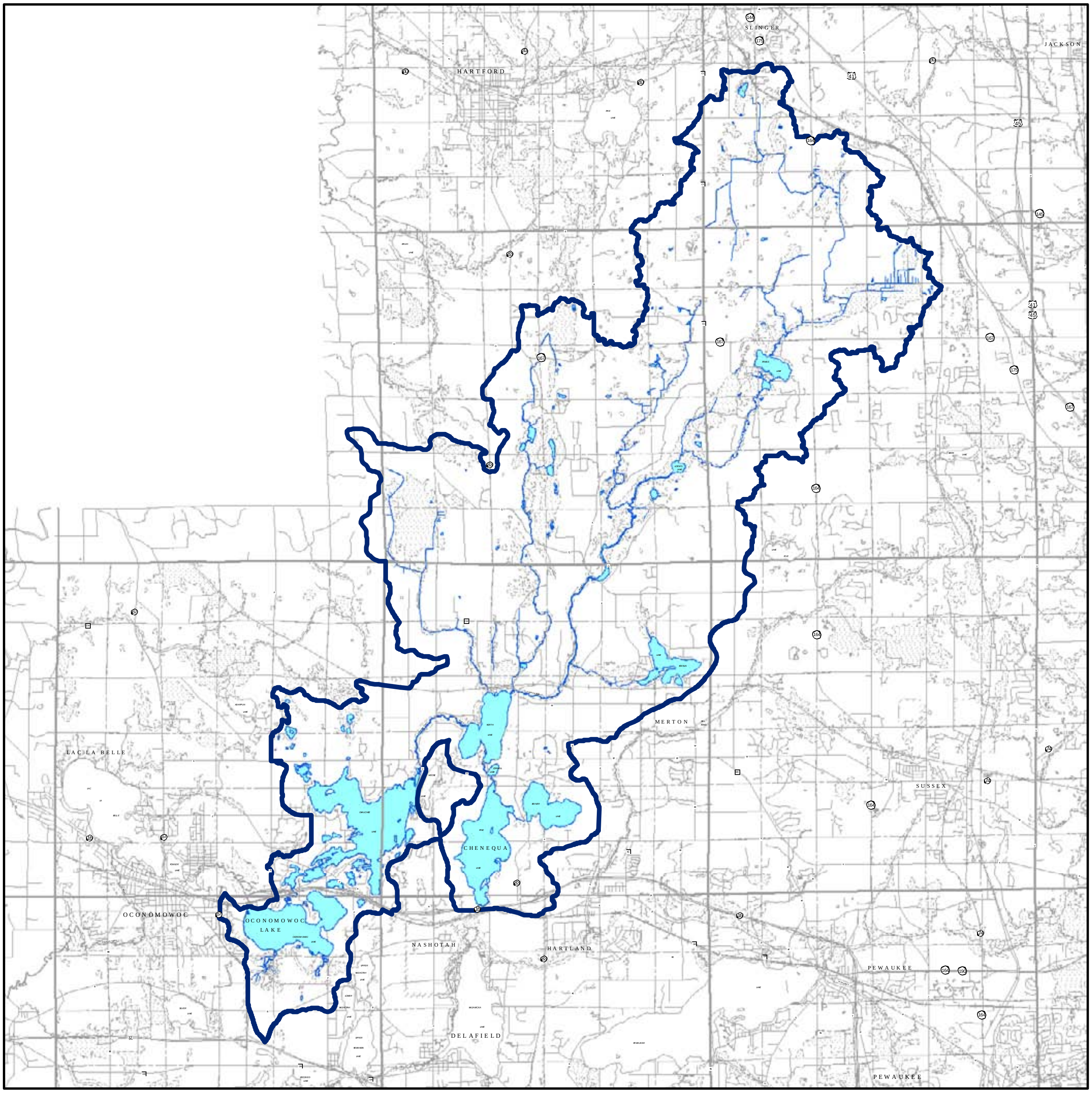
[1]*Lake management plans have been prepared by the Southeastern Wisconsin Regional Planning Commission for each of these six lakes: see SEWRPC Community Assistance Planning Report No. 47, 2nd Edition,* A Water Quality Management Plan for Lac La Belle, Waukesha County, Wisconsin*, May 2007; SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* A Water Quality Management Plan for Okauchee Lake, Waukesha County, Wisconsin, *October 2003; SEWRPC Community Assistance Planning Report No. 54,* A Water Quality Management Plan for North Lake, Waukesha County, Wisconsin*, July 1982; SEWRPC Community Assistance Planning Report No. 98, 2nd Edition,* A Lake Management Plan for Friess Lake, Washington County, Wisconsin*, November 1997; SEWRPC Community Assistance Planning Report No. 181,* A Water Quality Management Plan for Oconomowoc Lake, Waukesha County, Wisconsin, *March 1990; and, SEWRPC Community Assistance Planning Report No. 187,* A Management Plan for Fowler Lake, Waukesha County, Wisconsin, *March 1994.*

Map 1

LOCATION OF OCONOMOWOC LAKE



Total Tributary Area Boundary for Oconomowoc Lake

Surface Water

Source: SEWRPC.

N

0 10,000 20,000 Feet

Oconomowoc Lake lies in a preglacial erosion valley and is fed by the Oconomowoc River. The River enters the Lake from the north, and drains from the Lake from its northwestern corner. Upon leaving the Lake, the Oconomowoc River flows northerly and westerly toward the City of Oconomowoc, discharging into Fowler Lake and Lac La Belle prior to its confluence with the Rock River.

The Oconomowoc Lake basin originally was formed as a consequence of the retreat of the continental glaciers at the end of the Wisconsin stage of glaciation, approximately 12,500 years ago. The water level of the Lake has been augmented by a low head impoundment located on the outflowing Oconomowoc River. The Lake elevation is established by the Wisconsin Department of Natural Resources (WDNR) at an elevation between 861.60 feet and 860.27 feet, National Geodetic Vertical Datum 1929 adjustment (NGVD-29).[2]

Oconomowoc Lake has a surface area of 804 acres, with a maximum depth of 62 feet and a mean depth of about 30 feet. Approximately 16 percent of the lake area is less than five feet deep, about 41 percent of the Lake has a water depth of between five feet and 40 feet, and about 43 percent of the Lake is deeper than 40 feet. Oconomowoc Lake is 1.9 miles long and 1.2 miles wide at its widest point. The major axis of the Lake lies in a northeasterly-southwesterly direction. The Lake shoreline is 7.0 miles long, with a shoreline development factor of 1.8, indicating that the shoreline is about 1.8 times longer than a circular lake of the same area. The Lake has a total volume of approximately 23,099 acre-feet. These hydrographical and morphometric data are presented in Table 1 and the bathymetry of the Lake is shown on Map 2.

The shoreline of Oconomowoc Lake is mostly developed for single-family residential uses and is largely privately owned. Several significant wetland areas occur along the Lake's shoreline. A public recreational boating access site, owned by the Village of Oconomowoc Lake, is located on the Oconomowoc River inflow channel approximately 0.7 mile upstream of the Lake, just below the Okauchee Lake dam. This public recreational boating access site provides the Lake with adequate public access, pursuant to Chapter NR 1 of the *Wisconsin Administrative Code*.

Erosion of shorelines results in the loss of land, damage to shoreline infrastructure, and interference with recreational access and lake use. Such erosion is usually caused by wind-wave erosion, ice movement, and motorized boat traffic. A survey of the Oconomowoc Lake shoreline, conducted during the summer of 2005 by Southeastern Wisconsin Regional Planning Commission (SEWRPC) staff, identified existing shoreline protection structures around the Lake, as shown on Map 3. Much of the developed shoreland of Oconomowoc Lake had some form of shoreline protection in 2005. Most were in a good state of repair. However, improperly installed and failing shoreline protection structures and the erosion of natural shorelines on Oconomowoc Lake are a limited cause for concern.

Lake bottom sediment types, as reported in the initial SEWRPC study, consisted mainly of sand, gravel, and marl. The abundance of natural sand and gravel beach areas was considered to provide excellent swimming opportunities, while at the same time limiting aquatic plant growth, thus, helping to prevent nuisance levels of aquatic plants. Observations by Commission staff during the 2005 aquatic plant survey of the Lake suggest that there has been little change in the composition of the lake bottom substrate.

TRIBUTARY AREA CHARACTERISTICS

The total area tributary to Oconomowoc Lake—that is, the area which drains into the Lake from both the surrounding landscape and the inflowing streams and rivers—totals about 52,599 acres, or 82.2 square miles, in areal extent, as shown on Map 1. The size of a lake's tributary area compared to the size of the lake can have a significant impact on the flow and amount of nutrients in a lake. As the ratio of tributary area size to lake size

[2]*SEWRPC Community Assistance Planning Report No. 181,* op. cit.

Table 1

HYDROLOGY AND MORPHOMETRY CHARACTERISTICS OF OCONOMOWOC LAKE: 2005

Parameter	Measurement
Size (total)	
Surface Area	804 acres
Total Tributary Area	52,599 acres[a]
Volume	23,099 acre-feet
Residence Time[b]	0.45 years
Shape	
Maximum Length of Lake	1.9 miles
Maximum Width	1.2 miles
Length of Shoreline	7.0 miles
Shoreline Development Factor[c]	1.8
Depth	
Area of Lake Less than Five Feet	16 percent
Area of Lake Five to 40 Feet	41 percent
Area of Lake Greater than 40 Feet	43 percent
Mean Depth	30 feet
Maximum Depth	62 feet

[a]*In the initial SEWRPC report, the total tributary area was reported as 48,332 acres; current refinement of the tributary area boundaries includes areas in the vicinity of Pine and Beaver Lakes not included in the initial report.*

[b]*Residence Time: Time required for a volume equivalent to the full volume of the lake to enter the lake from the tributary area during a year of normal precipitation. The residence time of the smaller basin of Oconomowoc Lake (the northeast bay) is likely to be at least as long as the larger main basin because of the presence of a bedrock sill which significantly reduces the exchange of water between the two basins.*

[c]*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.

increases, so does the likelihood of a lake experiencing large nutrient inputs. In the initial SEWRPC report, Oconomowoc Lake was reported to have a tributary area to lake area ratio of 60:1; during the current study period, with refinement of tributary area boundaries for the Lake, the ratio was determined to be slightly larger, approximately 65:1. This is consistent with the Lake's location within the Oconomowoc River chain-of-lakes, resulting in a watershed-to-lake surface area ratio that is somewhat lower than that of Fowler Lake with a ratio of 448:1,[3] but slightly higher than that of Okauchee Lake with a ratio of 35:1.[4]

Oconomowoc Lake is fed by the Oconomowoc River from the north. Okauchee Lake is located immediately upstream. The Oconomowoc Lake outlet, located on the northwestern shoreline, is the Oconomowoc River which flows north and northwest before flowing into Fowler Lake and Lac La Belle, and eventually joining the Rock River downstream of Lac La Belle.

Soil Types and Conditions

Soil type, land slope, and land use are among the more important factors determining lake water quality conditions. Soil type, land slope, and vegetative cover are also important factors affecting the rate, amount, and quality of stormwater runoff. The texture of different soil types and the structure of soil particles influence the permeability, infiltration rate, and erodibility of soils. Land slopes are important determinants of stormwater runoff rates and of the susceptibility of soils to erosion. The erosivity of the runoff can be moderated or modified by vegetation or structural interventions. Soil types and land slope are discussed immediately below; land use is discussed in Chapter III of this report.

The U.S. Natural Resources Conservation Service (NRCS), formerly the U.S. Soil Conservation Service (SCS), under contract to SEWRPC, completed a detailed soil survey of the Oconomowoc Lake area in 1966.[5] The major soil associations within the Oconomowoc Lake direct tributary area are: Casco silt loam, Fox silt loam, Juneau silt loam, Warsaw silt loam, Casco loam, Casco Rodman loam, Houghton muck peat, and Palms muck. In general, the soils in the immediate vicinity of Oconomowoc Lake are those of the Casco-Fox association. The Casco and Fox series soils are typically well-drained soils that have formed on top of glacial outwash areas of sand and gravel. These soils have moderate- to low-fertility, and are moderately permeable. The native vegetation found on Casco and Fox soils is composed primarily of deciduous forest comprised mainly of hardwoods, such as oak and hickory.

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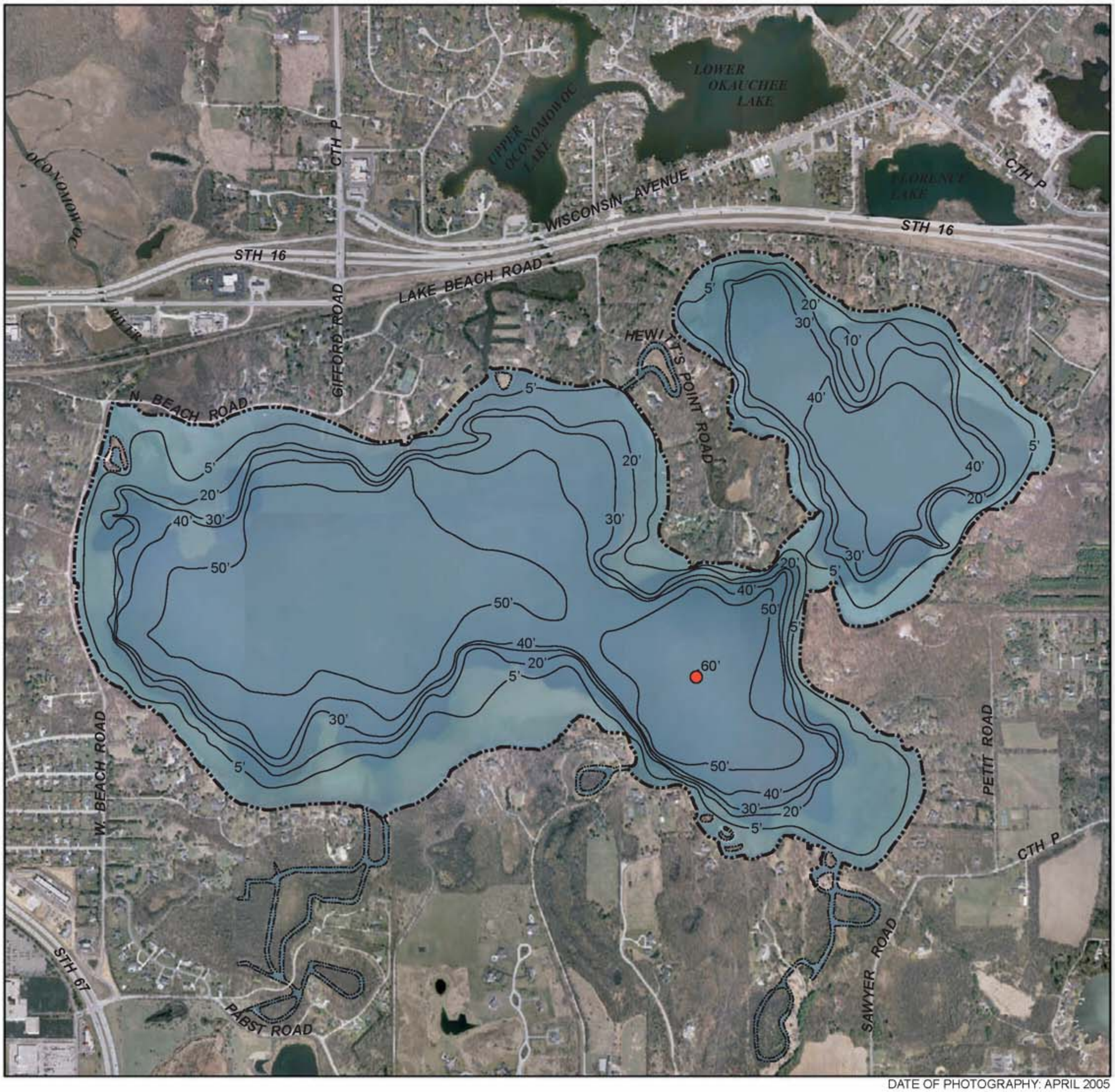
[3]*SEWRPC Community Assistance Planning Report No. 187,* op. cit.

[4]*SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* op. cit.

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

Map 2

BATHYMETRIC MAP OF OCONOMOWOC LAKE



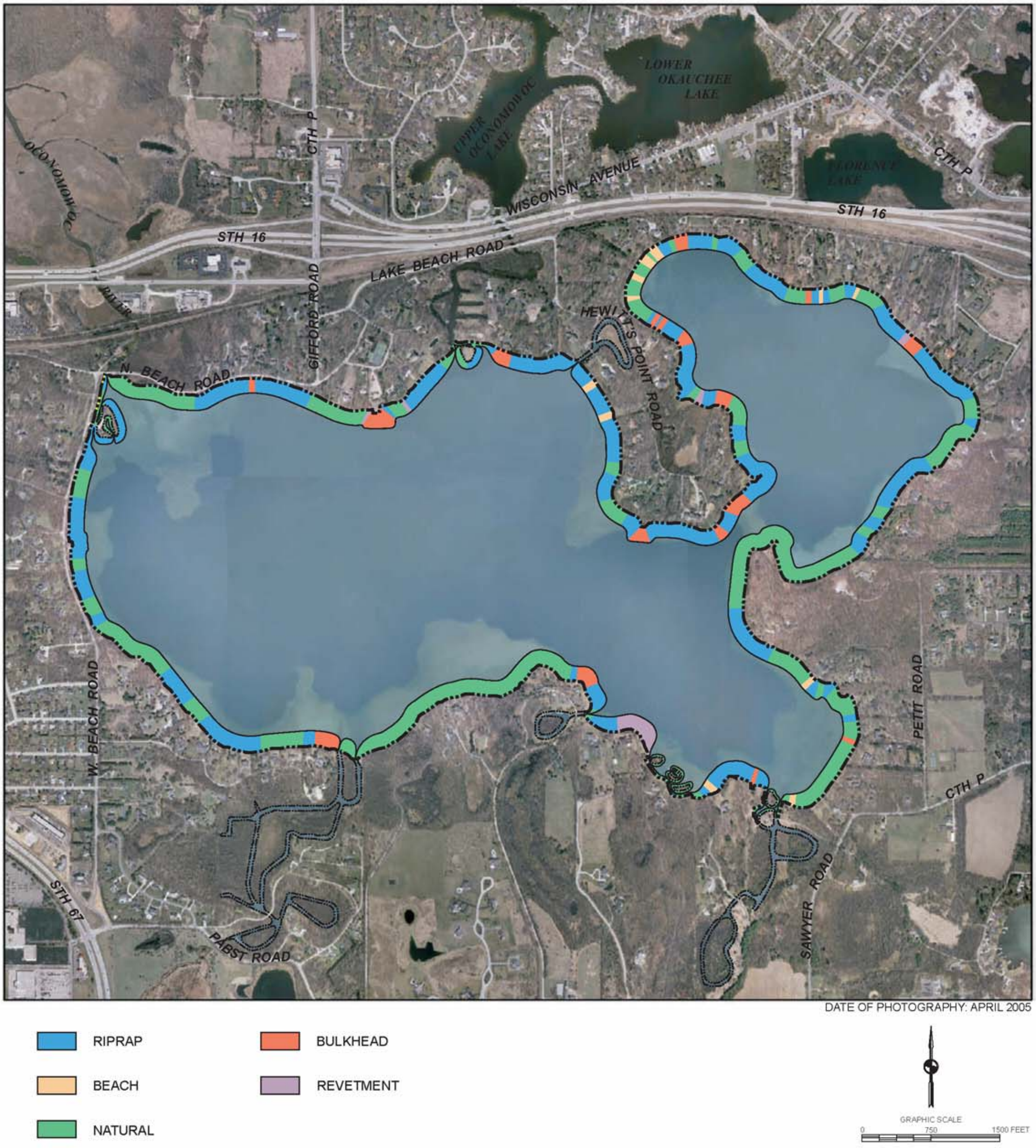
—20'— WATER DEPTH CONTOUR IN FEET

● MONITORING SITE

Source: U.S. Geological Survey and SEWRPC.

Map 3

SHORELINE PROTECTION STRUCTURES ON OCONOMOWOC LAKE: 2005



Source: SEWRPC.

Of the other major soils groups found within the area directly tributary to Oconomowoc Lake, the Juneau series soils are mostly well-drained or moderately well-drained soils, generally found in long, narrow areas, such as intermittent drainageways. Like the Casco and Fox series soils, the native vegetation found on Juneau series soils is composed primarily of deciduous forest comprised mainly of hardwoods, such as oak and hickory. These soils are underlain by older buried upland soils, are moderately permeable, and have a high natural fertility. The Warsaw series soils are well-drained, loamy soils that overlay glacial sand and gravel outwash. These soils were originally found in glacial plains and supported native vegetation, consisting mainly of prairie grasses and some scattered oaks. Houghton and Palm series soils, on the other hand, are soils whose native vegetation is comprised mainly of sedges, reeds, and forbs. These soils are poorly or very poorly drained soils consisting mainly of residue from water-tolerant plants that once grew in old, shallow glacial lakebeds.

Using the regional soil survey, an assessment was made of the hydrologic characteristics of the soils in the tributary area of Oconomowoc Lake. Soils were categorized generally into four principal hydrologic groups, as indicated in Table 2. Less than 1 percent of the total area tributary to Oconomowoc Lake is covered by well-drained soils; moderately well drained soils cover about 66 percent of the total tributary area; poorly drained soils and very poorly drained soils each cover about 17 percent of the total tributary area. The areal extent of these soils and their locations within the total area tributary to Oconomowoc Lake are shown on Map 4.

In addition to the identification and delineation of soil types, the soil survey contained interpretations for planning and engineering applications, as well as for agricultural applications. The suitability of the soils for urban residential development was assessed using different common development scenarios. These ratings reflected the requirements of the then-current Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems as it existed through the year 2000. The interpretations associated with the soil survey with respect to onsite sewage disposal systems are such that they provide insights into the potential for land-based sources of pollution to affect lake water quality, either as a consequence of overland flows during storm events, or through groundwater interflows in the Lake. Therefore, as an index of the likelihood of contaminants entering Oconomowoc Lake, the soil ratings for onsite sewage disposal systems in the total area tributary to Oconomowoc Lake, as determined pursuant to the then-existing requirements of Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems through early 2000, are shown on Map 5. During 2000, the Wisconsin Legislature amended Chapter Comm 83 and adopted new rules governing onsite sewage disposal systems. These rules, which had an effective date of July 1, 2000, significantly altered the existing regulatory framework. In effect, the year 2000 refinement of Chapter Comm 83 increased the area in which onsite sewage disposal systems may be utilized.

It is useful to note that, based upon the pre-year 2000 index, nearly 30 percent of the lands within the total area tributary to Oconomowoc Lake are covered by soils that are categorized as having few limitations for onsite sewage disposal systems, while about 25 percent is covered by soils that are classified as unsuitable for onsite sewage disposal systems. This latter value suggests some potential sensitivity to disturbance and likelihood of being permeable to nonpoint source pollutants. Consequently, based upon soil characteristics, measures to limit the influx of nonpoint source contaminants to the Lake appear to be warranted. The remaining 45 percent of the tributary area is covered by unclassified or undetermined soils.

Residential lands within the area directly tributary to Oconomowoc Lake currently are served primarily by onsite sewage disposal systems. A small portion of the residential lands located along the southwestern shores of Oconomowoc Lake along South Beach Road is served by public sanitary sewerage service provided by the City of Oconomowoc publicly owned wastewater treatment plant. Pursuant to the recommendations set forth in the adopted regional water quality management plan,[6] other areas of the Village surrounding Oconomowoc Lake are recommended for future public sewerage service development.[7] These areas are shown on Map 6.

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[6]*See 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*
(Footnote Continued on Next Page)

Table 2

GENERAL HYDROLOGIC SOIL TYPES WITHIN THE TOTAL AREA TRIBUTARY TO OCONOMOWOC LAKE

Group	Soil Characteristics	Total Tributary Area (acres)	Percent of Total Tributary Area[a]
A	Well drained; very rapidly to rapid permeability; low shrink-swell potential	199	<1
B	Moderately well drained; texture intermediate between coarse and fine; moderately rapid to moderate permeability; low to moderate shrink-swell potential	32,324	66
C	Poorly drained; high water table for part or most of the year; mottling, suggesting poor aeration and lack of drainage, generally present in A to C horizons	8,214	17
D	Very poorly drained; high water table for most of the year; organic or clay soils; clay soils having high shrink-swell potential	8,225	17
Total		48,962	100

[a]*Excludes water.*

Source: U.S. Geologic Survey and SEWRPC.

As stated above, land slope, along with soil type and vegetative cover, is an important factor affecting the rate, amount, and quality of stormwater runoff. Land surface slopes within the total area tributary to Oconomowoc Lake range from less than 1 percent to greater than 20 percent. In general, slopes of over 12 percent have limitations for urban residential development and, if developed, can present potential erosion and drainage problems. Based upon soil-slope interpretations, about 9,351 acres, or about 19 percent of the total area tributary to Oconomowoc Lake, have slopes within this range. A further 6,909 acres, or about 14 percent of the total area, have slopes of between 6 percent and 11 percent, while about 32,503 acres, or about 67 percent of the area, excluding surface waters, has slopes of less than 6 percent.

Climate and Hydrology

Long-term average monthly air temperature and precipitation values are set forth in Table 3. These data were taken from official National Oceanic and Atmospheric Administration records based on data from 17 reporting stations across the Southeastern Wisconsin Region. These data may be considered typical of the lake area. The long-term mean annual temperature for the Southeastern Wisconsin Region was 46.6 degrees Fahrenheit (°F). The 12-month period for calendar year 2007, as indicated in Table 3, was a period during which temperatures were generally about normal. The greatest temperature deviation above normal occurred during the month of January 2007 when temperatures were about 7°F above normal; the greatest deviation below normal occurred during February, with temperatures averaging just over 9°F below normal. Calendar year 2007 was a wetter year for the Southeastern Wisconsin Region in general, even though six of the 12 months experienced below normal amounts of precipitation. The long-term mean annual precipitation over the Southeastern Wisconsin Region is about 33.93 inches. Precipitation during calendar year 2007 was about 37.46 inches, or about 10 percent above normal, with the greatest increase above average, 5.98 inches, occurring during August, and the greatest decrease below the average, 2.15 inches, occurring during November.

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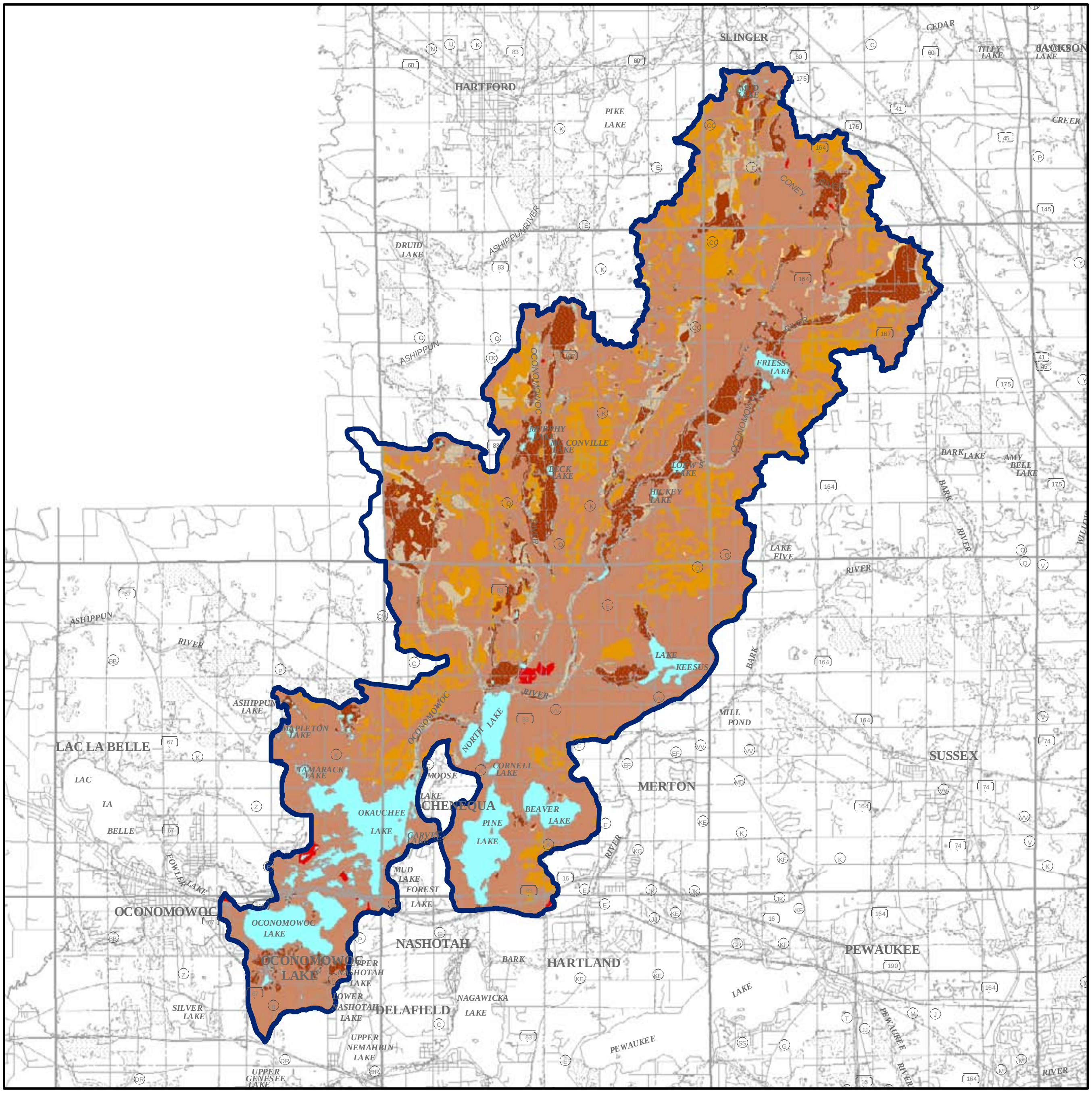
(Footnote Continued from Previous Page)
1979; and Volume Three, Recommended Plan, *June 1979; SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[7]*Amendment to SEWRPC Community Assistance Planning Report No. 172, 2nd Edition,* Sanitary Sewer Service Area for the City of Oconomowoc and Environs, Waukesha County, Wisconsin, *September 2005.*

Map 4

HYDROLOGIC SOIL GROUPS WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA



GROUP A:
WELL-DRAINED SOILS

GROUP A/D:
WELL-DRAINED SOIL/VERY POORLY DRAINED SOIL (WELL-DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM. VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED.)

GROUP B:
MODERATELY DRAINED SOILS

GROUP B/D:
MODERATELY DRAINED SOIL/VERY POORLY DRAINED SOIL (MODERATELY DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM. VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED.)

GROUP C:
POORLY DRAINED SOILS

GROUPS C/D AND D:
VERY POORLY DRAINED SOILS; POORLY DRAINED SOIL/VERY POORLY DRAINED SOIL (POORLY DRAINED IF WATER TABLE IS LOWERED THROUGH PROVISION OF A DRAINAGE SYSTEM. VERY POORLY DRAINED IF WATER TABLE IS NOT LOWERED.)

HYDROLOGIC SOIL GROUP NOT DETERMINED

SURFACE WATER

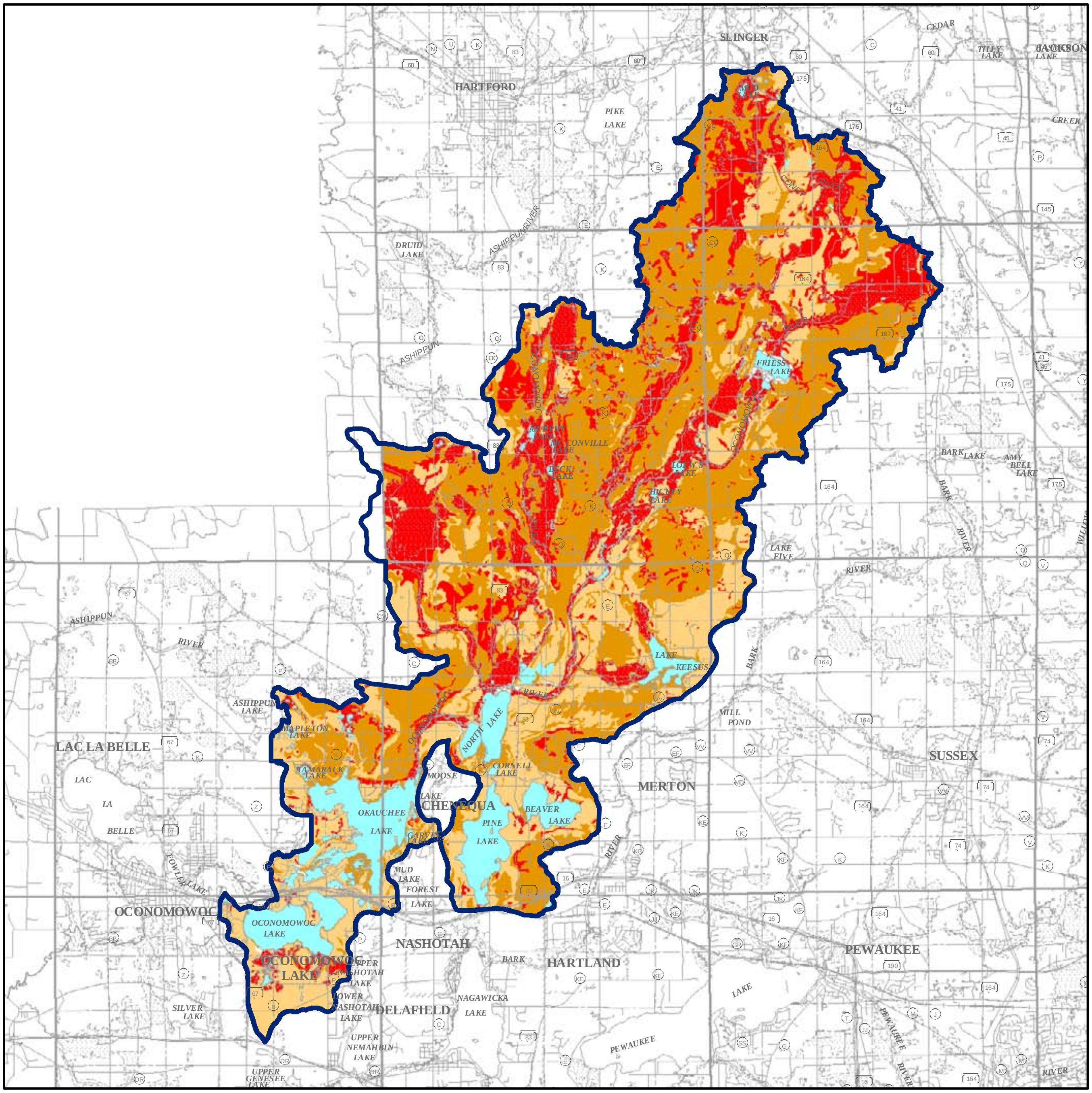
N

0 10,000 20,000 Feet

Source: SEWRPC.

Map 5

GROUNDWATER CONTAMINATION POTENTIAL WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA



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 which have 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 which have 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 area available

SURFACE WATER

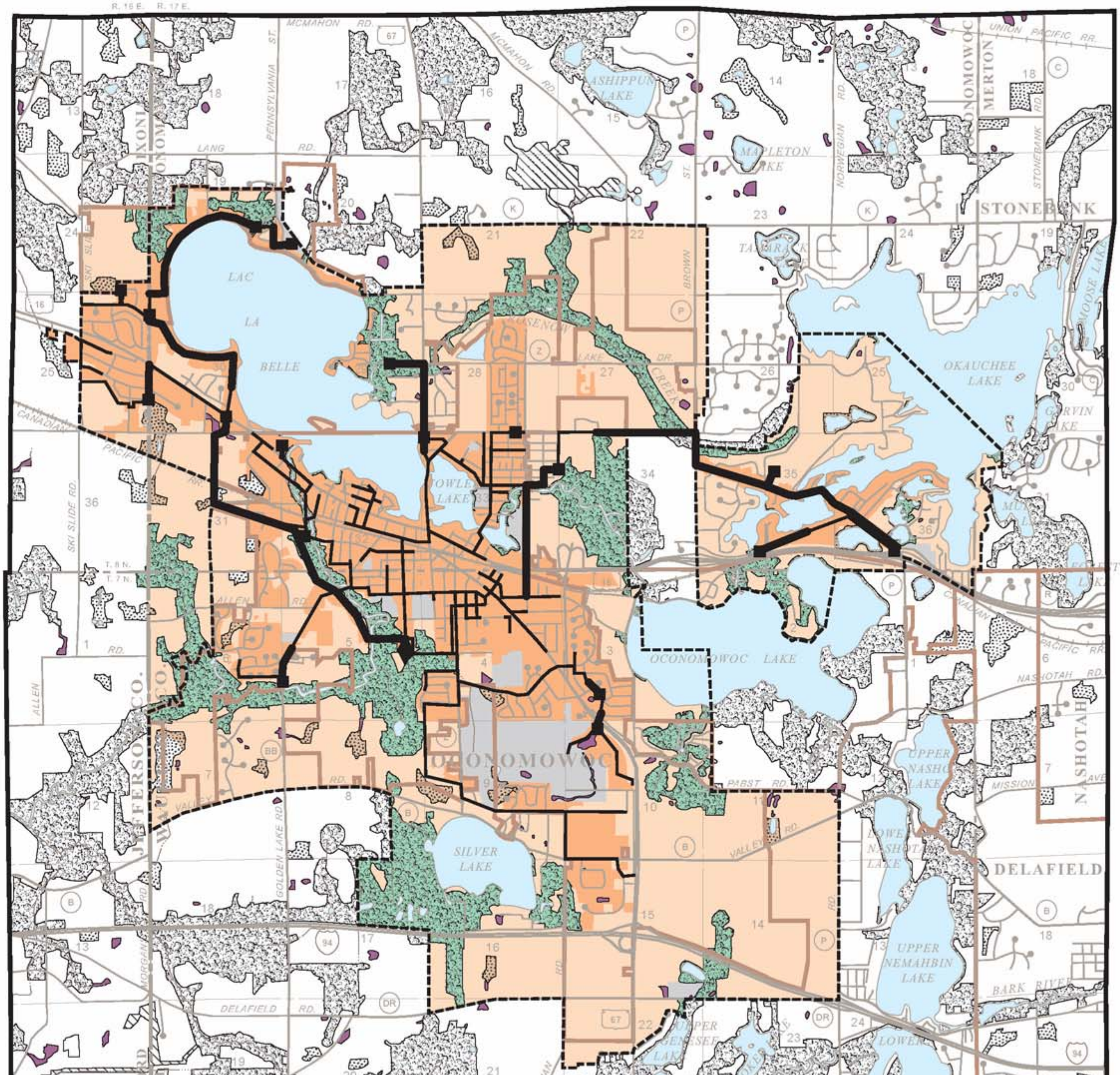
N

0 10,000 20,000 Feet

Source: SEWRPC.

Map 6

OCONOMOWOC AND ENVIRONS SANITARY SEWER SERVICE AREA AS AMENDED: 2005



PRIMARY ENVIRONMENTAL CORRIDOR

SECONDARY ENVIRONMENTAL CORRIDOR

ISOLATED NATURAL RESOURCE AREA

WETLANDS AND SURFACE WATER AREAS LESS THAN FIVE ACRES IN SIZE

EXISTING AREA SERVED BY PUBLIC SANITARY SEWER SYSTEM: 2000

PLANNED SANITARY SEWER SERVICE AREA

AIRPORTS, LARGE PARK AND RECREATION SITES, AND SIMILAR USES WITHIN THE SEWER SERVICE AREA

RESTRICTIONS ON SEWERED DEVELOPMENT

PRIMARY ENVIRONMENTAL CORRIDORS WITHIN THE PLANNED SANITARY SEWER SERVICE AREA: THE EXTENSION OF SEWERS TO SERVE NEW DEVELOPMENT IS CONFINED TO LIMITED RECREATIONAL AND INSTITUTIONAL USES AND RURAL-DENSITY RESIDENTIAL DEVELOPMENT IN AREAS OTHER THAN WETLANDS, FLOODLANDS, SHORELANDS, AND STEEP SLOPES.

PORTIONS OF SECONDARY ENVIRONMENTAL CORRIDORS AND ISOLATED NATURAL RESOURCE AREAS WITHIN THE PLANNED SANITARY SEWER SERVICE AREA WHICH ARE COMPRISED OF WETLANDS, FLOODLANDS, SHORELANDS, AND STEEP SLOPES: THE EXTENSION OF SEWERS TO SERVE NEW DEVELOPMENT IN THESE AREAS IS NOT PERMITTED.

PLANNED SANITARY SEWER SERVICE AREA BOUNDARY

EXISTING TRUNK SEWER

EXISTING FORCE MAIN

EXISTING PUMPING STATION

GRAPHIC SCALE

0 ¼ ½ 1 MILE

0 1250 2500 5000 FEET

Source: SEWRPC.

Table 3

LONG-TERM AND 2007 STUDY YEAR TEMPERATURE, PRECIPITATION, AND RUNOFF DATA FOR THE OCONOMOWOC LAKE AREA

Temperature													
Air Temperature Data (°F)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	18.9	24.0	34.0	45.0	56.3	66.0	71.2	69.4	61.4	49.9	37.0	24.7	46.4
2007 Mean Monthly	25.8	15.0	38.1	43.8	59.6	67.9	70.6	71.4	64.1	56.5	37.1	23.0	47.7
Departure from Long-Term Mean	6.9	-9.0	4.1	-1.2	3.3	1.9	-0.6	2.0	2.7	6.6	0.1	-1.7	1.3

Precipitation														
Precipitation Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Total
Long-Term Mean Monthly	1.56	1.32	2.19	3.48	3.13	3.76	3.82	4.22	3.48	2.51	2.55	1.91	2.83	33.93
2007 Mean Monthly	1.20	1.80	2.65	4.21	1.97	3.59	3.32	10.20	1.70	2.70	0.40	3.72	3.12	37.46
Departure from Long-Term Mean	-0.36	0.48	0.46	0.73	-1.16	-0.17	-0.50	5.98	-1.78	0.19	-2.15	1.81	0.29	3.53

Runoff[a]													
Runoff Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	0.46	0.49	1.15	1.36	0.91	0.64	0.49	0.39	0.40	0.48	0.53	0.52	0.65
2007 Mean Monthly	0.59	0.52	0.91	1.22	1.11	0.79	0.51	0.41	0.73	1.01	0.94	1.13	0.82
Departure from Mean Monthly	0.13	0.03	-0.24	-0.14	0.20	0.15	0.02	0.02	0.33	0.53	0.41	0.61	0.17

[a]Runoff data were computed for 2007, which was the most recent calendar year data available at time of print.

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

Table 3 also sets forth stormwater runoff values derived from the U.S. Geologic Survey (USGS) flow records for the Rock River at Afton. Typically, more than half the normal yearly precipitation falls during the growing season, from May to September. Runoff rates are generally low during this period, since evapotranspiration rates are high, vegetative cover is good, and soils are not frozen. Normally, about 20 percent of the summer precipitation is expressed as surface runoff, but intense summer storms occasionally produce higher runoff fractions. In contrast, approximately 45 percent of the annual precipitation occurs during the winter or early spring when the ground is frozen. This may result in higher surface runoff during those seasons. As shown in Table 3, runoff during the study year of 2007 was slightly above normal, a result consistent with other lakes in the Region at that time.

Lake Stage

The water level of Oconomowoc Lake is primarily determined by the rate of inflow and outflow of the Oconomowoc River. As noted above, the level of the Lake is maintained at an elevation of between 861.60 and 860.27 feet NGVD-29. There are control structures on both the inflow portion of the Oconomowoc River, at Okauchee Lake, and on the outflow of Oconomowoc Lake to the Oconomowoc River.

During the earlier study period, water level fluctuations in Oconomowoc Lake were associated with the then-current local precipitation volumes. Drought periods were reported to have had little effect on the water levels of

Oconomowoc Lake, as the control structure at the lake outlet permitted dam operators to maintain a fairly stable lake level. At that time, the lake level was lowered to 861.87 feet NGVD-29 in the autumn of 1976 to prevent winter ice damage. Above-average precipitation, snowmelt, and groundwater inflow raised the level of the Lake to an elevation of 862.31 feet NGVD-29 during the following spring.

Water Budget

In the initial SEWRPC report, a water budget for study period 1976 to 1977 was computed for Oconomowoc Lake based on estimated precipitation directly onto the lake surface, inflow from the Oconomowoc River, inflow from the springs located along the shoreline and groundwater, and runoff from the land surface directly tributary to the Lake, and based on evaporation from the Lake's surface and outflow through the Oconomowoc River. During the initial study period, eight pairs of groundwater level observation and groundwater quality sampling wells were used to measure the direction and rate of flow of groundwater around Oconomowoc Lake. These wells indicated that groundwater moved into Oconomowoc Lake from the south and flowed out of the Lake along the northern shores, with a net gain to the Lake of about 4,778 acre-feet annually. This earlier water budget indicated that about 76 percent of the water entering Oconomowoc Lake was contributed by the Oconomowoc River; about 16 percent by net groundwater inflows; about 5 percent by precipitation onto the lake surface; and about 3 percent as runoff from the tributary area directly adjacent to the Lake. Of the water flowing out of Oconomowoc Lake, evaporation accounted for about 6 percent of the total outflow of water, while the remaining 94 percent was discharged from the Lake via the Oconomowoc River.

During the current study period, using data from the USGS, long-term and study year 2004 hydrologic budgets for Oconomowoc Lake were developed, as shown in Table 4. To develop these hydrologic budgets, water entering Oconomowoc Lake was assumed to be comprised of direct precipitation onto the Lake's surface and runoff from the land surfaces within total tributary area, including direct precipitation onto the various waterbody surfaces in the total tributary area upstream of the Lake. The net inflow of groundwater to Oconomowoc Lake was assumed to be constant, as reported in the initial study, and was included as a water input in these hydrologic budgets. Water leaving the Lake consisted of water lost through evaporation from the Lake's surface, evaporation from other water surfaces in the tributary area, and outflow through the Oconomowoc River.

Results of the long-term water budget also are shown in Table 4, and represented graphically in Figure 1. About 2,177 acre-feet of water, or 4 percent of the total inflow, enter the Lake each year as a result of direct precipitation onto the Lake's surface; about 39,791 acre-feet, or 71 percent, as runoff from the land surfaces in the total tributary area; about 9,774 acre-feet, or 17 percent, as direct precipitation onto the water surfaces in the total tributary area; and about 4,778 acre-feet, or about 8 percent, as groundwater inflow. Over the long term, of the water lost from Oconomowoc Lake each year, about 1,943 acre-feet, or about 3 percent, were estimated to evaporate from the lake surface and about 54,577 acre-feet, or 97 percent, are discharged through the Oconomowoc River.

During the calendar year 2007, 61,811 acre-feet of water were estimated to have entered the Lake. Of this total, about 2,508 acre-feet, or about 4 percent, were contributed from direct precipitation onto the Lake's surface; about 43,262 acre-feet, or 70 percent, as runoff from the land surfaces in the total tributary area; about 11,263 acre-feet, or 18 percent, as direct precipitation to the water surfaces in the total tributary area; and about 4,778 acre-feet, or about 8 percent, as groundwater inflow. Of the water lost from Oconomowoc Lake during the study year, about 647 acre-feet, or about 1 percent, evaporated from the lake surface; 2,909 acre-feet, or about 5 percent, evaporated from water surfaces elsewhere in the drainage area; and, about 58,255 acre-feet, or 94 percent, were discharged through the Oconomowoc River. Water flows for 2007, compared to long-term amounts, are consistent with the increased precipitation observed during 2007.

Water Residence Time

As was stated above, Oconomowoc Lake has a tributary area-to-lake area ratio of about 65:1. Lakes with large tributary area-to-lake area ratios, in the range of several hundred or more to one, typically have shorter water residence times than lakes with smaller ratios. The water or hydraulic residence time, also referred to as the retention time or flushing rate, is the time needed for the full volume of a lake to be completely replaced by an

Table 4

HYDROLOGIC BUDGETS FOR OCONOMOWOC LAKE

Element	2004 (acre-feet)	Long-Term (acre-feet)
Inflows		
Direct Precipitation to Lake Surface	2,413	2,177
Runoff from Total Tributary Area Land	44,115	39,791
Precipitation to Total Tributary Area Water Surfaces	18,836	9,774
Groundwater Net Inflow[a]	4,778	4,778
Total	70,142	56,520
Outflows		
Evaporation from Lake Surface	1,943	1,943
Outflow to Oconomowoc River	68,199	54,577
Total	70,142	56,520

[a]*Based on data presented in initial SEWRPC report.*

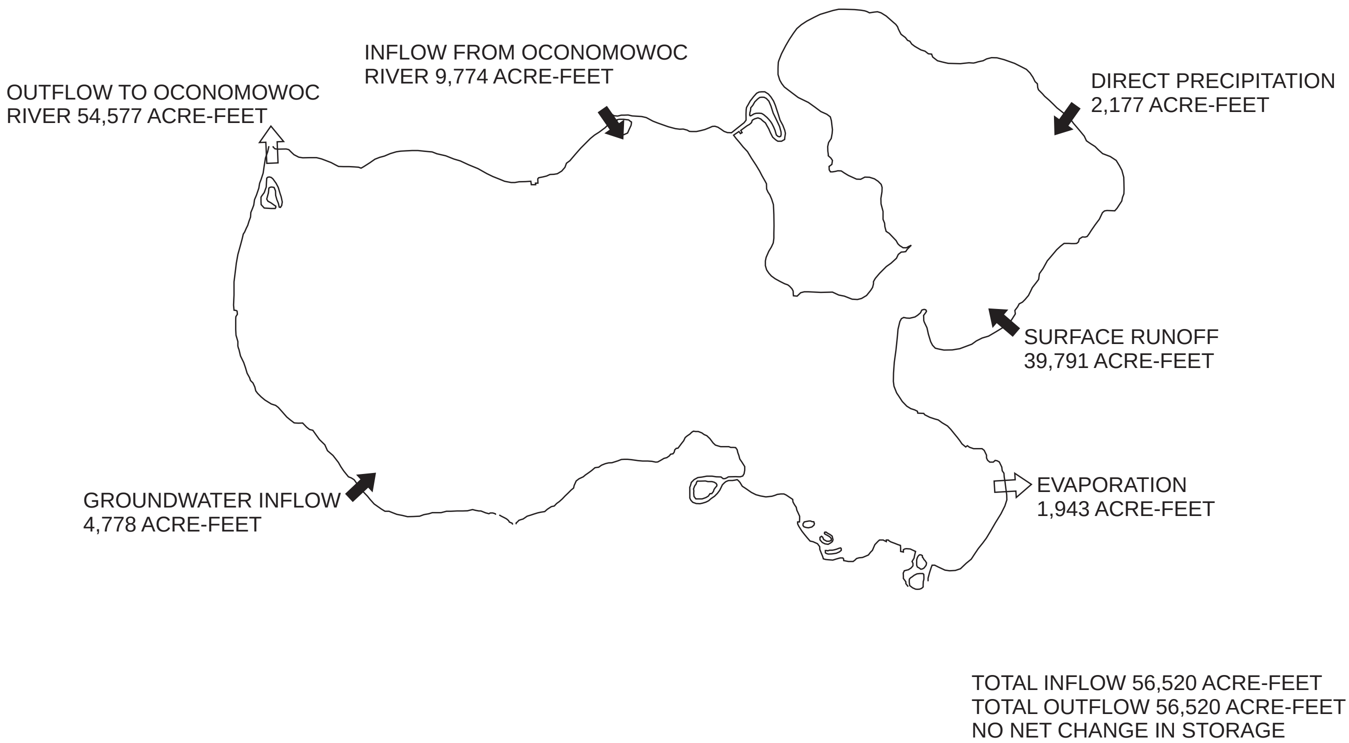
Source: National Oceanic and Atmospheric Administration and SEWRPC.

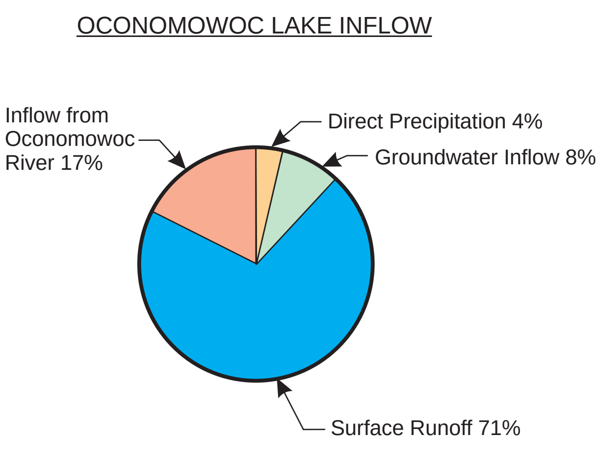
equal volume of inflowing water. Residence time is important in determining the expected response time of a lake to increased or reduced nutrient and other pollutant loadings. Lakes having a short residence time of less than a year, such as small drainage lakes, through-flow lakes, such as Oconomowoc Lake, and lakes with large amounts of groundwater inflow and outflow, will allow nutrients and pollutants to be flushed from the lake fairly rapidly and generally respond well when nutrient inputs are decreased. Lakes with longer residence times, such as seepage lakes having no outflow streams, typically respond slowly to changes in their tributary area, since it takes a long time for a volume equivalent to the full volume of the lake to enter the lake from its tributary area. Such lakes can accumulate nutrients for many years, recycling them each year during the periods spring and fall overturn, with the result that the effects of tributary area protection may not be immediately apparent.

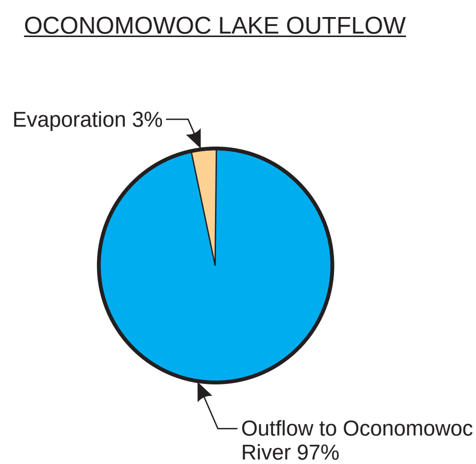
In the initial SEWRPC report, based on the observed water budget data for Oconomowoc Lake, the hydraulic residence time was reported to be about 0.53 year. Using the refined measurements of the total tributary area of Oconomowoc Lake and the estimated volumes of runoff, groundwater inflow, and direct precipitation, the current long-term water residence time has been calculated to be about 0.41 year, or about 150 days. These water residence times are indicative of a moderately well-flushed waterbody that should respond relatively quickly to changes in the external nutrient and contaminant loads.

Figure 1

LONG-TERM HYDROLOGIC BUDGET FOR OCONOMOWOC LAKE







Source: U.S. Geological Survey and SEWRPC.

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Chapter III

HISTORICAL, EXISTING, AND FORECAST LAND USE AND POPULATION

INTRODUCTION

Water pollution problems, and the ultimate solution of those problems, are primarily a function of the human activities within the tributary area to a waterbody, and of the ability of the underlying natural resource base to sustain those activities. This is especially true in an area directly tributary to a lake because lakes are highly susceptible to water quality degradation attendant to human activities in this area. Lake water quality degradation arising from human activities in the shoreland zone is more likely to interfere with desired water uses, and is often difficult and costly to correct. Accordingly, the land uses and population levels in the direct tributary area of a lake are important considerations in lake water quality management. In addition, in the case of drainage or through flow lakes, human activities in the larger tributary watershed also can influence the nature of potential water quality concerns and the nature of community responses to observed water quality conditions. Hence, consideration should also be given to the human activities in the wider watershed.

CIVIL DIVISIONS

The geographic distribution and functional jurisdictions of the general- and special-purpose units of government also are important factors which must be considered in lake water quality management, since these local units of government provide the basic structure of the decision-making framework within which intergovernmental environmental problems must be addressed. Superimposed on the irregular tributary area of Oconomowoc Lake are the local civil division boundaries, shown on Map 7. These governmental units include: the Towns of Erin, Hartford, and Polk, and the Villages of Richfield[1] and Slinger, all in Washington County; and the Towns of Lisbon, Merton, Oconomowoc, and Summit; the Cities of Delafield and Oconomowoc; and the Villages of Chenequa, Hartland, Merton, Nashotah, and Oconomowoc Lake, all in Waukesha County. The area and proportion of the tributary area lying within the jurisdiction of each civil division, as of 2000, is set forth in Table 5. Washington and Waukesha Counties also administer a number of programs and administrative functions which relate directly to lake and tributary area management in the Oconomowoc Lake area, as does the Wisconsin Department of Natural Resources (WDNR). The Village of Oconomowoc Lake is responsible for the management of the lands directly riparian to Oconomowoc Lake.

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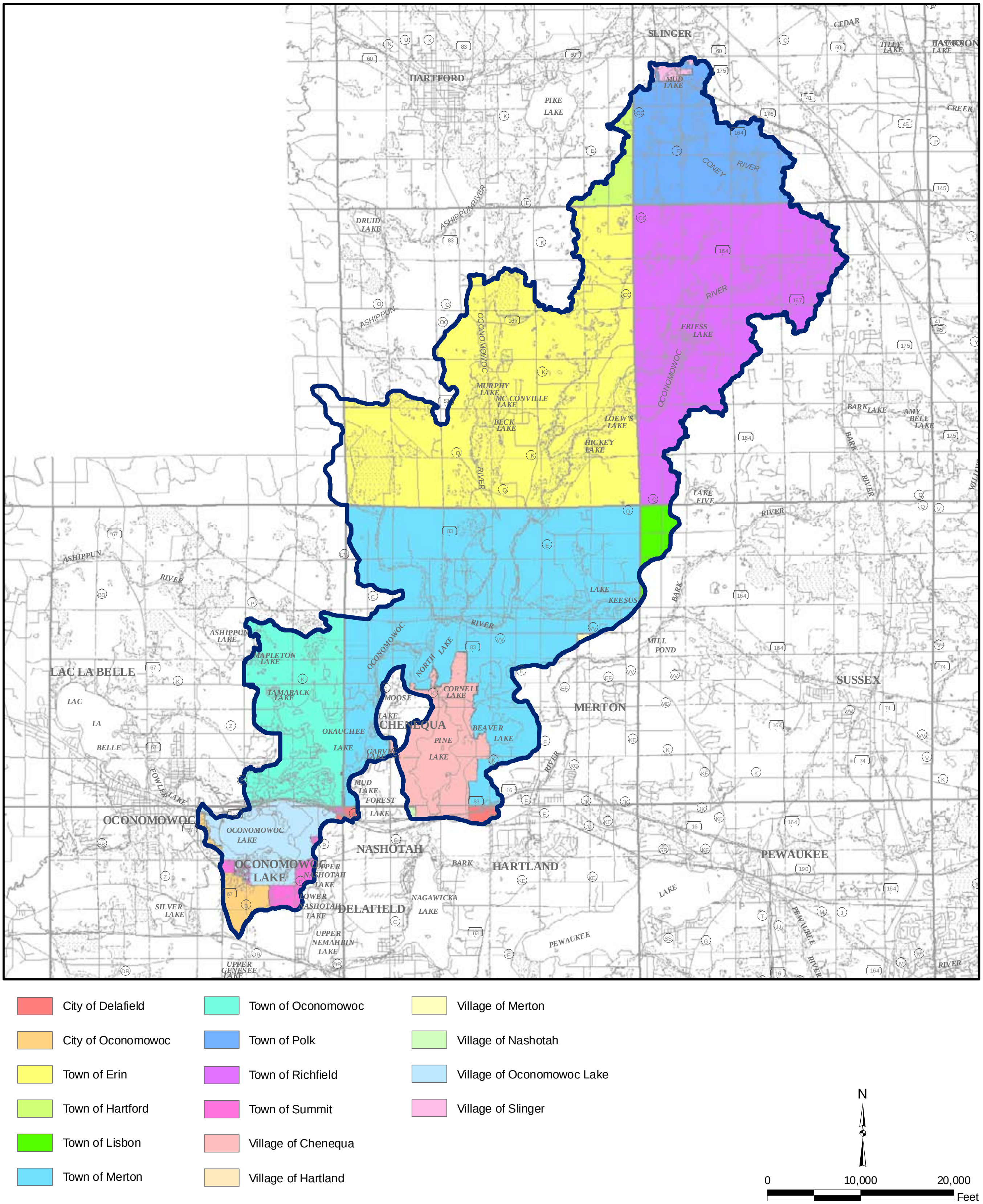
[1]*During November 2007, the electors of the Town of Richfield voted to approve the incorporation of the Town as the Village of Richfield, which became effective as of February 13, 2008.*

Map 7

CIVIL DIVISION BOUNDARIES WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA



Source: SEWRPC.

Table 5

AREAL EXTENT OF CIVIL DIVISION BOUNDARIES WITHIN THE TOTAL AREA TRIBUTARY TO OCONOMOWOC LAKE

Civil Division	Civil Division Area within Total Tributary Area (acres)	Percent of Total Tributary Area within Civil Division	Percent of Civil Division within Total Tributary Area
City of Delafield	183	0.3	2.6
City of Oconomowoc	550	1.0	9.6
Town of Erin	14,843	27.9	64.2
Town of Hartford	615	1.2	3.1
Town of Lisbon	483	0.9	2.5
Town of Merton	14,013	26.3	77.8
Town of Oconomowoc	4,127	7.7	19.7
Town of Polk	4,146	7.8	19.9
Town of Summit	438	0.8	2.6
Village of Chenequa	2,470	4.6	83.7
Village of Hartland	7	<0.1	0.2
Village of Merton	29	<0.1	1.8
Village of Nashotah	23	<0.1	2.1
Village of Oconomowoc Lake	1,885	3.5	92.4
Village of Richfield	9,433	17.7	40.5
Village of Slinger	155	0.3	7.0
Total	53,403	100.0	- -

Source: SEWRPC.

Table 6

POPULATION AND HOUSEHOLDS WITHIN THE DIRECT AND TOTAL AREAS TRIBUTARY TO OCONOMOWOC LAKE: 1963-2000

Year	Direct Tributary Area		Total Tributary Area	
	Population	Households	Population	Households
1963	809	194	6,771	1,943
1970	1,139	373	10,059	2,924
1980	1,570	432	13,053	4,323
1990	1,438	483	14,509	5,169
2000	1,645	602	17,619	6,462

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

POPULATION

As indicated in Table 6, with the exception of the period from 1980 to 1990, the resident population of the area directly tributary to Oconomowoc Lake has increased in a relatively steady manner since 1963. From 1963 to 1970, the population grew by about 330 persons; from 1970 to 1980, the population increased by about 431 persons; and, from 1990 to 2000, the population increased by about 207 persons. In contrast, during the period between 1980 and 1990, the population decreased by about 132 persons. The period of greatest growth in both population and the numbers of households in the area directly tributary to Oconomowoc Lake was from 1963 to 1980, during which the population experienced an increase of nearly 200 percent, as did the numbers of households. As of 2000, the resident population was reported to be approximately twice that of 1963, while the numbers of households were approximately three times that of 1963.

In the total tributary area of Oconomowoc Lake, both population and households increased steadily from 1963 to 2000. The greatest increase in population occurred during the period from 1963 to 1970 and the greatest increase in the numbers of households occurred during the same time period. As of 2000, the numbers of persons and the numbers of households within the total tributary area of Oconomowoc Lake had both increased to nearly three times those of 1963.

As development in the local area continues, the population of the area tributary to Oconomowoc Lake may be expected to continue to increase over the next two decades. This population growth may be expected to place continued and increasing stress on the natural resource base in the Oconomowoc Lake tributary area, and both water resource demands and use conflicts may be expected to increase.

LAND USE

The type, intensity, and spatial distribution of the various land uses within the area tributary to Oconomowoc Lake are important determinants of lake water quality and recreational use demands. The existing land use pattern placed in the context of the historical development of the area, therefore, is an important consideration in any lake management planning effort for Oconomowoc Lake.

The movement of European settlers into the Southeastern Wisconsin Region began in about 1830. Completion of the U.S. Public Land Survey of southeastern Wisconsin in 1836, and the subsequent sale of the public lands, brought a rapid influx of settlers into the area. Map 8 shows an 1836 plat of the U.S. Public Land Survey for the Oconomowoc Lake area.

Map 9 and Table 7 indicate the historical urban growth pattern in the total tributary area to the Lake since 1880. Significant urban land use development began in the Oconomowoc Lake area in about 1920. The largest increases in the amounts of land converted to urban land use in the direct tributary area of Oconomowoc Lake occurred between 1950 and 1963, although significant amounts of land along the northern and eastern shorelines were already developed by 1940. Some additional offshore areas within the southern portions of the direct tributary area were developed around 1990. Some of this development is associated with the conversion of the Pabst Farms properties to urban land uses that occurred during the mid-1990s and is ongoing at the time of writing.

In the initial lake management plan,[2] the existing 1980 land uses in the direct tributary area were presented. At that time, rural land uses constituted about 77 percent of the land uses in the direct tributary area, with agricultural uses comprising about 41 percent of rural land uses, and 31 percent of the land use in the direct tributary area, overall. Urban land uses at that time occupied about 23 percent of the direct tributary area, with residential uses comprising the major portion of urban uses. Residential land uses accounted for about 69 percent of all urban land uses, and 22 percent of the land uses identified in the direct tributary area, overall.

During the current study period, the existing land uses in the direct tributary area for Oconomowoc Lake are shown on Map 10 and in Table 8. During 2000, rural land uses still constituted about 68 percent of the land uses in the direct tributary area, with agricultural uses comprising about 37 percent of rural land uses, and about 25 percent of the direct tributary area, overall.

Under planned 2035 conditions, much of the existing agricultural lands are anticipated to be converted to urban land uses, primarily residential, as shown in Table 8 and on Map 11.[3] Within the direct tributary area of Oconomowoc Lake, rural land uses are expected to decrease to about 48 percent of the land uses in the direct tributary area, with agricultural uses comprising only about 11 percent of rural uses, and about 5 percent of the

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[2]*SEWRPC Community Assistance Planning Report No. 181,* A Water Quality Management Plan for Oconomowoc Lake, Waukesha County, Wisconsin, *March 1990.*

[3]*SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006.*

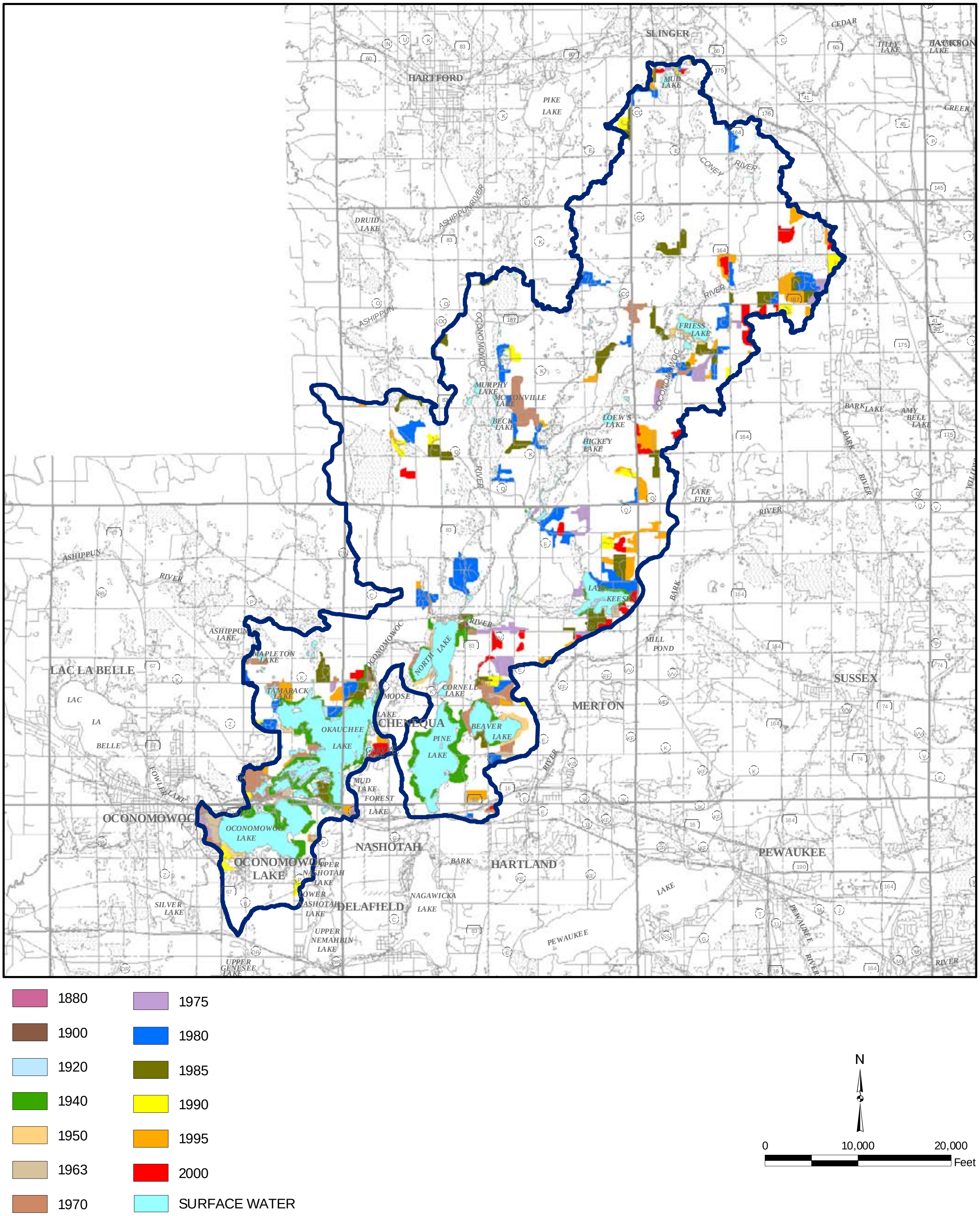
Map 8

ORIGINAL U.S. PUBLIC LAND SURVEY MAP FOR THE OCONOMOWOC LAKE AREA: 1836

Source: U.S. Public Land Survey and SEWRPC.

Map 9

HISTORICAL URBAN GROWTH WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA



Source: SEWRPC.

direct tributary area, overall. Urban land uses are expected to increase to about 52 percent of the direct tributary area, with residential uses comprising about 65 percent of urban uses, and about 33 percent of the direct tributary area, overall.

During the current study, the existing land use patterns in the total tributary area for Oconomowoc Lake are shown on Map 12 and quantified in Table 9. During 2000, as shown in Table 9, about 21 percent of the total area tributary to Oconomowoc Lake was in various urban land uses, with the dominant urban land use being residential, encompassing about 7,637 acres, or about 14 percent of the total tributary area. Rural land uses, such as agriculture, wetlands, woodlands, and surface waterbodies, comprised about 42,385 acres, or about 79 percent of the total tributary area. Map 12 shows the land uses in existence as of the year 2000 in the total area tributary to Oconomowoc Lake.

Table 7

EXTENT OF HISTORICAL URBAN GROWTH IN THE TOTAL TRIBUTARY AREA OF OCONOMOWOC LAKE: 1880-2000

	Tributary Area	
Year	Extent of New Urban Development Occurring Since Previous Period (acres)[a]	Cumulative Extent of Urban Development (acres)[a]
1880	9.3	9.3
1900	12.3	21.6
1920	162.8	184.4
1940	1,152.1	1,336.5
1950	232.5	1,569.0
1963	351.5	1,920.5
1970	889.1	2,809.6
1975	555.7	3,365.3
1980	1,642.0	5,007.3
1985	1,181.6	6,188.9
1990	469.1	6,658.0
1995	1,040.8	7,698.8
2000	653.7	8,352.5

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

Source: SEWRPC.

Under planned 2035 conditions, the trend toward more intense urban land usage in the Southeastern Wisconsin Region is expected to be reflected in the area tributary to Oconomowoc Lake, as shown in Table 9 and on Map 13. Much of this development is expected to occur as agricultural lands are converted to urban lands, primarily for residential use. Within the total area tributary to the Lake, urban residential uses are expected to increase by about 4,040 acres, to about 15,057 acres, or approximately 28 percent, of the Lake's tributary area. If this trend continues, some of the open space areas remaining in the total tributary area are likely to be replaced with large-lot urban residential development, resulting in the potential for increased pollutant loadings to the Lake. This development could occur in the form of residential clusters on smaller lots within conservation subdivisions, thereby preserving portions of the remaining open space and, thus, reducing the impacts on the Lake.[4] Certain other lands immediately surrounding the Lake, together with connected areas containing a concentration of high-value woodlands, wetlands, and wildlife habitat areas, as described in Chapter V, have been designated as environmental corridor lands in the adopted regional land use and regional natural areas and critical species habitat protection and management plans, and are recommended to be preserved in essentially natural or open space uses, also contributing to reducing the impacts on the Lake.

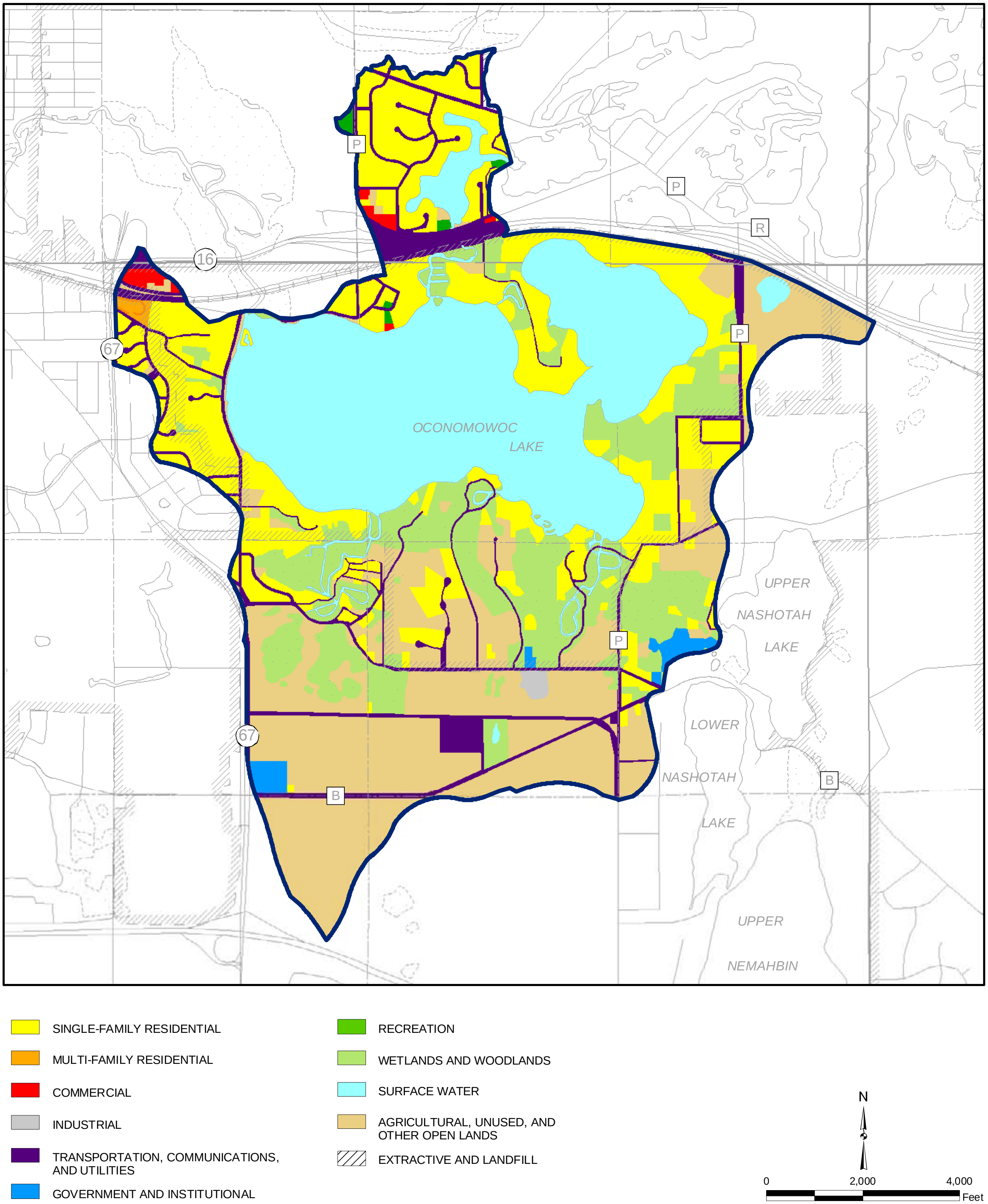
LAND USE REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their areas of jurisdiction. As already noted, the area tributary to Oconomowoc Lake includes portions of: the Towns of Erin, Hartford, Lisbon, Merton, Oconomowoc, Polk, and Summit; the Villages of Chenequa, Hartland, Merton, Nashotah, Oconomowoc Lake,

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

Map 10

EXISTING LAND USE WITHIN THE OCONOMOWOC LAKE DIRECT TRIBUTARY AREA: 2000



Source: SEWRPC.

Table 8

EXISTING AND PLANNED LAND USE WITHIN THE OCONOMOWOC LAKE DIRECT TRIBUTARY AREA: 2000 AND 2035

Land Use Categories[a]	2000 Acres	2000 Percent of Total	2035 Acres	2035 Percent of Drainage Area
Urban				
Residential	697	22.5	1,034	33.3
Commercial	13	0.4	120	3.9
Industrial	7	0.2	7	0.2
Governmental and Institutional	27	0.9	81	2.6
Transportation, Communication, and Utilities	230	7.4	343	11.1
Recreational	7	0.2	18	0.6
Subtotal	981	31.6	1,603	51.7
Rural				
Agricultural and Other Open Lands	788	25.4	161	5.2
Wetlands	257	8.3	257	8.3
Woodlands	224	7.2	224	7.2
Water	849	27.4	856	27.6
Extractive	2	0.1	- -	- -
Landfill	- -	- -	- -	- -
Subtotal	2,120	68.4	1,498	48.3
Total	3,101	100.0	3,101	100.0

[a]*Parking included in associated use.*

Source: SEWRPC.

Richfield, and Slinger; the Cities of Delafield and Oconomowoc; and, Washington and Waukesha Counties. Table 10 shows the land use regulations adopted and in use in these various civil divisions within the total tributary area of Oconomowoc Lake.

General Zoning

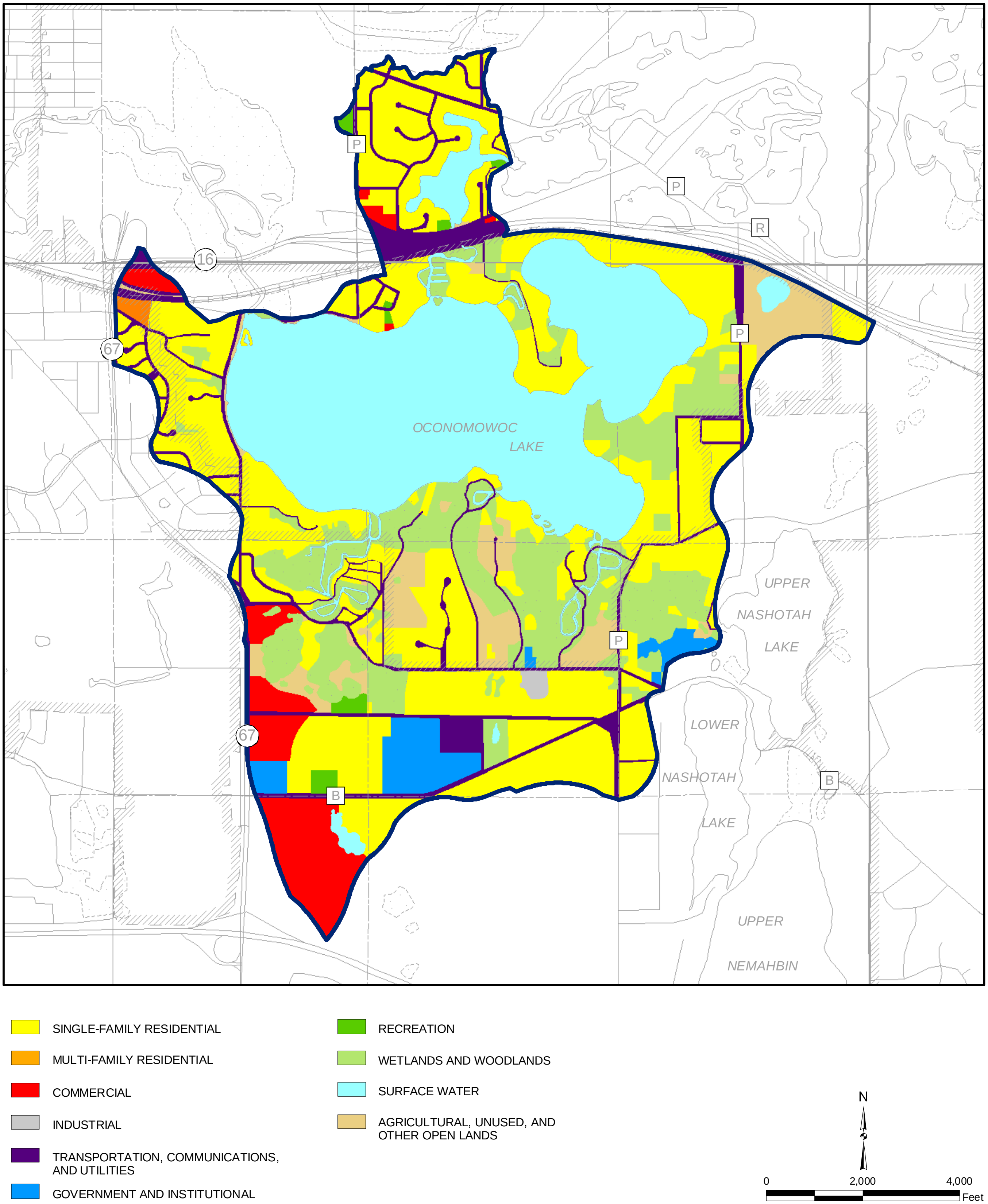
Cities in Wisconsin are granted comprehensive, or general, zoning powers under Section 62.23 of the *Wisconsin Statutes*. The same powers are granted to villages under Section 61.35 of the *Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.69 of the *Statutes*. Washington and Waukesha Counties have both adopted their own general zoning ordinances, although, in 1986, Washington County rescinded its general zoning ordinance and the nine towns which were subject to the county ordinance have since adopted their own town zoning ordinances. In Waukesha County, a county zoning ordinance becomes effective only in those towns that ratify the county ordinance. Towns that have not adopted a county zoning ordinance may adopt village powers, and subsequently utilize the village zoning authority conferred in Section 60.22(3), subject, however, to county board approval where a general-purpose county zoning ordinance exists. Alternatively, a town may adopt a zoning ordinance under Section 60.61 of the *Wisconsin Statutes* where a general-purpose county zoning ordinance has not been adopted, but only after the county board fails to adopt a county ordinance at the petition of the governing body of the town concerned. All the cities, villages and towns within the Oconomowoc Lake total tributary area have each adopted their own general zoning regulations, with the exception of the Town of Oconomowoc, which has adopted the Waukesha County ordinance.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that cities, villages, and counties with respect to their unincorporated areas, adopt floodland zoning to preserve the floodwater conveyance and storage capacity of floodplain

Map 11

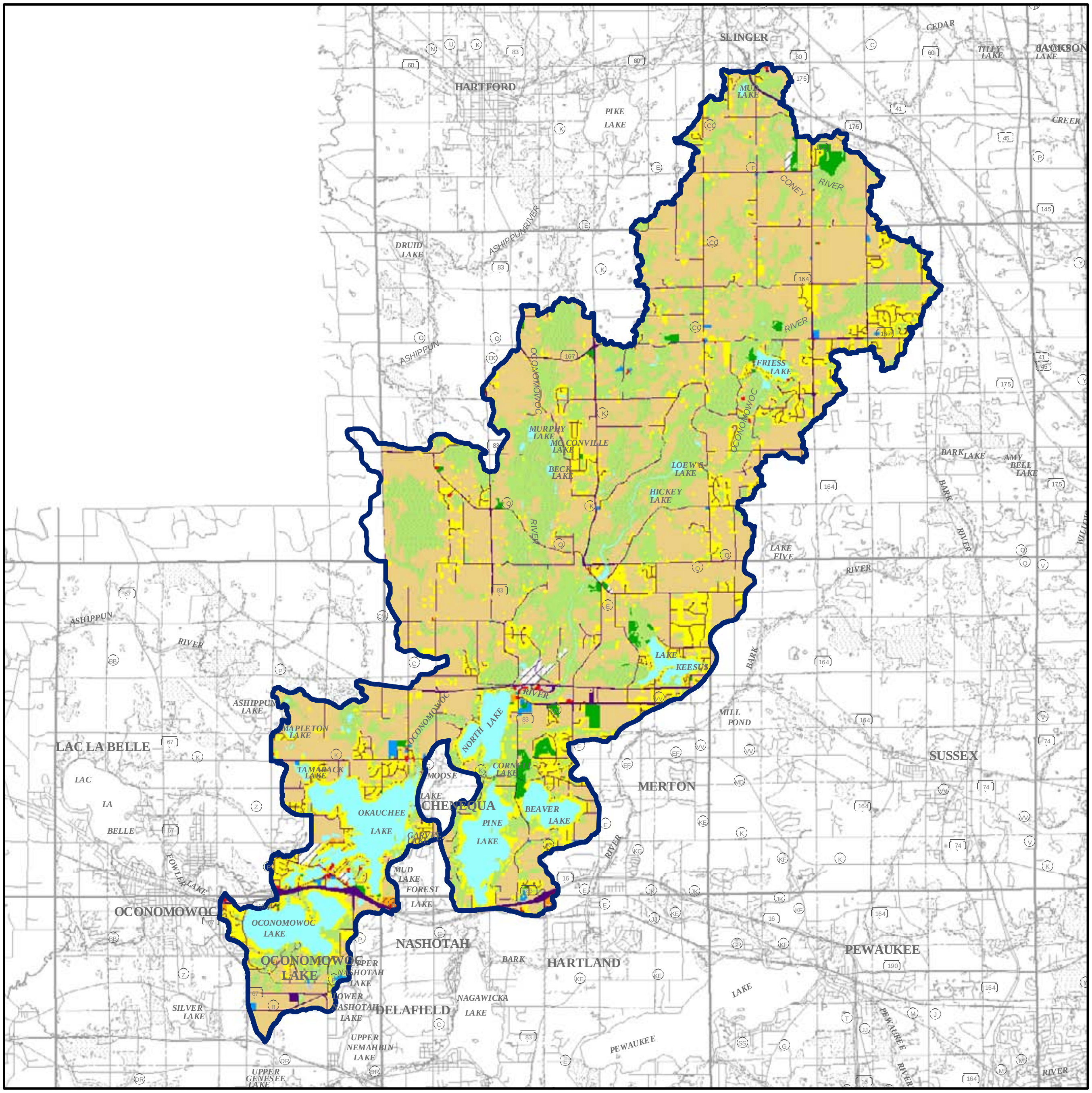
PLANNED LAND USE WITHIN THE OCONOMOWOC LAKE DIRECT TRIBUTARY AREA: 2035



Source: SEWRPC.

Map 12

EXISTING LAND USE WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA: 2000



SINGLE-FAMILY RESIDENTIAL

MULTI-FAMILY RESIDENTIAL

COMMERCIAL

INDUSTRIAL

TRANSPORTATION, COMMUNICATIONS, AND UTILITIES

GOVERNMENT AND INSTITUTIONAL

RECREATION

WETLANDS AND WOODLANDS

SURFACE WATER

AGRICULTURAL, UNUSED, AND OTHER OPEN LANDS

EXTRACTIVE AND LANDFILL

N

0 10,000 20,000 Feet

Source: SEWRPC.

Table 9

EXISTING AND PLANNED LAND USE WITHIN THE TOTAL AREA TRIBUTARY TO OCONOMOWOC LAKE: 2000 AND 2035

Land Use Categories[a]	2000 Acres	2000 Percent of Total Tributary Drainage Area	2035 Acres	2035 Percent of Total Tributary Drainage Area
Urban				
Residential	7,637	14.3	10,405	19.5
Commercial	102	0.2	241	0.5
Industrial	43	0.1	173	0.3
Governmental and Institutional	175	0.3	328	0.6
Transportation, Communication, and Utilities	2,470	4.6	3,217	6.0
Recreational	590	1.1	693	1.3
Subtotal	11,017	20.6	15,057	28.2
Rural				
Agricultural	24,064	45.0	20,028	37.5
Wetlands	6,332	11.9	6,332	11.9
Woodlands	7,358	13.8	7,341	13.7
Water	4,414	8.3	4,425	8.3
Extractive	218	0.4	219	0.4
Subtotal	42,385	79.4	38,345	71.8
Total	53,402	100.0	53,402	100.0

[a]*Parking included in associated use.*

Source: SEWRPC.

areas and to prevent the location of new flood damage-prone development in flood hazard areas. The minimum standards which such ordinances must meet are set forth in Chapter NR 116 of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area subject to inundation by the one-percent-annual-probability (100-year recurrence interval) flood event. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 100-year recurrence peak flood flow. Local regulations also must restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the one-percent-annual-probability peak flood flow. Permitting the filling and development of the flood fringe area, however, reduces the floodwater storage capacity of the natural floodplain, and may thereby increase downstream flood flows and stages. It should be noted that towns may enact floodland zoning regulations which may be more restrictive than those in the county shoreland and floodland zoning ordinances.

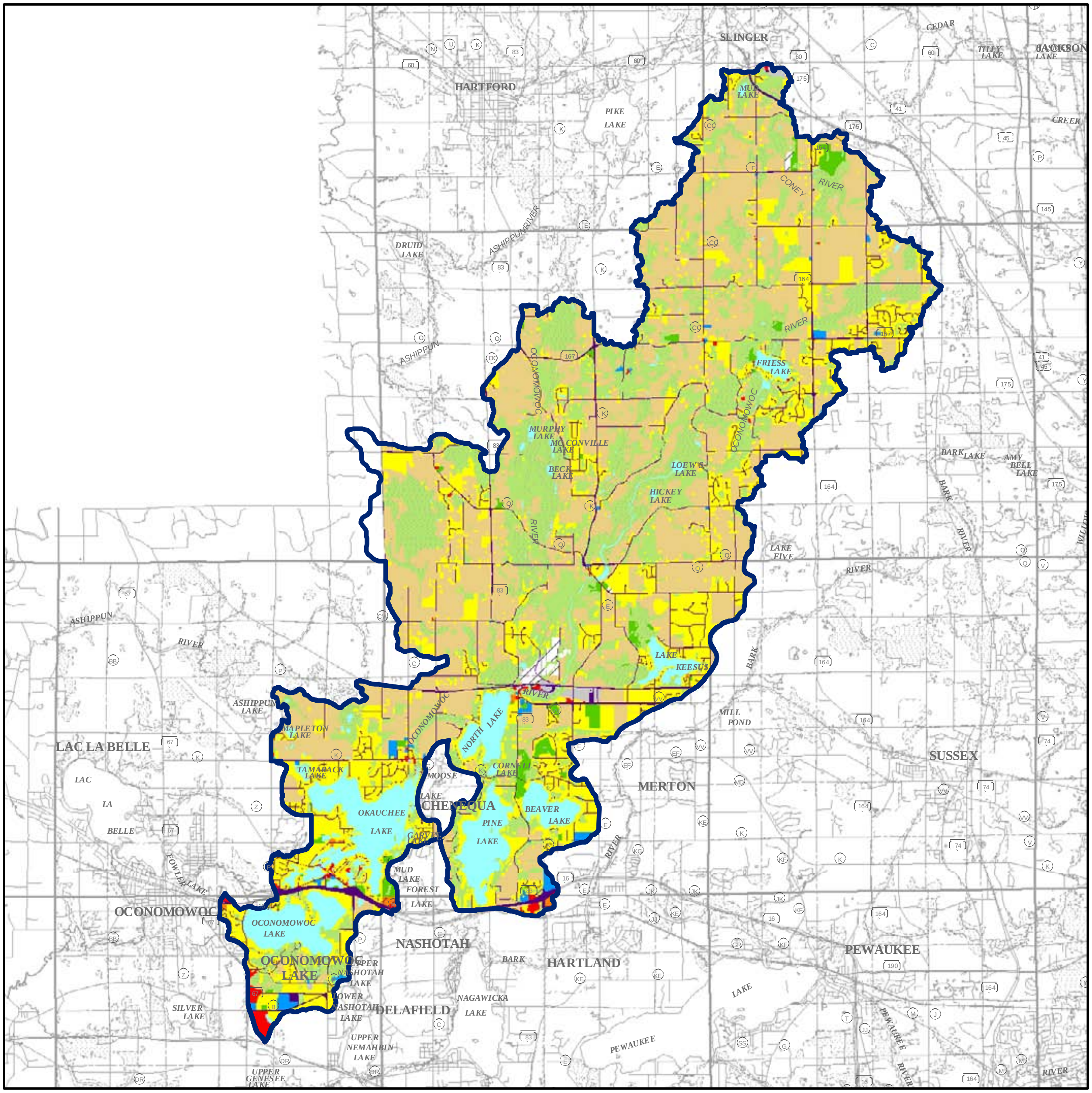
Within the total area tributary to Oconomowoc Lake, Washington and Waukesha Counties have each adopted a countywide floodland zoning ordinance. The Towns of Erin, Hartford, Lisbon, Merton, Oconomowoc, Polk, and Summit have adopted their respective County's floodland zoning ordinance, while the Cities of Delafield and Oconomowoc and the Villages of Hartland, Merton, Nashotah, Richfield, and Slinger, have adopted their own floodland zoning ordinances, as shown in Table 10. The Village of Chenequa has not adopted a floodland zoning ordinance, including floodland protections within their building code.

Shoreland Zoning

Under Section 59.692 of the *Wisconsin Statutes*, counties in Wisconsin are required to adopt zoning regulations within statutorily defined shoreland areas within their unincorporated areas; namely, those lands within 1,000 feet

Map 13

PLANNED LAND USE WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA: 2035



SINGLE-FAMILY RESIDENTIAL	RECREATION
MULTI-FAMILY RESIDENTIAL	WETLANDS AND WOODLANDS
COMMERCIAL	SURFACE WATER
INDUSTRIAL	AGRICULTURAL, UNUSED, AND OTHER OPEN LANDS
TRANSPORTATION, COMMUNICATIONS, AND UTILITIES	EXTRACTIVE AND LANDFILL
GOVERNMENT AND INSTITUTIONAL	

N

0 10,000 20,000 Feet

Source: SEWRPC.

Table 10

LAND USE REGULATIONS WITHIN THE TOTAL AREA TRIBUTARY TO OCONOMOWOC LAKE BY CIVIL DIVISION: 2000

Community	Type of Ordinance				
	General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Construction Site Erosion Control and Stormwater Management
Washington County	- -[a]	Adopted	Adopted and WDNR approved	Floodland and shoreland only	Adopted
Village of Richfield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Village of Slinger	Adopted	Adopted	Adopted	Adopted	None
Town of Erin	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Hartford	Adopted	County ordinance	County ordinance	County ordinance	County ordinance
Town of Polk	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Waukesha County	Adopted	Adopted	Adopted and WDNR approved	Floodland and shoreland only	Adopted
City of Delafield	Adopted	Adopted	Adopted	Adopted	Adopted
City of Oconomowoc	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Chenequa	Adopted	None[b]	Adopted	None	Adopted[c]
Village of Hartland	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Merton	Adopted	Adopted	Adopted	Adopted	None
Village of Nashotah	Adopted	Adopted[b]	Adopted and WDNR approved	Adopted	None
Village of Oconomowoc Lake	Adopted	Adopted	Adopted	Adopted	Adopted
Town of Lisbon	Adopted	County ordinance	County ordinance	Adopted	Adopted
Town of Merton	Adopted	County ordinance	County ordinance	Adopted	None
Town of Oconomowoc	County ordinance	County ordinance	Adopted and WDNR approved	Adopted	Adopted
Town of Summit	Adopted	County ordinance	Adopted and WDNR approved	Adopted	None

[a]*In 1986, Washington County rescinded its general zoning ordinance, and all nine towns which were subject to the general County zoning ordinance have since adopted a town zoning ordinance.*

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

[c]*No erosion control ordinance.*

Source: SEWRPC.

of a navigable lake, pond, or flowage, or 300 feet of a navigable stream, or to the landward side of the floodplain, whichever distance is greater. Minimum standards for county shoreland zoning ordinances are set forth in Chapter NR 115 of the *Wisconsin Administrative Code*. Chapter NR 115 sets forth minimum requirements regarding lot sizes and building setbacks; restrictions on cutting of trees and shrubbery; and restrictions on filling, grading, lagooning, dredging, ditching, and excavating that must be incorporated into county shoreland zoning regulations. In addition, Chapter NR 115, as recodified during 1980, requires that counties place all wetlands five acres or larger and within the statutory shoreland zoning jurisdiction area into a wetland conservancy zoning district to ensure their preservation after completion of appropriate wetland inventories by the WDNR.

In 1982, the State Legislature extended shoreland-wetland zoning requirements to cities and villages in Wisconsin. Under Sections 62.231 and 61.351, respectively, of the *Wisconsin Statutes*, cities and villages in Wisconsin are required to place wetlands five acres or larger and located in statutory shorelands into a shoreland-wetland conservancy zoning district to ensure their preservation. Minimum standards for city and village shoreland-wetland zoning ordinances are set forth in Chapter NR 117 of the *Wisconsin Administrative Code*. It should be noted that the basis for the identification of wetlands to be protected under Chapters NR 115 and NR 117 is the Wisconsin Wetlands Inventory. Mandated by the State Legislature in 1978, the Wisconsin Wetlands Inventory resulted in the preparation of wetland maps covering each U.S. Public Land Survey township in the State. The inventory was completed for counties in the Southeastern Wisconsin Region during 1982, the wetlands being delineated by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) on its 1980, one-inch-equals-2,000-feet scale, ratioed and rectified aerial photographs.

Within the total area tributary to Oconomowoc Lake, both Washington and Waukesha Counties have each adopted a countywide shoreland zoning ordinance. The Towns of Erin, Hartford, Lisbon, Merton, and Polk have adopted their county's shoreland zoning ordinance, while the Cities of Delafield and Oconomowoc, along with the Villages of Chenequa, Hartland, Merton, Nashotah, Oconomowoc Lake, Richfield, and Slinger, and the Towns of Oconomowoc and Summit, have each adopted their own shoreland zoning ordinances, as shown in Table 10.

Subdivision Regulations

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

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

Within the total tributary area to Oconomowoc Lake, Washington and Waukesha Counties have each adopted a countywide subdivision zoning ordinance with respect to floodlands and shorelands. The Town of Hartford has adopted the Washington County ordinance, and all other municipalities within the total tributary area to Oconomowoc Lake have adopted their own subdivision ordinances, with the exception of the Village of Chenequa, as shown in Table 10. The Village of Chenequa has not adopted a subdivision control ordinance.

Construction Site Erosion Control and Stormwater Management Regulations

Section 62.234 of the *Wisconsin Statutes* grants authority to cities and Section 61.354 of the *Wisconsin Statutes* grants authority to villages in Wisconsin to adopt ordinances for the prevention of erosion from construction sites and the management of stormwater runoff from lands within their jurisdiction. Towns may adopt village powers and subsequently utilize the authority conferred on villages under Section 62.23 to adopt their own erosion control and stormwater management ordinances, subject to county board approval where a county ordinance exists.

The administrative rules for the State stormwater discharge permit program are set forth in Chapter NR 216 of the *Wisconsin Administrative Code*, which initially took effect on November 1, 1994. Chapter NR 216 was most recently recreated as of August 1, 2004. Within the total area tributary to Oconomowoc Lake, Washington and Waukesha Counties; the Towns of Lisbon, Merton, Oconomowoc, and Summit; the City of Oconomowoc; and the Villages of Hartland, Merton, Nashotah, and Richfield, have been identified by the WDNR as being in urbanized areas that have been, or will be, required to obtain stormwater discharge permits unless they receive exemptions.

Through 1997 Wisconsin Act 27, the State Legislature required the WDNR and the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[5] Chapter NR 216 of the *Wisconsin Administrative Code* identifies several categories of municipalities, industries, and construction sites that must obtain permits. The permit requirements are based on the performance standards set forth in Chapter NR 151 of the *Wisconsin Administrative Code*, which became effective on October 1, 2002. These latter standards were revised in July 2004.

Agricultural Performance Standards

Agricultural performance standards cover the following areas:

- Cropland sheet, rill, and streambank erosion control;
- Manure storage;
- Clean water diversions; and
- Nutrient management.

For existing land that does not meet the Chapter NR 151 standards and that was cropped or enrolled in the U.S. Department of Agriculture (USDA) Conservation Reserve Program (CRP) or Conservation Reserve Enhancement Program (CREP) as of October 1, 2002, agricultural performance standards are required to be met only if cost-share funding is available. Existing cropland that met the standards as of October 1, 2002, must continue to be managed so as to meet the Chapter NR 151 standards. New cropland must meet the standards, regardless of whether cost-share funds are available.

Nonagricultural (urban) Performance Standards

The nonagricultural performance standards set forth in Chapter NR 151 of the *Wisconsin Administrative Code* encompass two major types of land management. The first includes standards for areas of new development and redevelopment, and the second includes standards for developed urban areas. The performance standards address the following areas:

- Construction sites for new development and redevelopment,
- Post-construction sites following new development and redevelopment,
- Developed urban areas, and
- Nonmunicipal property fertilizing.

Chapter NR 151 requires municipalities with Wisconsin Pollution Discharge Elimination Systems (WPDES) stormwater discharge permits to reduce the amount of total suspended solids in stormwater runoff from areas of

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[5] *The State performance standards are set forth in the Chapter NR 151, "Runoff Management," of the* Wisconsin Administrative Code. *Additional Code chapters that are related to the State nonpoint source pollution control program include: Chapter NR 152, "Model Ordinances for Construction Site Erosion Control and Storm Water Management," Chapter NR 153, "Runoff Management Grant Program," Chapter NR 154, "Best Management Practices, Technical Standards and Cost-Share Conditions," and Chapter NR 155 "Urban Nonpoint Source Water Pollution Abatement and Stormwater Management Grant Program." Those chapters of the* Wisconsin Administrative Code *became effective during October 2002. Chapter NR 120, "Priority Watershed and Priority Lake Program," and Chapter NR 243, "Animal Feeding Operations," were repealed and recreated in October 2002. The Wisconsin Department of Agriculture, Trade, and Consumer Protection revised Chapter ATCP 50, "Soil and Water Resource Management," to incorporate the changes required under 1997 Wisconsin Act 27.*

existing development that were in place as of October 2004 to the maximum extent practicable, according to the following standards:

- By March 10, 2008, the NR 151 standards call for a 20 percent reduction, and

- By October 1, 2013, the standards call for a 40 percent reduction.

Also, permitted municipalities must implement: 1) public informational and educational programs relative to specific aspects of nonpoint source pollution control; 2) municipal programs for the collection and management of leaf and grass clippings; and, 3) site-specific programs for the application of lawn and garden fertilizers on municipally controlled properties with over five acres of pervious surface. Under the requirements of Chapter NR 151, by March 10, 2008, incorporated municipalities with average population densities of 1,000 people per square mile or more that are not currently required to obtain municipal stormwater discharge permits must implement these same programs.

Regardless of whether a municipality is required to have a stormwater discharge permit under Chapter NR 216 of the *Wisconsin Administrative Code*, Chapter NR 151 requires that all construction sites that disturb one acre or more of land must achieve an 80 percent reduction in the sediment load generated from the site. With certain limited exceptions, those sites required to have construction erosion control permits must also have post-development stormwater management practices to reduce the total suspended solids load from the site by 80 percent for new development, 40 percent for redevelopment, and 40 percent for infill development occurring prior to October 1, 2012. After October 1, 2012, infill development will be required to achieve an 80 percent reduction. If it can be demonstrated that the solids reduction standard cannot be met for a specific site, Chapter NR 151 requires that total suspended solids be controlled to the maximum extent practicable.

Stormwater management practices in urban areas, under the provisions of Section NR 151.12 of the *Wisconsin Administrative Code*, require infiltration, subject to specific exclusions and exemptions as set forth in Sections 151.12(5)(c)5 and 151.12(5)(c)6, respectively. In residential areas, either 90 percent of the predevelopment infiltration volume or 25 percent of the post-development runoff volume from a two-year recurrence interval, 24-hour storm, is required to be infiltrated. However, no more than 1 percent of the area of the project site is required to be used as effective infiltration area. In commercial, industrial and institutional areas, 60 percent of the predevelopment infiltration volume or 10 percent of the post-development runoff volume from a two-year recurrence interval, 24-hour storm, is required to be infiltrated, provided that no more than 2 percent of the rooftop and parking lot areas are required to be used as effective infiltration area. Impervious area setbacks of 50 feet from streams, lakes, and wetlands generally apply. This setback distance is increased to 75 feet around Chapter NR 102-designated outstanding or exceptional resource waters or Chapter NR 103-designated wetlands of special natural resource interest. Reduced setbacks from less susceptible wetlands and drainage channels of not less than 10 feet may be allowed.

In addition to these provisions, Section NR 151.13 of the *Wisconsin Administrative Code* requires municipalities to implement informational and educational programming to promote good housekeeping practices in developed urban areas, as well as related operational programs in those municipalities subject to stormwater permitting requirements pursuant to Chapter NR 216 of the *Wisconsin Administrative Code*.

Within the total area tributary to Oconomowoc Lake, as of 2000, Washington and Waukesha Counties had adopted their own countywide erosion control and stormwater management ordinances; the Towns of Erin, Hartford, and Polk, had adopted the Washington County ordinance; and, the Cities of Delafield and Oconomowoc, the Villages of Chenequa, Hartland, and Richfield, and the Towns of Lisbon and Oconomowoc had each adopted their own construction site erosion control and stormwater management ordinances. The Village of Oconomowoc Lake has an erosion control ordinance, and utilizes the practices and procedures set forth in the Waukesha County stormwater management ordinance within the Village. The Villages of Merton, Nashotah, and Slinger, and the Towns of Merton and Summit had not adopted specific erosion control or stormwater management ordinances.

Waukesha County has adopted construction site erosion control and stormwater management ordinances. These ordinances apply to the unincorporated lands within the County. The construction site erosion control ordinance requires persons engaging in land disturbing activities to employ soil erosion control practices on affected sites that are consistent with those set forth in the *Wisconsin Construction Site Best Management Practice Handbook*[6] or equivalent practices. In general, these practices are designed to minimize soil loss from disturbed sites through prior planning and phasing of land disturbing activities and use of appropriate onsite erosion control measures. The Waukesha County stormwater management ordinance applies to residential lands of five acres or more in areal extent, residential lands of between three to five acres where there is at least 1.5 acres of impervious surface, nonresidential lands of 1.5 acres in areal extent where there is at least 0.5 acre of impervious surface, or other lands on which development activities may result in stormwater runoff likely to harm public property or safety.[7] The stormwater management ordinance establishes performance standards to manage both rate and volume of stormwater flows from regulated sites and water quality. Performance standards adopted in this ordinance and the resultant design of appropriate management practices are based on calculation procedures and principles set forth in *Urban Hydrology for Small Watersheds*.[8]

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[6]*Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook, *April 1994.*

[7]*See Waukesha County Code, Chapter 14, Article VIII, "Storm Water Management and Erosion Control Ordinance," adopted by the Waukesha County Board on March 22, 2005.*

[8]*U.S. Department of Agriculture Technical Release 55,* Urban Hydrology of Small Watersheds*, June 1992.*

Chapter IV

WATER QUALITY

INTRODUCTION

Most water quality information on conditions in Oconomowoc Lake has been acquired relatively recently. Prior to 1985, there were only limited data on Oconomowoc Lake water quality. The earliest data on water quality conditions in Oconomowoc Lake date back to the early 1900s, when E.A. Birge and C. Juday, widely recognized, pioneering lake researchers from the University of Wisconsin-Madison, collected basic information on the Lake.[1] Since that time, water chemistry data for Oconomowoc Lake have been collected under the auspices of various Wisconsin Department of Natural Resources (WDNR) programs, including: the Self-Help Monitoring Program from 1986 through 2001, the Base Line Monitoring Program in 2003, and the Small Lake Grant Program in 2005. U.S. Geological Survey (USGS) water quality monitoring of Oconomowoc Lake has been ongoing since 1986 to the present, and has involved the determination of the physical and chemical characteristics of the Lake's water, including: dissolved oxygen concentration and water temperature profiles, pH and specific conductance profiles, water clarity, and nutrient and chlorophyll-*a* concentrations. In 1976, the Southeastern Wisconsin Regional Planning Commission (SEWRPC), in cooperation with the WDNR, undertook a study of water quality conditions in Oconomowoc Lake for the purpose of, among other things, describing and evaluating recommended measures to improve water quality of the Lake.[2]

EXISTING WATER QUALITY CONDITIONS

For purposes of the initial 1990 SEWRPC water quality management plan for Oconomowoc Lake, data from water samples collected by the WDNR from the deepest point in the Lake, over the period from May 1976 to April 1977, along with some selected historical data for the period 1973 to 1975 and for 1979, including some data from the inlet and outlet to Oconomowoc Lake dating from 1973 to 1975, were used to determine water quality conditions in the Lake, and to characterize the suitability of the Lake for recreational use and for the support of fish and aquatic life. These data suggested that Oconomowoc Lake was a mesotrophic, or moderately enriched, waterbody, bordering on eutrophy.

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[1]*E.A. Birge and C. Juday,* The Inland Lakes of Wisconsin, 1. The Dissolved Gases and their Biological Significance, *Bulletin, Wisconsin Geological and Natural History Survey, Volume 22, 1911*.

[2]*SEWRPC Community Assistance Planning Report No. 181,* A Water Quality Management Plan for Oconomowoc Lake, Waukesha County, Wisconsin, *1990.*

For the purposes of this study, water quality data gathered primarily by USGS during the period from 1986 through 2005, along with some data gathered under the auspices of the abovementioned WDNR programs, were used to assess lake water quality in Oconomowoc Lake. Water quality samples generally were taken seasonally from the main basin of the Lake and from the northeastern bay, as shown on Map 2 in Chapter II of this report. These data are discussed below. Where appropriate, and as a means of revealing trends or drawing comparisons, data from the aforereferenced initial SEWRPC report are included in this discussion.

Thermal Stratification

Thermal stratification, illustrated diagrammatically in Figure 2, is a result of the differential heating of lake water, and the resulting water temperature-density relationships at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit of volume, at about 39°F. The development of summer thermal stratification begins in early summer, reaches its maximum in late summer, and disappears in the fall. Stratification may also occur during winter under ice cover. The annual thermal cycle within Oconomowoc Lake is described below.

As summer begins, the 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, created by differing water densities between warmer and cooler water, begins to form between the warmer surface water and the colder, heavier bottom water, as shown in Figure 3. This "barrier" is marked by a sharp temperature gradient known as the thermocline (also called the metalimnion) and is characterized by a 1°C drop in temperature per one meter (or 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), as shown in Figure 3. 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. During the aforementioned initial SEWRPC study, data collected at the deepest part of the main basin of the Lake indicated that Oconomowoc Lake appeared to stratify during the summer at a depth of about 25 feet,[3] with the epilimnion extending from the surface to a depth of about 20 feet, the thermocline extending from a depth of 20 feet to about 30 feet, and the hypolimnion extending from the 30 foot depth to the bottom. Data from the current study period indicate that this pattern has continued to the present.

The autumnal mixing period occurs when air temperatures cool the surface water and wind action results in the erosion of the thermocline: as the surface water cools, it becomes heavier, sinking and displacing the now relatively warmer water below. The colder water sinks and mixes under wind action until the entire column of water is of uniform temperature, as shown in Figure 2. This action, which follows summer stratification, is known as "fall turnover."

From fall turnover until freeze-up, surface waters continue to cool in response to the decline in ambient air temperatures. Once the temperature of the water at the surface drops to the point of maximum water density, these waters become denser than the warmer waters below them, and, as a consequence of this density difference, the surface waters begin to "sink" to the bottom. Eventually, the entire water column is cooled to the point of maximum density. The surface waters continue to cool until they reach about 32°F, and are, once again, less dense than the waters below which remain at about 39°F. At 32°F, the lake surface may then become ice covered, isolating the lake water from the atmosphere for a period of up to four months. As shown in Figure 2, winter stratification occurs as the colder, lighter water and ice remains at the surface, separated from the relatively warmer, heavier water near the bottom of the lake. The ice shuts the water column off from the atmospheric source of oxygen.

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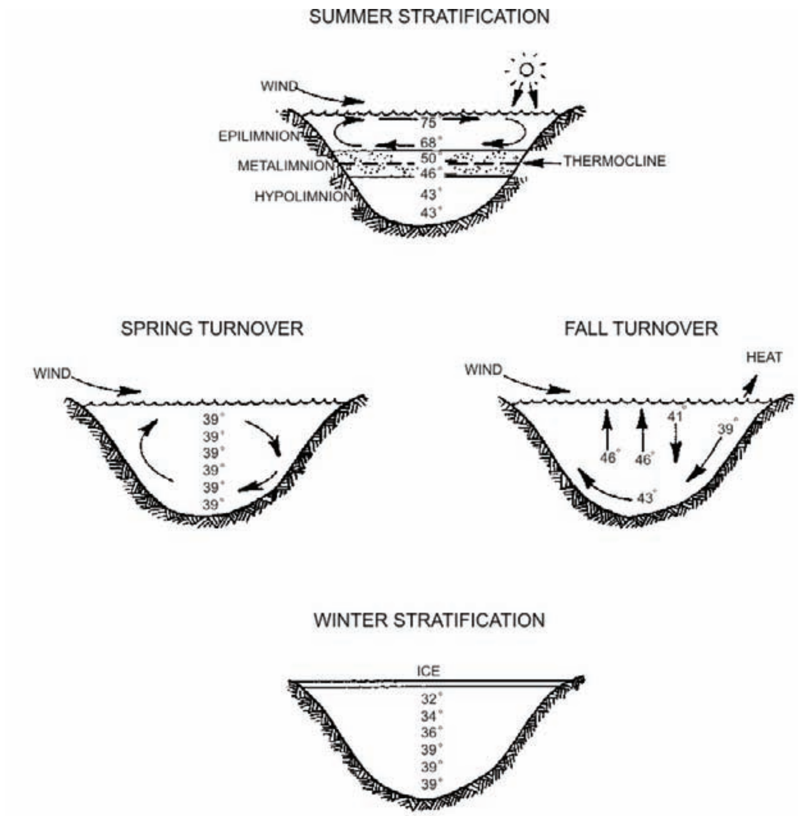
[3]Ibid.

Figure 2

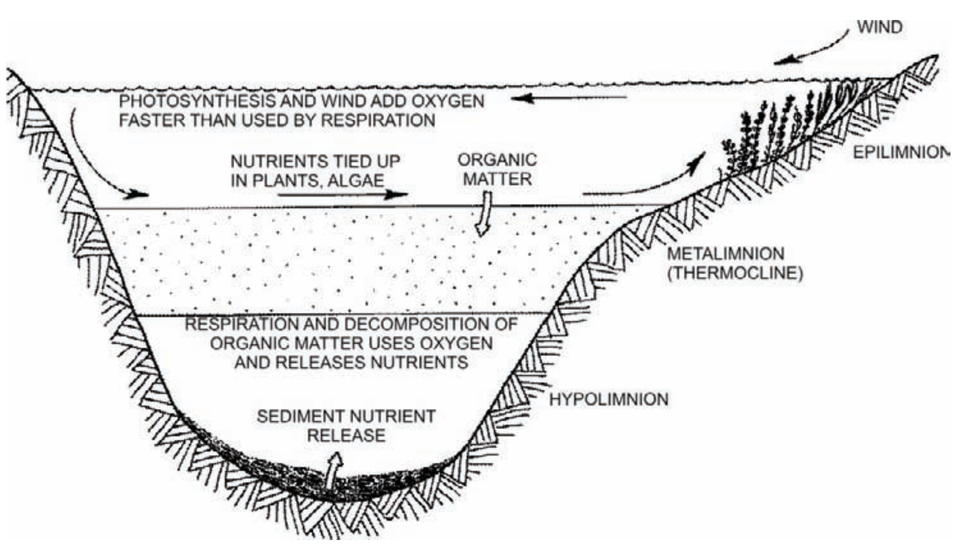
THERMAL STRATIFICATION OF LAKES



Source: University of Wisconsin-Extension and SEWRPC.

Figure 3

LAKE PROCESSES DURING SUMMER STRATIFICATION



Source: University of Wisconsin-Extension and SEWRPC.

Spring brings a reversal of the process of lake stratification. Once the surface ice has melted, the upper layer of water continues to warm until it reaches 39°F, the maximum density point of water and, coincidentally, the temperature of the deeper waters below it. At this point, the entire water column is, once again, the same temperature (and density) from surface to bottom, and wind action results in a mixing of the entire lake. This is referred to as "spring turnover" and usually occurs within weeks after the ice goes out, as shown in Figure 2. After spring turnover, the water at the surface continues to warm and become less dense, causing it to float above the colder, deeper water. Wind and resulting waves carry some of the energy of the warmer, lighter water to lower depths, but only to a limited extent. Thus begins the formation of the thermocline and another period of summer thermal stratification.

Thermal profiles for Oconomowoc Lake during the current study period, as shown in Figure 4, indicate that the Lake is subject to thermal stratification during summer and winter and is, therefore, dimictic, which means that it mixes completely two times per year. During the current study period, water temperatures in the main basin of the Lake ranged from a minimum of 32.5°F during the winter to 84.2°F during the summer, as shown in Table 11; waters in the northeast bay of the Lake ranged from a minimum of 32.7°F during the winter to 83.3°F during the summer, as shown in Table 12. In recent years, the range in water temperatures was approximately 5°F warmer than that measured during the initial SEWRPC study which indicated a maximum water temperature of 78.8°F.

Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms in a lake ecosystem, since most organisms require oxygen to survive. As shown in Figure 4, during the current study period, dissolved oxygen levels were generally higher at the surface of Oconomowoc Lake, where there was an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis, than in the bottom waters of the Lake. Dissolved oxygen levels were lowest at the bottom of the Lake, where decomposer organisms and chemical oxidation processes utilized oxygen in the decay process. When any lake becomes thermally stratified, as described above, the surface supply of dissolved oxygen to the hypolimnion is cut off. Gradually, if there is not enough dissolved oxygen to meet the total demands from the bottom dwelling aquatic life and decaying organic material, the dissolved oxygen levels in the bottom waters may be reduced, even to zero, a condition known as anoxia or anaerobiasis, as shown in Figure 3.

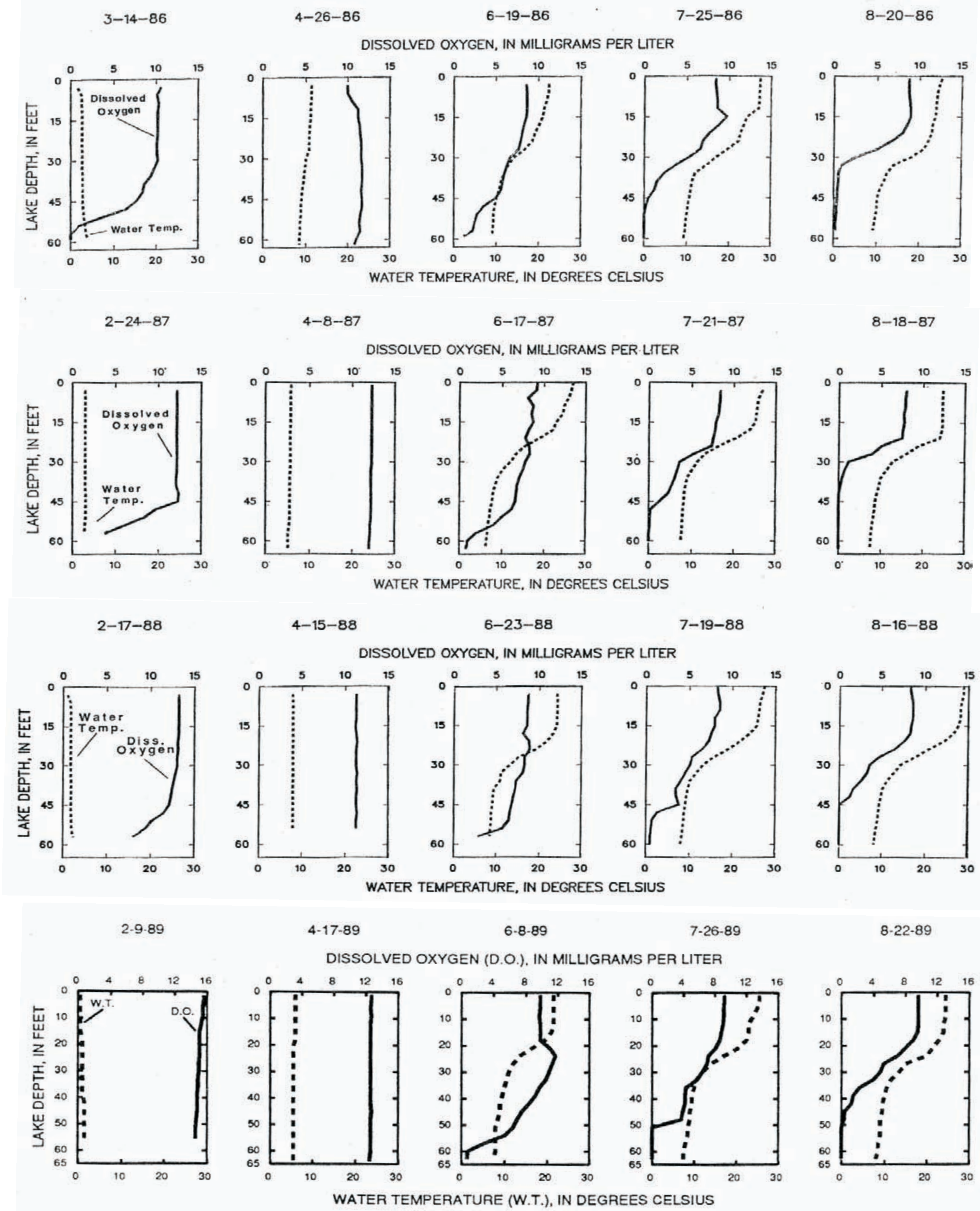
During the initial SEWRPC study, dissolved oxygen profiles during summer stratification on Oconomowoc Lake showed a pattern of total oxygen depletion in the hypolimnion, mostly during the months of July, August and September. Dissolved oxygen concentrations during winter appeared adequate for the support of fish and other aquatic life and winterkill was not considered a severe problem on the Lake, although there had been some reports of winterkill of a portion of the cisco (*Coregonus artedi*) population during the 1970s.

A similar pattern was observed during the current study period, with the hypolimnion of Oconomowoc Lake frequently becoming anoxic during summer stratification. Dissolved oxygen concentrations at the bottom of the main basin and in the northeastern embayment of the Lake often fell to zero by mid- to late-July, as shown in Figure 4. Even at a depth of approximately 30 feet, oxygen concentrations were at or below the recommended concentration of 5 mg/l, the minimum level considered necessary to support many species of fish during most years studied. Nevertheless, it is worth noting that, for the period between 2001 and 2005, there were no recorded incidents of hypolimnetic anoxia in either the main basin or the northeastern embayment of the Lake, although dissolved oxygen concentrations dropped to less than 1 mg/l during this period.

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 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. Under these conditions, anoxia can contribute to the winter-kill of fish. In Oconomowoc Lake during the current study period, hypolimnetic anoxia was not observed during winter stratification. 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.

Figure 4

DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR OCONOMOWOC LAKE: 1986-2007



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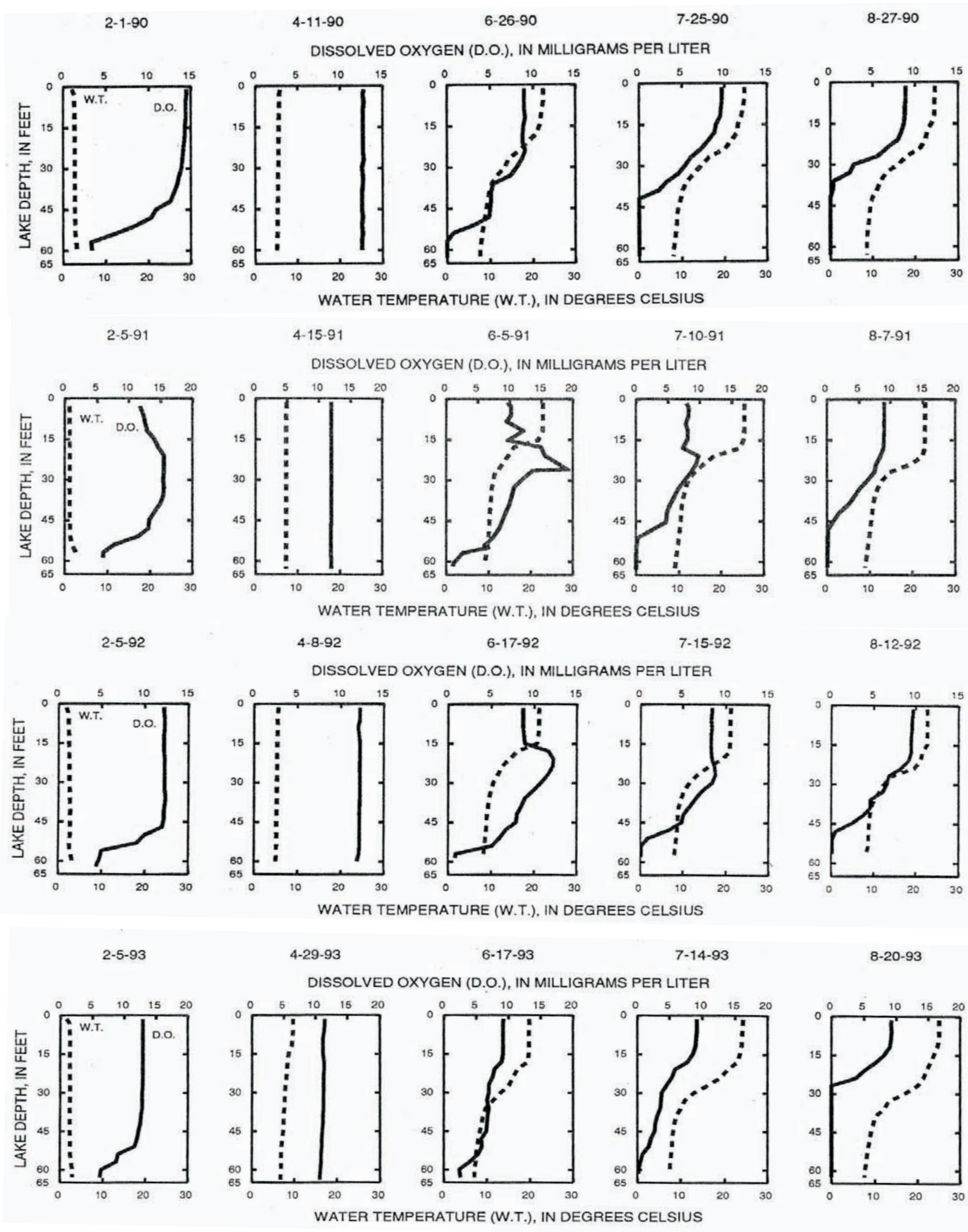

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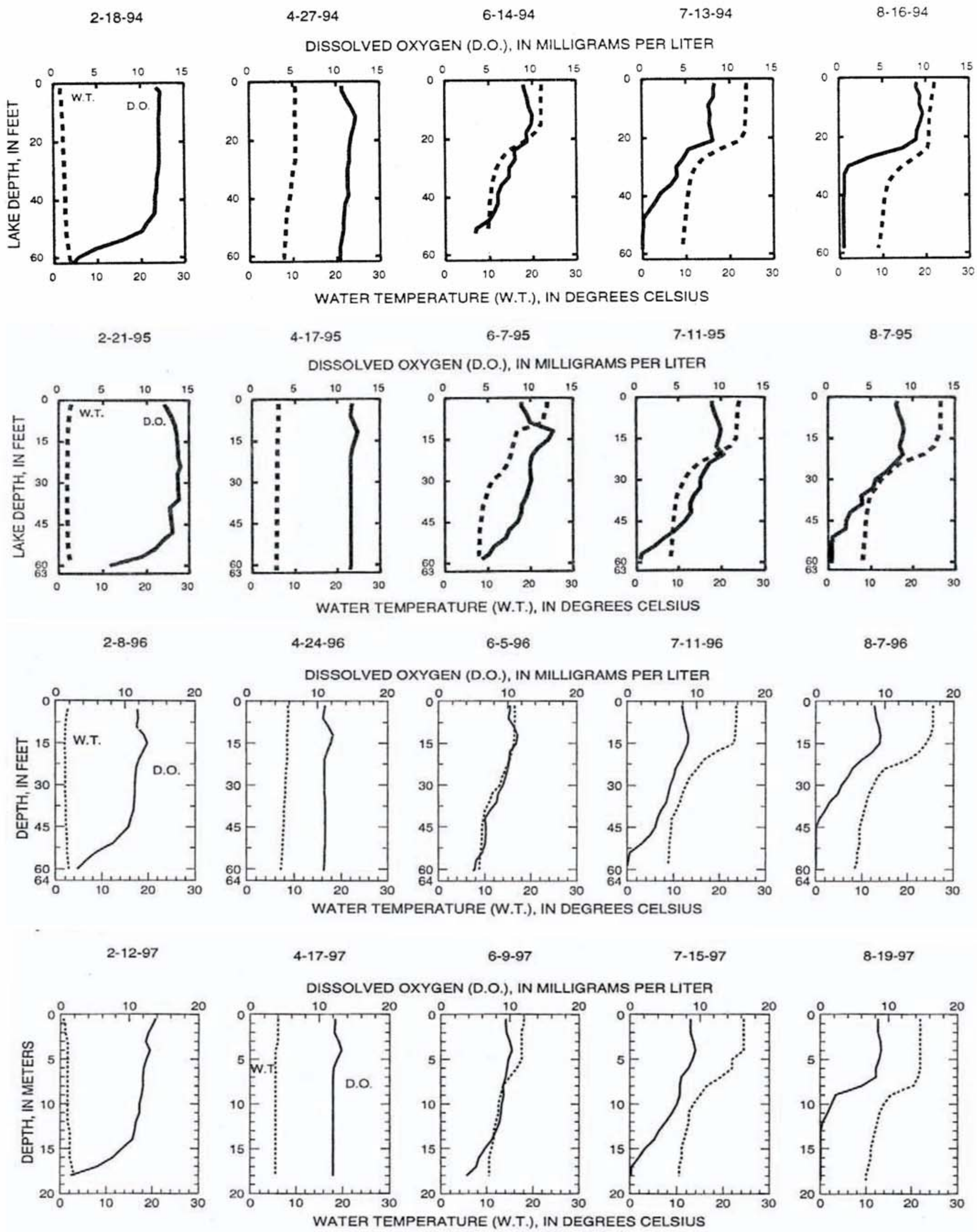

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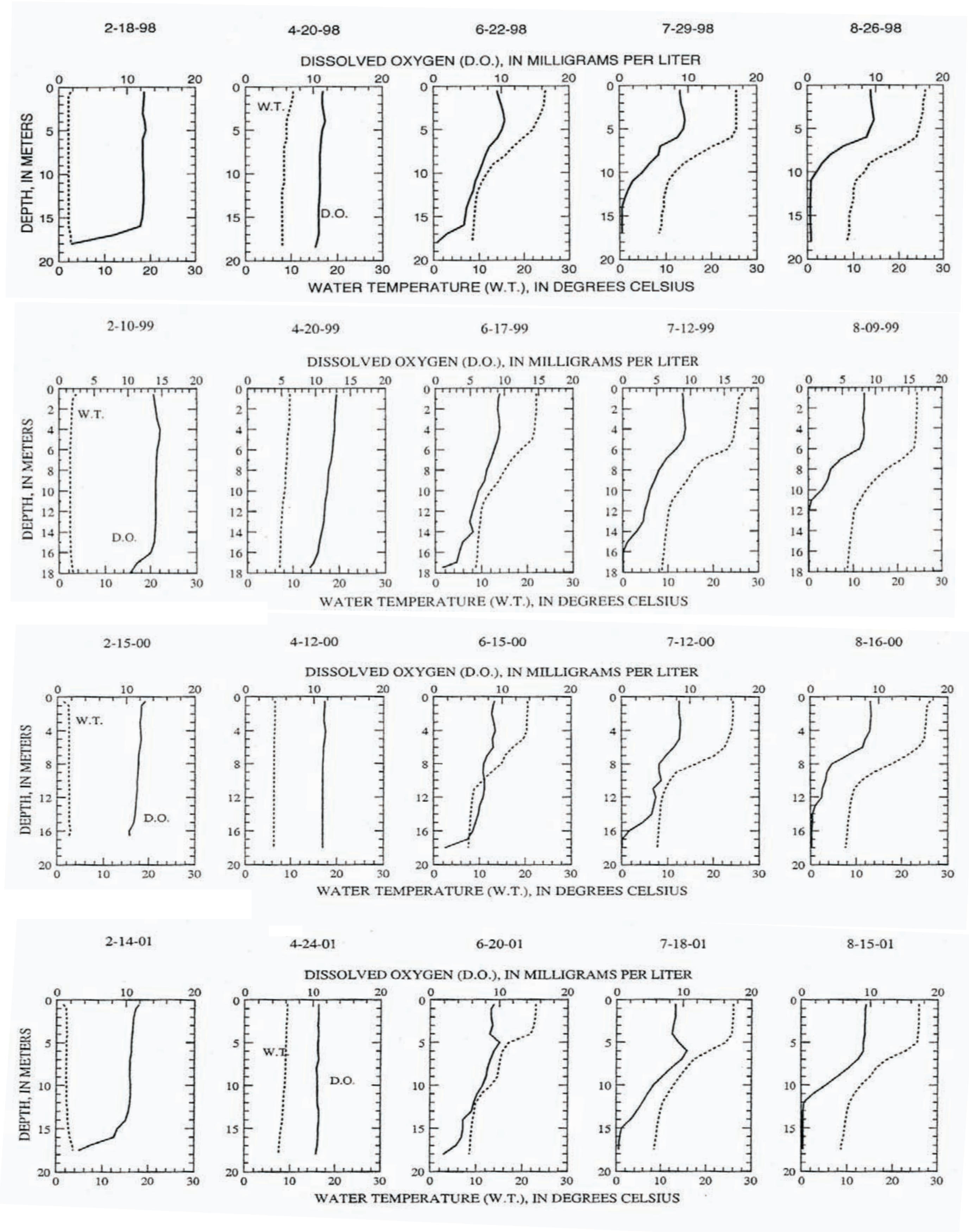

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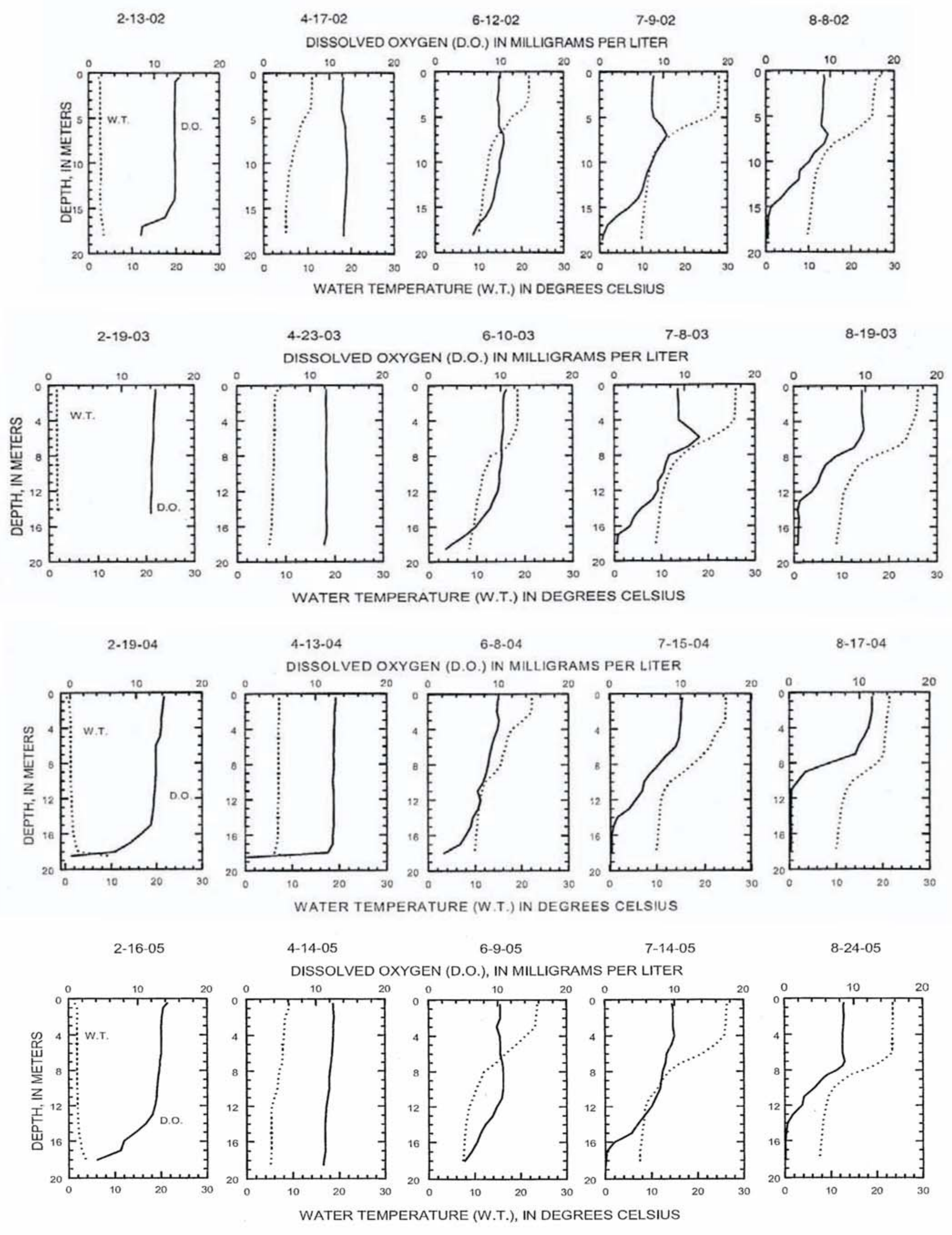

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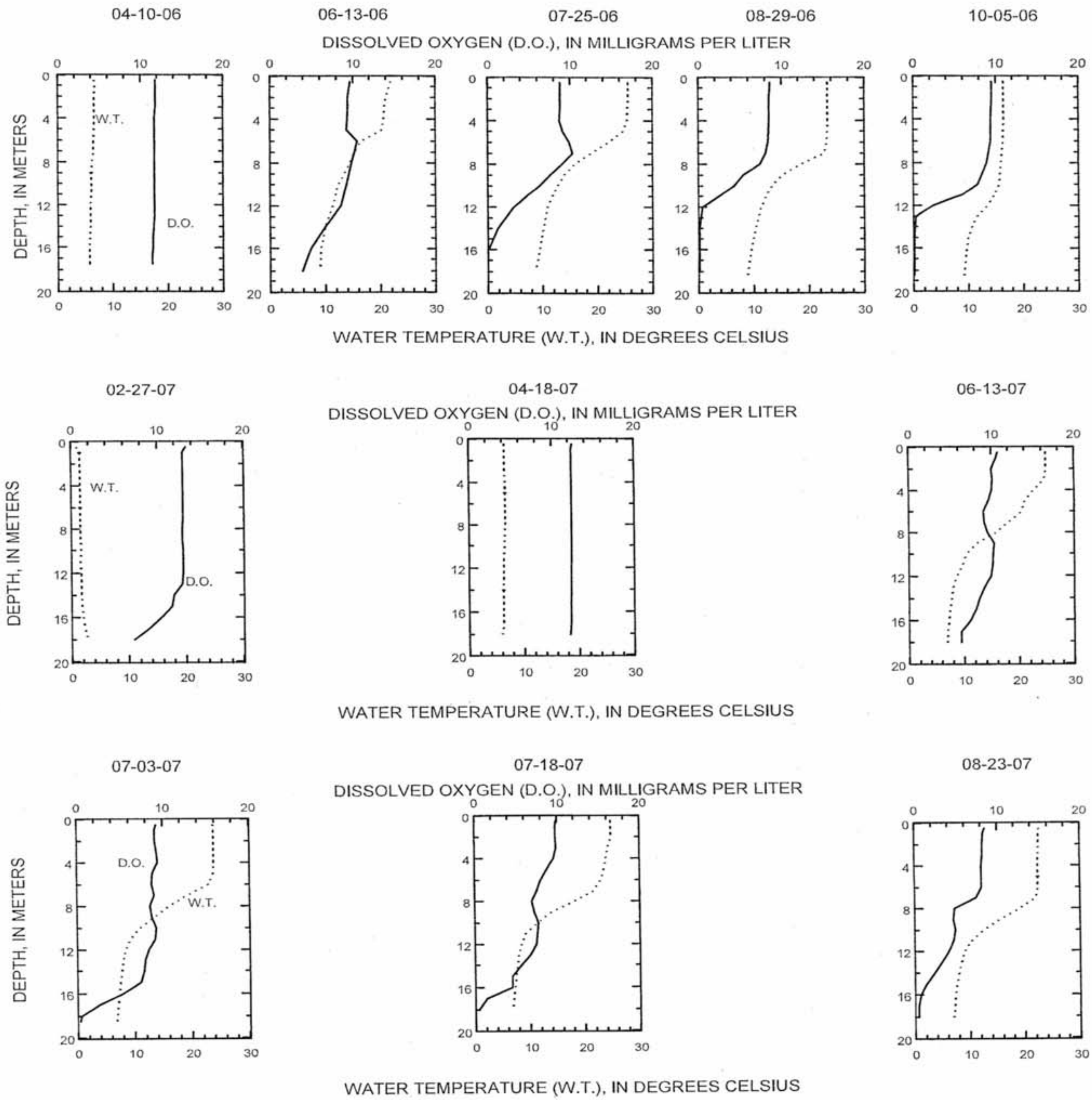

Source: U.S. Geological Survey and SEWRPC.

Table 11

SEASONAL WATER QUALITY CONDITIONS IN MAIN BASIN OF OCONOMOWOC LAKE: 1986-2005

	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	- -	- -	- -	- -	206-232	190-232	208-208	- -
Mean	- -	- -	- -	- -	219	219	208	- -
Standard Deviation	- -	- -	- -	- -	7.4	11	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1.0	- -
Hardness, as $CaCO_3$								
Range	- -	- -	- -	- -	240-270	250-270	250-250	- -
Mean	- -	- -	- -	- -	256	257	250	- -
Standard Deviation	- -	- -	- -	- -	8	8	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Color (Pt-Co. scale)								
Range	- -	- -	- -	- -	4-20	5-20	5.0-5.0	- -
Mean	- -	- -	- -	- -	11	10	5.0	- -
Standard Deviation	- -	- -	- -	- -	5	4	0	- -
Number of Samples	- -	- -	- -	- -	18	11	1	- -
Dissolved Oxygen								
Range	- -	- -	10.6-15.6	0.0-14.6	9.0-13.0	0.7-12.6	7.9-12.2	0.0-11.8
Mean	- -	- -	13.0	5.9	11.2	8.5	9.0	0.8
Standard Deviation	- -	- -	1.3	4.0	1.2	4.1	0.8	2.0
Number of Samples	- -	- -	20	20	29	28	52	51
pH (units)								
Range	- -	- -	7.4-8.6	7.2-8.4	7.8-8.5	7.5-8.4	8.0-8.7	7.0-8.4
Mean	- -	- -	8.1	7.8	8.2	8.0	8.3	7.6
Standard Deviation	- -	- -	0.3	0.3	0.2	0.3	0.2	0.3
Number of Samples	- -	- -	20	20	29	28	52	51
Secchi Depth (feet)								
Range	10.0-18.5	- -	21.3-26.6	- -	4.6-27.9	- -	4.9-24.3	- -
Mean	13.6	- -	24.0	- -	14.8	- -	9.7	- -
Standard Deviation	2.7	- -	3.7	- -	5.8	- -	3.3	- -
Number of Samples	13	- -	2	- -	51	- -	121	- -
Specific Conductance (µS/cm)								
Range	- -	- -	452-642	527-666	478-574	404-617	400-561	410-612
Mean	- -	- -	540	587	538	538	509	558
Standard Deviation	- -	- -	41	42	23	39	29	29
Number of Samples	- -	- -	20	20	29	28	51	50
Temperature (°F)								
Range	- -	- -	32.5-38.5	34.7-39.2	41.9-75.2	41.0-50.9	47.1-84.2	43.2-50.9
Mean	- -	- -	35.1	37.4	54.6	45.2	75.7	47.1
Standard Deviation	- -	- -	33.6	33.1	44.0	35.0	37.4	33.6
Number of Samples	- -	- -	20	20	29	28	52	51
Turbidity (NTU)								
Range	- -	- -	- -	- -	0.4-1.4	0.4-1.0	- -	- -
Mean	- -	- -	- -	- -	0.8	0.6	- -	- -
Standard Deviation	- -	- -	- -	- -	0.3	0.2	- -	- -
Number of Samples	- -	- -	- -	- -	18	11	- -	- -
Dissolved Solids								
Range	- -	- -	- -	- -	291-352	290-344	316-316	- -
Mean	- -	- -	- -	- -	313	306	316	- -
Standard Deviation	- -	- -	- -	- -	16	14	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Metals/Salts								
Dissolved Calcium								
Range	- -	- -	- -	- -	44-57	44-55	45-45	- -
Mean	- -	- -	- -	- -	48	49	45	- -
Standard Deviation	- -	- -	- -	- -	4	4	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Dissolved Chloride								
Range	- -	- -	- -	- -	0.1-43.9	0.1-34.0	43.1-43.1	- -
Mean	- -	- -	- -	- -	29.7	25.0	43.1	- -
Standard Deviation	- -	- -	- -	- -	10.1	9.3	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Dissolved Iron (µg/l)								
Range	- -	- -	- -	- -	3-100	4-50	100-100	- -
Mean	- -	- -	- -	- -	38	26	100	- -
Standard Deviation	- -	- -	- -	- -	35	21	0	- -
Number of Samples	- -	- -	- -	- -	17	10	1	- -
Dissolved Magnesium								
Range	- -	- -	- -	- -	31-36	31-36	34.2-34.2	- -
Mean	- -	- -	- -	- -	33	33	34.2	- -
Standard Deviation	- -	- -	- -	- -	1	1.3	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -

Table 11 (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 Manganese (μg/l)								
Range	- -	- -	- -	- -	0.4-40.0	0.4-40.0	- -	- -
Mean	- -	- -	- -	- -	12.3	16.5	- -	- -
Standard Deviation	- -	- -	- -	- -	18.4	20.2	- -	- -
Number of Samples	- -	- -	- -	- -	17	10	- -	- -
Dissolved Potassium								
Range	- -	- -	- -	- -	1.6-2.3	2-3	2-2	- -
Mean	- -	- -	- -	- -	2.0	2.1	2	- -
Standard Deviation	- -	- -	- -	- -	0.1	0.3	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Dissolved Silica								
Range	- -	- -	- -	- -	3.0-6.6	3.0-6.1	5.5-5.5	- -
Mean	- -	- -	- -	- -	4.8	4.5	5.5	- -
Standard Deviation	- -	- -	- -	- -	1.0	0.9	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Dissolved Sodium								
Range	- -	- -	- -	- -	9.2-19.5	9.3-15.0	18.4-18.4	- -
Mean	- -	- -	- -	- -	13.8	12.2	18.4	- -
Standard Deviation	- -	- -	- -	- -	2.9	1.9	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Dissolved Sulfate SO_4								
Range	- -	- -	- -	- -	25-34	23-34	24.7-24.7	- -
Mean	- -	- -	- -	- -	27	27	24.7	- -
Standard Deviation	- -	- -	- -	- -	3	3	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Nutrients								
Dissolved Nitrogen, Ammonia								
Range	- -	- -	- -	- -	0.013-0.113	0.01-0.11	0.039-0.039	- -
Mean	- -	- -	- -	- -	0.050	0.06	0.039	- -
Standard Deviation	- -	- -	- -	- -	0.033	0.03	0	- -
Number of Samples	- -	- -	- -	- -	19	12	1	- -
Dissolved Nitrogen, NO_2+NO_3								
Range	- -	- -	- -	- -	0.02-0.39	0.02-0.41	0.188-0.188	- -
Mean	- -	- -	- -	- -	0.26	0.24	0.188	- -
Standard Deviation	- -	- -	- -	- -	0.10	0.11	0	- -
Number of Samples	- -	- -	- -	- -	17	10	1	- -
Total Nitrogen, Organic								
Range	- -	- -	- -	- -	0.43-1.06	0.46-0.60	- -	- -
Mean	- -	- -	- -	- -	0.64	0.54	- -	- -
Standard Deviation	- -	- -	- -	- -	0.26	0.06	- -	- -
Number of Samples	- -	- -	- -	- -	6	4	- -	- -
Total Nitrogen, Amm. + Organic								
Range	- -	- -	- -	- -	0.10-0.64	0.44-0.70	0.49-0.49	- -
Mean	- -	- -	- -	- -	0.51	0.57	0.49	- -
Standard Deviation	- -	- -	- -	- -	0.13	0.08	0	- -
Number of Samples	- -	- -	- -	- -	16	9	1	- -
Total Nitrogen								
Range	- -	- -	- -	- -	0.66-1.60	0.68-1.10	0.45-0.45	- -
Mean	- -	- -	- -	- -	0.87	0.92	0.45	- -
Standard Deviation	- -	- -	- -	- -	0.23	0.12	0	- -
Number of Samples	- -	- -	- -	- -	14	8	1	- -
Dissolved Orthophosphorus								
Range	- -	- -	- -	- -	0.001-0.004	0.001-0.004	0.002-0.007	0.002-0.075
Mean	- -	- -	- -	- -	0.002	0.002	0.005	0.017
Standard Deviation	- -	- -	- -	- -	0.001	0.001	0.004	0.022
Number of Samples	- -	- -	- -	- -	17	11	2	15
Total Phosphorus								
Range	- -	- -	0.005-0.020	0.006-0.138	0.002-0.021	0.005-0.053	0.004-0.032	0.005-0.159
Mean	- -	- -	0.010	0.037	0.010	0.017	0.010	0.049
Standard Deviation	- -	- -	0.005	0.049	0.004	0.012	0.005	0.040
Number of Samples	- -	- -	9	9	27	26	50	50
Biological								
Chlorophyll-*a* (μg/l)								
Range	- -	- -	- -	- -	0.4-6.3	- -	0.2-6.0	- -
Mean	- -	- -	- -	- -	2.9	- -	2.7	- -
Standard Deviation	- -	- -	- -	- -	1.7	- -	1.3	- -
Number of Samples	- -	- -	- -	- -	26	- -	49	- -

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

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

[c]*Depth of sample greater than 40 feet.*

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

Table 12

SEASONAL WATER QUALITY CONDITIONS IN NORTHEAST BAY OF OCONOMOWOC LAKE: 1986-2005

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	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Hardness, as $CaCO_3$								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Color (Pt-Co. scale)								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Oxygen								
Range	- -	- -	9.7-16.7	1.1-10.0	8.9-12.6	0.3-12.6	0.0-12.0	0.0-11.9
Mean	- -	- -	12.7	4.6	11.0	7.9	8.8	0.4
Standard Deviation	- -	- -	1.5	2.6	1.0	4.5	1.5	1.7
Number of Samples	- -	- -	20	20	28	30	52	51
pH (units)								
Range	- -	- -	7.5-8.5	7.2-8.1	8-8.4	7.5-8.3	7.4-8.7	7.0-8.1
Mean	- -	- -	8.1	7.6	8.2	7.9	8.3	7.5
Standard Deviation	- -	- -	0.2	0.2	0.1	0.3	0.2	0.2
Number of Samples	- -	- -	20	20	28	30	52	51
Secchi Depth (feet)								
Range	10.0-17.5	- -	15.4-26.6	- -	5.6-25.6	- -	1.5-28.5	- -
Mean	13.0	- -	21.0	- -	14.2	- -	9.1	- -
Standard Deviation	1.9	- -	7.9	- -	5.6	- -	2.9	- -
Number of Samples	26	- -	2	- -	66	- -	168	- -
Specific Conductance (µS/cm)								
Range	- -	- -	387-660	578-711	507-624	413-685	406-610	426-679
Mean	- -	- -	566	629	568	575	541	602
Standard Deviation	- -	- -	58	38	29	49	37	36
Number of Samples	- -	- -	20	20	28	30	51	50
Temperature (°F)								
Range	- -	- -	32.7-39.2	37.4-40.1	42.3-75.6	40.5-52.5	46.4-83.3	43.0-53.1
Mean	- -	- -	36.1	38.8	56.3	45.2	75.3	47.7
Standard Deviation	- -	- -	33.6	32.7	43.6	35.0	38.6	34.0
Number of Samples	- -	- -	20	20	28	30	52	51
Turbidity (NTU)								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Solids								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Metals/Salts								
Dissolved Calcium								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Chloride								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Iron (µg/l)								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Magnesium								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -

Table 12 (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 Manganese (µg/l)								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Potassium								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Silica								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Sodium								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Dissolved Sulfate SO_4								
Range	- -	- -	- -	- -	- -	- -	- -	- -
Mean	- -	- -	- -	- -	- -	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	- -	- -	- -	- -
Number of Samples	- -	- -	- -	- -	- -	- -	- -	- -
Nutrients								
Dissolved Nitrogen, Ammonia								
Range	- -	- -	- -	- -	0.08-0.09	0.09-0.09	- -	- -
Mean	- -	- -	- -	- -	0.08	0.09	- -	- -
Standard Deviation	- -	- -	- -	- -	<0.01	0	- -	- -
Number of Samples	- -	- -	- -	- -	2	1	- -	- -
Dissolved Nitrogen, NO_2+NO_3								
Range	- -	- -	- -	- -	0.5-0.5	0.40-0.40	- -	- -
Mean	- -	- -	- -	- -	0.5	0.40	- -	- -
Standard Deviation	- -	- -	- -	- -	0	0	- -	- -
Number of Samples	- -	- -	- -	- -	1	1	- -	- -
Total Nitrogen, Organic								
Range	- -	- -	- -	- -	0.52-0.52	0.51-0.51	- -	- -
Mean	- -	- -	- -	- -	0.52	0.51	- -	- -
Standard Deviation	- -	- -	- -	- -	0	0	- -	- -
Number of Samples	- -	- -	- -	- -	1	1	- -	- -
Total Nitrogen, Amm. + Organic								
Range	- -	- -	- -	- -	0.55-0.55	- -	- -	- -
Mean	- -	- -	- -	- -	0.55	- -	- -	- -
Standard Deviation	- -	- -	- -	- -	0	- -	- -	- -
Number of Samples	- -	- -	- -	- -	1	- -	- -	- -
Total Nitrogen								
Range	- -	- -	- -	- -	0.77-1.10	1.0-1.0	- -	- -
Mean	- -	- -	- -	- -	0.94	1.0	- -	- -
Standard Deviation	- -	- -	- -	- -	0.23	0	- -	- -
Number of Samples	- -	- -	- -	- -	2	1	- -	- -
Dissolved Orthophosphorus								
Range	- -	- -	- -	- -	0.001-0.225	0.001-0.006	- -	0.002-0.009
Mean	- -	- -	- -	- -	0.113	0.003	- -	0.004
Standard Deviation	- -	- -	- -	- -	0.158	0.002	- -	0.002
Number of Samples	- -	- -	- -	- -	2	5	- -	14
Total Phosphorus								
Range	- -	- -	0.005-0.019	0.007-0.049	0.004-0.22	0.001-0.064	0.004-0.040	0.007-0.097
Mean	- -	- -	0.009	0.016	0.008	0.014	0.009	0.041
Standard Deviation	- -	- -	0.004	0.013	0.004	0.013	0.006	0.020
Number of Samples	- -	- -	9	9	25	29	51	51
Biological								
Chlorophyll-*a* (µg/l)								
Range	- -	- -	- -	- -	0.7-8.7	- -	0.0-8.9	- -
Mean	- -	- -	- -	- -	2.4	- -	2.6	- -
Standard Deviation	- -	- -	- -	- -	2.0	- -	1.6	- -
Number of Samples	- -	- -	- -	- -	25	- -	47	- -

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

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

[c]*Depth of sample greater than 40 feet.*

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

Hypolimnetic anoxia is common in many of the lakes in southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion may 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. When there is insufficient oxygen at these depths, these fish are susceptible to summer-kills, or, alternatively, are driven into the warmer water portions of the lake where their condition and competitive success may be severely impaired.

In addition to these biological consequences, 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 states 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 and rooted aquatic plant growth. These mixing events can be caused by severe weather, which both has the potential to cool the surface waters decreasing the surface-to-bottom thermal gradient and wind action associated with the storms. While shallow lakes and/or embayments are frequently subject to these multiple mixing events, the USGS dissolved oxygen profiles from Oconomowoc Lake suggest that such events are rare. The likely import of internal loading to the nutrient budget of Oconomowoc Lake is discussed further below.

Specific Conductance

Specific conductance, the ability of water to conduct an electric current, is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. As such, specific conductance is often useful as an indication of possible pollution in a lake’s waters. Freshwater lakes commonly have a specific conductance range of from 10 to 1,000 microSiemens per centimeter (µS/cm), although measurements in polluted waters or in lakes receiving large amounts of land runoff can sometimes exceed 1,000 µS/cm.[4] Additionally, during periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion. This is a consequence of the “internal loading” phenomenon noted above.

During the initial SEWRPC study, specific conductance in the main lake basin ranged from 418 µS/cm to 525 µS/cm with an annual mean of 474 µS/cm. Surface-to-bottom conductivity gradients were not reported. At that time, conductivity averaged 477 µS/cm in spring, 460 µS/cm in summer, 458 µS/cm in fall, and 510 µS/cm in winter.

During the current study, specific conductance of Oconomowoc Lake ranged from 400 to 666 µS/cm in the main basin and from 387 to 711 µS/cm in the northeast bay, as shown in Tables 11 and 12. Surface to bottom conductivity gradients were observed both in the main basin and in the northeast bay, especially during the summer period. The conductivity stratification in the main lake basin is shown in Figure 5. During spring, the specific conductance of Oconomowoc Lake ranged from 413 to 685 µS/cm, values considered within the normal range for lakes in southeastern Wisconsin.

Regionwide increases in specific conductance over the years appear to be associated with increases in the chloride concentrations in lakes. Long-term continued increases of specific conductance can serve as an indicator of increased contamination of the region’s lakes with concomitant deleterious effects on the plants and animals inhabiting those environments.

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[4]*Deborah Chapman,* Water Quality Assessments, second edition, *E&FN Spon, 1996.*

Figure 5

SPECIFIC CONDUCTANCE AND pH PROFILES FOR OCONOMOWOC LAKE: 1986-2007

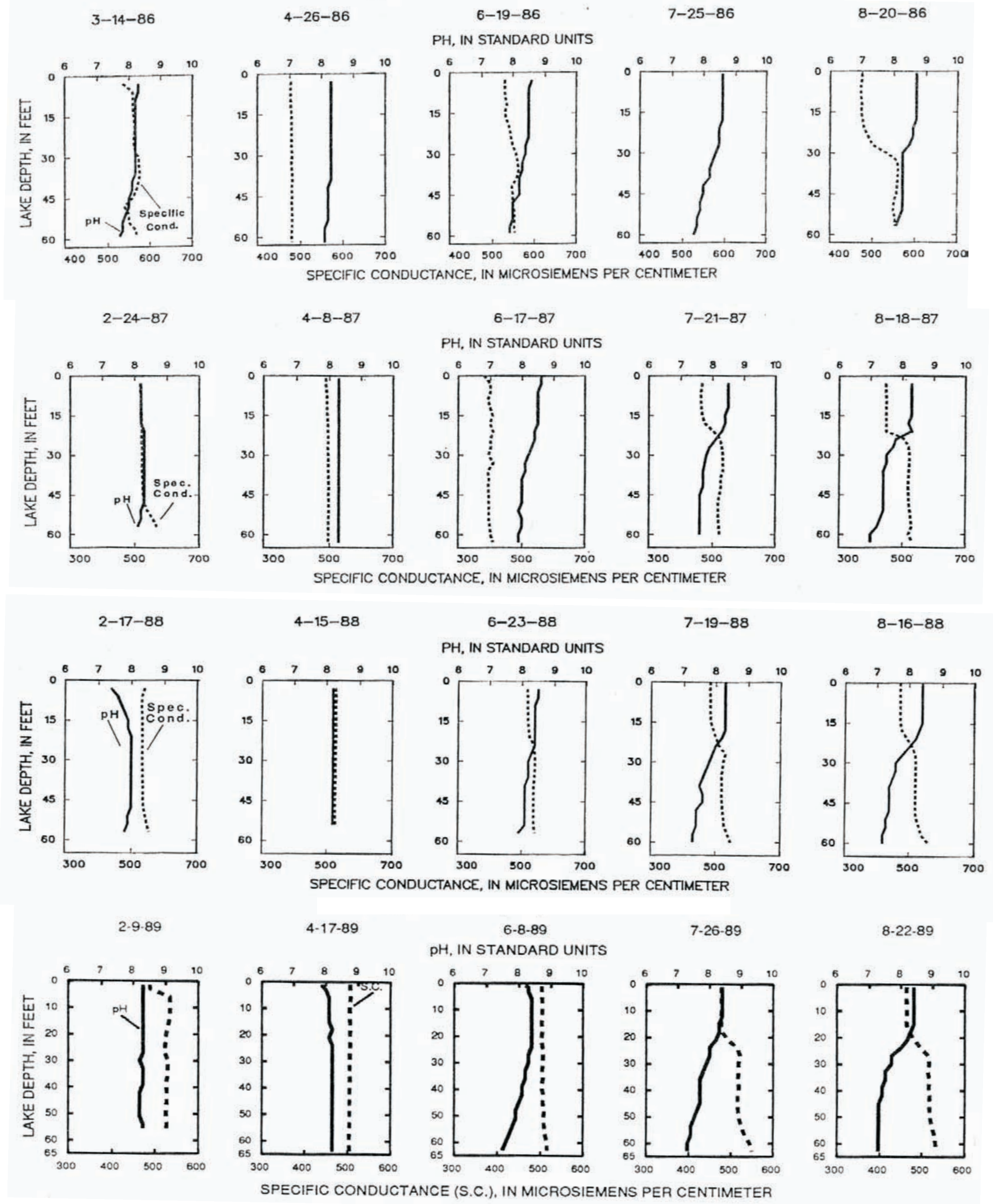


Figure 5 (continued)

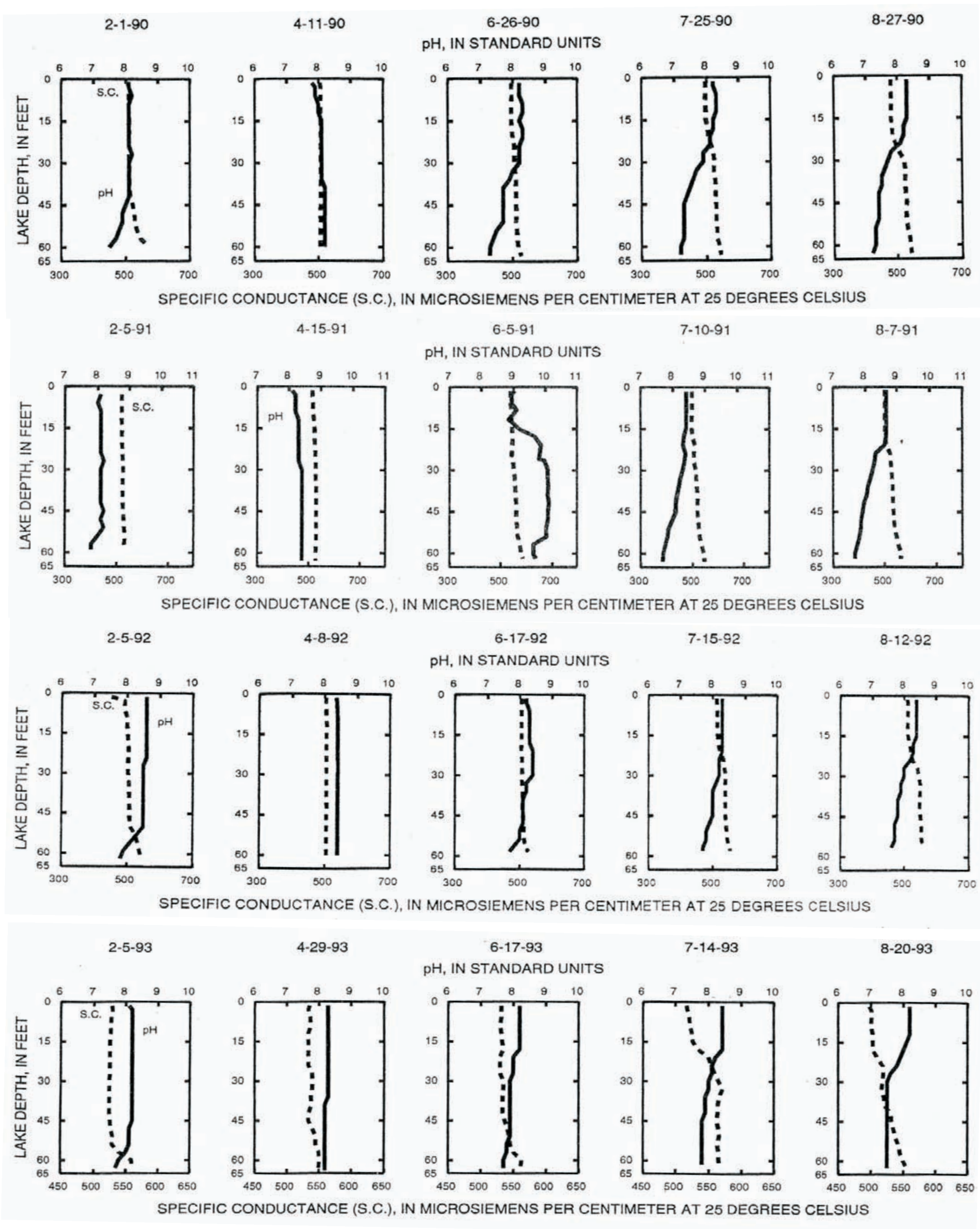


Figure 5 (continued)

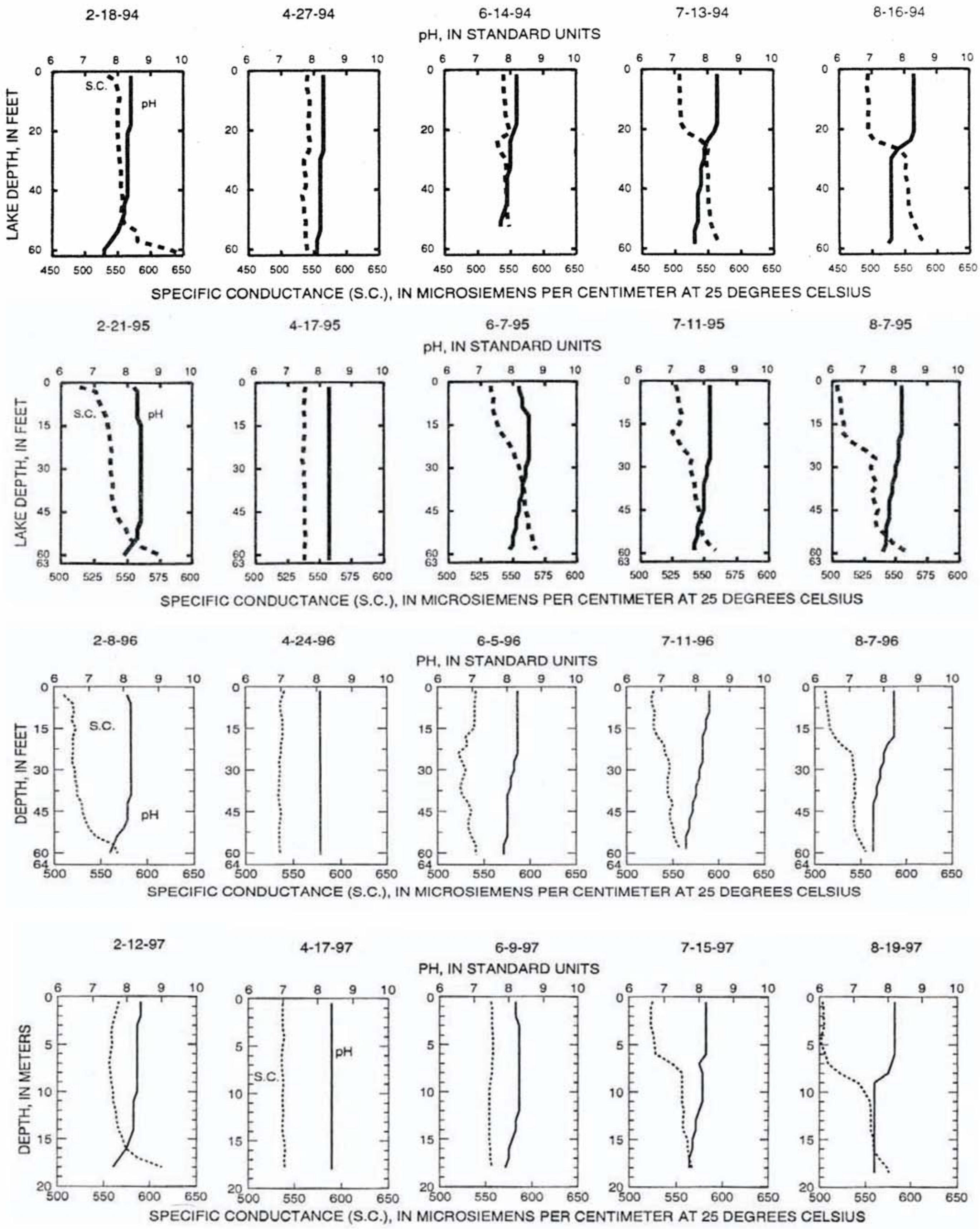


Figure 5 (continued)

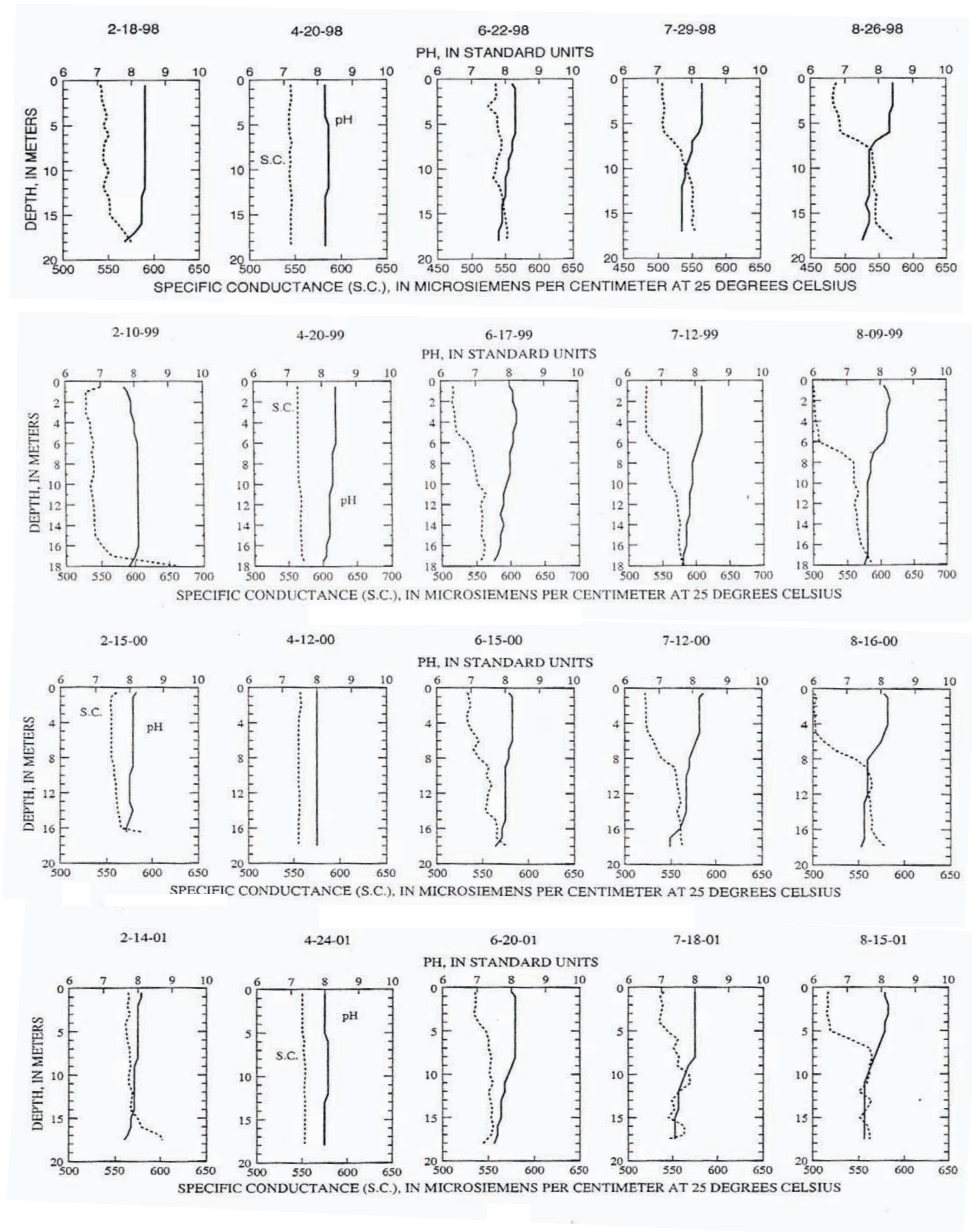
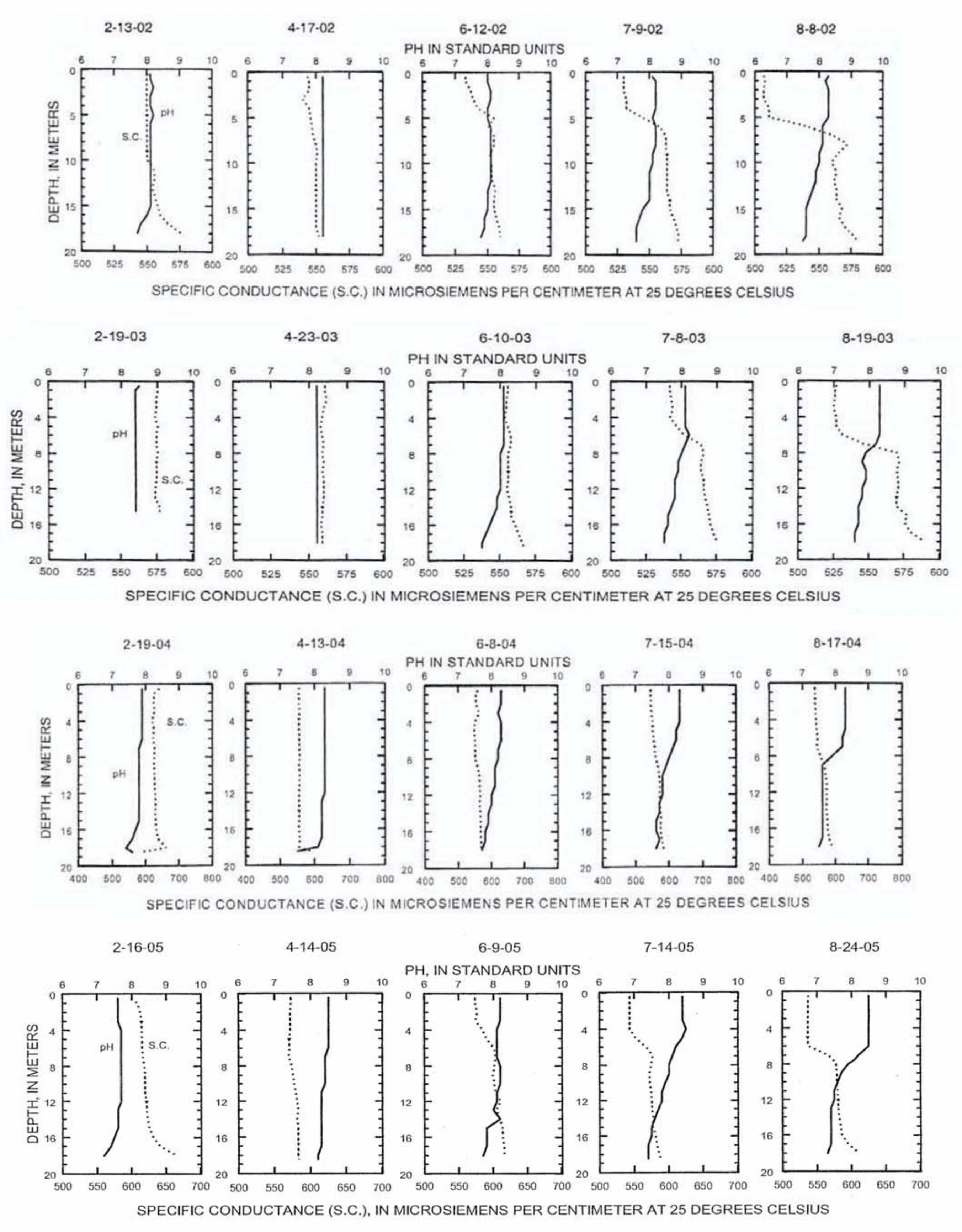


Figure 5 (continued)



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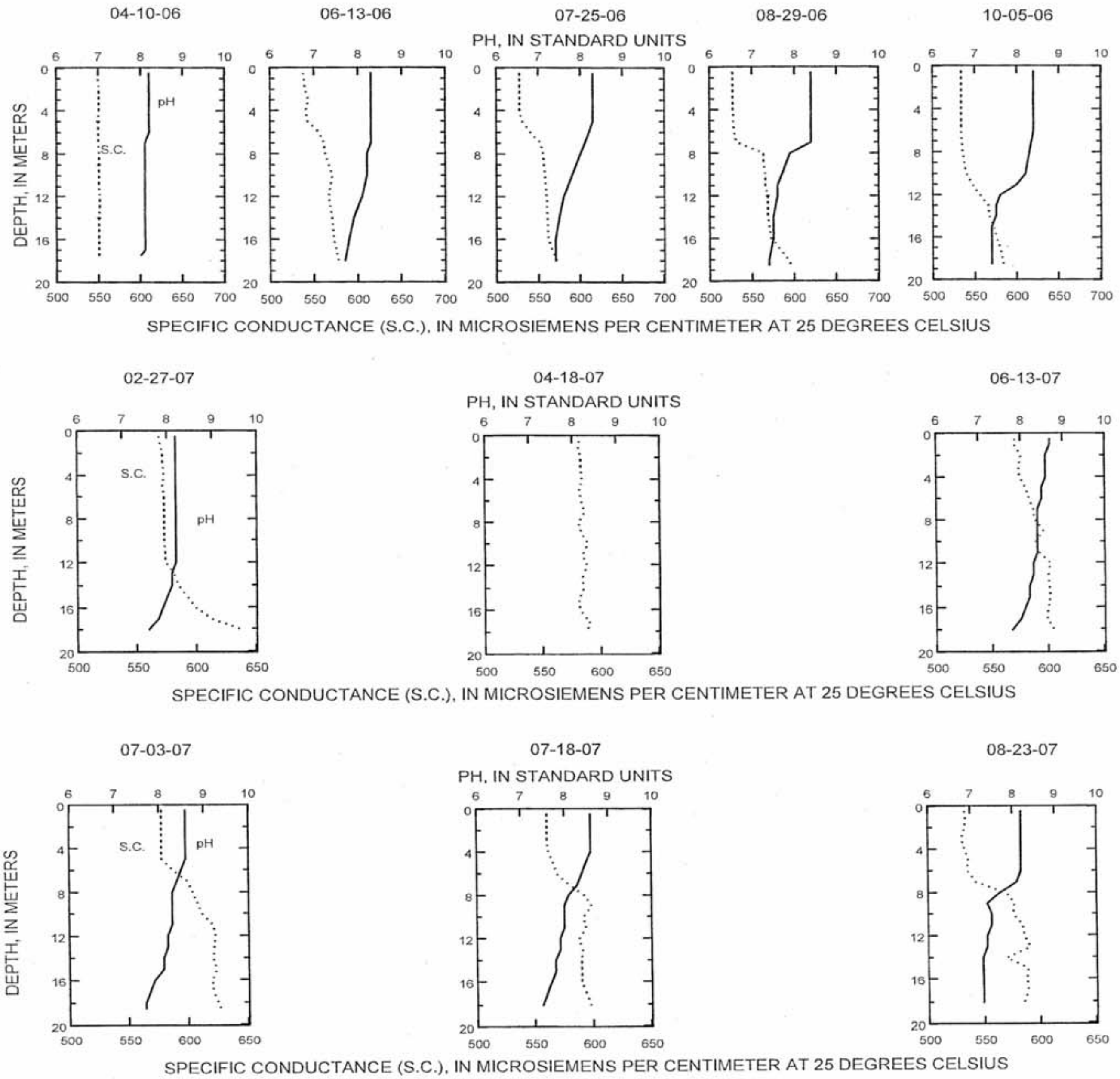

Source: U.S. Geological Survey and SEWRPC.

Chloride

At high concentrations, chloride can directly affect aquatic plant growth and pose a threat to aquatic organisms. The effects of chloride contamination begin to manifest at about 250 milligrams per liter (mg/l) and become severe at concentrations in excess of 1,000 mg/l.[5] Natural chloride concentrations in lake water are directly affected by leaching from underlying bedrock and soils, and by deposition from precipitation events. Higher concentrations can reflect pollution. Lakes in southeastern Wisconsin typically have very low natural chloride concentrations due to the limestone bedrock found in the Region. Limestone is primarily composed of calcium carbonate and magnesium carbonate, and, as such, is rich in carbonates rather than chlorides. Hence, the sources of chloride in southeastern Wisconsin are largely anthropogenic, including sources such as salts used on streets and highways for winter snow and ice control, salts discharged from water softeners, and salts from sewage and animal wastes. The significance of human-originated chlorides is reflected in the chloride concentrations found in lakes in the different regions of Wisconsin, where geological sources of the element are rare. Chloride concentrations in the more populated and urban southeastern region average about 19 mg/l as contrasted with about 2.0 mg/l in the northeastern and northwestern regions of the State, about 4.0 mg/l in the central region, and about 7.0 mg/l in the southwestern region.[6]

In the initial study, chloride concentrations in the main basin of the Lake ranged from 10 mg/l to 22 mg/l, with an annual average of 16 mg/l, which was somewhat lower than the concentrations found in most lakes in southeastern Wisconsin. Chloride concentrations averaged 15 mg/l in spring and summer, 17 mg/l in autumn, and 18 mg/l in winter.

During the current study, these concentrations have continued to increase, with chloride concentrations in the main basin of Oconomowoc Lake ranging from 0.1 to 43.9 mg/l, as shown in Table 11. These values are similar to the concentrations found in many other lakes in southeastern Wisconsin,[7] where an increasing trend in chloride concentrations has been observed, as shown in Figure 6.[8] The most important anthropogenic source of chlorides to Oconomowoc Lake is believed to be the salts used on streets and highways for winter snow and ice control.[9] This is borne out by the fact that chloride concentrations in the Oconomowoc River continue to increase from upstream to downstream despite the fact that much of the downstream tributary area is served by public sanitary

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[5]*Frits van der Leeden, Fred L. Troise and David Keith Todd,* The Water Encyclopedia, Second Edition, *Lewis Publishers 1990.*

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

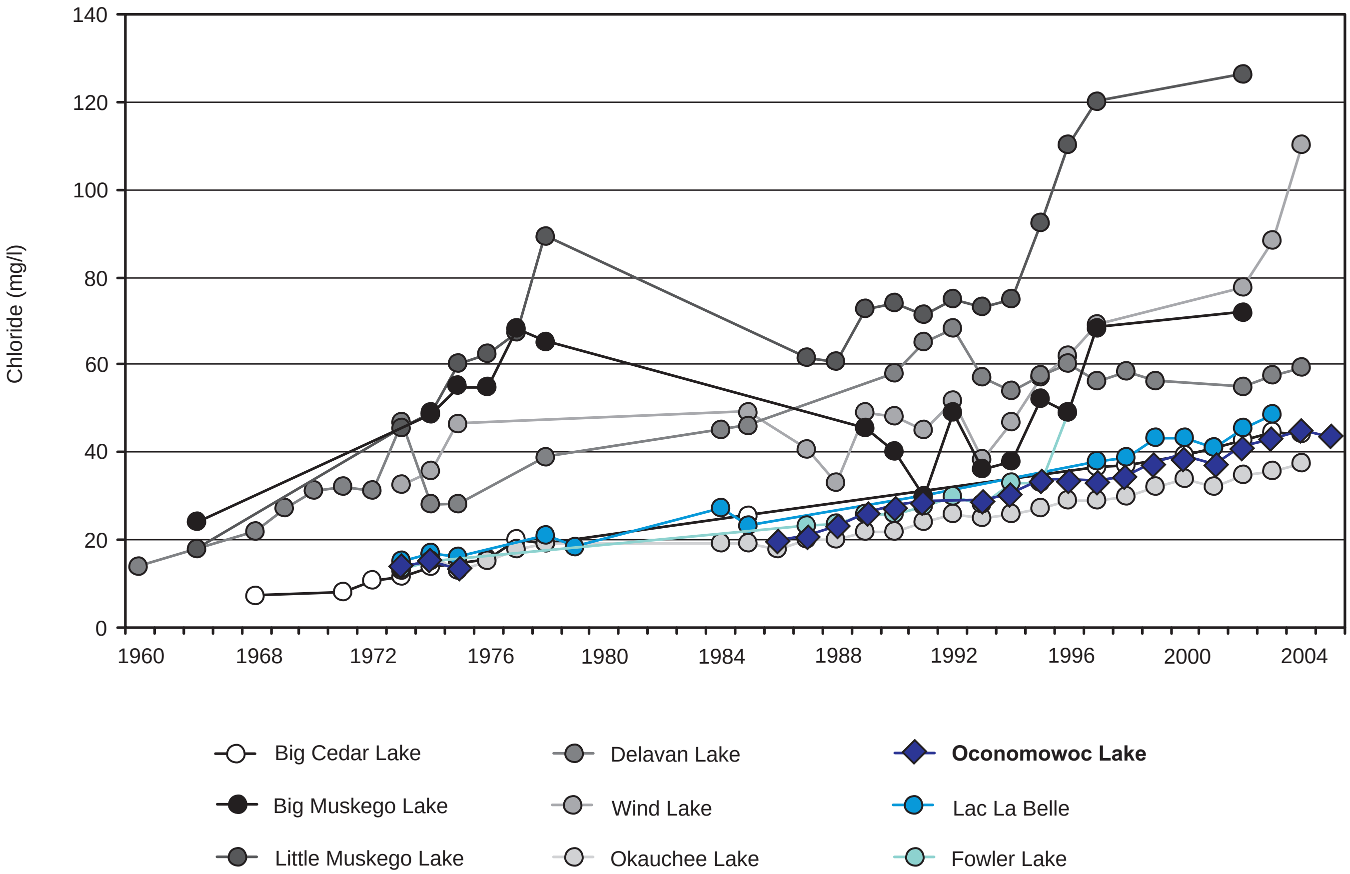
[7]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[8]*The WDNR, as part of the National Atmospheric Deposition Program/National Trends Network (NADP), has operated a precipitation monitoring station for the Southeastern Wisconsin Region at Geneva Lake since 1984, the purpose of which is to collect precipitation chemistry data in order to develop geographical and temporal long-term trends. A trend plot for samples collected at the Lake Geneva monitoring station indicates a gradually decreasing trend in chloride concentrations in precipitation from 1984 through 2005, further bolstering the presumption that chloride is being introduced through anthropogenic actions on the land surface. See National Atmospheric Deposition Program, http://nadp.sws.uiuc.edu.*

[9]*The major sources of chlorides to lakes in the Southeastern Wisconsin Region include both road salt applications during winter months and salts discharged from water softeners. In the case of those communities served by public sanitary sewerage systems, the softener salts are conveyed away from the lakes to the wastewater treatment plant and, in the case of the City of Oconomowoc treatment plant, discharged to the Oconomowoc River downstream of Lac La Belle.*

Figure 6

CHLORIDE CONCENTRATION TRENDS FOR SELECTED LAKES IN SOUTHEASTERN WISCONSIN: 1960-2004



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

sewerage systems and many of the riparian communities including the Village of Oconomowoc Lake utilize salt-reduction practices as part of their winter roadway maintenance programs. Figure 6 presents comparative data for the upstream Okauchee Lake, which show a slightly lower chloride concentration in that Lake compared with Oconomowoc Lake, and the downstream Fowler Lake and Lac La Belle, which show incrementally higher chloride concentrations.

Alkalinity and Hardness

Alkalinity is an index of the buffering capacity of a lake, or the ability of a lake to absorb and neutralize acids. Lakes having a low alkalinity and, therefore, a low buffering capacity, may be more susceptible to the effects of acidic atmospheric deposition. The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Due, in large part, to the deposits of limestone and dolomite that make up much of the bedrock underlying many of the lakes and their associated tributary areas, lakes in southeastern Wisconsin typically have a high alkalinity, with an average concentration of about 173 milligrams per liter (mg/l) expressed as calcium carbonate.[10]

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[10]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

During the initial SEWRPC study period, Oconomowoc Lake alkalinity was found to range from 191 mg/l to 217 mg/l, with an annual average of 206 mg/l, which was slightly above the average for lakes in southeastern Wisconsin, at that time.[11] Alkalinity averaged 202 mg/l in spring, 206 mg/l in summer, 200 mg/l in fall, and 213 mg/l in winter.

During the current study period, alkalinity ranged from 190 to 232 mg/l, with an average of 219 mg/l in spring and 208 mg/l during summer, as shown in Table 11.

In contrast to alkalinity, water hardness is a measure of the multivalent metallic ion concentrations, such as those of calcium and magnesium, present in a lake. Generally, lakes with high levels of hardness produce more fish and aquatic plants than lakes whose water is soft.[12] Hardness is usually reported as an equivalent concentration of calcium carbonate ($CaCO_3$). During the current study period, hardness ranged from 240 to 270 mg/l, with an average of 257 mg/l in spring and 250 mg/l during summer, as shown in Table 11.

Applying these measures to the study lake, Oconomowoc Lake may be classified as a hard-water alkaline lake, which is typical of most lakes in southeastern Wisconsin.

Hydrogen Ion Concentration (pH)

The pH is a logarithmic measure of hydrogen ion concentration on a scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, and a pH below 7 indicates acidic water. The pH of lake water influences many of the chemical and biological processes that occur there. Even though moderately low / high pH may not directly harm fish or other organisms, pH near the ends of the scale can have adverse effects on the organisms living in a lake. Additionally, under conditions of very low (acidic) pH, certain metals, such as aluminum, zinc, and mercury, can become soluble if present in a lake's bedrock or tributary area soils, leading to an increase in concentrations of such metals in a lake's waters with subsequent potentially harmful effects to not only the fish but also to those organisms, including humans, who eat them.[13]

As in the case of alkalinity, the chemical makeup of the underlying bedrock has a great influence on the pH of lake waters. In the case of lakes in the Southeastern Wisconsin Region, where the bedrock is comprised largely of limestone and dolomite, the pH typically is in the alkaline range above a pH of 7, even though the pH of rain in the Southeastern Wisconsin Region is typically on the order of 4.4.[14] Data collected as part of the National Atmospheric Deposition Program (NADP) indicate that there has been a gradual upward trend in precipitation pH at the City of Lake Geneva monitoring station, from about 4.4 in 1984 to about 5.0 in 2005.[15]

In general, the pH for most natural waterbodies is within the range of about 6.0 to about 8.5.[16] Measurements of pH from lakes in the Southeastern Wisconsin Region averaged about 8.1, which, due to the underlying geology of the Region, was the highest recorded from any region in the State; by contrast, lakes in the northeast are slightly

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[11]Ibid.

[12]*Byron Shaw, Lowell Klessig, and Christine Mechenich*, Understanding Lake Data, *University of Wisconsin-Extension Publication No. G3582, 2004.*

[13]*See National Atmospheric Deposition Program, http://nadp.sws.uiuc.edu,* op. cit.

[14]Ibid.

[15]*National Atmospheric Deposition Program, http://nadp.sws.uiuc.edu,* op. cit.

[16]*Deborah Chapman*, op. cit.

acidic with an average pH of about 6.9.[17] Other factors influencing pH include precipitation, as well as biological (algal) activity within the Lake.

In the initial SEWRPC study, pH ranged from 7.6 to 8.5, annually. Measurements of pH ranged from 7.9 to 8.4 in spring, 7.7 to 8.5 in summer, 7.6 to 8.5 in fall, and 7.7 to 8.3 in winter.

During the current study period, as shown in Tables 11 and 12, pH values ranged from 7.2 to 8.7 in the main lake basin, and from 7.0 to 8.7 in the northeastern bay. As in the case of specific conductance, surface to bottom conductivity gradients were observed both in the main basin and in the northeast bay, especially during the summer period, when the Lake was stratified with respect to temperature and dissolved oxygen concentrations. Figure 5 shows the pH stratification at the main basin monitoring station.

Since Oconomowoc Lake has a high alkalinity or buffering capacity, and because the pH does not fluctuate below 7, the Lake is not considered to be susceptible to the harmful effects of acidic deposition. This is consistent with data acquired from elsewhere in southeastern Wisconsin, where the natural buffering of rainfall by carbon dioxide in the atmosphere and the carbonate system in the Lake, its tributary streams, and drainage area, all tend to moderate the pH levels.

Water Clarity

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

Water clarity generally varies throughout the year as algal populations increase and decrease in response to changes in weather conditions and nutrient loadings. But, water clarity can also vary from region to region in the State as a reflection of regional differences in lake biogeochemistry. Lakes in the northeastern Wisconsin region generally have low levels of turbidity, as indicated by the region's average Secchi-disk reading of 8.9 feet, compared to the average in the Southeastern Wisconsin Region of 4.9 feet.[18]

During the initial SEWRPC study, Secchi-disk measurements taken by USGS ranged from about 7.5 feet to more than 24.0 feet.

During the current study period, USGS Secchi-disk readings for Oconomowoc Lake were between 4.6 and 27.9 feet, with an average of about 15.5 feet, in the main lake basin, and between 1.5 and 28.5 feet, with an average of about 14.3 feet, in the northeastern bay, as shown in Tables 11 and 12, respectively. Secchi-disk measurements taken by WDNR Self-Help (now the UWEX Citizen Lake Monitoring Network) volunteers during the current study period were generally consistent with those taken by USGS. As shown in Figure 7, during recent years, these values indicate fair to very good water quality compared to other lakes in southeastern Wisconsin.[19]

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[17]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[18]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[19]Ibid.

Figure 7

PRIMARY WATER QUALITY INDICATORS FOR OCONOMOWOC LAKE: 1981-2008

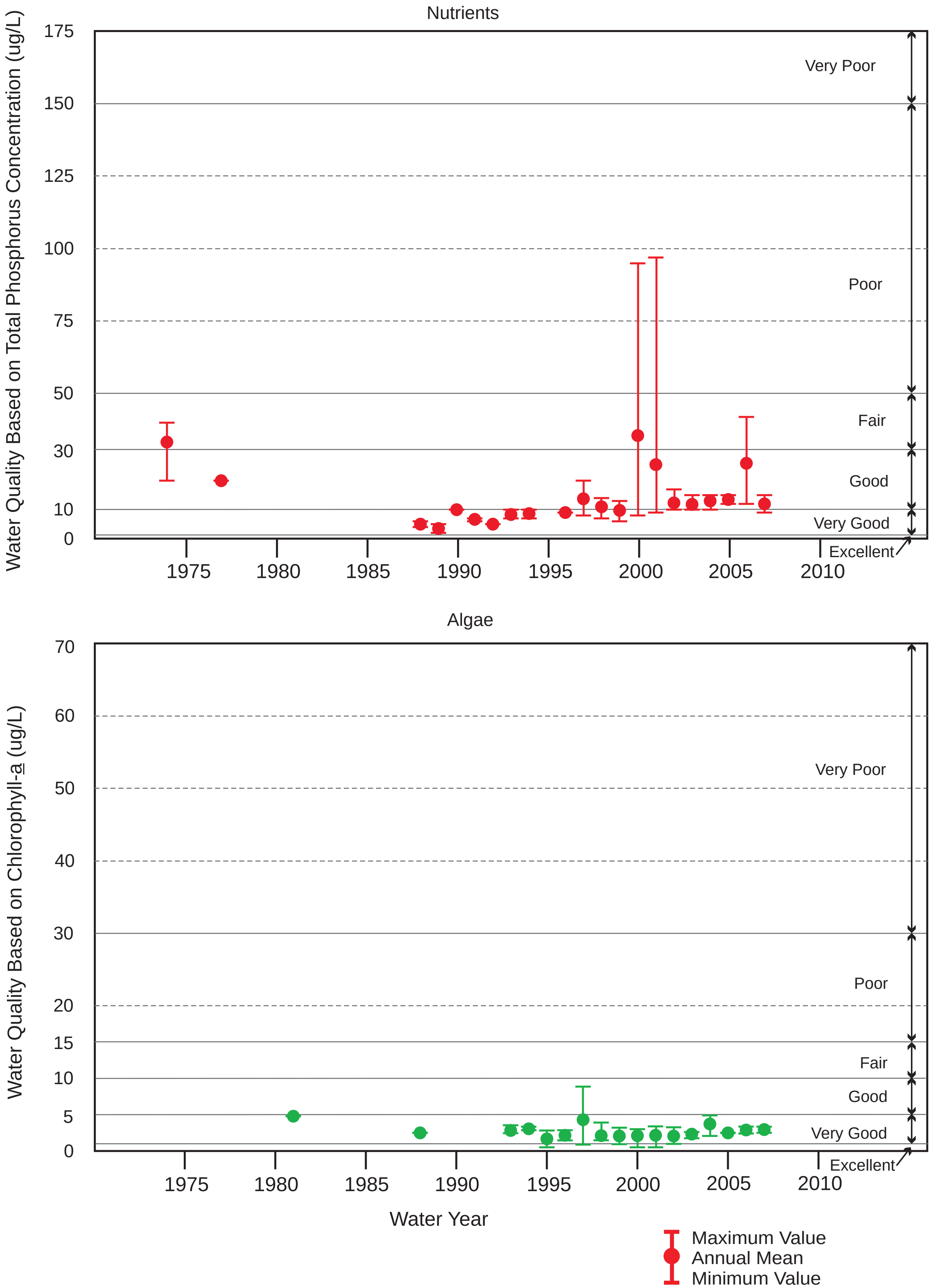
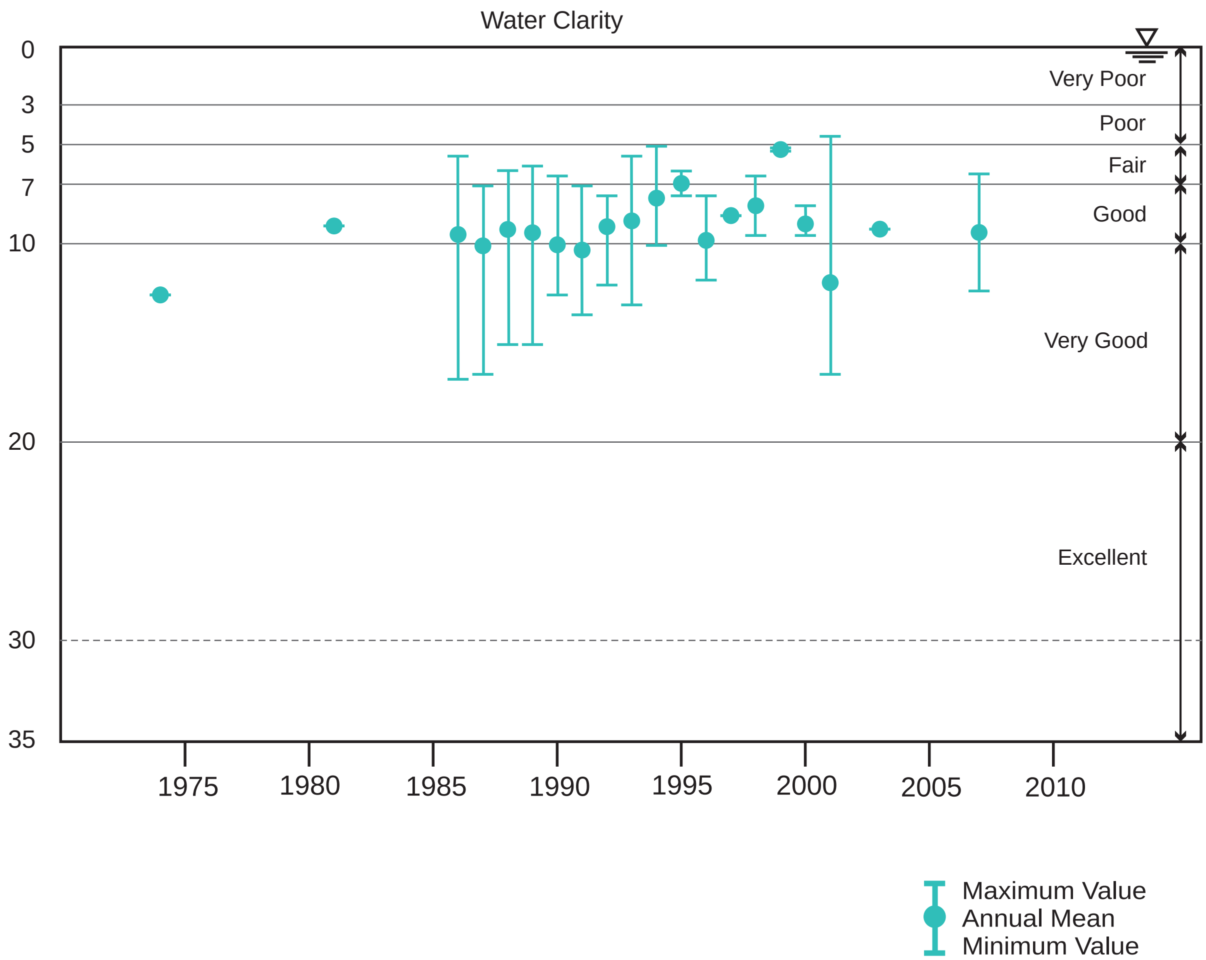


Figure 7 (continued)



Source: U.S. Geological Survey and SEWRPC.

Seasonal variations in Secchi-disk measurements, as reported in Tables 11 and 12, indicate a trend of gradually diminishing Secchi-disk depths as the seasons progress from winter, when Secchi-disk readings are typically highest, through spring and summer. Lower Secchi-disk readings in spring are not unusual for lakes in the region, and reflect the growths of algae and zooplankton during the warmer months, as well as the effects of surface runoff from the tributary area and inflows into the Lakes.

As described above, two important characteristics affecting water transparency are color and turbidity. Perceived color of lakes is often described as "green" or "brown" or some combination of these colors, and is influenced by dissolved and suspended materials in the water, phytoplankton population levels, as well as various physical factors. Actual, or true, color of lake waters is the result of substances that are dissolved in the water. For example, the brown-stained color of lakes in the northern part of the State is the result of organic acids from certain dissolved humic materials present in those waters. Oconomowoc Lake, during the current study period, consistently had low water color measurements in the main basin with values generally below 10, far below the average of 46 for lakes in the Region, indicating that Oconomowoc Lake has clearer water than most lakes in the southeastern Wisconsin.[20]

[20]Ibid.

Turbidity is another way to measure the clarity of a lake's waters. Turbidity is caused by particles of material in the water that scatter light, affecting plant growth and aesthetics of the lake. Lakes which receive large amounts of runoff from soils containing clay and silt often have high turbidities. Measured values of turbidity in the main basin of Oconomowoc Lake during the initial study period averaged about 2.0 formazin units annually between 1975 and 1977. These measurements were significantly lower the average of 6.7 formazin units reported for lakes in the Southeastern Wisconsin Region,[21] indicating clearer water than most of the lakes in the Region.

During the current study, turbidity was reported in nephelometric turbidity units (NTUs), which are not directly comparable with the data reported in formazin units used in the initial study. On average, water clarity in Oconomowoc Lake has not changed significantly over the study period. Turbidity values reported during the period from 1986 to 2005 ranged from 0.4 to 1.4 NTU in the main lake basin, as shown in Table 11.

In recent years, some lakes in southeastern Wisconsin have experienced improved water clarity that may be related to the presence of the zebra mussel, *Dreissena polymorpha,* an invasive, nonnative filter feeding mollusk known to impact water clarity in inland lakes. The WDNR lists Oconomowoc Lake as having had an established population of this species since 1999. Aside from a slight improvement in mean water clarity during 2000 as shown in Figure 7, the presence of this filter-feeding mollusk does not seem to have had any impact on water clarity in Oconomowoc Lake.

The Environmental Remote Sensing Center (ERSC), established during 1970 on the University of Wisconsin-Madison campus, was one of the first remote sensing facilities in the United States. Using data gathered by satellite remote sensing over a three year period, the ERSC generated a map based on a mosaic of satellite images showing the estimated water clarity of the largest 8,000 lakes in Wisconsin. The WDNR, through its volunteer Self-Help Monitoring Program, was able to gather clarity measurements from Secchi-disk readings for about 800 lakes, or about 10 percent of the Wisconsin's largest lakes; the satellite remote sensing technology utilized by ERSC was able to accurately estimate clarity for the remaining 90 percent. ERSC remote sensing for Oconomowoc Lake estimated average water clarity at 8.6 feet.

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 the amount of algae in the water, and its level of concentration is useful in determining the trophic status of lakes and hence the suitability of a lake for certain uses. The median chlorophyll-*a* concentration for lakes in the Southeastern Wisconsin Region is about 9.9 μg/l.[22]

During the initial study period, chlorophyll-*a* concentrations in the main basin of Oconomowoc Lake ranged from a low of 0.1 micrograms per liter (μg/l) in February 1976, to a high of 8.4 μg/l in June 1976, indicating that, at that time, algae concentrations in Oconomowoc Lake were unlikely to interfere with recreational activities.

During the current study period, chlorophyll-*a* concentrations in Oconomowoc Lake ranged from 0.2 to 6.3 μg/l in the main lake basin, and from undetectable to 8.9 μg/l in the northeastern bay, as shown in Tables 11 and 12. During these latter years, mean chlorophyll-*a* concentrations were consistently below 10 μg/l. All of these values are within the range of chlorophyll-*a* concentrations recorded in other lakes in the Region[23] and indicate very

[21]Ibid.

[22]Ibid.

[23]Ibid.

good water quality, as illustrated in Figure 7. Chlorophyll-*a* levels above about 10 μg/l range result in a green coloration of the water that may be severe enough to impair recreational activities such as swimming and skiing.[24]

Nutrient Characteristics

Nitrogen to Phosphorus Ratios

Aquatic plants and algae require such nutrients as phosphorus and nitrogen 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. The ratio of total nitrogen (N) to total phosphorus (P) in lake water indicates which nutrient is the factor most likely limiting aquatic plant growth in a lake.[25] Where the N:P ratio is greater than 14:1, phosphorus is most likely to be the limiting nutrient. If the ratio is less than 10:1, nitrogen is most likely to be the limiting nutrient.

During the initial study, the nitrogen-to-phosphorus ratios in samples collected from Oconomowoc Lake following spring turnover were always greater than 14:1. This indicates that plant production was most likely consistently limited by phosphorus.

During the current study period, the nitrogen-to-phosphorus ratios in samples collected from Oconomowoc Lake following spring turnover also were greater than 14:1.

Phosphorus Concentrations

Phosphorus in a lake can exist in several forms. 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 recommended water quality guideline for phosphorus, set forth for lakes in the adopted regional water quality management plan, is 0.02 milligrams per liter (mg/l) of total phosphorus or less during spring turnover. This is the level considered in the regional plan as necessary to limit algal and aquatic plant growth to levels consistent with the recreational and warmwater fishery and other aquatic life water use objectives. Currently, there are no State standards adopted for phosphorus concentrations in lakes, although a statewide phosphorus standard is being developed by the WDNR.

During the initial SEWRPC study period, total phosphorus concentrations averaged 0.03 mg/l annually and during spring turnover, indicating that total phosphorus concentrations in Oconomowoc Lake exceeded the levels necessary to support periodic nuisance algae blooms. The total phosphorus level in the hypolimnion at the end of the summer stratification during the initial study averaged 0.672 mg/l. Dissolved phosphorus concentrations ranged from 0.01 mg/l to 0.14 mg/l.

Following the provision of public sanitary sewerage service to the riparian communities, the spring surface water total phosphorus concentrations in Oconomowoc Lake were generally found to be less than 0.02 mg/l, as shown in Tables 11 and 12. During the current study, total phosphorus concentrations in the surface waters averaged

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[24] *J.R. Vallentyne, "The Process of Eutrophication and Criteria for Trophic State Determination," in* Modeling the Eutrophication Process—Proceedings of a Workshop at St. Petersburg, Florida, *November 19-21, 1969, pp. 57-67.*

[25] *M.O. Allum, R.E. Gessner, and T.H. Gakstatter, U.S. Environmental Protection Agency Working Paper No. 900,* An Evaluation of the National Eutrophication Data, *1976.*

0.01 mg/l annually and during spring turnover. Throughout the study period, total phosphorus in the surface waters of Oconomowoc Lake generally averaged less than 0.02 mg/l, indicating good water quality, as illustrated in Figure 7. Total phosphorus concentrations were found to be significantly higher in the bottom waters of Oconomowoc Lake during stratification. This is likely to be the result of the release of phosphorus from the anoxic bottom sediments. The average bottom water total phosphorus concentration in Oconomowoc Lake during the study period was 0.04 mg/l.

The seasonal gradients of phosphorus concentration between the epilimnion and hypolimnion reflect the biogeochemistry of this growth element. During the growing season, nutrients become depleted in the upper waters as plants utilize them for growth. When aquatic organisms die, they usually sink to the bottom of the lake, where they are decomposed resulting in an accumulation of nutrients. Phosphorus from these organisms is then either stored in the bottom sediments or rereleased into the water column, particularly under conditions of oxygen depletion, a phenomenon mentioned above as "internal loading". 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 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 the phosphorus becomes soluble again and is released from the sediments. This internal loading 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. When the mixing process is relatively slow, on the order of days to weeks, minerals and nutrients released from the sediments into the hypolimnion of the lake tend to recombine with the multivalent cations in the lake sediments and precipitate out of the water column; if the mixing process is relatively rapid, on the order of hours to days, as may occur due to the passage of an intense storm, the minerals and nutrients may be mixed upward into the epilimnion or surface waters where they are available for plant growth.[26] The magnitude of this release and its concomitant effects in contributing to algal growth in the surface waters of the Lake, therefore, may be moderated by a number of circumstances, including the rate of mixing during the spring and fall overturn events. Hence, internal loading is not considered to be a significant component of the phosphorus budget of the Lake.

CHARACTERISTICS OF THE BOTTOM SEDIMENTS

Sediment contributions also have an important effect on water quality of a lake. As the lake bottom is covered by material washed into the lake or by dead aquatic plant and animal remains, valuable benthic habitats and fish spawning sites may be covered and aesthetic nuisances may develop. Additionally, sediment composition has an important effect on the biogeochemistry of a lake. Sediment particles serve as transport mechanisms for nutrients, especially phosphorus, as well as for a variety of pollutants, and play a key role in establishing benthic habitat and macrophyte substrate.

The WDNR has estimated that sediment is accumulating in Oconomowoc Lake at a rate of about 0.03 grams per square centimeter per year ($gm/cm^2/yr$), which rate is similar to that estimated prior to European settlement in the Region.[27] This rate has been considerably higher in the past, during periods that correspond to the introduction of

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[26]*See, for example, R.D. Robarts, P.J. Ashton, J.A. Thornton, H.J. Taussig, and L.M. Sephton, "Overturn in a hypertrophic, warm, monomictic impoundment (Hartbeespoort Dam, South Africa),"* Hyperbiologia, *Volume 97, 1982, pp. 209-224.*

[27]*Bob Wakeman, Wisconsin Department of Natural Resources, "A Paleolimnological Study of the Water Quality Trends in Oconomowoc Lake, Waukesha County, Wisconsin," February 1997.*

mechanized farming techniques in the Region. However, changes in crops and cropping patterns, combined with a shift in agricultural production from row cropping to dairy farming, and the introduction of soil conservation measures, have reduced sediment transport into the Lake and, consequently, the rate of sediment deposition. These changes are discussed further below in the discussion of in-lake sinks.

POLLUTION LOADINGS AND SOURCES

Pollutant loads to a lake are generated by various natural processes and human activities that take place in the 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 through-flow lakes, like Oconomowoc Lake, pollutant loadings transported across land surfaces and inflowing streams, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities, comprise the principal routes by which contaminants enter a waterbody.[28] Currently, there are no significant point source discharges of pollutants to Oconomowoc Lake or to the surface waters tributary to Oconomowoc Lake. For this reason, the discussion that follows is based upon nonpoint source pollutant loadings to Oconomowoc Lake.

The initial report included estimated pollutant loadings from nonpoint sources of water pollution within the area directly tributary to Oconomowoc Lake. These sources included 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. Estimates were made of the nitrogen, phosphorus, and suspended solid loads to the Lake from the direct tributary area, based upon surface runoff and atmospheric contributions. Losses through the outlet also were estimated during the study year.

In addition, the initial plan reported contaminant inputs and outputs to and from surface water sources based on flow and water quality data collected from the Oconomowoc River where it enters Oconomowoc Lake; at eight paired groundwater wells strategically placed around Oconomowoc Lake; and, from the Oconomowoc River where it leaves Oconomowoc Lake. Atmospheric contributions of nitrogen, phosphorus, and suspended solids were calculated based on precipitation records and literature values for the different constituents that are considered to be the most representative for the Oconomowoc Lake region.

During the current study, the WILMS and unit area loading models were used to forecast nutrient, sediment, and metals loads to Oconomowoc Lake based upon year 2000 land use and planned year 2035 land use conditions.[29] The forecast contaminant loads to Oconomowoc Lake are set forth in Tables 13 and 14. Nonpoint-sourced phosphorus, suspended solids, and urban-derived metals input to and output from Oconomowoc Lake were estimated using the Wisconsin Lake Model Spreadsheet (WILMS version 3.0),[30] and unit area load-based (UAL-

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[28]*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.*

[29]*The Village of Oconomowoc Lake is currently exempted from the stormwater management permitting requirements set forth in Chapter NR 216 of the* Wisconsin Administrative Code *pursuant to the provisions of Section NR 216.023.*

[30]*Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-94,* Wisconsin Lake Modeling Suite Program Documentation and User's Manual, Version 3.3 for Windows*, August 2002*.

Table 13

ESTIMATED EXTERNAL SOURCES OF PHOSPHORUS IN THE TOTAL AREA TRIBUTARY TO OCONOMOWOC LAKE: 2000 AND 2035

Source	2000		2035	
	Pounds[a]	Percentage[a]	Pounds[a]	Percentage[a]
Urban				
High-Density (commercial and industrial uses)	2,242.5	21.3	3,025.2	29.0
Medium-Density (multi-family and institutional uses)	74.9	0.7	152.1	1.5
Low-Density (single-family and suburban-density residential uses)	341.8	3.2	465.2	4.4
Recreational Lands	52.9	0.5	61.7	0.5
Subtotal	2,712.1	25.7	3,704.2	35.4
Rural				
Mixed Agriculture	6,443.0	61.2	5,362.6	51.4
Extractive	97.0	0.9	97.0	0.9
Wetlands	886.4	8.4	888.6	8.5
Woodlands	328.5	3.1	328.5	3.1
Water	72.7	0.7	72.7	0.7
Subtotal	7,827.6	74.3	6,749.4	64.6
Total	10,539.7	100.0	10,453.6	100.0

[a]*Percentages estimated from WILMS model results.*

Source: SEWRPC.

based) models developed for use within the Southeastern Wisconsin Region. These estimates are contrasted with the initial nutrient and sediment load estimates set forth in the initial report in the discussion below.

It should be noted that the several lakes upstream of Oconomowoc Lake retain some proportion of the contaminant loads being generated from the tributary area. The retention of contaminants within the upstream Friess and Okauchee Lakes has been documented in recent lake management plans prepared for those lakes.[31] Similar processes occur within North Lake, although these have not been documented as recently.[32] The estimated phosphorus load to Oconomowoc Lake is net of these retained amounts of phosphorus.

Phosphorus Loading

Phosphorus has been identified as the factor generally limiting aquatic plant growth in Oconomowoc Lake. Thus, excessive levels of phosphorus in the lake are likely to result in conditions that interfere with the desired use of the lake. Consequently, knowledge of, and managing the mass of, phosphorus entering Oconomowoc Lake is a critical element in restoring and maintaining acceptable water quality in this waterbody. Phosphorus loads to the Lake were measured during the 1976 to 1977 field season, and estimated for existing 1980 and anticipated 2000

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[31]*See SEWRPC Community Assistance Planning Report No. 98, 2nd Edition,* A Water Quality Management Plan for Friess Lake, Washington County, Wisconsin, *November 1997; and, SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* A Water Quality Management Plan for Okauchee Lake, Waukesha County, Wisconsin, *December 2003.*

[32]*See SEWRPC Community Assistance Planning Report No. 54,* A Water Quality Management Plan for North Lake, Waukesha County, Wisconsin, *July 1982.*

land use conditions using land use data derived from the SEWRPC water quality simulation model and the Commission's then-current land use plan.[33]

Based upon field studies conducted during the initial 1976-1977 study year, it was estimated that 173 tons of sediment, 86,904 pounds of nitrogen, and 2,799 pounds of phosphorus entered Oconomowoc Lake. Of these loads, 3 percent of the phosphorus and 17 percent of the nitrogen entering Oconomowoc Lake came from ground-water; 3 percent of the phosphorus and 3 percent of the nitrogen from direct tributary area runoff; 72 percent of the phosphorus and 63 percent of the nitrogen from the Oconomowoc River inlet; and, 22 percent of the phosphorus and 17 percent of the nitrogen from precipitation and dry fallout being deposited directly onto the lake surface. The largest source of sediment input, estimated to be 86 percent of the total load, was from the tributary lands draining to the Oconomowoc River. Because the initial study was conducted during a drought period, the percentages of the contaminant loads attributed to the direct tributary area, 72 percent of the total phosphorus load, 63 percent of the total nitrogen load, and 86 percent of the sediment load, were noted as likely to be higher during years of more normal precipitation than were recorded during the study period.

Of these loads, it was estimated that 2,027 pounds of phosphorus, or 72 percent of the phosphorus load; 61,515 pounds of nitrogen, or 71 percent of the nitrogen load; and, 84 tons of sediment, or 49 percent of the sediment load, left Oconomowoc Lake through the outlet to the Oconomowoc River. The balance of the contaminants loads were retained within the Lake.

Existing year 1980 and forecast year 2000 phosphorus loads to the Lake also were modeled during the initial study. It was estimated that, under existing 1980 land use conditions, the total phosphorus load to Oconomowoc Lake from the lands directly tributary to the Lake was 3,560 pounds. Of this total, the major contributions of phosphorus to the Lake were delivered as: inflow from the Oconomowoc River, amounting to about 2,500 pounds, or 70 percent, of the phosphorus load; direct atmospheric contributions to the water surface, including that of Oconomowoc Lake, amounting to about 630 pounds, or 18 percent; and, inputs from onsite sewage disposal systems, amounting to about 220 pounds, or 6 percent. Under the then-forecast year 2000 conditions, the total phosphorus loadings to the Lake was anticipated to decrease to approximately 2,520 pounds per year, or by about 29 percent, below the estimated 1980 loadings. This decrease in phosphorus loadings was due to the presumed implementation of recommended water pollution control measures in the upstream and direct tributary areas, and, in particular, to the implementation of public wastewater sewerage services within the urban portions of the tributary drainage area.

The estimated phosphorus budget for Oconomowoc Lake of 10,540 pounds delivered to the Lake under existing year 2000 land use conditions is shown in Table 13. Of this total, the annual phosphorus load from the lands directly tributary to the Lake was estimated to be between 574 pounds and 2,380 pounds of phosphorus, with a most likely phosphorus load of 1,223 pounds. Approximately 22 pounds of this phosphorus load are estimated to be generated from onsite sewage disposal systems located in the area directly tributary to Oconomowoc Lake. The forecast phosphorus load from the lands directly tributary to the Lake is slightly higher than the 870 pounds of phosphorus estimated to be contributed from those lands during the initial study.

The balance of the total annual phosphorus load estimated to be delivered to Oconomowoc Lake based on 2000 land use conditions, or a further 9,317 pounds of phosphorus, was estimated to be contributed from the upstream watershed. This estimated load is significantly higher that the estimated 2,520 pounds documented in the initial study, and may reflect higher than forecast growth of urban lands within this drainage basin. Of the annual

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[33]*SEWRPC Planning Report No. 25,* A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin—2000*, Volume One,* Inventory Findings*, April 1975, and Volume Two,* Alternative and Recommended Plans*, May 1978; see also SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000*, Volume Two,* Alternative Plans*, February 1979.*

total phosphorus load, it was estimated that 2,712 pounds per year, or 26 percent of the total loading, was contributed by runoff from urban lands; 7,755 pounds per year, or 74 percent, was contributed by runoff from rural lands; and, 73 pounds, or about 1 percent, by direct precipitation onto the lake surface.

Phosphorus release from the lake bottom sediments, or “internal loading,” may also contribute phosphorus to the Lake. In the initial report, the portion of the total load contributed to the Lake from internal recycling was estimated at 3 percent of the total load, or at 80 pounds of phosphorus per year. As noted above, internal loading was not considered to be a significant component of the phosphorus budget of the Lake during the current study.

Under year 2035 conditions, as set forth in the County development plan and adopted regional land use plan, the annual total phosphorus load to the Lake is anticipated to remain relatively stable. The forecast annual phosphorus load to the Lake under buildout conditions is estimated to be 10,450 pounds or 90 pounds less than estimated under year 2000 land use conditions. This slight decline reflects the ongoing loss of agricultural lands within the drainage basin. However, this trend may be offset by the increasing utilization of agro-chemicals in urban landscaping.[34] Studies within the Southeastern Wisconsin Region indicate that urban residential lands fertilized with a phosphorus-based fertilizer can contribute up to two-times more dissolved phosphorus to a lake than lawns fertilized with a phosphorus-free fertilizer or not fertilized at all.[35] Thus, it may be anticipated that the distribution of the sources of the phosphorus load to the Lake may change, with approximately one-third of phosphorus being contributed from urban sources. To this end, the Village of Oconomowoc Lake has adopted a turf management ordinance limiting the application of lawn fertilizers containing phosphorus within the Village.[36]

Sediment Loading

As described above, sediment loads to Oconomowoc Lake were calculated during the initial study period based on direct tributary area runoff, inflow from the Oconomowoc River, and atmospheric contributions. The mass of sediment retained within the Lake and exported downstream also was estimated. This sediment budget estimated that 149 tons, or 86 percent, of the sediment entering Oconomowoc Lake arrived through inflow from the Oconomowoc River; 17 tons, or 10 percent, entered as precipitation and dry fallout to the lake surface; and, seven tons, or 4 percent, was from direct tributary area runoff. About 84 tons of sediment, or 49 percent, of the amount entering the Lake was estimated to flow out of the Lake through the Oconomowoc River, while the remaining 89 tons, or 51 percent, was retained in the Lake.

Sediments loads to Oconomowoc Lake were estimated during the current study based upon year 2000 and forecast year 2035 land use conditions. Comparable sediment loads to those calculated during the initial planning period were estimated using land use information for the area directly tributary to Oconomowoc Lake. These data, shown in Table 14, suggest an annual sediment load to the Lake of about 280 tons under year 2000 land use conditions, and of about 200 tons under planned year 2035 land use conditions.

The estimated sediment load from the total tributary area upstream of Oconomowoc Lake under existing 2000 land use conditions is shown in Table 15. An annual sediment load of 6,098 tons of sediment was estimated to be contributed to Oconomowoc Lake. Of the likely annual sediment load, it was estimated that 5,414 tons per year, or 89 percent of the total loading, was contributed by runoff from agricultural land, with about 195 tons of sediment being contributed from urban lands and 415 tons of sediment being contributed by direct precipitation onto the lake surface.

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[34]*U.S. Geological Survey Water-Resources Investigations Report No. 02-4130,* Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin, *July 2002.*

[35]Ibid.

[36]*On April 14, 2009, 2009 Wisconsin Act 9 created Section 94.643 of the* Wisconsin Statutes *relating to restrictions on the use and sale of fertilizer containing phosphorus in urban areas throughout the State of Wisconsin.*

Table 14

ESTIMATED CONTAMINANT LOADS FROM THE AREA DIRECTLY TRIBUTARY TO OCONOMOWOC LAKE: 2000 AND 2035

Land Use	2000					2035				
	Area (acres)	Sediment (tons)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (tons)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Residential	697	6.8	0.0	1.6	0.0	1,034	10.0	0.0	1.6	0.0
Commercial	13	5.1	2.9	3.0	0.1	120	47.0	26.4	3.0	1.2
Industrial	7	2.6	1.5	1.5	0.1	7	2.6	1.5	1.5	0.1
Transportation, Communications, and Utilities	230	1.1	0.0	0.0	0.0	343	1.6	0.0	0.0	0.0
Governmental	27	6.9	1.9	24.8	0.0	81	20.7	5.7	24.8	0.0
Recreational	7	0.1	0.0	0.0	0.0	18	0.2	0.0	0.0	0.0
Water	849	79.8	- -	- -	- -	856	80.5	- -	- -	- -
Wetlands	257	0.5	- -	- -	- -	257	0.5	- -	- -	- -
Woodlands	224	0.4	- -	- -	- -	224	0.4	- -	- -	- -
Extractive	2	0.5	- -	- -	- -	- -	- -	- -	- -	- -
Agricultural	788	177.3	- -	- -	- -	161	36.2	- -	- -	- -
Total	3,101	280.5	6.3	30.9	0.2	3,101	199.7	33.6	30.9	1.3

Source: SEWRPC.

Table 15

ESTIMATED CONTAMINANT LOADS FROM THE TOTAL AREA TRIBUTARY TO OCONOMOWOC LAKE: 2000 AND 2035

Land Use	2000					2035				
	Area (acres)	Sediment (tons)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (tons)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Residential	7,637	74.4	0.0	1.5	0.0	10,405	101.4	0.0	1.5	0.0
Commercial	102	39.9	22.4	3.0	1.0	241	94.4	53.0	3.0	2.4
Industrial	43	16.1	9.5	1.5	0.4	173	65.0	38.0	1.5	1.7
Transportation, Communications, and Utilities	2,470	11.7	0.0	0.0	0.0	3,217	15.3	0.0	0.0	0.0
Governmental	175	44.7	12.2	24.8	0.0	328	83.8	23.0	24.8	0.0
Recreational	590	7.8	0.0	0.0	0.0	693	8.3	0.0	0.0	0.0
Water	4,414	414.9	- -	- -	- -	4,425	415.9	- -	- -	- -
Wetlands	6,332	11.7	- -	- -	- -	6,332	11.7	- -	- -	- -
Woodlands	7,358	13.6	- -	- -	- -	7,341	13.6	- -	- -	- -
Extractive	218	49.0	- -	- -	- -	219	49.2	- -	- -	- -
Agricultural	24,063	5,414.4	- -	- -	- -	20,028	4,506.3	- -	- -	- -
Total	53,402	6,098.2	44.1	30.8	1.4	53,402	5,364.9	114.0	30.8	4.1

Source: SEWRPC.

Under 2035 conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual sediment load to the Lake from the total drainage area is anticipated to decrease by about 12 percent, with the annual sediment load to the Lake under buildout conditions being estimated to be 5,365 tons. The distribution of the sources of the sediment load to the Lake also are expected to change, with an increased mass of sediment being contributed from urban lands, estimated to contribute 368 tons of sediment per year, and less sediment being contributed from agricultural lands, estimated to be 4,510 tons of sediment per year. An estimated 415 tons of sediment per year are estimated to be contributed by direct precipitation onto the lake surface.

Urban Heavy Metals Loadings

Urbanization brings with it increased use of metals and other materials that contribute pollutants to aquatic systems.[37] The majority of these metals become associated with sediment particles,[38] and is likely to be encapsulated into the bottom sediments of the Lake. Estimated loadings of copper, zinc, and cadmium likely to be contributed to Oconomowoc Lake from the total tributary area are shown in Table 15. About 44 pounds of copper, 31 pounds of zinc, and 1 pound of cadmium were estimated to be contributed annually to Oconomowoc Lake from urban lands under year 2000 conditions, while, under year 2035 conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual heavy metal loads to the Lake are anticipated to generally increase. The annual loads to the Lake under buildout conditions are estimated to be 114 pounds of copper, 31 pounds of zinc, and 4 pounds of cadmium.

Groundwater Quality

During the initial planning program, eight paired groundwater monitoring wells around Oconomowoc Lake were installed. The purpose of the well pairs was to measure groundwater flow into or out of the Lake and to gather data on groundwater quality. Groundwater was determined to flow into the Lake from the southeast, and out of the Lake to the west and north. Groundwater flows into Oconomowoc Lake were estimated to be on the order of 4,800 acre-feet.

Groundwater contributions for nitrites and nitrates ranged from 0.10 mg/l to 4.17 mg/l; and for ammonia from 0.02 mg/l to 0.3 mg/l. Mean values of 1.15 mg/l for nitrites and nitrates, and 0.10 mg/l for ammonia, were also recorded. Total phosphorus values ranged from less than 0.01 mg/l to 0.04 mg/l, with a mean value of 0.02 mg/l. Combined with the flow measurements reported above, these concentrations resulted in inputs of phosphorus to the Lake of about 80 pounds per year and of nitrogen of about 15,214 pounds per year.

Groundwater quality was not measured during the current study period; however, for the purposes of contaminant load assessments, the measured loads reported during the initial planning period were assumed to be applicable.

In-Lake Sinks

During the initial study period, of the annual total phosphorus load entering Oconomowoc Lake, it was estimated that 28 percent of the total phosphorus load, or 772 pounds of phosphorus, was retained within the Lake.[39] This mass of phosphorus is either used by the biomass within the Lake or deposited in the lake sediments. The balance of the phosphorus entering the Lake was transported downstream.

During the current study period, it was estimated that about one-half of the phosphorus load is retained within Oconomowoc Lake.

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[37] *Jeffrey A. Thornton, et al.,* op. cit.

[38] *Werner Stumm and James J. Morgan,* op. cit.

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

The WDNR conducted a paleolimnological study of Oconomowoc Lake, which examined sediment cores from the lake bottom of approximately one-foot in length.[40] Using lead-210 dating techniques, this length of core was estimated to date from the early-1800s to the present. Examination of the core sample suggested sedimentation rates that ranged from 0.03 grams per square centimeter per year ($g/cm^2/yr$) to 0.72 $g/cm^2/yr$, with the highest rates of sediment deposition being coincident with the post-Civil War era, 1850 to 1870, and pre-First World War era, 1920 to 1930. Since the 1960s, sedimentation rates in the Lake were estimated to be 0.04 $g/cm^2/yr$. The highest sedimentation rates coincided with a period of intensive wheat farming during the 1800s and the introduction of mechanized farming techniques in the 1920s. Changes in cropping patterns, with a switch to dairying in the 1940s, contributed to the recent reduction in sedimentation. Dairying, however, did result in higher nutrient loads to the Lake, which were reflected in a change in the diatom flora of the Lake to species more indicative of enriched conditions. Many of these species have remained present in the sediments, although there is an indication that water quality has improved in recent years, which findings are consistent with the water quality data set forth in this chapter.

RATING OF TROPHIC CONDITION

Lakes are commonly classified according to their degree of nutrient enrichment, or trophic status. The ability of lakes to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated to the degree of nutrient enrichment which has occurred. There are three terms generally 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 very productive fisheries. Oligotrophic lakes may provide excellent opportunities for swimming, boating, and waterskiing. Because of the naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

Mesotrophic lakes are moderately fertile lakes which may support abundant aquatic plant growths and productive fisheries. However, nuisance growths of algae and macrophytes are usually not exhibited by mesotrophic lakes. These lakes may provide opportunities for all types of recreational activities, including boating, swimming, fishing, and waterskiing. Many lakes in southeastern Wisconsin are mesotrophic.

Eutrophic lakes are nutrient-rich lakes. These lakes often exhibit excessive aquatic macrophyte growths and/or experience frequent algae blooms. If the lakes are shallow, fish winterkills may be common. While portions of such lakes are not ideal for swimming and boating, eutrophic lakes may support very productive fisheries.

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 appropriate for Wisconsin lakes have been used; namely, the Vollenweider-OECD open-boundary trophic classification system,[41] and the Carlson Trophic State Index (TSI).[42] In addition, the Wisconsin Trophic

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[40]*Bob Wakeman,* op. cit.

[41]*Organization for Economic Cooperation and Development (OECD),* Eutrophication of Waters: Monitoring, Assessment, and Control, *Paris, 1982; see also H. Olem and G. Flock, U.S. Environmental Protection Agency Report EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *Washington, D.C., August 1990.*

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

State Index value (WTSI) is presented.[43] The WTSI is a refinement of the Carlson TSI designed to account for the greater humic acid content—brown water color—present in Wisconsin lakes, and has been adopted by the WDNR for use in lake management investigations.

Vollenweider Trophic State Classification

Vollenweider's Model assigns a trophic condition rating based on the ration of mean lake depth to hydraulic residence time and phosphorus loading per unit of lake surface. The phosphorus loadings to Oconomowoc Lake during the current study, based on USGS study results, indicated that Oconomowoc Lake was mesotrophic, or moderately enriched. Using the Vollenweider trophic system and applying the current data in Table 10, Oconomowoc Lake would be classified as having about a 50 percent probability of being oligotrophic based upon phosphorus levels, as shown in Figure 8. The Lake would have about a 40 percent probability of being mesotrophic, and less than a 5 percent probability of being either eutrophic or ultra-oligotrophic, based upon mean annual phosphorus concentrations. Based upon chlorophyll-*a* levels, the Lake would be classified as having about a 50 percent probability of being mesotrophic, with about a 40 percent probability of being eutrophic and about a 5 percent probability of being either ultra-oligotrophic or eutrophic, as shown in Figure 8. Based upon Secchi-disk readings, the Lake would be classified as having a 50 percent probability of being eutrophic, with a 30 percent probability of being mesotrophic, a 15 percent probability of being hypertrophic and a 5 percent probability of being oligotrophic, as shown in Figure 8. While these indicators result in slightly differing lake trophic state classifications, it may be concluded that Oconomowoc 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 (TSI) assigns a numerical trophic condition rating based on Secchi-disk transparency, total phosphorus, and chlorophyll-*a* concentrations. The original Trophic State Index developed by Carlson has been modified for Wisconsin lakes by the WDNR using data on 184 lakes throughout the State.[44] Based on the Trophic State Index ratings during the initial study, Oconomowoc Lake was classified as mesotrophic. Remote sensing data gathered as part of the aforementioned ERSC program, estimated a TSI rating of 46 for Oconomowoc Lake, which places Oconomowoc Lake in the mesotrophic category with fair to good water clarity. The Wisconsin Trophic State Index (WTSI) ratings for Oconomowoc Lake based on current data are shown in Figure 9 as a function of sampling date. The Secchi-disk-based Wisconsin Trophic State Index ratings of between 40 and 50 suggest that Oconomowoc Lake may be classified as mesotrophic. These values remain relatively constant throughout the study period. In contrast, based upon the WTSI values calculated from total phosphorus concentration, Figure 9 clearly shows an improvement in lake trophic status between the 1970s and 1990s, with the WTSI decreasing from between 50 and 60 to about 30. This improvement in water quality is likely to be, in part, the result of the construction of the sewerage system and diversion of treated wastewater treatment plant effluent to a discharge point downstream of Oconomowoc Lake. Since the late 1980s, average total phosphorus-based WTSI values have increased to between 40 and 50, with a similar trend being observed in the chlorophyll-*a* based WTSI values, which have increased from about 35 to about 45. These increasing WTSI values in recent years may indicate some cause for concern, although median WTSI values have been relatively constant since 1997, fluctuating around a value of about 45 for the total phosphorus-based WTSI value and around 40 for the chlorophyll-*a* based WTSI value. All of these recent values are indicative of a mesotrophic state.

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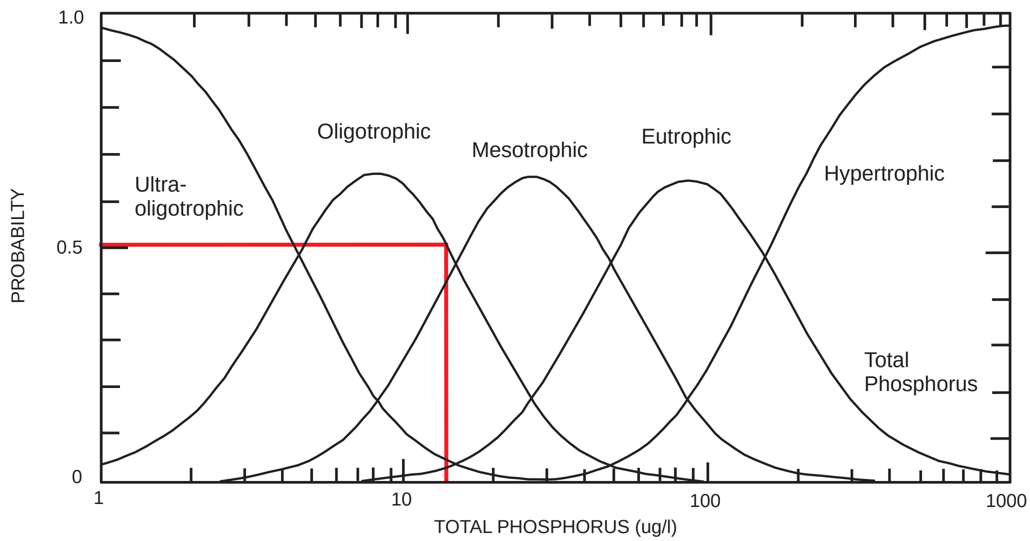
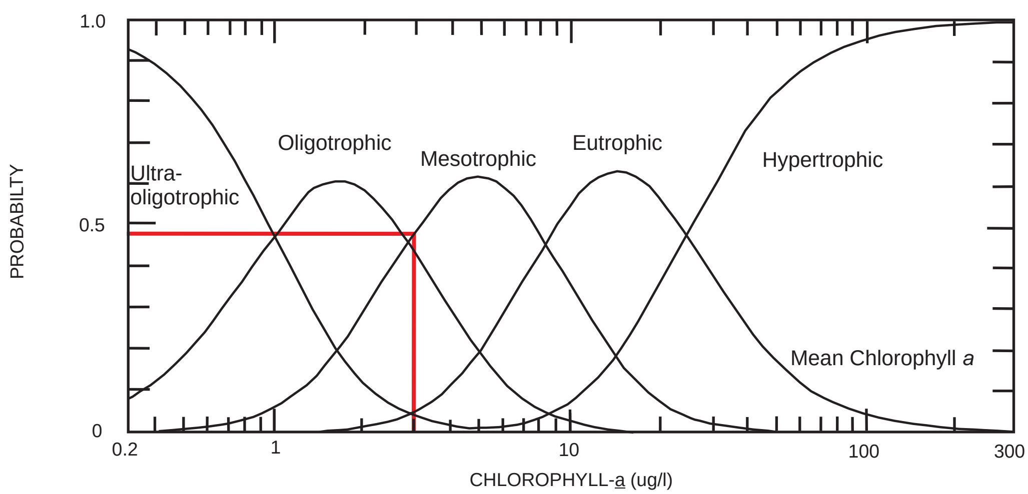
[43] *See R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings, *Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

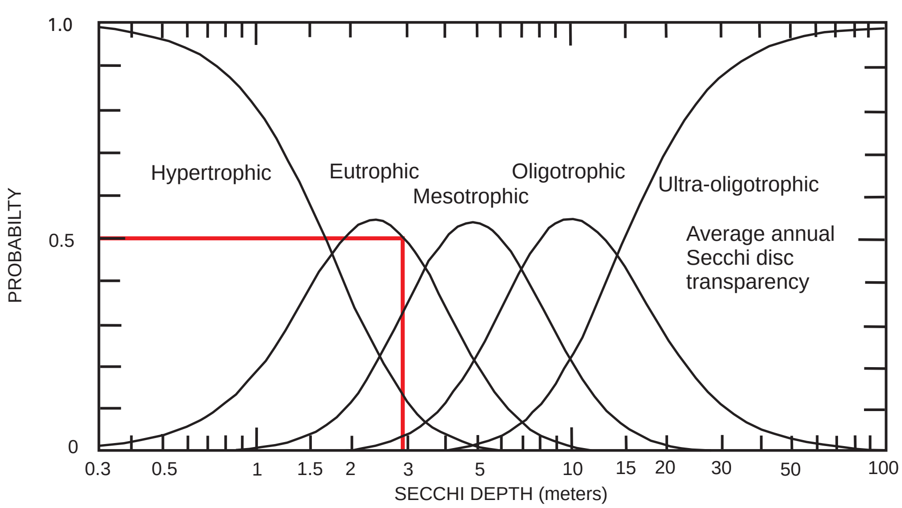
[44] *R.A. Lillie, S. Graham, and P. Rasmussen*, op. cit.

Figure 8

TROPHIC STATE CLASSIFICATION OF OCONOMOWOC LAKE BASED UPON THE VOLLENWEIDER MODEL: 2007



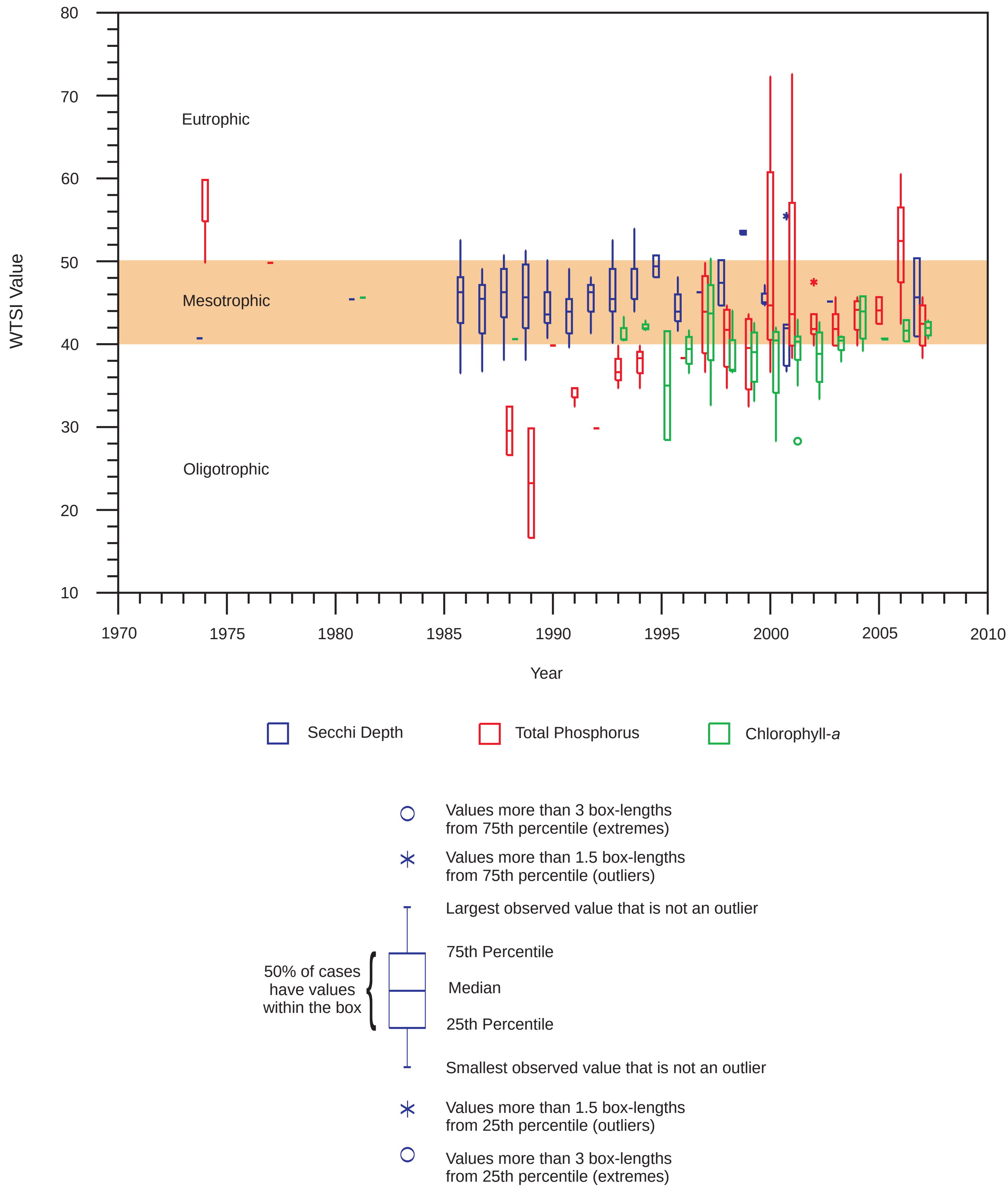




Source: U.S. Geological Survey and SEWRPC.

Figure 9

WISCONSIN TROPHIC STATE INDICES FOR OCONOMOWOC LAKE



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

SUMMARY

Oconomowoc Lake represents a typical hard-water, alkaline lake that is considered to have relatively good water quality. Total phosphorus levels were found to be generally below the level considered to cause nuisance algal and macrophytic growths. Summer stratification was commonly observed in Oconomowoc Lake. Nevertheless, the surface waters of the Lake remained well oxygenated and supported a healthy fish population. Winterkill was not a problem in Oconomowoc Lake because of the substantial volume of the Lake that provided adequate oxygenated water volume for the support of fish throughout the winter. Internal releases of phosphorus from the bottom sediments were not considered to be a problem in Oconomowoc Lake.

There were no significant point sources of pollutants in the Oconomowoc Lake tributary area. Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. In 2000, the total annual phosphorus load to Oconomowoc Lake was estimated to be 10,500 pounds. Runoff from the rural lands contributed the largest amount of phosphorus, about 74 percent of the total phosphorus load, with the runoff from urban lands contributing about 25 percent of the total phosphorus load. In addition, direct precipitation onto the lake surface contributed about 1 percent of the total phosphorus load, or a relatively minor amount of phosphorus, to the Lake. Agricultural lands constituted the primary source of phosphorus to the Lake under current land use conditions within the area tributary to the Lake. Under forecast buildout conditions, the phosphorus load to the Lake is expected to remain at about 10,500 pounds per year, although the load generated from rural lands is expected to diminish slightly, to about 64 percent of the total load. In contrast, the phosphorus load from urban lands is anticipated to increase to about 35 percent of the phosphorus load to Oconomowoc Lake, although this anticipated increase in phosphorus load from urban lands may be moderated when the restrictions (enacted during 2009, to take effect in 2010) on the use of fertilizers containing phosphorus on residential properties, golf courses, and publicly owned lands take effect. Direct precipitation onto the lake surface is expected to continue to contribute about 1 percent of the total phosphorus load to the Lake.

Approximately 50 percent, or 5,300 pounds, of the total phosphorus loading is estimated to remain in the Lake by conversion to biomass or through sedimentation.

Based on the Vollenweider phosphorus loading model and the Wisconsin Trophic State Index ratings of between 40 and 50 calculated from Oconomowoc Lake data, Oconomowoc Lake may be classified as a mesotrophic lake.

Chapter V

AQUATIC BIOTA AND ECOLOGICALLY VALUABLE AREAS

INTRODUCTION

Oconomowoc Lake is an important element of the natural resource base of northwestern Waukesha County. The Lake and its biota contribute to the quality of life of the residential community in the area, and to the quality experiences of area visitors. In urban settings, natural resource features such as lakes and wetlands typically are subjected to extensive recreational use pressures and high levels of pollutant discharges. These common forms of stress to aquatic systems may result in the deterioration of the natural resource features, altering the nature and quality of the experiences of residents and visitors alike, and modifying the species compositions in both terrestrial and aquatic ecosystems. For this reason, the formulation of sound management strategies must be based on a thorough knowledge of the pertinent characteristics of the individual resource features, as well as of the urban development in the area concerned. Accordingly, this chapter provides information on the natural resource features of the Oconomowoc Lake tributary area, including data on aquatic macrophytes, fish, wildlife, wetlands and woodlands, and environmental corridors. Water quality conditions have been described in Chapter IV, while recreational activities are described and quantified in Chapter VI.

AQUATIC PLANTS

Aquatic plants include larger plants, or macrophytes, and microscopic algae, or phytoplankton. These plants form an integral part of the aquatic food web, converting inorganic nutrients present in the water and sediments into organic compounds that are directly available as food for other aquatic organisms. In the process known as photosynthesis, plants utilize energy from sunlight and release oxygen also required by other aquatic life forms. These plants form both the food stocks for, and habitat of, the larger aquatic animals present in the Lake and associated stream systems.

To document the types, distribution, and relative abundance of the aquatic plants in Oconomowoc Lake, the initial planning report compiled by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) presented data from surveys conducted by the Wisconsin Department of Natural Resources (WDNR) during 1976 and 1977.[1] Phytoplankton and macrophyte populations were sampled during those surveys. As part of the current planning effort, the Commission staff conducted a further aquatic plant survey during the summer of 2005. Data from these various phytoplankton and aquatic macrophytes surveys are summarized below.

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[1]*SEWRPC Community Assistance Planning Report No. 181*, A Water Quality Management Plan for Oconomowoc Lake, Waukesha County, Wisconsin, *March 1990.*

Phytoplankton
Phytoplankton or algae are small, generally microscopic, plants that are found in all lakes and streams. They occur in a wide variety of forms, as single cells or as multiple-celled colonies or filaments, and can be either attached or free floating. Algae are primary producers that form one of the bases of the aquatic food web. As primary producers, they utilize the process of photosynthesis to convert energy and nutrients to the compounds necessary to support life in the aquatic system. Oxygen, which is vital to higher forms of life in a lake or stream, also is produced during the photosynthetic process.

Algae are generally classified according to their dominant pigment; for example, green, blue-green, yellow-brown, and golden brown. Green algae (Chlorophyta) are the most important sources of food for zooplankton, or microscopic animals, in the lakes of southeastern Wisconsin. Blue-green algae (Cyanophyta) are not ordinarily utilized by zooplankton or fish populations, and may become over-abundant and out of balance with the organisms that feed on them. Dramatic population increases, or "blooms," of blue-green algae may occur when excessive nutrient supplies are available, optimum sunlight and temperature conditions exist, and there is a lack of competition from other aquatic plant species and insufficient grazing by zooplankton. In contrast, yellow-brown algae and golden-brown algae are adapted to growth under low-light conditions and cooler water temperatures.

Phytoplankton communities and abundances vary seasonally with fluctuations in solar irradiance, turbulence due to prevailing winds, and nutrient availability. In temperate lakes, there is a typical seasonal succession of algae, beginning with a spring diatom maximum and progressing through a period of green algal and blue-green algal dominance during the summer months. Chrysophytes, or yellow-brown algae, tend to dominate during the autumn and winter months. In lakes with high nutrient levels, heavy growths of phytoplankton, or algal blooms, may occur. Algal blooms have occasionally been perceived as a problem on Oconomowoc Lake.

Algal blooms may reach nuisance proportions in fertile, or eutrophic-lakes, resulting in the accumulation of surface scums or slimes. In some cases, heavy concentrations of wind-blown algae accumulate on shorelines, where they die and decompose, causing noxious odors and unsightly conditions. The decaying algae consume oxygen, sometimes depleting available supplies and resulting in fish kills. Also, certain species of decomposing blue-green algae may release toxic materials into the water.

Algal species present in Oconomowoc Lake were identified and enumerated as part of the aforementioned initial SEWRPC report.[2] At that time, the blue-green algae dominated the algal population in samples collected from May through October 1976. During the peak population periods, late-June and mid-September, blue-green algae comprised about 78 percent and 96 percent of the total algal population, respectively. During November, cooler water temperatures and low-light conditions favored the diatoms and golden-brown algae whose populations peaked, with diatoms and golden-brown algae comprising as much as 65 percent of the total algal population. *Asterionella formosa* was reported as the dominant alga (diatom) observed, being present at an abundance of 2,750 cells per milliliter (cells/ml). By mid-December, blue-green algae regained their dominant status, totaling 43 percent of the total algae population. The lowest number of algae was recorded in January 1977, when *Chroomonas* sp. and *Cryptomonas* sp., were the dominant species of golden-brown algae. After ice-out the following March, the diatoms increased in numbers once again and became the dominant algal group, comprising 41 percent of the total population. Such a spring diatom increase is typical of north temperate lakes because diatoms thrive in cold water temperatures when adequate light and nutrients are available. As temperatures warmed, golden-brown algae became more common, reaching their maximum level of growth by mid-April, when they made up about 67 percent of the algal population. By the end of April, the blue-green algae had again become the dominant algal group, the result of a combination of slow growth rates and low loss rates.

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[2]Ibid.

The low loss rates amongst cyanophytes can be attributed, in part, to special adaptations by some blue-green species. Some blue-green algae, for example, possess air cells which allow them to regulate their buoyancy, minimizing the loss of cells by sedimentation and maximizing their growths by allowing them to control their vertical position in the water in order to obtain optimal levels of light and nutrients. The blue-green alga, *Coelosphaerium naegelianum*, for example, forms hollow spheres of numerous coccoid algae and, during bloom periods and the ensuing decomposition period, may be deposited as wind-concentrated accumulations along shorelines. Blue green algae, because of this bloom forming capacity and scum formation on windward shores, are often associated with odor problems, and thereby have a negative impact on recreational and aesthetic qualities of a lake.

Data on the types and concentrations of algae found in Oconomowoc Lake were not collected during the current study period. Rather, the density of algal populations was evaluated based upon the concentrations of the green algal pigment, chlorophyll-*a*. The chlorophyll-*a* concentrations of less than 10 mg/m^3, reported in Tables 11 and 12 in Chapter IV of this report, generally indicate relatively low populations of algae and very good water quality, as illustrated in Figure 6, also in Chapter IV of this report. Concentrations above this threshold level generally indicate that algal populations are at densities that result in a green coloration of the water that may be severe enough to impair recreational activities such as swimming and skiing.[3]

Aquatic Macrophytes

Aquatic macrophytes play an important role in the ecology of southeastern Wisconsin lakes. Depending on their type, distribution, and abundance, they can be either beneficial or a nuisance. Macrophytes growing in the locations and in densities that do not significantly interfere with human access to the water and recreational uses, such as boating and swimming, are beneficial in maintaining lake fisheries and wildlife populations. Macrophytes provide habitat for other forms of aquatic life and may remove nutrients from the water that otherwise could contribute to excessive algal growth. When their densities become so great as to interfere with swimming and boating activities, when their growth forms limit habitat diversity, and when the plants reduce the aesthetic appeal of the resource, some form of control may be required to ensure the ongoing multiple-purpose use of the Region’s lakes. Many factors, including lake shape, depth, water clarity, nutrient availability, bottom substrate composition, wave action, and the type and size of fish populations present, determine the distributions and abundance of aquatic macrophytes in a lake.

To document the types, distribution, and relative abundance of aquatic macrophytes in Oconomowoc Lake, an aquatic plant survey was conducted on the Lake in 1976.[4] This survey indicated that the macrophyte flora in Oconomowoc Lake was sparse to moderate during the initial study period, but relatively diverse. The dominant species in all areas of the Lake was muskgrass (*Chara* spp.). Muskgrass and coontail (*Ceratophyllum demersum*) were especially abundant along the eastern shoreline of the Lake. Emergent shoreline species were comprised primarily of bulrush (*Scirpus* sp.) and rush (*Juncus* sp.). Floating plants, such as water lilies (*Nuphar* sp. and *Nymphaea* sp.), were not common in Oconomowoc Lake at that time, although isolated patches were observed in the southeastern and southwestern corners of the main lake basin and in some of the shallow areas along the northern shoreline. Other macrophytes species recorded at that time included several varieties of pondweed (*Potamogeton foliosus*, *P. pectinatus*, *P. natans*, *P. crispus*, and *P. richardsonii*), eel-grass (*Vallisneria* sp.), and northern water milfoil (*Myriophyllum exalbenscens*, *M. sibiricum*). Eurasian water milfoil (*Myriophyllum spicatum*) was not recorded during this initial survey.

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[3]*J.R. Vallentyne, 1969 “The Process of Eutrophication and Criteria for Trophic State Determination.” in* Modeling the Eutrophication Process—Proceedings of a Workshop at St. Petersburg, Florida*, November 19-21, 1969, pp. 57-67.*

[4]*SEWRPC Community Assistance Planning Report No. 181,* op. cit.

Eurasian water milfoil is one of eight milfoil species found in Wisconsin and the only one known to be an exotic or nonnative plant as defined pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*. Consequently, the presence of Eurasian water milfoil in lakes is a reason for concern. Because of its nonnative nature, Eurasian water milfoil has few natural enemies that can control its potentially explosive growth, which the plant typically exhibits in lakes with organic-rich sediments or where the lake bottom has been disturbed. In such cases, the Eurasian water milfoil populations can displace native plant species. This, in turn, can lead to the loss of plant diversity, degradation of water quality, and reduction in habitat value for fish, invertebrates, and wildlife. In addition, the plant has been known to cause severe aesthetic and recreational use problems in lakes in southeastern Wisconsin. The WDNR lists Oconomowoc Lake as a Wisconsin waterbody in which a hybrid of Eurasian water milfoil and native northern water milfoil, as determined by DNA analysis, has been present since 1994, albeit in relatively confined distributions of limited geographic area.

In 2005, SEWRPC staff conducted an aquatic plant survey of Oconomowoc Lake, the results of which are shown in Table 16. Illustrations of representative macrophyte species identified in Oconomowoc Lake at that time are set forth in Appendix A. Of the 18 submergent aquatic plants observed in Oconomowoc Lake during August of 2005, the dominant species was muskgrass (*Chara* spp.). Also present in significant numbers were bladderwort *(Utricularia vulgaris)*, eel-grass (*Vallisneria americana*), Illinois pondweed (*Potamogeton illinoensis)*, and northern water milfoil (*Myriophyllum sibiricum*). Eurasian water milfoil (*Myriophyllum spicatum*) was present, but not in significant numbers. Based upon the observations of the WDNR staff, the water milfoil community within Oconomowoc Lake should be considered as being comprised in part of hybridized varietals of Eurasian water milfoil and northern water milfoil, with these hybrid varietals co-existing with the nonhybridized varietals of the two species.

In general, Oconomowoc Lake supports a healthy and diverse aquatic macrophyte community. The distribution of the aquatic plant communities in Oconomowoc Lake is shown on Map 14. The beneficial nature of the aquatic plant community in Oconomowoc Lake, as well as the importance of this community in maintaining the ecological balance in the Lake, is generally recognized by the lakeshore residents, although some residents have reported difficulties with navigation in portions of the Lake. Generally, the diversity of the plant community in and adjacent to the Lake contributes to the wildlife habitat value of the area, as set forth below. Fish, waterfowl, muskrats, and other wetland wildlife species dependent on aquatic vegetation for feeding and nesting, brooding, or resting areas are known to make use of the Lake. The positive ecological values of the aquatic plants reported from Oconomowoc Lake are set forth in Table 17.

Aquatic Plant Management

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the WDNR prior to 1950. Thus, while previous interventions were likely, the recorded efforts to manage the aquatic plants in Oconomowoc Lake have taken place since 1950. Aquatic plant management activities in Oconomowoc Lake can be categorized as primarily chemical control. Currently, all forms of aquatic plant management are subject to permitting by the WDNR pursuant to authorities granted the Department under Chapters NR 107 and NR 109 of the *Wisconsin Administrative Code*.

Chemical Controls

Perceived excessive growths of macrophytes in Oconomowoc Lake have generally resulted in the application of chemical controls. Recorded herbicide treatments that have been applied to Oconomowoc Lake are set forth in Table 18. In Wisconsin, the use of chemicals to control aquatic plants and algae has been regulated since 1941, even though records of aquatic herbicide applications have only been maintained by the WDNR since 1950.

In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison area, and, by the 1930s, sodium arsenite was widely used throughout the State for aquatic plant control. No other chemicals were applied in significant amounts to control macrophytes until recent years, when a number of organic chemical herbicides came into general use. The amounts of sodium arsenite applied to Oconomowoc Lake, and years of application during the period 1950 through 1967, are listed in Table 18. The total amount of sodium arsenite applied over this 17-year period was about 33,322 pounds.

Table 16

FREQUENCY OF OCCURRENCE AND DENSITY RATINGS OF SUBMERGENT PLANT SPECIES IN OCONOMOWOC LAKE: AUGUST 2005

Aquatic Plant Species Present	Number of Sites Found	Frequency of Occurrence[a] (percent)	Relative Density[b]	Importance Value[c]
Bladderwort *(Utricularia vulgaris)*	125	61.9	2.2	136.1
Bushy Pondweed *(Najas flexilis)*	62	30.7	2.0	60.0
Clasping-Leaf Pondweed *(Potamogeton richardsonii)*	5	2.5	2.0	5.0
Coontail (*Ceratophyllum demersum*)	24	1.9	2.1	25.2
Curly-Leaf Pondweed *(Potamogeton crispus)*	2	1.0	1.5	1.5
Eel-Grass/Wild Celery *(Vallisneria americana)*	93	46.0	2.7	126.2
Elodea *(Elodea Canadensis)*	1	0.5	2.0	1.0
Eurasian Water Milfoil *(Myriophyllum spicatum)*	39	19.3	2.2	42.1
Flat-Stem Pondweed *(Potamogeton zosteriformis)*	5	2.5	1.4	3.5
Illinois Pondweed *(Potamogeton illinoensis)*	81	40.1	1.8	71.3
Leafy Pondweed *(Potamogeton foliosis)*	6	3.0	1.2	3.5
Muskgrass *(Chara vulgaris)*	185	91.6	3.5	321.3
Northern Water Milfoil *(Myriophyllum sibiricum)*	78	38.6	2.2	83.2
Sago Pondweed *(Potamogeton pectinatus)*	64	31.7	2.2	68.3
Spiny Naiad *(Najas marina)*	47	23.3	1.8	41.1
Variable Pondweed *(Potamogeton gramineus)*	17	8.4	1.2	9.9
White-Stem Pondweed (*Potamogeton praelongus*)	15	7.4	1.4	10.4
White-Water Crowfoot (*Rannunculus longirostris*)	1	0.5	3.0	1.5

NOTE: There were 202 sites sampled during the August 2005 survey.

[a]*The percent frequency of occurrence is the number of occurrences of a species divided by the number of samplings with vegetation, expressed as a percentage. It is the percentage of times a particular species occurred when there was aquatic vegetation present, and is analogous to the Jesson and Lound point system.*

[b]*The average or relative density is the sum of density ratings for a species divided by the number of sampling points with vegetation. The maximum density possible of 4.0 is assigned to plants that occur at all four points sampled at a given depth and is an indication of how abundant a particular plant is throughout a lake.*

[c]*The importance value is the product of the relative frequency of occurrence and the average density, expressed as a percentage. This number provides an indication of the dominance of a species within a community.*

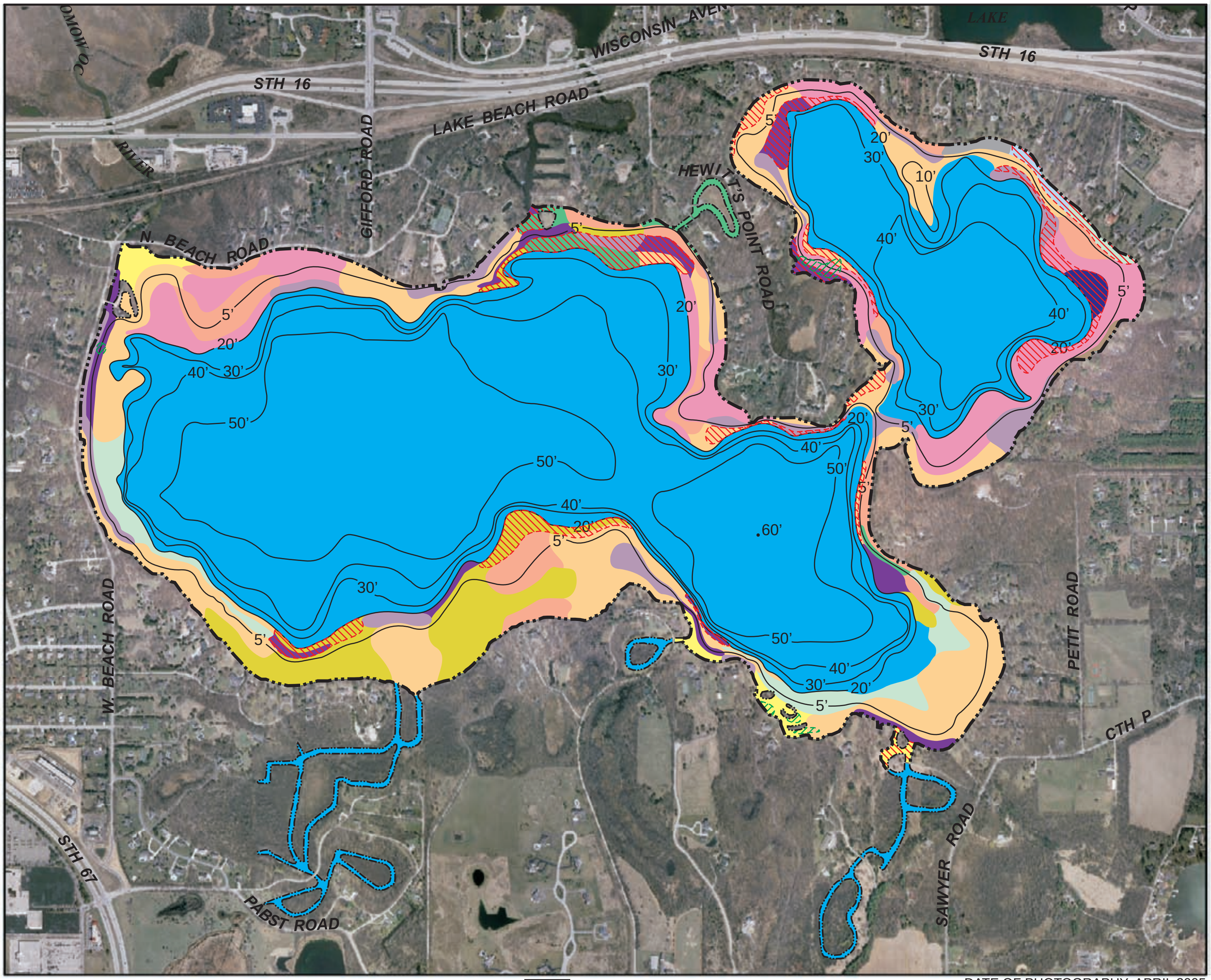
Source: SEWRPC.

Sodium arsenite was typically sprayed onto the surface of Oconomowoc Lake within an area up to 200 feet from the shoreline. Treatment typically occurred between mid-June and mid-July. The amount of sodium arsenite used was calculated to result in a concentration of about 10 milligrams per liter (mg/l) sodium arsenite (about five mg/l arsenic) in the treated lake water. The sodium arsenite typically remained in the water column for less than 120 days. Although the arsenic residue was naturally converted from a highly toxic form to a less toxic and less biologically active form, much of the arsenic residue was deposited in the lake sediments. When it became apparent that arsenic was accumulating in the sediments of treated lakes and that the accumulations of arsenic were found to present potential health hazards both to humans and aquatic life, the use of sodium arsenite was discontinued in the State in 1969. Draft sediment quality criteria limits set forth by the WDNR are shown in Table 19.

As shown in Table 18, the aquatic herbicides diquat, endothall, and 2,4-D also have been applied to Oconomowoc Lake to control aquatic macrophyte growths. Diquat and endothall (Aquathol®) are contact herbicides that kill aquatic plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Endothall primarily kills pondweeds, but does not control other potentially nuisance species, such as

Map 14

AQUATIC PLANT COMMUNITY DISTRIBUTION IN OCONOMOWOC LAKE: 2005



DATE OF PHOTOGRAPHY: APRIL 2005

- 20' — WATER DEPTH CONTOUR IN FEET
- OPEN WATER
- WATER LILIES
- EURASIAN WATER MILFOIL
- MUSKGRASS, BLADDERWORT, AND BUSHY PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, AND ILLINOIS PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, SAGO PONDWEED, NATIVE WATER MILFOIL, AND NITELLA
- MUSKGRASS, WILD CELERY, COONTAIL, NATIVE WATER MILFOIL, WATERWEED, BUSHY PONDWEED, AND SAGO PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, BUSHY PONDWEED, NATIVE WATER MILFOIL, AND ILLINOIS PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, SAGO PONDWEED, NATIVE WATER MILFOIL, SPINY NAIAD, BUSHY PONDWEED, AND ILLINOIS PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, ILLINOIS PONDWEED, SAGO PONDWEED, AND WHITE WATER CROWFOOT
- MUSKGRASS, BLADDERWORT, WILD CELERY, SAGO PONDWEED, FLAT-STEM PONDWEED, SPINY NAIAD, NATIVE WATER MILFOIL, ILLINOIS PONDWEED, BUSHY PONDWEED, CLASPING-LEAF PONDWEED, AND COONTAIL
- MUSKGRASS, BLADDERWORT, WILD CELERY, BUSHY PONDWEED, SAGO PONDWEED, COONTAIL, SPINY NAIAD, NATIVE WATER MILFOIL, WHITE-STEM PONDWEED, AND LEAFY PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, BUSHY PONDWEED, NATIVE WATER MILFOIL, SAGO PONDWEED, CURLY-LEAF PONDWEED, AND WHITE-STEM PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, ILLINOIS PONDWEED, NATIVE WATER MILFOIL, BUSHY PONDWEED, SPINY NAIAD, AND SAGO PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, ILLINOIS PONDWEED, COONTAIL, NATIVE WATER MILFOIL, BUSHY PONDWEED, SPINY NAIAD, VARIABLE PONDWEED, AND SAGO PONDWEED
- MUSKGRASS, BLADDERWORT, WILD CELERY, ILLINOIS PONDWEED, NATIVE WATER MILFOIL, BUSHY PONDWEED, SPINY NAIAD, SAGO PONDWEED, VARIABLE PONDWEED, AND WHITE-STEM PONDWEED

GRAPHIC SCALE

0 750 1500 FEET

Source: SEWRPC.

Table 17

POSITIVE ECOLOGICAL SIGNIFICANCE OF AQUATIC PLANT SPECIES PRESENT IN OCONOMOWOC LAKE

Aquatic Plant Species Present	Ecological Significance
Ceratophyllum demersum (coontail)	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris (muskgrass)	Excellent producer of fish food, especially for young trout, bluegills, small and largemouth bass, stabilizes bottom sediments, and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis (waterweed)	Provides shelter and support for insects which are valuable as fish food
Myriophyllum sibiricum (northern water milfoil)	Provides food for waterfowl, insect habitat and foraging opportunities for fish
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
Najas marina (spiny naiad)	Important food source for ducks
Potamogeton crispus (curly-leaf pondweed)	Provides food, shelter and shade for some fish and food for wildfowl
Potamogeton foliosis (leafy pondweed)	Provides food for geese and ducks; food for muskrat, beaver and deer; good surface area for insects and cover for juvenile fish
Potamogeton gramineus (variable pondweed)	Provides habitat for fish and food for waterfowl, muskrat, beaver and deer
Potamogeton illinoensis (Illinois pondweed)	Provides shade and shelter for fish; harbor for insects; seeds are eaten by wildfowl
Potamogeton pectinatus (Sago pondweed)	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton praelongus (white-stem pondweed)	Good food provider for waterfowl, muskrat, and some fish species; valuable habitat for musky. Considered an indicator species for water quality due to its intolerance of turbid water conditions
Potamogeton richardsonii (clasping-leaf pondweed)	Provides food, shelter and shade for some fish, food for some wildfowl, and food for muskrat. Provides shelter and support for insects, which are valuable as fish food
Potamogeton zosteriformis (flat-stem pondweed)	Provides some food for ducks
Rannunculus longirostris (white-water crowfoot)	Fruit and foliage are consumed by waterfowl and some upland game birds when it grows in shallow water; stems and leaves provide habitat for insects and other invertebrates
Utricularia spp. (bladderwort)	Provides cover and foraging for fish
Vallisneria americana (water celery/eel-grass)	Provides good shade and shelter, supports insects, and is valuable fish food

NOTE: Information obtained from *A Manual of Aquatic Plants* by Norman C. Fassett, University of Wisconsin Press; *Guide to Wisconsin Aquatic Plants*, Wisconsin Department of Natural Resources; and, *Through the Looking Glass...A Field Guide to Aquatic Plants*, Wisconsin Lakes Partnership, University of Wisconsin-Extension.

Source: SEWRPC.

Table 18

CHEMICAL CONTROL OF AQUATIC PLANTS IN OCONOMOWOC LAKE: 1950-2005

Year	Total Acres Treated	Algae Control: Copper Sulfate (pounds)	Algae Control: Blue Vitriol (pounds)	Algae Control: Cutrine or Cutrine-+ (pounds)	Macrophyte Control: Sodium Arsenite (pounds)	Macrophyte Control: 2, 4-D (gallons)	Macrophyte Control: Diquat (gallons)	Macrophyte Control: Endothall (gallons)	Macrophyte Control: Aquathol (gallons)
1950-1984[a]	- -	3,447	4,456	3 pounds + 1.0 gallon	33,322	75 gallons + 481 pounds	15	115 gallons + 40 pounds	305 pounds + 15 gallons
1985-1987	- -	- -	- -	- -	- -	- -	- -	- -	- -
1988	0.16	- -	- -	- -	- -	- -	- -	65	- -
1989	0.58	- -	- -	0.58	- -	- -	0.58	- -	0.58
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991	1.15	- -	- -	1.5 gallons	- -	2.5	1.50	- -	- -
1992	0.50	- -	- -	- -	- -	- -	0.33	- -	0.33
1993-1997	- -	- -	- -	- -	- -	- -	- -	- -	- -
1998	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999-2002	- -	- -	- -	- -	- -	- -	- -	- -	- -
2003	0.14	- -	- -	- -	- -	20.0	- -	- -	- -
2004	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2005	4.30	- -	- -	- -	- -	428 pounds	- -	- -	- -
2006	0.30	- -	- -	- -	- -	50 pounds	- -	- -	- -
2007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2008	0.11	- -	- -	- -	- -	20 pounds	0.20	6 pounds	- -
Total	- -	3,447	4,456	3.58 pounds + 2.5 gallons	33,322	97.5 gallons + 979 pounds	17.61	180 gallons + 46 pounds	305 pounds + 15.91 gallons

NOTE: N/A = records are not available for this time period.

[a]*During this time period, to control swimmer's itch, Oconomowoc Lake was treated with an additional 18,600 pounds of copper sulfate, 4,875 pounds of lime, and 2,430 pounds of calcium carbonate.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 19

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

Chemical	Lowest Effect Level (LEL)	Medium Effect Level (MEL)	Severe Effect Level (SEL)
Arsenic	6.00	33.0	85.0
Copper	25.00	110.0	390.0
Lead	31.00	110.0	250.0
Mercury	0.15	0.2	1.3
Ammonia-Nitrogen	75.00	- -	- -

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

Source: Wisconsin Department of Natural Resources and SEWRPC.

Eurasian water milfoil (*Myriophyllum spicatum*). 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 beneficial species, such as water lilies (*Nymphaea* sp. and *Nuphar* sp.). The present restrictions on water use after application of these herbicides are given in Table 20.

Table 20

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

Use	Days after Application					
	Copper Sulfate	Diquat	Glyphosate	Endothall	2,4-D	Fluridone
Drinking..............................	- -[b]	14	- -[c]	7-14	- -[d]	- -[e]
Fishing	0	14	0	3	0	0
Swimming	0	1	0	- -	0	0
Irrigation.............................	0	14	0	7-14	- -[d]	7-30

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

[b]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the residual copper content cannot exceed one part per million (ppm).*

[c]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the drinking water tolerance of glyphosate (Rodeo®) is one part per million (ppm).*

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

[e]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the drinking water tolerance of fluridone (Sonar®) is 0.15 parts per million (ppm).*

Source: Wisconsin Department of Natural Resources and SEWRPC.

During the period between June 2005 and September 2005, experimental herbicide-based treatments were applied to Oconomowoc Lake to control stands of hybrid water milfoil (*Myriophyllum spicatum* x *sibiricum*),[5] with a follow up treatment applied in June 2006.[6] The aquatic herbicide 2,4-D was applied in granular form at rates of 0 pounds per acre (lb/ac)—a control plot, 80 lb/ac, 100 lb/ac, and 120 lb/ac during June 2005, and monitored at two-weekly intervals through September. Decreased densities of hybrid water milfoil were observed, as well as decreased densities of coontail (*Ceratophyllum demersum*) and northern water milfoil (*Myriophyllum sibiricum*), with the latter being confined to the treatment plots and the former including both treated and control plots. It was noted, however, that the hybrid water milfoil in the treated plots appeared to be less robust than in the control plot. Treatment during June 2006 was undertaken at a rate of 150 lb/ac of granular 2,4-D. This treatment resulted in a decreased abundance and frequency of occurrence of hybrid water milfoil, with few impacts on nontarget, native species, including northern water milfoil, being reported.

In addition to the chemical herbicides used to control large aquatic plants, algicides have been applied to Oconomowoc Lake. As shown in Table 18, copper sulfate, blue vitriol, and Cutrine®, a copper-based product, have been applied to Oconomowoc Lake, on occasion, between 1958 and 1991. Like arsenic, copper, the active

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[5]*Angela L. Ortenblad, Allison M. Zappa, Abby R. Kroken, and Robert C. Anderson, "Effectiveness of Granular 2,4-D Treatment on Hybrid Watermilfoil (*Myriophyllum sibiricum *x* spicatum*) in Oconomowoc Lake, Wisconsin," Wisconsin Lutheran College Biology Department Technical Bulletin 008, March 2006.*

[6]*Allison M. Zappa and Robert C. Anderson, "Follow up Study on the Effectiveness of Granular 2,4-D Treatment on Hybrid Watermilfoil (*Myriophyllum sibiricum *x* spicatum*) in Oconomowoc Lake, Wisconsin," Wisconsin Lutheran College Biology Department Technical Bulletin 010, April 2007.*

ingredient in many algicides, including Cutrine Plus®, may accumulate in the bottom sediments. Excessive levels of copper may be toxic to fish and benthic organisms, but, generally, have not been found to be harmful to humans.[7] As reported in the initial SEWRPC report, [8] between 1965 and the late-1970s, a mixture of copper sulfate and lime or calcium carbonate had been utilized on certain areas of Oconomowoc Lake to kill snails, the intermediate host of a microscopic parasite of waterfowl that occurs in some lakes in southeastern Wisconsin and whose presence in the water can lead to the development in humans of a condition known as "swimmers itch." Restrictions on water uses after application of Cutrine Plus® and other copper-containing compounds are also given in Table 20.

Macrophyte Harvesting

Although the excessive macrophyte growths in Oconomowoc Lake have resulted in a control program primarily based upon chemical treatments, manual harvesting of aquatic plants around piers and docks also is practiced. While this control mechanism has not been quantified previously, permits governing manual removal of aquatic plants are now required under Chapter NR 109 of the *Wisconsin Administrative Code*. A general, statewide permit allowing riparian owners to clear a 30-foot-wide corridor along a given 100-foot length of shoreline is contained within the *Code*, which came into effect during 2003. Outside of the 30-foot-wide linear shoreland corridor, a specific permit is required under Chapter NR 109. No data on permits issued to Oconomowoc Lake residents are available, although riparian property owners and residents report periodic utilization of manual harvesting techniques along portions of the shoreline of the Lake.

Biological and Physical Controls

The use of physical control measures, such as placement of bottom barriers, pea gravel blankets, or surface water colorants, has not been reported from Oconomowoc Lake. Likewise, with the exception of the use of the purple loosestrife weevils, *Galerucella* spp. and *Hylobius* sp., the use of biological control agents to manage aquatic plant populations in Oconomowoc Lake has not been reported. The use of grass carp, *Ctenopharyngodon idella*, to control aquatic plant growths is expressly prohibited in Wisconsin.

AQUATIC ANIMALS

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

Zooplankton

Zooplankton are microscopic animals which inhabit the same environment as phytoplankton, the microscopic plants. An important link in the food chain, crustacean zooplankton, feed mostly on algae and, in turn, are a good food source for fish. Zooplankton populations were surveyed during the initial SEWRPC study.[9] At that time, 15 species of zooplankton were identified in Oconomowoc Lake. Populations were at their peaks in spring, early summer, and fall, with *Daphnia* species—*D. galeata mendotae* and *D. pulicaria*—being the dominant and largest animals in the zooplankton community throughout most of the year. *Cyclops bicuspidatus thomasi* was the most common copepod found year round. During the current study period, no new records of zooplankton numbers and species composition were available, and the current state of the zooplankton community is not known.

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

[8]*SEWRPC Community Assistance Planning Report No. 181,* op.cit.

[9]Ibid.

Benthic Invertebrates

The benthic, or bottom dwelling, macroinvertebrate communities of lakes include such organisms as sludge worms, midges, and caddis fly larvae. These organisms are frequently used to assess the existing and recent past water quality of a lake. In addition, these organisms form an important part of the food web, acting as processors of the organic material that accumulates on the lake bottom and frequently being grazed, in turn, by bottom feeding fishes. Some benthic macroinvertebrate organisms are opportunistic in their feeding habits, while others are openly predaceous. The diversity of the benthic community reflects the trophic status of a lake, with less enriched lakes typically having a greater diversity. Nevertheless, there is no single “indicator organism” that determines the trophic status, or level of enrichment of a lake; rather the entire community must be assessed. The time of year for this assessment consequently becomes an important consideration, since these populations fluctuate widely during the summer months as a result of life stage of the organisms, climatic variability, and localized water quality changes. An early spring or winter sampling is considered to be the best opportunity for making an overall assessment of the benthic community composition.

In the initial study period, the benthic community of Oconomowoc Lake was reported to consist of five species. The dominant species were two phantom midge species, *Chaoborus flavicans* and *Charborus punctipennis*, which both feed on zooplankton and are typically found in mesotrophic lakes. Other species present at that time included the midges *Chironomus attenuatus*, *Procladius* sp., and *Paratendipes* sp. There were no data on benthic populations in Oconomowoc Lake collected during the current study period.

Zebra mussels, *Dreissenia polymorpha*, a nonnative species of shellfish with known negative impacts on native benthic populations, are currently spreading into inland lakes from the Laurentian Great Lakes system where they are considered to be an invasive species. This mollusk, originally introduced into the Great Lakes in ballast water carried by ships from Europe, is now widespread in southeastern Wisconsin inland waters. According to WDNR records, Oconomowoc Lake has been listed as an inland lake with an established community of zebra mussels since 1999.

Zebra mussels are having a varied impact on inland lakes in the Upper Midwest. They disrupt the food chain by removing significant amounts of phytoplankton which serve as food, not only for themselves, but also for larval and juvenile fish and many forms of zooplankton. However, many lakes experience improved water clarity as a result of the filter feeding proclivities of these animals. This improved clarity has led to increased growths of rooted aquatic plants, including Eurasian water milfoil. Curiously, within the Southeastern Wisconsin Region, zebra mussels have been observed attaching themselves to the stalks of the Eurasian water milfoil plants, dragging these stems out of the zone of light penetration, due to the weight of the zebra mussel shells, and interfering with the competitive strategy of the Eurasian water milfoil plants. This, in turn, has contributed to improved growths of native aquatic plants, in some cases, and to the growths of filamentous algae too large to be ingested by the zebra mussels, in others. Regardless as to the seeming beneficial impacts of these animals, the overall effect is that, as zebra mussels and other invasive species spread to inland lakes and rivers, so do the environmental, aesthetic, and economic costs to water users.

Fishes of Oconomowoc Lake

Oconomowoc Lake supports a relatively large and diverse fish community. In the initial report, Oconomowoc Lake was considered to have a generally well-balanced population of gamefish and panfish. WDNR surveys in 1970 and 1975 indicated the presence of at least 34 fish species whose populations were reflective of the good water quality of the Lake, as well as of the influence of the river system from which individual species move into a lake. In these surveys, the bluntnose minnow (*Pimephales notatus*), white sucker (*Catostomus commersoni*), banded killifish (*Fundulus diaphanus*), and Iowa darter (*Etheostoma exile*) were the most numerous species captured.

In 1994 and 2004, the WDNR conducted additional comprehensive fisheries surveys of Oconomowoc Lake. The 2004 comprehensive survey generally found that population densities of walleye and northern pike had increased over the 10-year period since the 1994 survey; muskellunge (musky) populations had increased by 80 percent, even though the WDNR does not stock musky directly into Oconomowoc Lake; largemouth and smallmouth bass had increased in number and biomass since 1994; and the bluegill catch rate had increased dramatically over the 1994 catch rate. [10] SEWRPC reported the presence of the lake chubsucker (*Erimyzon sucetta*) and the least darter (*Etheostoma microperca*), both State-designated special concern species, and the pugnose shiner (*Notropis anogeus*), a State-designated threatened species, in the Lake during this period.[11]

During 2004, the WDNR conducted a seine net survey of Oconomowoc Lake using the same gear and level of effort as was used during the surveys of the 1970s. The purpose of this survey was to compare and document changes in fish populations over the intervening period. Using the same gear types eliminated the biases that can be created in fisheries surveys arising from differing gear types and survey methodologies. The 2004 comparison survey indicated a net loss of species in the Lake. Eight fewer native species were collected during 2004 than were collected during the earlier surveys of the 1970s. Additionally, there were two fewer “pollution intolerant” species, which are fishes that are sensitive to water quality degradation. There were no changes in the rare species, such as the lake chubsucker, observed between the two surveys.

“Panfish” is a common term applied to a broad group of smaller fish with a relatively short and usually broad shape that makes them a perfect size for the frying pan. A wide range of panfish is present in the Lake, as discussed above. Panfish species known to exist in Oconomowoc Lake include yellow perch (*Perca flavescens*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), rock bass (*Ambloplites rupestris*), and black crappie (*Pomoxis nigromaculatus*). During the 2004 WDNR comprehensive survey, bluegill and rock bass dominated the panfish sample. The habitats of panfish vary widely among the different species, but their cropping of the plentiful supply of insects and plants, coupled with prolific breeding rates, leads to large populations with a rapid turnover. Some lakes within southeastern Wisconsin have stunted or slow-growing panfish populations, because their numbers are not being adequately controlled by predator fishes. In turn, panfish frequently feed on the fry of predatory fishes and, if the panfish population is overabundant, they may quickly deplete the predator fry population. Figure 10 illustrates the importance of a balanced predator-prey relationship, using walleyed pike and perch as an example.

“Roughfish” is a broad term applied to species, such as carp, that do not readily bite on hook and line, but feed on gamefish, destroy habitat needed by more desirable species, and are commonly considered in southeastern Wisconsin as undesirable for human consumption. Roughfish species which have been found in Oconomowoc Lake include the common carp (*Cyprinus carpio*), quillback (*Carpiodes cyrinus*), bowfin (*Amia calva*), and white sucker (*Catostomos commersoni*).

“Gamefish” is the term applied to those fishes that are typically sought by anglers, and which are generally considered to be desirable species. Gamefish that have been found in Oconomowoc Lake include muskellunge (*Esox masquinongy*), northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), and walleye (*Stizostedion vitreum vitreum*). All gamefish species found in Oconomowoc Lake, except muskellunge, are known to reproduce naturally in the Lake.

Fisheries Management

The Lake is judged to have a good fishery. Currently, the WDNR manages Oconomowoc Lake as a warmwater sportfishery. Fisheries management efforts have included passive maintenance through compliance with State of Wisconsin fishing regulations, with modification of the size limit restriction for walleye, the size limitation being

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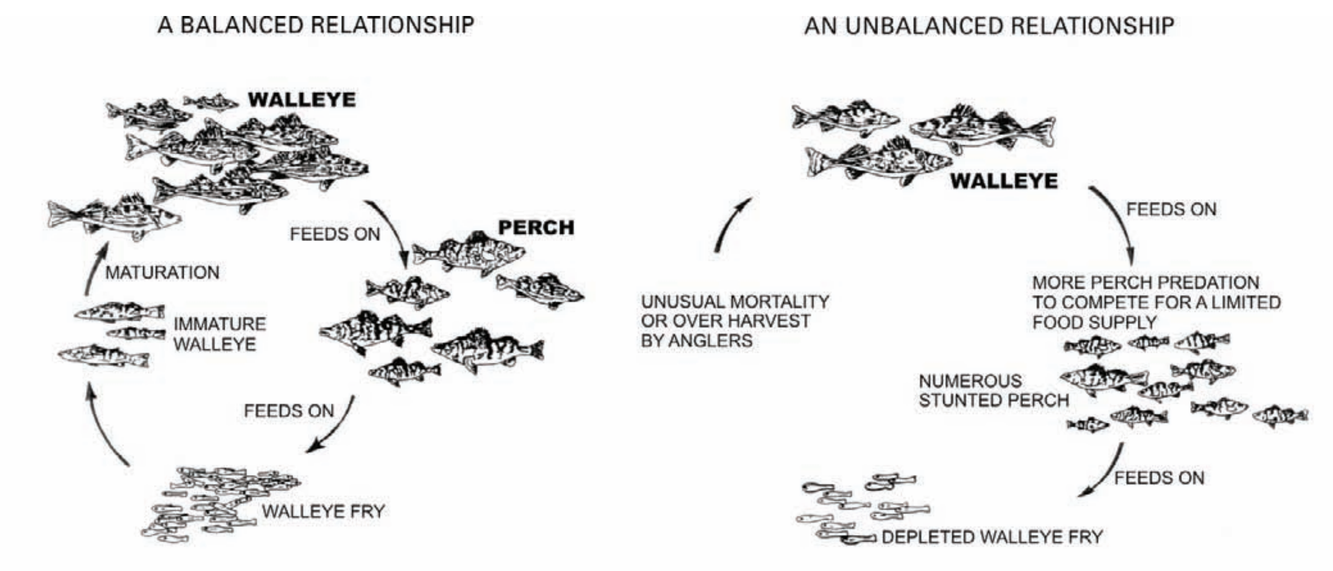
[10] *Wisconsin Department of Natural Resources Memorandum to Randy Schumacher from Sue Beyler and Steve Gospodarek, dated January 25, 2005*.

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

Figure 10

THE PREDATOR-PREY RELATIONSHIP



Source: Wisconsin Department of Natural Resources and SEWRPC.

increased to 18 inches for Oconomowoc Lake, with a daily bag limit of three fishes.[12] The 2008-2009 regulations governing the harvest of fishes from the waters of the State, as amended to include Oconomowoc Lake, are summarized in Table 21. Additionally, recommended species-specific management measures set forth in the aforementioned 2004 comprehensive survey included continued stocking of northern pike and protection of largemouth and smallmouth bass spawning habitat.[13]

The Lake is judged to provide adequate spawning, nursery, and feeding habitat for largemouth bass, bluegill, and other native panfish, and, as such, is not considered to need to have these populations supplemented by stocking. However, due largely to the popularity among anglers of northern pike and walleye, supplemental stocking of these species has been recommended. Stocking data for Oconomowoc Lake are shown in Table 22. All stocking of lakes in Wisconsin is regulated by the WDNR through the granting of stocking permits.

The protection of existing, remnant populations of the lake chubsucker (*Erimyzon sucetta*) and the least darter (*Etheostoma microperca*), both State-designated special concern species, and the pugnose shiner (*Notropis anogeus*), a State-designated threatened species, is recommended in the adopted regional natural areas and critical species habitat protection and management plan.[14]

Other Wildlife

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the current Oconomowoc Lake study, it was possible, by polling naturalists and wildlife managers familiar

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[12]*Wisconsin Department of Natural Resources Publication No. PUBL-FH-301 2008,* Guide to Wisconsin Hook and Line Fishing Regulations 2008-2009*, 2008.*

[13]*Wisconsin Department of Natural Resources Memorandum,* op. cit.

[14]*SEWRPC Planning Report No. 42,* op. cit.

Table 21

FISHING REGULATIONS APPLICABLE TO OCONOMOWOC LAKE: 2006-2007

Species	Open Season	Daily Limit	Minimum Size
Northern Pike	May 6 to March 4	2	26 inches
Walleyed Pike	May 6 to March 4	5	18 inches
Largemouth and Smallmouth Bass	May 6 to March 4	5 in total	14 inches
Rock, Yellow and White Bass	Open all year	None	None
Bluegill, Pumpkinseed (sunfish), Crappie, and Yellow Perch	Open all year	25 in total	None
Bullhead and Rough Fish	Open all year	None	None

Source: Wisconsin Department of Natural Resources Publication No. PUBL-FH-301 2006, Guide to Wisconsin Hook and Line Fishing Regulations 2006-2007*, January 2006; and SEWRPC.*

Table 22

FISH STOCKED INTO OCONOMOWOC LAKE: 1995-2005

Year	Species Stocked	Number Stocked	Size
1995	Northern pike	1,913	8.6 inches
1995	Walleye	30,050	2.0 inches
1997	Walleye	36,050	1.5 inches
1998	Northern pike	3,650	N/A
1999	Walleye	79,000	1.3 inches
2000	Northern pike	4,100	3.4 inches
2001	Walleye	70,700	1.7 inches
2001	Northern pike	2,280	5.45 inches
2002	Northern pike	1,900	3.1 inches
2003	Walleye	76,380	2.2 inches
2005	Walleye	38,421	1.5 inches
2005	Northern pike	2,500	3.0 inches

NOTE: N/A = records are not available for this time period.

Source: Wisconsin Department of Natural Resources and SEWRPC.

with the area, to complete a list of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed, in the Oconomowoc Lake area; associating these lists with the historic and remaining habitat areas in the Oconomowoc Lake area as inventoried; and projecting the appropriate amphibian, reptile, bird, and mammal species into the Oconomowoc Lake area. The net result of the application of this technique is a listing, summarized in Tables 23 through 25, of those species which were probably once present in the tributary area; those species which may be expected to still be present under currently prevailing conditions; and those species which may be expected to be lost or gained as a result of urbanization within the area.

A variety of mammals, ranging in size from large animals like the northern white-tailed deer to small animals like the least shrew, are expected to be found in the Oconomowoc Lake area. Mink, muskrat, beaver, white-tailed deer, red and grey fox, grey and fox squirrel, and cottontail rabbits are mammals reported to frequent the area. Table 23 lists 38 mammals whose ranges are known to extend into the area.

A large number of birds, ranging in size from large game birds to small songbirds, also are expected to be found in the Oconomowoc Lake area. Table 24 lists those birds that normally occur in the tributary area. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Oconomowoc Lake tributary area supports a significant population of waterfowl, including mallard and teal. Larger numbers of birds move through the tributary area during migrations when most of the regional species may also be present.

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

Because of the mixture of lowland and upland woodlots, wetlands, and agricultural lands still present in the area, along with the favorable summer climate, the area supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, whippoorwills, woodpeckers, nuthatches, and flycatchers as well as several other species serve as the major insect predators. In addition to their ecological roles, birds such as robins, red-winged blackbirds, orioles, cardinals, kingfishers, and mourning doves, serve as subjects for bird watchers and photographers. Threatened species migrating in the vicinity of Oconomowoc Lake include the Cerulean warblers, Acadian flycatcher, great egret, and osprey. Endangered species migrating in the vicinity of Oconomowoc Lake include the common tern, Caspian tern, Forster's tern, and loggerhead shrike.

Amphibians and reptiles are vital components of the ecosystem in an environmental unit like the Oconomowoc Lake tributary area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Oconomowoc Lake area. Table 25 lists the 14 amphibian and 15 reptile species normally expected to be present in the Oconomowoc Lake area under present conditions, and identifies those species most sensitive to urbanization. It is noteworthy that Oconomowoc Lake falls within the range of Blanding's turtle (*Emydoidea blandingii*), a State-designated threatened species, and that the area contains suitable habitat and nesting areas. The threatened status of this species is explained by its poor reproduction caused by nest predation by mammals, such as skunks, opossums,

Table 23

MAMMALS OF THE OCONOMOWOC LAKE AREA

Scientific (family) and Common Name	Scientific Name
Didelphidae	
Virginia Opossum	*Didelphis virginiana*
Soricidae	
Cinereous Shrew	*Sorex cinereus*
Short-Tailed Shrew	*Blarina brevicauda*
Least Shrew	*Cryptotis parva*
Vespertilionidae	
Little Brown Bat	*Myotis lucifugus*
Silver-Haired Bat	*Lasisoncteris octivagans*
Big Brown Bat	*Eptesicus fuscus*
Red Bat	*Lasiurus borealus*
Hoary Bat	*Lasiurus cinereus*
Leporidae	
Cottontail Rabbit	*Sylvilgus floridanus*
Sciuridae	
Woodchuck	*Marmota monax*
Thirteen-lined Ground Squirrel (gopher)	*Spermophilus tridencemilineatus*
Eastern Chipmunk	*Tamias striatus*
Grey Squirrel	*Sciurus carolinensis*
Western Fox Squirrel	*Sciurus niger*
Red Squirrel	*Tamiasciurus hudsonicus*
Southern Flying Squirrel	*Glaucomys volans*
Castoridae	
American Beaver	*Castor canadensis*
Cricetidae	
Woodland Deer Mouse	*Peromyscus maniculatus*
Prairie Deer Mouse	*Peromyscus leucopus bairdii*
White-Footed Mouse	*Microtus pennsylvanicus*
Meadow Vole	*Microtus ochrogaster*
Common Muskrat	*Ondatra zibethicus*
Muridae	
Norway Rat (introduced)	*Rattus norvegicus*
House Mouse (introduced)	*Mus musculus*
Zapodidae	
Meadow Jumping Mouse	*Zapas hudonius*
Canidae	
Coyote	*Canis latrans*
Eastern Red Fox	*Vulpes vulpes*
Gray Fox	*Urocyon cinereoargenteus*
Procyonidae	
Raccoon	*Procyon lotor*
Mustelidae	
Least Weasel	*Mustela nivalis*
Short-Tailed Weasel	*Mustela erminea*
Long-Tailed Weasel	*Mustela frenata*
Mink	*Mustela vison*
Badger (occasional visitor)	*Taxidea taxus*
Striped Skunk	*Mephitis mephitis*
Otter (occasional visitor)	*Lontra canadensis*
Cervidae	
White-Tailed Deer	*Odecoileus virginianus*

Source: H.T. Jackson, Mammals of Wisconsin*, 1961, U.S. Department of Agriculture Integrated Taxonomic Information System, National Museum of Natural History, Smithsonian Institute, and SEWRPC.*

Table 24

BIRDS KNOWN OR LIKELY TO OCCUR IN THE OCONOMOWOC LAKE AREA

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Gaviidae			
Common Loon[a]	- -	- -	X
Podicipedidae			
Pied-Billed Grebe	X	- -	X
Horned Grebe	- -	- -	X
Phalacrocoracidae			
Double-Crested Cormorant	- -	- -	X
Ardeidae			
American Bittern[a]	X	- -	X
Least Bittern[a]	X	- -	X
Great Blue Heron[a]	X	R	X
Great Egret[b]	- -	- -	X
Cattle Egret[a,c]	- -	- -	R
Green Heron	X	- -	X
Black-Crowned Night Heron[a]	- -	- -	X
Anatidae			
Tundra Swan	- -	- -	X
Mute Swan[c]	X	X	X
Snow Goose	- -	- -	X
Canada Goose	X	X	X
Wood Duck	X	- -	X
Green-Winged Teal	- -	- -	X
American Black Duck[a]	- -	X	X
Mallard	X	X	X
Northern Pintail[a]	- -	- -	X
Blue-Winged Teal	X	- -	X
Northern Shoveler	- -	- -	X
Gadwall	- -	- -	X
American Widgeon[a]	- -	- -	X
Canvasback[a]	- -	- -	X
Redhead[a]	- -	- -	X
Ring-Necked Duck	- -	- -	X
Lesser Scaup[a]	- -	- -	X
Greater Scaup	- -	- -	R
Common Goldeneye[a]	- -	X	X
Bufflehead	- -	- -	X
Red-Breasted Merganser	- -	- -	X
Hooded Merganser[a]	R	- -	X
Common Merganser[a]	- -	- -	X
Ruddy Duck	- -	- -	X
Cathartidae			
Turkey Vulture	X	- -	X
Accipitridae			
Osprey[a]	- -	- -	X
Bald Eagle[a,d]	- -	- -	R
Northern Harrier[a]	X	R	X
Sharp-Shinned Hawk	X	X	X
Cooper's Hawk[a]	X	X	X

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Accipitridae (continued)			
Northern Goshawk[a]	- -	R	X
Red-Shouldered Hawk[b]	R	- -	X
Broad-Winged Hawk	R	- -	X
Red-Tailed Hawk	X	X	X
Rough-Legged Hawk	- -	X	X
American Kestrel	X	X	X
Merlin[a]	- -	- -	X
Phasianidae			
Grey Partridge[c]	R	R	- -
Ring-Necked Pheasant[c]	X	X	- -
Wild Turkey	X	X	- -
Rallidae			
Virginia Rail	X	- -	X
Sora	X	- -	X
Common Moorhen	X	- -	X
American Coot	X	R	X
Gruidae			
Sandhill Crane	X	- -	X
Charadriidae			
Black-Bellied Plover	- -	- -	X
Semi-Palmated Plover	- -	- -	X
Killdeer	X	- -	X
Scolopacidae			
Greater Yellowlegs	- -	- -	X
Lesser Yellowlegs	- -	- -	X
Solitary Sandpiper	- -	- -	X
Spotted Sandpiper	X	- -	X
Upland Sandpiper[a]	R	- -	X
Semi-Palmated Sandpiper	- -	- -	X
Pectoral Sandpiper	- -	- -	X
Dunlin	- -	- -	X
Common Snipe	R	- -	X
American Woodcock	X	- -	X
Wilson's Phalarope	- -	- -	X
Laridae			
Ring-Billed Gull	- -	- -	X
Herring Gull	- -	X	X
Common Tern[e]	- -	- -	R
Caspian Tern[e]	- -	- -	R
Forster's Tern[e]	- -	- -	R
Black Tern[a]	X	- -	X
Columbidae			
Rock Dove[c]	X	X	- -
Mourning Dove	X	X	X
Cuculidae			
Black-Billed Cuckoo	X	- -	X
Yellow-Billed Cuckoo[a]	X	- -	X

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Strigidae			
Eastern Screech Owl	X	X	- -
Great Horned Owl	X	X	- -
Snowy Owl	- -	R	- -
Barred Owl	X	X	- -
Long-Eared Owl[a]	- -	X	X
Short-Eared Owl[a]	- -	R	X
Northern Saw-Whet Owl	- -	- -	X
Caprimulgidae			
Common Nighthawk	X	- -	X
Whippoorwill	- -	- -	X
Apodidae			
Chimney Swift	X	- -	X
Trochilidae			
Ruby-Throated Hummingbird	X	- -	X
Alcedinidae			
Belted Kingfisher	X	X	X
Picidae			
Red-Headed Woodpecker[a]	X	R	X
Red-Bellied Woodpecker	X	X	- -
Yellow-Bellied Sapsucker	- -	R	X
Downy Woodpecker	X	X	- -
Hairy Woodpecker	X	X	- -
Northern Flicker	X	R	X
Tyrannidae			
Olive-Sided Flycatcher	- -	- -	X
Eastern Wood Pewee	X	- -	X
Yellow-Bellied Flycatcher[a]	- -	- -	X
Acadian Flycatcher[b]	R	- -	X
Alder Flycatcher	R	- -	X
Willow Flycatcher	X	- -	X
Least Flycatcher	R	- -	X
Eastern Phoebe	X	- -	X
Great Crested Flycatcher	X	- -	X
Eastern Kingbird	X	- -	X
Alaudidae			
Horned Lark	X	X	X
Hirundinidae			
Purple Martin[a]	X	- -	X
Tree Swallow	X	- -	X
Northern Rough-Winged Swallow	X	- -	X
Bank Swallow	X	- -	X
Cliff Swallow	X	- -	X
Barn Swallow	X	- -	X
Corvidae			
Blue Jay	X	X	X
American Crow	X	X	X
Paridae			
Tufted Titmouse	R	R	- -
Black-Capped Chickadee	X	X	X

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Sittidae			
Red-Breasted Nuthatch	R	X	X
White-Breasted Nuthatch	X	X	- -
Certhiidae			
Brown Creeper	- -	X	X
Troglodytidae			
Carolina Wren	- -	- -	R
House Wren	X	- -	X
Winter Wren	- -	- -	X
Sedge Wren[a]	X	- -	X
Marsh Wren	X	- -	X
Regulidae			
Golden-Crowned Kinglet	- -	X	X
Ruby-Crowned Kinglet[a]	- -	- -	X
Blue-Gray Gnatcatcher	X	- -	X
Eastern Bluebird	X	- -	X
Veery[a]	X	- -	X
Gray-Cheeked Thrush	- -	- -	X
Swainson's Thrush	- -	- -	X
Hermit Thrush	- -	- -	X
Wood Thrush[a]	X	- -	X
American Robin	X	X	X
Mimidae			
Gray Catbird	X	- -	X
Brown Thrasher	X	- -	X
Bombycillidae			
Bohemian Waxwing	- -	R	- -
Cedar Waxwing	X	X	X
Laniidae			
Northern Shrike	- -	- -	X
Loggerhead Shrike[e]	- -	- -	R
Sturnidae			
European Starling[c]	X	X	X
Vireonidae			
Bell's Vireo	- -	- -	R
Solitary Vireo	- -	- -	X
Yellow-Throated Vireo	X	- -	X
Warbling Vireo	X	- -	X
Philadelphia Vireo	- -	- -	X
Red-Eyed Vireo	X	- -	X
Parulidae			
Blue-Winged Warbler	X	- -	X
Golden-Winged Warbler[a]	R	- -	X
Tennessee Warbler[a]	- -	- -	X
Orange-Crowned Warbler	- -	- -	X
Nashville Warbler[a]	- -	- -	X
Northern Parula	- -	- -	X
Yellow Warbler	X	- -	X
Chestnut-Sided Warbler	- -	- -	X
Magnolia Warbler	- -	- -	X

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Parulidae (continued)			
Cape May Warbler[a]	- -	- -	X
Black-Throated Blue Warbler	- -	- -	X
Yellow-Rumped Warbler	- -	R	X
Black-Throated Green Warbler	- -	- -	X
Cerulean Warbler[b]	R	- -	R
Blackburnian Warbler	- -	- -	X
Palm Warbler	- -	- -	X
Bay-Breasted Warbler	- -	- -	X
Blackpoll Warbler	- -	- -	X
Black-and-White Warbler	- -	- -	X
Prothonotary Warbler[a]	- -	- -	R
American Redstart	X	- -	X
Ovenbird	X	- -	X
Northern Waterthrush	- -	- -	X
Connecticut Warbler[a]	- -	- -	X
Mourning Warbler	R	- -	X
Common Yellowthroat	X	- -	X
Wilson's Warbler	- -	- -	X
Kentucky Warbler[b]	- -	- -	R
Canada Warbler	R	- -	X
Hooded Warbler[b]	R	- -	R
Thraupidae			
Scarlet Tanager	X	- -	X
Cardinalidae			
Northern Cardinal	X	X	- -
Rose-Breasted Grosbeak	X	- -	X
Indigo Bunting	X	- -	X
Emberizidae			
Dickcissel[a]	R	- -	X
Eastern Towhee	X	- -	X
American Tree Sparrow	- -	X	X
Chipping Sparrow	X	- -	X
Clay-Colored Sparrow	R	- -	X
Field Sparrow	X	- -	X
Vesper Sparrow[a]	X	- -	X
Savannah Sparrow	X	- -	X
Grasshopper Sparrow[a]	X	- -	X
Henslow's Sparrow[b]	R	- -	X
Fox Sparrow	- -	R	X
Song Sparrow	X	X	X
Lincoln's Sparrow	- -	- -	X
Swamp Sparrow	X	X	X
White-Throated Sparrow	- -	R	X
White-Crowned Sparrow	- -	- -	X
Dark-Eyed Junco	- -	X	X
Lapland Longspur	- -	R	X
Snow Bunting	- -	R	X
Icteridae			
Bobolink[a]	X	- -	X
Red-Winged Blackbird	X	X	X
Eastern Meadowlark[a]	X	R	X
Western Meadowlark[a]	R	- -	X

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Icteridae (continued)			
Yellow-Headed Blackbird	X	- -	X
Rusty Blackbird	- -	R	X
Common Grackle	X	X	X
Brown-Headed Cowbird	X	R	X
Orchard Oriole[a]	R	- -	R
Baltimore Oriole	X	- -	X
Fringillidae			
Purple Finch	- -	X	X
Common Redpoll	- -	X	X
Pine Siskin[a]	- -	X	X
American Goldfinch	X	X	X
House Finch	X	X	X
Evening Grosbeak	- -	X	X
Passeridae			
House Sparrow[c]	X	X	- -

NOTE: Total number of bird species: 219
Number of alien, or nonnative, bird species: 7 (3 percent)

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

X - Present, not rare
R - Rare

[a]*State-designated species of special concern. Fully protected Federal and State laws under the Migratory Bird Act.*

[b]*State-designated threatened species.*

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

[d]*Federally designated threatened species.*

[e]*State-designated endangered species.*

Source: Samuel D. Robbins, Jr., Wisconsin Birdlife, Population & Distribution, Past and Present*, 1991; John E. Bielefeldt, Racine County Naturalist; Zoological Society of Milwaukee County and Birds Without Borders-Aves Sin Fronteras,* Report for Landowners on the Avian Species Using the Pewaukee, Rosendale and Land O' Lakes Study Sites*, April-August, 1998; Wisconsin Department of Natural Resources; and SEWRPC.*

and raccoons. The prevalence of such predators, which readily adapt to the urban environment, has been greatly increased by scattered urban and suburban sprawl.

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

The complete spectrum of wildlife species originally native to Waukesha County has, along with its habitat, undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and

Table 25

AMPHIBIANS AND REPTILES OF THE OCONOMOWOC LAKE AREA

Scientific (family) and Common Name	Scientific Name	Species Reduced or Dispersed with Full Area Urbanization	Species Lost with Full Area Urbanization
Amphibians			
Proteidae			
Mudpuppy	*Necturus maculosus maculosus*	X	- -
Ambystomatidae			
Blue-Spotted Salamander	*Ambystoma laterale*	- -	X
Spotted Salamander	*Ambystoma maculatum*		
Eastern Tiger Salamander	*Ambystoma tigrinum tigrinum*	X	- -
Salamandridae			
Central Newt	*Notophthalmus viridescens louisianensi*	X	- -
Bufonidae			
American Toad	*Bufo americanus americanus*	X	- -
Hylidae			
Western Chorus Frog	*Pseudacris triseriata triseriata*	X	- -
Blanchard's Cricket Frog[a,b]	*Acris crepitans blanchardi*	X	- -
Northern Spring Peeper	*Hyla crucifer crucifer*	- -	X
Gray Tree Frog	*Hyla versicolor*	- -	X
Ranidae			
Bull Frog[c]	*Rana catesbeiana*	- -	X
Green Frog	*Rana clamitans melanota*	X	- -
Northern Leopard Frog	*Rana pipiens*	- -	X
Pickerel Frog[c]	*Rana palustris*	- -	X
Reptiles			
Chelydridae			
Common Snapping Turtle	*Chelydra serpentina serpentina*	X	- -
Kinosternidae			
Musk Turtle (stinkpot)	*Sternotherus odoratus*	X	- -
Emydidae			
Western Painted Turtle	*Chrysemys picta belli*	X	- -
Midland Painted Turtle	*Chrysemys picta marginata*	X	- -
Blanding's Turtle[d]	*Emydoidea blandingii*	- -	X
Trionychidea			
Eastern Spiny Softshell	*Trionyx spiniferus spiniferus*	X	- -
Colubridae			
Northern Water Snake	*Nerodia sipedon sipedon*	X	- -
Midland Brown Snake	*Storeria dekayi wrightorum*	X	- -
Northern Red-Bellied Snake	*Storeria occipitomaculata occipitomaculata*	X	- -
Eastern Garter Snake	*Thamnophis sirtalis sirtalis*	X	- -
Chicago Garter Snake	*Thamnophis sirtalis semifasciata*	X	- -
Butler's Garter Snake[d]	*Thamnophis butleri*	X	- -
Eastern Hognose Snake	*Heterodon platyrhinos*	- -	X
Smooth Green Snake	*Opheodrys vernalis vernalis*	- -	X
Eastern Milk Snake	*Lampropeltis triangulum triangulum*	- -	X

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

[b] *State-designated endangered species.*

[c] *State-designated special concern species.*

[d] *State-designated threatened species.*

Source: Gary S. Casper, Geographical Distribution of the Amphibians and Reptiles of Wisconsin, *1996, Wisconsin Department of Natural Resources, Kettle Moraine State Forest, Lapham Peak Unit; and SEWRPC.*

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 also include the use of fertilizers, herbicides, and pesticides, as well as the use of road salt for snow and ice control; the presence of heavy motor vehicle traffic that produce disruptive noise levels and air pollution; nonpoint source water pollution from human activities on the landscape; and the introduction of domestic pets.

WILDLIFE HABITAT AND RESOURCES

Wildlife habitat areas within southeastern Wisconsin were initially inventoried by SEWRPC during 1985 in cooperation with the WDNR. The five major criteria used to determine the value of these wildlife habitat areas are listed below:

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

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

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

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

5. Disturbance: Minimal levels of disturbance by human activities are necessary (other than those activities of a wildlife management nature).

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

In the initial report, delineation of Oconomowoc Lake wildlife areas focused primarily on the direct tributary area of the Lake. At that time, the direct tributary area contained about 125 acres of wildlife habitat, which constituted about 6 percent of the direct tributary area. Wetlands south of the Lake and adjacent to man-made channels provided most of the habitat identified. Additional wildlife habitat was provided within the total area tributary to Oconomowoc Lake. The extent of these latter habitat areas was not quantified during that study.

In contrast to the initial plan, the current report presents data for the total tributary area of Oconomowoc Lake. As shown on Map 13 in Chapter III of this report, approximately 18,595 acres, or about 35 percent of the total area tributary to Oconomowoc Lake, were classified in the 1985 inventory as wildlife habitat, with about 8,343 acres, or about 16 percent of the total tributary area, classified as Class I habitat; about 6,341 acres, or about 12 percent, classified as Class II habitat; and about 3,911 acres, or about 7 percent, classified as Class III habitat. Of the 18,595 acres of wildlife habitat in the total tributary area of Oconomowoc Lake, about 45 percent is considered Class I habitat, 34 percent is Class II habitat, and 21 percent is Class III. Based upon the finding set forth in the initial plan, much of this habitat is located in the upper reached of the drainage area, which are more rural in character.

NATURAL AREAS AND CRITICAL SPECIES HABITAT

The total area tributary to Oconomowoc Lake contains several natural areas of local, countywide, and regional importance, due to the richness of its natural habitat and biota, as shown on Map 15. As shown on Map 15, approximately 3,618 acres, or about 7 percent of the total area tributary to Oconomowoc Lake, were identified as containing natural areas. Of the 3,618 acres designated as natural areas, about 1,220 acres, or about 34 percent, were rated as NA-1, identifying these as areas of statewide or greater significance; 1,251 acres, or about 35 percent, were rated as NA-2, identifying these as areas of countywide or regional significance; and about 1,147 acres, or about 31 percent, were rated as NA-3, identifying these as areas of local significance.

Within the immediate vicinity of the Lake, two areas were specially designated as natural areas in the adopted regional natural areas and critical species habitat protection and management plan.[15] These areas were:

1. <u>Oconomowoc River Marsh</u>: This area, located along the Oconomowoc River just downstream of the Lake, is a 100-acre, cattail-dominated, deep and shallow water marsh. Disturbed by channelization and highway construction, it has, nevertheless, received an NA-3 designation identifying it as a natural area of local significance.

2. <u>Oconomowoc Lake</u>: Oconomowoc Lake is designated as a Critical Lake of Southeastern Wisconsin and has been given a rating of AQ-2, identifying it as an aquatic area of countywide or regional significance. The Lake, in addition to providing good water quality, contains critical fish species as mentioned above.

WETLANDS

Wetlands are defined by SEWRPC 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 (USACE) and the U.S. Environmental Protection Agency (USEPA), is essentially the same as the definition used by the U.S. Natural Resources Conservation Service (NRCS).[16]

Another definition, which is applied by the WDNR and which is set forth in Chapter 23 of the *Wisconsin Statutes*, defines a wetland as “an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which has soils indicative of wet conditions.” In practice, the

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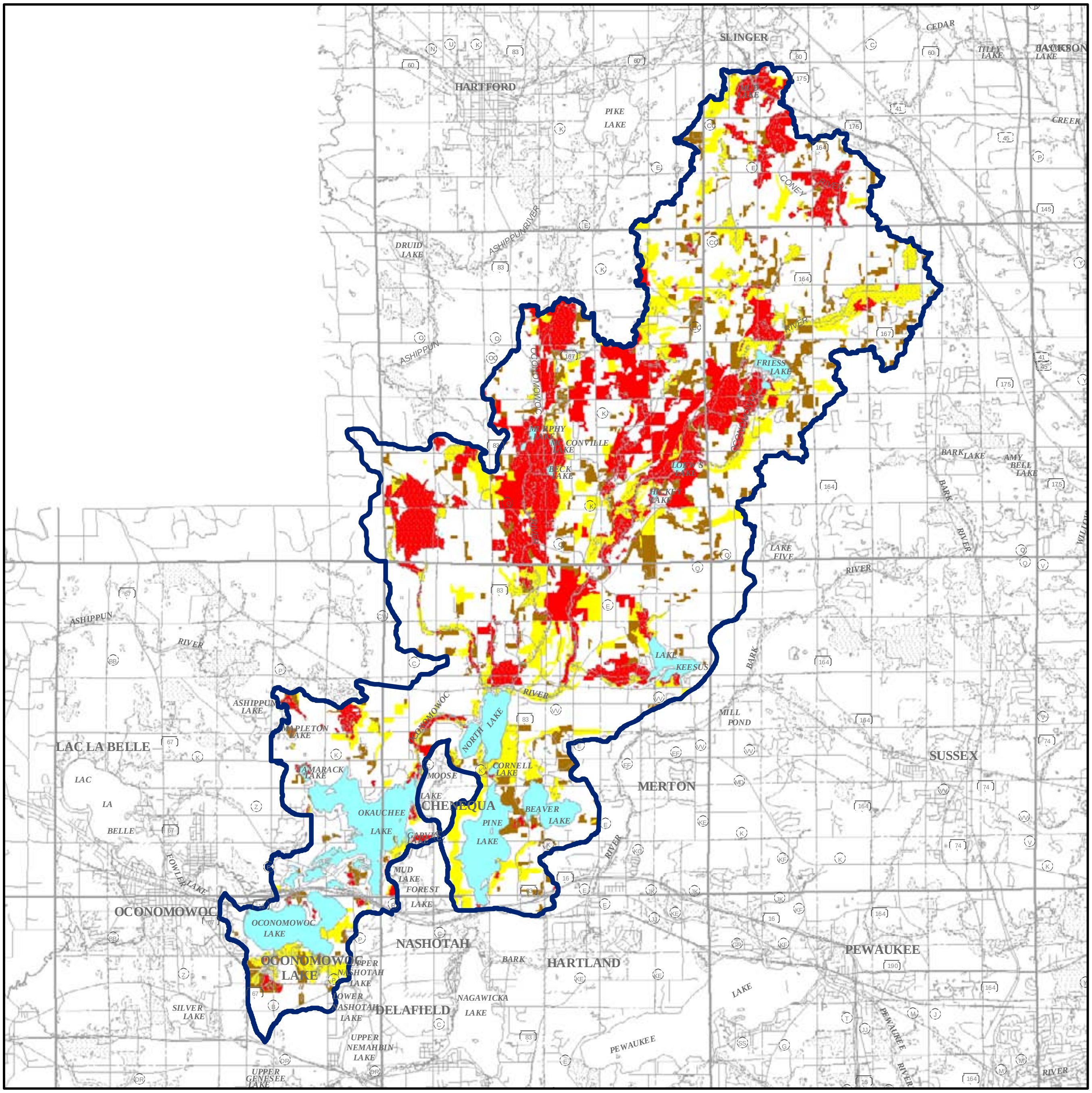
[15]Ibid.

[16]*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 NRCS 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 15

WILDLIFE HABITAT AREAS WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA: 1985



Class I, High-Value Habitat

Class II, Medium-Value Habitat

Class III, Good-Value Habitat

Surface Water

Source: SEWRPC.

N

0 10,000 20,000 Feet

WDNR definition differs from that of SEWRPC in that the WDNR considers very poorly drained, poorly drained, and some of the somewhat poorly drained soils as wetland soils meeting the WDNR “wet condition” criterion. The SEWRPC definition only considers the very poorly drained and poorly drained soils as meeting the “hydric soil” criterion. Thus, the State definition, as actually applied, is more inclusive than the Federal and regional definitions, in that the WDNR may include some soils that do not show hydric field characteristics as wet soils capable of supporting wetland vegetation, a condition that may occur in some floodlands.[17]

As a practical matter, experience has shown that application of the WDNR, the USEPA and USACE, and the SEWRPC definitions produce reasonably consistent wetland identifications and delineations in the majority of situations within the Southeastern Wisconsin Region. That consistency is due, in large part, to the provision in the Federal wetland delineation manual that allows for the application of professional judgment in cases where satisfaction of the three criteria for wetland identification is unclear.

Wetlands in southeastern Wisconsin are classified predominantly as deep marsh, shallow marsh, bog, fen, low prairie, southern sedge meadow, fresh (wet) meadow, shrub carr, southern wet and wet-mesic hardwood forest, and conifer swamp.

Wetlands perform a variety of valuable functions in natural communities: serving as stormwater and floodwater storage and retention and aid in the moderation of water level fluctuations; participating in various important groundwater-wetland water exchanges; providing filtration or storage of sediments, nutrients or toxic substances that would otherwise adversely impact the quality of other waters; protecting shoreline areas against erosion through dissipation of wave energy and water velocity and anchoring of sediments; providing habitat for aquatic organisms in the food web, including, but not limited to, fish, crustaceans, mollusks, insects, annelids, planktonic organisms, and the plants and animals upon which these aquatic organisms feed and depend on for their needs in all life stages; providing habitat for both resident and transient wildlife species, including mammals, birds, reptiles, and amphibians for breeding, resting, nesting, escape cover, travel corridors, and food; and, enhancing recreational, cultural, educational, scientific, and natural aesthetic values and uses.[18]

In the initial report, based on 1980 survey data for the area directly tributary to Oconomowoc Lake, wetlands encompassed approximately 248 acres, or 12 percent of the direct tributary area of the Lake. These wetlands were located south of the Lake, primarily adjacent to man-made channels and along the Oconomowoc River.

As noted with respect to wildlife habitat, the 2000 survey included the major wetland communities located within the total area tributary to Oconomowoc Lake. These areas, as shown on Map 16, encompassed approximately 6,332 acres, or approximately 12 percent of the total area tributary to the Lake. Wetland types reported included sedge meadow, shrub carr, fresh (wet) meadow, deep and shallow marsh, and southern wet and wet-mesic hardwood forest.

Sedge meadows are stable wetland plant communities that tend to perpetuate themselves if dredging activities and water level changes are prevented from occurring. Sedge meadows in southeastern Wisconsin are characterized by the tussock sedge (*Carex stricta*) and, to a lesser extent, by Canada blue-joint grass (*Calamagrostis canadensis*). Sedge meadows that are drained or disturbed to some extent typically succeed to shrub carrs. Shrub carrs, in addition to the sedges and grasses found in the sedge meadows, contain an abundance of shrubs, such as

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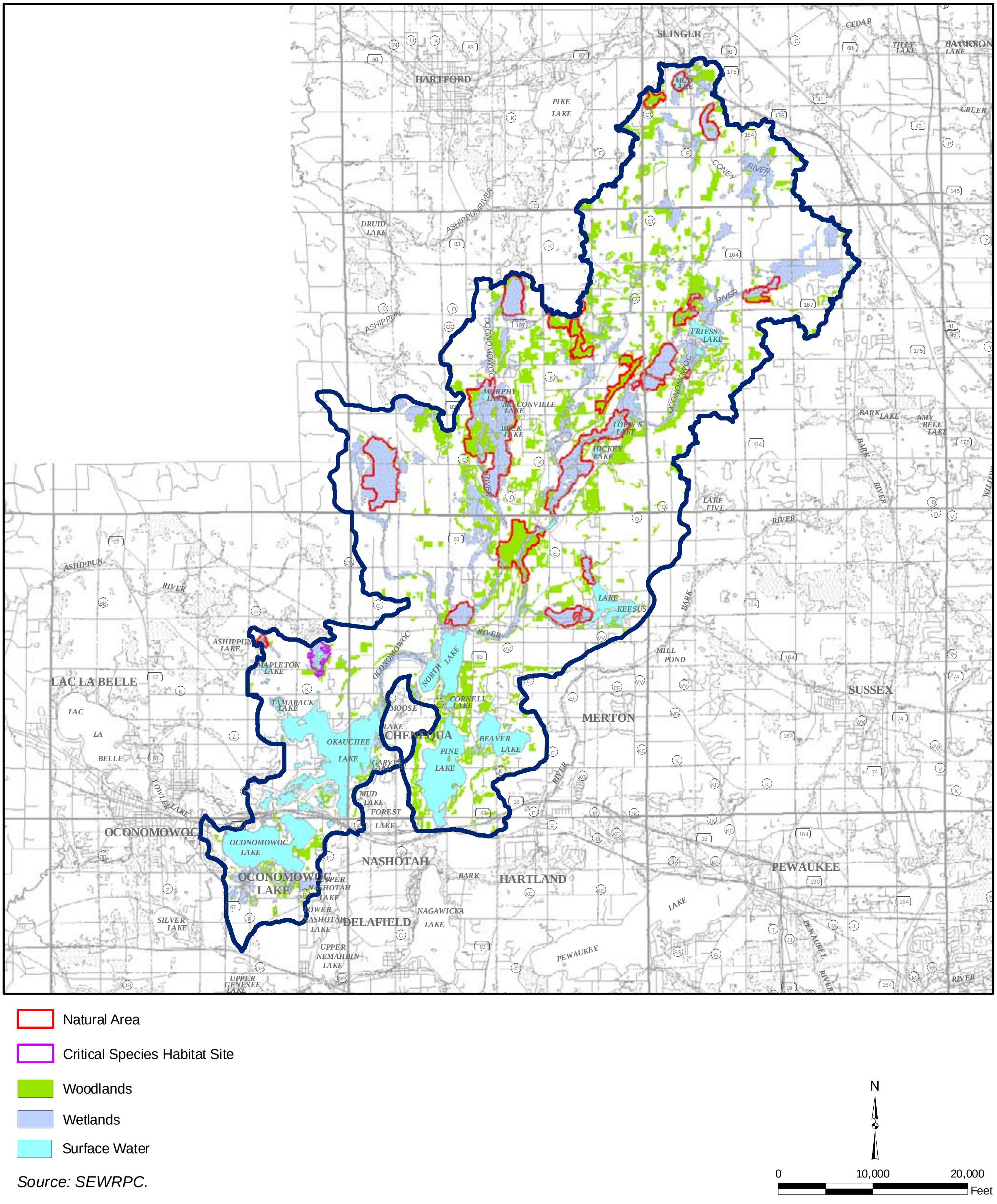
[17]*Although prior converted cropland is not subject to Federal wetland regulations unless cropping ceases for five consecutive years and the land reverts to a wetland condition, the State may consider prior converted cropland to be subject to State wetland regulations if the land meets the criteria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

[18]*SEWRPC Planning Report No. 42,* op. cit.

Map 16

WETLANDS, WOODLANDS, NATURAL AREAS, AND CRITICAL SPECIES HABITAT WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA: 2000



Source: SEWRPC.

willows (*Salix* spp.) and red osier dogwood (*Cornus stolonifera*). In extremely disturbed shrub carrs, willows, red osier dogwood, and sedges are replaced by exotic plants, such as honeysuckle (*Lonicera* sp.), buckthorn (*Rhamnus* sp.), and the very aggressive reed canary grass (*Phalaris arundinacea*).

Fresh (wet) meadows are essentially lowland grass meadows which are dominated by Canada blue-joint grass, and forbes, such as marsh (*Aster simplex*), red-stem (*A. puniceus*), and New England (*A. novae-angliae*) aster, and giant goldenrod (*Solidago gigantea*). Several disturbed fresh (wet) meadows are located throughout the Oconomowoc Lake tributary area, and are largely associated with sedge meadows and shrub carrs. Many of these fresh meadows have been subject to grazing, plowing, and drainage, and, consequently, are dominated by reed canary grass.

Areas of deep and shallow marsh also occurred in the Oconomowoc Lake tributary area. In the initial study, these areas were reported to be located primarily adjacent to the artificial channels along the southern shore of the Lake. These deep and shallow marsh areas were dominated by broadleaf cattail (*Typha latifolia*), soft-stem bulrush (*Scirpus validus*), and hard-stem bulrush (*Scirpus atrovirens*). It also was noted in the initial report that the quality and diversity of some of these deep and shallow marsh areas in the area directly tributary to the Lake were threatened by the invasion of the aggressive, alien plant species called purple loosestrife (*Lythrum salicaria*) and that significant stands of purple loosestrife were located in the wetland complex adjacent to the outlet of the Lake and in a wetland complex adjacent to Hewitt's Point on the northern shore of the Lake. These plants also were observed during the current planning period.

Southern wet and wet-mesic hardwood forest occurred in scattered areas of the tributary area. In the initial report, southern wet and wet-mesic hardwood forest areas were reported to be present in scattered areas adjacent to the eastern shoreline of the Lake and in the south-central portion of the direct tributary area. These lowland forests were characterized by the prevalence of black willow (*Salix nigra*), cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), silver maple (*Acer saccharinum*), and American elm (*Ulmus americana*).

As shown on Map 16, a large area of wetland within the total area tributary to Oconomowoc Lake was located south of the Lake. This wetland, known as the Oconomowoc River Marsh, is located along the Oconomowoc River just downstream of the Lake, and is comprised of a 100-acre, cattail-dominated, deep and shallow water marsh. Unfortunately, this wetland system has been disturbed by channelization and highway construction. Other wetland areas were located in scattered areas to the north and east of the Lake, throughout the total tributary area.

WOODLANDS

Woodlands in southeastern Wisconsin are defined as those areas containing 17 or more trees per acre which have at least a four-inch-diameter at breast height, that is, at a height of 4.5 feet above ground. In addition, the native woodlands are classified as dry, dry-mesic, mesic, wet-mesic, and wet hardwoods, and conifer swamp forests. The latter three woodland classifications are also considered to be wetlands.

As reported in the initial study, in 1980, the direct tributary area of Oconomowoc Lake contained 228 acres of woodlands, or about 11 percent of the direct tributary area. These woodlands consisted of the full range of native upland woodland habitats, and spanned the range of classifications noted above. Woodland tracts in the Oconomowoc Lake area occurred primarily as scattered woodlots, although a relatively large contiguous upland woodland was located on the eastern shore of the Lake.

In 2000, the extent of woodlands within the drainage basin was assessed on the basis of the total area tributary to Oconomowoc Lake. This total tributary area contained about 7,358 acres of woodlands, covering approximately 14 percent of the total tributary area to the Lake. These woodlands consisted of all of the native upland woodland habitats. Specifically, as shown on Map 16, upland woodlands in the area tributary to Oconomowoc Lake included southern dry hardwoods, consisting primarily of white oak (*Quercus alba*), burr oak (*Quercus macrocarpa*), shagbark hickory (*Carya ovata*), and black cherry (*Prunus serotina*); southern dry-mesic hardwoods, consisting primarily of northern red oak (*Quercus borealis*), paper birch (*Betula papyrifera*), and white ash (*Fraxinus americana*); and mesic hardwoods, consisting primarily of sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), and basswood (*Tilia americana*).

The amount and distribution of woodlands in the tributary area should remain relatively stable if the recommendations contained in the regional land use and county development plans are followed.[19] However, if urban development continues within the tributary area much of the remaining woodland cover may be expected to be lost.

ENVIRONMENTAL CORRIDORS

The Environmental Corridor Concept

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

The delineation of these 12 natural resource and natural resource-related elements on a map results in an essentially linear pattern of relatively narrow, elongated areas which have been termed “environmental corridors” by SEWRPC. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are, by definition, at least 400 acres in size, two miles in length, and 200 feet in width. The primary environmental corridors identified in the Oconomowoc Lake tributary area are, in some cases, contiguous with other environmental corridors and isolated natural resource areas lying outside the lake tributary area boundary and, consequently, meet these size and natural resource element criteria.

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

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[19] *SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006; SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996.*

and preserve the remaining environmental corridors within the Oconomowoc Lake tributary area, thus, becomes apparent.

In the area tributary to Oconomowoc Lake, the streambanks and lakeshores located within the environmental corridors should be candidates for immediate protection through proper zoning or through public ownership. Of the areas not already publicly owned, the remaining areas of natural shoreline, and riparian wetland areas, are perhaps the most sensitive areas in need of greatest protection. In this regard, the regional natural areas and critical species habitat protection and management plan recommends public acquisition of specific lands.[20] In close proximity to Oconomowoc Lake is the Oconomowoc River Marsh. Of the 100 acres comprising this valuable natural area, 65 acres are under protective public ownership; the remaining 35 acres under private ownership are recommended for acquisition by the WDNR.[21]

Primary Environmental Corridors

The primary environmental corridors in southeastern Wisconsin generally lay along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. As shown on Map 17, primary environmental corridors encompassed about 12,940 acres, or about 24 percent of the Oconomowoc Lake total tributary area, as of 2000.

Primary corridors may be subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems, as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems. The preservation of such corridors, thus, is one of the major ways in which the water quality of Oconomowoc Lake can be maintained and perhaps improved.

Secondary Environmental Corridors

Secondary environmental corridors are located generally along intermittent streams or serve as links between segments of primary environmental corridors. Secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses, and facilitate surface water drainage, maintain “pockets” of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species. As shown on Map 17, secondary environmental corridors encompassed about 1,110 acres, or about 2 percent of the total tributary area, as of 2000.

Isolated Natural Resource Areas

In addition to the environmental corridors, other small concentrations of natural resource base elements exist within the Oconomowoc Lake tributary area. These concentrations are isolated from the environmental corridors by urban development or agricultural lands and, although separated from the environmental corridor network, have important natural values. These isolated natural resource areas may provide the only available wildlife habitat in a localized area, provide good locations for local parks and nature study areas, and lend a desirable aesthetic character and diversity to the area. Important isolated natural resource features include a variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource features should also be protected and preserved in a natural state whenever possible. Such isolated areas, five or more acres in size within the area tributary to Oconomowoc Lake, also are shown on Map 17 and total about 952 acres, or about 2 percent

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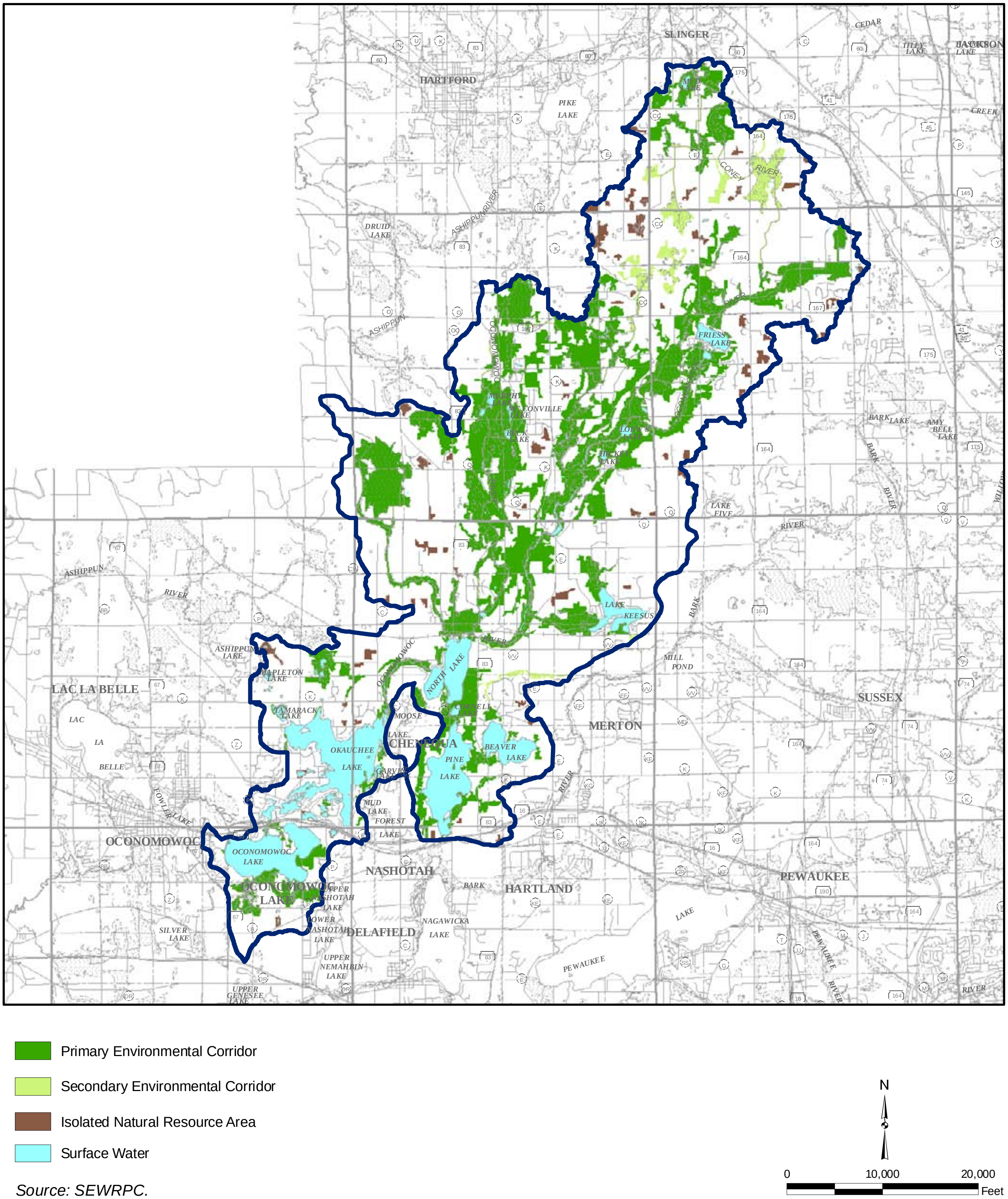
[20]*SEWRPC Planning Report No. 42*, op. cit.

[21]Ibid.

Map 17

ENVIRONMENTAL CORRIDORS AND NATURAL RESOURCE AREAS WITHIN THE OCONOMOWOC LAKE TOTAL TRIBUTARY AREA: 2000



Source: SEWRPC.

of the total tributary area. Because of its more limited study area—being limited to the area directly tributary to Oconomowoc Lake, the initial study identified only about 20 acres of isolated natural areas, covering about 1 percent of the area directly tributary to the Lake.

WDNR-Delineated Sensitive Areas

Within lakes, the WDNR may identify sites that have special importance biologically, historically, geologically, ecologically, or even archaeologically, pursuant to authorities granted under Chapter NR 107 of the *Wisconsin Administrative Code* and/or Chapter 30 of the *Wisconsin Statutes*. Areas are identified as sensitive areas after comprehensive examination and study by WDNR staff from many different disciplines and fields of study. Currently, however, Oconomowoc Lake contains no WDNR-designated sensitive areas.

SUMMARY

Oconomowoc Lake is a reflection of its tributary area. As noted in Chapter IV, Oconomowoc Lake is a typical hard-water, alkaline lake that is considered to have good water quality. Total phosphorus levels were found to be generally below the level considered to cause nuisance algal and macrophytic growths, and chlorophyll-*a* concentrations were such in recent years as to suggest that algal growth was not an issue in the Lake during the study period. In contrast, the increasing abundance of rooted aquatic plants, especially Eurasian water milfoil, was remarked as an issue of concern. Nevertheless, the Lake provides suitable habitat for a self-sustaining game fish population.

The Oconomowoc Lake tributary area provides a range of habitats for birds, large and small mammals, and reptiles and amphibians, with about 35 percent of the total tributary area being considered to be valuable wildlife habitat. While the area of wildlife habitat has declined in the total tributary area since the initial delineation of habitat areas in 1985, about one-half of the area delineated as wildlife habitat is considered to be of very high value.

The primary environmental corridors contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, as well as the major surface water resources and related undeveloped floodlands and shorelands. The preservation of such corridors, thus, is one of the major ways in which the water quality of Oconomowoc Lake can be maintained and perhaps improved.

Chapter VI

CURRENT WATER USES AND WATER USE OBJECTIVES

INTRODUCTION

Nearly all major lakes in the Southeastern Wisconsin Region serve multiple purposes, ranging from recreation to receiving waters for stormwater runoff. Recreational uses range from noncontact, passive recreational activities, such as picnicking and walking along the shoreline, to full-contact, active recreational activities, such as swimming, boating, and waterskiing. To accommodate this range of uses, the State of Wisconsin has developed water use objectives for the surface waters of the State, and has promulgated these objectives in Chapters NR 102 and NR 104 of the *Wisconsin Administrative Code*. Complementary water use objectives and supporting water quality guidelines have been adopted by the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and set forth in the adopted regional water quality management plan for all major lakes and streams in the Region.[1] The current water uses, as well as the water use objectives and supporting water quality guidelines for Oconomowoc Lake, are discussed in this chapter.

RECREATIONAL USES AND FACILITIES

Oconomowoc Lake is located within about a one half-hour drive from much of the metropolitan area of Milwaukee. Its location, accessibility, and degree and type of shoreline development, contribute to a moderate degree of recreational usage by residents and nonresidents alike. The Lake supports a full range of lake uses, providing opportunities for a variety of water-based outdoor recreational activities, including fishing, boating, swimming, and nature studies. Winter recreational uses include cross-country skiing, ice skating, and snowmobiling. The scope of these recreational uses engaged in on Oconomowoc Lake is sufficiently broad to be consistent with the recommended use objectives of full recreational use and the support of a healthy warmwater sportfishery, as set forth in the adopted regional water quality management plan.

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

Park and Open Space Sites

Oconomowoc Lake provides an ideal setting for the provision of parks and open space sites and facilities. As shown on Map 18, there are two public access sites serving Oconomowoc Lake. The first site, which is owned by the Village of Oconomowoc Lake, is located on the Oconomowoc River just below the dam at Okauchee Lake, about 0.7 mile upstream from the main basin of Oconomowoc Lake. A paved ramp, pier, and paved lot with regular and handicapped-accessible car/trailer unit parking spaces are provided. The ramp and parking lot facilities along the Oconomowoc River were found to be well maintained and in good condition. Parking at this site was deemed to be adequate pursuant to Chapter NR 1 of the *Wisconsin Administrative Code*.

Recreational Boating

In the initial SEWRPC report, a survey of boating pressure conducted during 1976 indicated that the Lake was used primarily by fishing boats. The heaviest use of the Lake by anglers was during spring and early autumn, and during summer weekdays. Recreational boating pressure was highest on summer weekends, with the greatest usage being by powered (fishing) boats, followed by sailing craft and powered water ski boats. Boat traffic was described as relatively constant throughout the boating season. No conditions of crowding or unsafe boating pressures were apparent during the 1976 survey.

During the current study period, surveys were conducted by Commission staff to determine the degree and types of recreational activities, including boating, in which people participate on Oconomowoc Lake. In recent years, lakes in the Region have generally experienced an increase in growth of recreational boating. This has, at times, resulted in periods of heavy boating pressure on some of the Region's lakes. This reported boating pressure is discussed further below, in terms of public recreational boating access, recreational boating use, and recreational boating regulations.

Recreational Boating Access Standards

There is a range of opinion on the issue of what constitutes optimal boating density on a lake. In the mid-1970s, an average area of about 16 acres per powered- or sail-boat was, at that time, considered suitable for the safe and enjoyable use of a boat on a lake, and, for safe waterskiing and fast boating, an area of 40 acres per boat was suggested in the regional guidelines as the minimum area necessary for safe operations.[2] Subsequently, Chapter NR 1 of the *Wisconsin Administrative Code* was amended during 1994 to define maximum and minimum public recreational boating access standards for public inland lakes. These standards, defined in Section NR 1.91 of the *Wisconsin Administrative Code*, are based upon the boatable lake surface area, ranged from a minimum of one car/trailer parking space per 30 to 70 open water acres of lake surface to a maximum of one car/trailer parking space per 15 to 50 open water acres, with additional accommodation for handicapped access, for lakes with surface areas ranging upwards from 100 acres. Lakes of less than 100 surface acres have a minimum and maximum standard of five parking spaces, with these spaces being for car-top parking if the lake has less than 50 boatable acres.

Pursuant to the standards set forth in Chapter NR 1 of the *Wisconsin Administrative Code*, the 804-acre Oconomowoc Lake would be expected to be served by public recreational boating access sites with a capacity ranging from a minimum of 23 car/trailer units to a maximum of 33 car/trailer units, plus at least one car/trailer space for handicapped individuals. The provision for vehicle parking at the Oconomowoc Lake public recreational boating access site is consistent with these standards, and the Lake is deemed by the WDNR to have adequate public recreational boating access.

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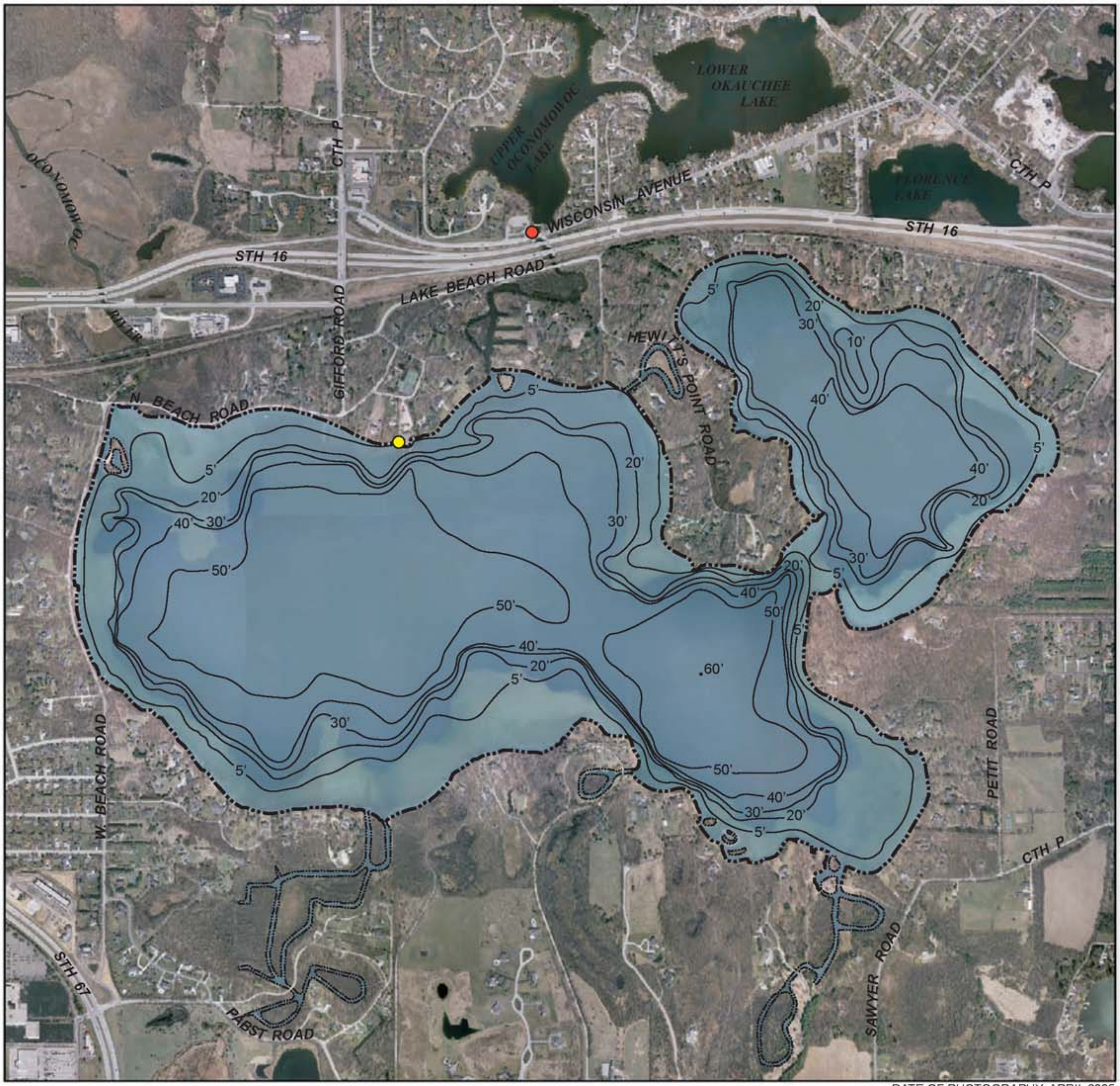
[2]*See SEWRPC Planning Report No. 27,* A Park and Open Space Plan for Southeastern Wisconsin: 2000, *November 1977.*

Map 18

RECREATIONAL BOATING ACCESS SITES ON OCONOMOWOC LAKE: 2008



DATE OF PHOTOGRAPHY: APRIL 2005

—20'— WATER DEPTH CONTOUR IN FEET

PUBLIC BOAT ACCESS SITE

PRIVATE BOAT ACCESS SITE

GRAPHIC SCALE 0 750 1500 FEET

Source: Wisconsin Department of Natural Resources and SEWRPC.

Recreational Boating Use

One method of indirectly assessing the degree of recreational boating use of a lake is through counts of docked and moored boats on and around a lake. It has been estimated that, in southeastern Wisconsin, the number of watercraft operating at any given time is approximately 2 to 5 percent of the total number of watercraft docked and moored. It can be anticipated that, with the exception of major holiday weekends, when greater numbers of watercraft are in operation, that knowledge of the total watercraft population will inform both an assessment of the intensity of water use, as well as the nature of water use.

During 2005, about 515 watercraft of various descriptions were observed to be docked or moored on Oconomowoc Lake, or observed as trailered watercraft or watercraft on land around Oconomowoc Lake, as shown in Table 26. Of the motorized watercraft, power boats and pontoon boats comprised the largest proportion of the watercraft observed, with a combined total of 241 watercraft or about one-half of the motorized watercraft on the Lake. Fishing boats and personal watercraft (PWCs or "jetskis"®) comprised the remainder of the motorized watercraft. Of the nonmotorized watercraft, kayaks formed the largest proportion of the watercraft observed, accounting for about 51 boats, or about one-third of the nonmotorized watercraft on the Lake. Canoes and sailboats made up most of the other nonmotorized watercraft. There was one seaplane on the Lake. Applying the 2 to 5 percent estimation described above to the number of watercraft in Table 26 assumed to be capable of high speeds results in high-speed boating densities that range from 62 acres per boat to 161 acres per boat. Such estimated densities would be within the range considered appropriate for the conduct of safe high-speed boating activities recommended in the regional guidelines.

On Oconomowoc Lake, about 67 percent of all watercraft on the Lake were motorized, with the two largest categories, pontoon boats and powerboats, being about equally represented. By comparison, on Pewaukee Lake, a 2,493-acre lake located just east of Oconomowoc Lake, nearly 80 percent of all watercraft on the Lake were motorized with the largest category of motorized boats being powerboats which comprised nearly 40 percent of all boats on the Lake; on Ashippun Lake, an 84-acre lake just to the north of Oconomowoc Lake, motorized watercraft account for just over 60 percent of all watercraft on the lake with the largest categories of motorized watercraft being fishing boats and pontoon boats, which accounted for about 17 percent of all watercraft, each. Of the nonmotorized watercraft, canoes and kayaks formed the largest contributions to the fleets on Oconomowoc Lake and Ashippun Lake, while on Pewaukee Lake the largest percentage of the nonmotorized category was comprised of sailboats. From this perspective, Oconomowoc Lake falls along the continuum of recreational boating usage that is typical of the major lakes in the Southeastern Wisconsin Region.

Another way to assess the degree of recreational boat use on a lake is through direct counts of boats in use on a specific lake at a given time. These counts can be used to calculate the boating density, or the numbers of acres of open water available in which to operate a boat, and are, therefore, an indication of the intensity of recreational boating occurring on a lake. Such counts are made generally during off-peak periods during the summer, in other words, it is assumed that holiday weekends will be periods when the typical numbers of watercraft are exceeded, in order to understand the "normal" level of lake use during the larger part of the open water season. Table 27 shows direct counts made by Commission staff of watercraft in use during a typical weekday and weekend day in the late summer of 2006. As shown in the table, fishing boats represented the majority of watercraft in operation during both the weekday and weekend day observation periods. A significant percentage of powerboats and pontoon boats also were observed to be in operation on those days. Based on the data in Table 27, direct counts of boats in use on Oconomowoc Lake would result in densities of high-speed watercraft on the Lake ranging from about one boat per 57 acres on a summer weekend afternoon to about one boat per 200 acres on a summer weekday morning. Boating densities based on direct counts of boats on Oconomowoc Lake, as described above, are consistent with those considered appropriate for the conduct of safe high-speed boating activities pursuant to the adopted regional guidelines.

Recreational Boating Regulations

Recreational boating activities on Oconomowoc Lake are regulated by State boating and water safety laws, and by the specific provisions of the Village of Oconomowoc Lake Ordinance, Chapter 20, *Lakes and Beaches*. The ordinance is summarized in Appendix B.

Table 26

WATERCRAFT ON OCONOMOWOC LAKE: 2005[a]

Type of Watercraft										
Powerboat	Fishing Boat	Pontoon Boat	Personal Watercraft	Paddleboat	Sailboat	Canoe	Kayak	Rowboat	Sea Plane	Total
118	36	123	71	28	33	36	51	18	1	515

[a]*Including trailered watercraft and watercraft on land observable during survey.*

Source: SEWRPC.

Table 27

WATERCRAFT IN USE ON OCONOMOWOC LAKE: 2006

	Weekday Participants					
Date and Time	Powerboat/ Pontoon Boat	Fishing Boat	Personal Watercraft	Sailboat	Canoe/Kayak	Total
Thursday, September 7						
10:00 a.m. to 11:00 a.m.	1	6	0	0	0	7
1:30 p.m. to 2:30 p.m.	1	8	0	0	1	10
Total for the Day	2	14	0	0	1	17
Percent	12	82	0	0	6	100

	Weekend Participants					
Date and Time	Powerboat/ Pontoon Boat	Fishing Boat	Personal Watercraft	Sailboat	Canoe/Kayak	Total
Saturday, September 16						
10:00 a.m. to 11:00 a.m.	0	16	0	0	0	16
1:30 p.m. to 2:30 p.m.	5	15	1	1	2	24
Total for the Day	5	31	1	1	2	40
Percent	13	79	2	2	4	100

Source: SEWRPC.

Angling

During the summer of 2006, Commission staff also conducted a survey of all other recreational activities observed in and around Oconomowoc Lake. The results of this survey are shown in Table 28. Of the various recreational activities being engaged in or around Oconomowoc Lake during the observational sessions, anglers fishing from boats represented a majority of recreational users of the Lake during both weekdays and weekends. Fishing from boats represented over 80 percent of recreational use of the Lake observed on the weekday morning, over 55 percent of activity observed on the weekday afternoon, all of the activity observed on the weekend morning, and 70 percent of activity observed on the weekend afternoon. Clearly, angling forms a dominant recreational activity on this Lake.

Oconomowoc Lake provides a high-quality habitat for gamefish, such as walleye, smallmouth and largemouth bass, and panfish, as noted in Chapter V of this report. The sizes and the numbers of fish in the Lake provide a range of angling opportunities for both the lake residents and other lake users alike. Evidence of good fishing is

Table 28

RECREATIONAL ACTIVITIES IN/ON OCONOMOWOC LAKE: 2006

Date and Time	Weekday Participants						
	Pleasure Boating	Skiing/ Tubing	Sailing	Operating Personal Watercraft	Fishing from Boats	Canoeing/ Paddle Boating	Total
Thursday, September 7							
10:00 a.m. to 11:00 a.m.	2	0	0	0	9	0	11
1:30 p.m. to 2:30 p.m.	8	3	0	0	15	1	27
Total for the Day	10	3	0	0	24	1	38
Percent	26	8	0	0	63	3	100

Date and Time	Weekend Participants						
	Pleasure Boating	Skiing/ Tubing	Sailing	Operating Personal Watercraft	Fishing from Boats	Canoeing/ Paddle Boating	Total
Saturday, September 16							
10:00 a.m. to 11:00 a.m.	0	0	0	0	22	0	22
1:30 p.m. to 2:30 p.m.	3	0	1	2	19	2	27
Total for the Day	3	0	1	2	41	2	49
Percent	6	0	2	4	84	4	100

Source: SEWRPC.

provided by the numbers of fishing boats and shoreline anglers using the Lake during the summer and by the numbers of ice fishing shelters observed on the ice during the winter months. The good water quality and suitable bottom substrate provide habitat appropriate for the natural reproduction of walleye and smallmouth bass, in addition to largemouth bass and northern pike. Although not directly stocked with muskellunge (muskie), Oconomowoc Lake has benefited from fishes that were stocked into Okauchee Lake, which have migrated downstream into Oconomowoc Lake. The adult muskie density in Oconomowoc Lake is nearly the same as that in Okauchee Lake.[3]

Wisconsin Department of Natural Resources Recreational Rating

As summarized above, Oconomowoc Lake provides a venue for a variety of outdoor recreational opportunities. Based upon the outdoor recreation rating system developed by the Wisconsin Department of Natural Resources (WDNR), Oconomowoc Lake received a total of 63 of a possible 72 points, as shown in Table 29. This rating indicates that the Lake provides a range of recreational opportunities, including a moderately productive fishery, water quality moderately conducive to swimming and boating, an adequate number of boat launching sites with water depths and a lake surface area conducive to boating, and a varied landscape that enhances the natural aesthetics of the Lake.

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[3]*Wisconsin Department of Natural Resources Correspondence/Memorandum to Randy Schumacker from Sue Beyler and Steve Gospodarek, dated January 25, 2005.*

Table 29

WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECREATIONAL RATING OF OCONOMOWOC LAKE: 1967

Space: Total Area = 804 acres			Total Shore Length = 7.0 miles		
Quality (18 maximum points for each item)					
Fish:					
__ 9	High production	X 6	Medium production	__ 3	Low production
X 9	No problems	__ 6	Modest problems, such as infrequent winterkill, small rough fish problems	__ 3	Frequent and overbearing problems, such as winterkill, carp, excessive fertility
Swimming:					
__ 6	Extensive sand or gravel substrate (75 percent or more)	X 4	Moderate sand or gravel substrate (25 to 50 percent)	__ 3	Minor sand or gravel substrate (less than 25 percent)
X 6	Clean water	__ 4	Moderately clean water	__ 3	Turbid or darkly stained water
__ 6	No algal or weed problems	X 4	Moderate algal or weed problems	__ 3	Frequent or severe algal or weed problems
Boating:					
X 6	Adequate water depths (75 percent of basin more than five feet deep)	__ 4	Marginally adequate water depths (50 to 75 percent of basin more than five feet deep)	__ 3	Inadequate depths (less than 50 percent of basin more than five feet deep)
__ 6	Adequate size for extended boating (more than 1,000 acres)	X 4	Adequate size for some boating (200 to 1,000 acres)	__ 3	Limit of boating challenge and space (less than 200 acres)
X 6	Good water quality	__ 4	Some inhibiting factors, such as weedy bays, algal blooms, etc.	__ 3	Overwhelming inhibiting factors, such as weedbeds throughout
Aesthetics:					
X 6	Existence of 25 percent or more wild shore	__ 4	Less than 25 percent wild shore	__ 3	No wild shore
X 6	Varied landscape	__ 4	Moderately varied	__ 3	Unvaried landscape
X 6	Few nuisances, such as excessive algae, carp, etc.	__ 4	Moderate nuisance conditions	__ 3	High nuisance condition
Total Quality Rating: 63 out of a possible 72					

Source: Wisconsin Department of Natural Resources and SEWRPC.

WATER USE OBJECTIVES

The regional water quality management plan recommended adoption of full recreational use and warmwater fisheries objectives for Oconomowoc Lake. The findings of the inventories of the natural resource base, set forth in Chapters III through V, indicate that the use of the Lake and the resources of the area are generally supportive of such objectives, although it is expected that remedial measures will be required if the Lake is to fully meet the objectives. The recommended warmwater fishery objective is supported in Oconomowoc Lake by a sport fishery based largely on largemouth bass and panfish. These fishes have traditionally been sought after in Oconomowoc Lake. Likewise, the range of recreational activities observed on and around the Lake by Commission staff suggest that the Lake is accommodating a full range of recreational uses, although such uses are dominated by recreational boating and angling.

WATER QUALITY GUIDELINES

The water quality guidelines supporting the warmwater fishery and full recreational use objectives, as established for planning purposes in the regional water quality management plan, are set forth in Table 30. These guidelines are similar to the standards set forth in Chapters NR 102 and 104 of the *Wisconsin Administrative Code*, but were refined for planning purposes in terms of their application. Guidelines are recommended for temperature; pH; and dissolved oxygen, fecal coliform, and total phosphorus concentrations. These guidelines apply to the epilimnion or surface waters of lakes and to streams. The total phosphorus concentration guideline applies to spring turnover concentrations measured in the surface waters. Such contaminants as oil, debris, and scums; odors, tastes, and color-producing substances; and toxins are not permitted in waters of the State in concentrations harmful to the aquatic life, as set forth in Chapter NR 102 of the *Wisconsin Administrative Code*. Application of these guidelines as water quality objectives for Oconomowoc Lake is recommended.

The adoption of these guidelines is intended to specify conditions in the waterways concerned that mitigate excessive macrophyte and algal growths, and promote all forms of recreational use, including angling, in these waters. Implementation of actions consistent with these guidelines will ensure that Oconomowoc Lake is maintained in a mesotrophic condition. As noted in Chapter IV of this report, such a condition is the likely natural state of the major lakes in the Southeastern Wisconsin Region and represents an achievable water quality goal for the Region’s lakes.

Table 30

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

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

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

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

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

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

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

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

Source: SEWRPC.

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Chapter VII

ALTERNATIVE LAKE MANAGEMENT MEASURES

INTRODUCTION

Based upon a review of the inventories and analyses set forth in Chapters II through VI, issues were identified that required consideration in the formulation of alternative and recommended lake management measures. These issues are related to: 1) land use; 2) pollution abatement; 3) water quality; 4) aquatic biota; and, 5) water uses. The management measures considered herein are focused primarily on those measures which are applicable to the Village of Oconomowoc Lake and to Oconomowoc Lake, although larger scale measures are noted where such drainage area measures may be applicable to the Lake. In this chapter, the full range of possible management measures is considered and reviewed for inclusion in the recommended lake management plan for Oconomowoc Lake, which is set forth in Chapter VIII.

TRIBUTARY AREA MANAGEMENT ALTERNATIVES

Land Use

A basic element of any water quality management effort for a lake is the promotion of sound land use development and management in the tributary area. The types and locations of future urban and rural land uses in the tributary area to Oconomowoc Lake will determine, to a large degree, the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, stormwater management; and, to some degree, the water quality of the Lake. Potentially applicable measures start at the lake shore and extend into the tributary area surrounding the Lake, as well as into the larger watershed draining to Oconomowoc Lake. Interventions at each of these scales are outlined below.

Existing 2000 and planned buildout land use patterns and existing zoning regulations in the tributary area to Oconomowoc Lake have been described in Chapter II. If the recommendations set forth in the adopted Waukesha County development plan and the regional land use plan are followed, under buildout conditions, some additional urban-density residential development would occur within the area directly tributary to Oconomowoc Lake.[1] Much of this residential development is likely to occur on agricultural lands, within the drainage area upstream of Oconomowoc Lake. Infilling of existing platted lots and some backlot development, as well as the redevelopment and reconstruction of existing single-family homes around the Lake itself, also may be expected to occur.

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[1]*See SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996; SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

Recent surveillance indicates that this type of development is currently occurring. Considerable urban density development, primarily residential in character, has been noted in the total drainage basin. Accordingly, given the potential impact of lakeshore development on the lake resources, land use development or redevelopment proposals around the shoreline of Oconomowoc Lake and within the area tributary to the Lake should be evaluated for potential impacts on the Lake, as such proposals are advanced.

Development in the Shoreland Zone

Recent studies of the potential impact of riparian landscaping activities on the nutrient loadings to lakes in southeastern Wisconsin have suggested that urban residential lands can contribute up to twice the mass of phosphorus to a lake when subjected to an active program of urban lawn care than similar lands managed in a more natural fashion.[2] The application of agrochemicals to such lands, in excess of the plant requirements, results in enhanced nutrient loading directly to the adjacent waterbodies. To address these concerns, the State of Wisconsin adopted new turf management regulations during 2009 to limit the application of fertilizers containing phosphorus to lands in urban areas. Similar requirements had previously been enacted by the Village of Oconomowoc Lake prior to the statewide regulations, as noted in Chapter IV.

Development in the Tributary Area

The level of development envisioned in the Waukesha County development plan for the area tributary to Oconomowoc Lake indicates continuing urban development, generally on large suburban-density lots. Careful review of applicable zoning ordinances, to incorporate levels and patterns of development consistent with the plan within the area tributary to Oconomowoc Lake, is recommended. Changes in the zoning ordinances should be considered to better reflect the land use patterns recommended in the County development plan. Consideration should be given to minimizing the areal extent of development by developing specific provisions and incentives to encourage cluster residential development on smaller lots while preserving, to the greatest extent practicable, the open space on each property or group of properties considered for development, utilizing the principles of conservation development.[3] In addition, consideration of other provisions to ensure appropriate monitoring and maintenance of onsite sewage disposal systems, where such systems exist, and effective stormwater and runoff control and management, is recommended. Each of these latter measures is addressed in greater detail below.

Wastewater Management

At the time of the current study, residential urban development located in some areas of the total tributary area of Oconomowoc Lake had been included within public sanitary sewer service areas, as recommended in the adopted regional water quality management plan.[4] As noted in Chapter II, a small portion of the residential lands located along the southwestern shores of Oconomowoc Lake along South Beach Road is served by public sanitary sewerage service provided by the City of Oconomowoc publicly-owned wastewater treatment plant. However, isolated developments lying outside these areas, but within the total area tributary to Oconomowoc Lake, as well as the urban density development located along the southern shoreline of Oconomowoc Lake, are expected to continue to be served by onsite sewage disposal systems. The regional water quality management plan recommends that sewerage needs in such areas be periodically reevaluated in light of changing conditions, and that the provision of wastewater management services be modified accordingly. This recommendation is consistent with the recommendations set forth in the comprehensive land use plan for the Village.[5]

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[2]*U.S. Geological Survey Water-Resources Investigations Report No. 02-4130,* Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from Lakeshore Lawns, Lauderdale Lakes, Wisconsin, *July 2002.*

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

[4]*SEWRPC Memorandum Report No. 93,* op. cit.*; SEWRPC Community Assistance Planning Report No. 172, 2nd Edition,* Sanitary Sewer Service Area for the City of Oconomowoc and Environs, Waukesha County, Wisconsin, *September 1999, as amended.*

[5]*Village of Oconomowoc Lake,* Smart Growth Plan for the Village of Oconomowoc Lake, *March 2008.*

Currently, portions of the northern and western lakeshores of Oconomowoc Lake, as well as portions of the total area tributary to Oconomowoc Lake, are recommended to be served by public sanitary sewers.[6] Sewage treatment is recommended to be provided by the City of Oconomowoc sewerage treatment facility.

As reported in Chapter IV, total phosphorus loadings from onsite sewage disposal systems are estimated to contribute only a minor proportion, less than 2 percent, of the total phosphorus load to the Lake, which proportion is anticipated to decline as public sanitary sewerage services are extended within the tributary area pursuant to the adopted regional water quality management plan.[7] In addition to lake water quality considerations, sewage disposal in the area has implications for groundwater quality and property values. Consequently, onsite sewage disposal remains an important consideration in the portions of the tributary area not currently served by a public wastewater conveyance system or outside of the planned public sanitary sewer service areas.

Where onsite sewage disposal systems remain the primary wastewater treatment method, it is recommended that an onsite sewage disposal system management program be carried out, including the conduct of an ongoing informational and educational effort to enhance awareness of the need for regular maintenance of these systems. Homeowners in areas served by onsite systems should be advised of the rules, regulations, and system limitations governing onsite sewage disposal systems, and should be encouraged to undertake preventive maintenance programs.

Stormwater Management

With respect to stormwater management, Waukesha County adopted a stormwater management ordinance in 2000. The Village of Oconomowoc Lake utilizes this ordinance within the Village. The County ordinance reflects best practices insofar as the determination of stormwater flows, mitigation of flooding potential, and the control of contaminants from land use activities are concerned. Periodic review of this ordinance and its provisions for consistency with best practices, and to ensure its currency with the state-of-the-art, should be undertaken to facilitate control of urban-sourced contaminants that could potentially be delivered to the Lake. Further, inclusion of the Village of Oconomowoc Lake within the Pabst Farms Joint Stormwater District, currently comprised of the City of Oconomowoc and the Town of Summit, is recommended for consideration, given that the northern portion of the Pabst Farms development drains to Oconomowoc Lake through the constructed channels within the LaLumiere subdivision. Regardless, it is recommended that the Village of Oconomowoc Lake consider attending the meetings of the Pabst Farms Joint Stormwater District in an *ex officio* capacity.

Protection of Environmentally Sensitive Lands

Environmentally sensitive lands within the area tributary to Oconomowoc Lake include wetlands, woodlands, and wildlife habitat areas. Nearly all of these areas within the Oconomowoc Lake tributary area are included within the environmental corridors and isolated natural resource features delineated by the Southeastern Wisconsin Regional Planning Commission (SEWRPC). Upland areas, woodlands, and wildlife habitat areas, currently, are protected primarily through local land use regulation, while wetlands enjoy a wider range of protections set forth in State and Federal legislation.

Wetland protection can be accomplished through land use regulation and, in cases where land use regulations may not offer an adequate degree of protection, through public acquisition of sensitive sites. Many of the wetland areas are currently protected to a degree by current zoning and regulatory programs administered by the U.S. Army Corps of Engineers (US ACE), Wisconsin Department of Natural Resources (WDNR), and County and municipal authorities under one or more of the Federal, State, County, and local regulations. Additional protections may be

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[6]*SEWRPC Community Assistance Planning Report No. 172, 2nd Edition*, Sanitary Sewer Service Area for the City of Oconomowoc and Environs, Waukesha County, Wisconsin, *September 1999, as amended.*

[7]*SEWRPC Community Assistance Planning Report No. 172, 2nd Edition,* loc. cit.

warranted, as recommended, for example, in the regional natural areas and critical species habitat protection and management plan.

Pollution Abatement

All human activities upon the land surface result in some degree of mobilization of contaminants and modification of surface runoff patterns that can affect lakes and streams, their quality, and biotic condition. Many human activities can be mitigated to a large extent by the implementation of sound planning, appropriate nonpoint source pollution abatement measures, and the actions of an informed public. In the first instance, sound land use development and management in the tributary area, and protection of environmentally sensitive lands, are the fundamental building blocks for protecting lake and stream water quality and habitat, and preserving human use opportunities that will support a broadly based recreational and residential community. In addition, specific nonpoint source pollution control and abatement measures should be integrated into land use regulations and promoted by a far-reaching informational and educational program within the area tributary to individual lakes and streams. These land-based regulations have been summarized to a large extent in the foregoing section of this report; this section discusses relevant pollution control and abatement measures that could be applicable to the tributary area of Oconomowoc Lake.

Nonpoint Source Pollution Abatement

Tributary area management measures may be used to minimize nonpoint source pollutant loadings from the tributary area by locating development within a tributary basin in accordance with sound land use planning practices. Beyond such actions, specific interventions may be required to control the mass of contaminants generated by various types of land use activity that are transported to the Lake. Rural sources of contaminants arise as pollutants transported by runoff from cropland and pastureland, while urban sources include contaminants transported by runoff from residential, commercial, industrial, transportation, and recreational land uses, and from construction activities. Alternative, tributary area-based nonpoint source pollution control measures considered in this report are based upon the recommendations set forth in the regional water quality management plan as refined,[8] in the Oconomowoc River priority watershed plan,[9] and in the Waukesha County land and water resource management plan.[10]

The regional water quality management plan recommends that the nonpoint source pollutant loadings from the areas tributary to Oconomowoc Lake be reduced by up to 25 percent in urban areas and by up to 25 percent in rural areas, in addition to implementation of urban construction erosion controls, stream bank erosion controls, and onsite sewage disposal system management practices. These values were further refined as a part of the Oconomowoc River Priority Watershed Pollution Abatement Program which established pollution reduction goals of between 30 and 50 percent for sediment loadings and between 28 and 76 percent for phosphorus loadings. Generally, the higher phosphorus load reductions were proposed for the more urban, lower portions of the watershed, below Okauchee Lake, while the higher sediment load reductions were proposed for the upper, more rural portions of the watershed, upstream of Oconomowoc Lake.

As described in Chapter IV, the most readily controllable loadings are associated primarily with runoff from urban lands within the area tributary to the Lake, and from urbanizing lands throughout the area tributary to the Lake, that are linked to the Lake by way of streams and stormwater drainage systems. These loadings constituted

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

[9]*Wisconsin Department of Natural Resources Publication No. WR-194-86,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *March 1986.*

[10]*Waukesha County,* Land and Water Resource Management Plan: 1999-2002, *December 1998.*

about 3 percent of the sediment load, 25 percent of the total phosphorus load, and 100 percent of the heavy metals load to Oconomowoc Lake, based upon year 2000 land use patterns. Phosphorus loadings from the remainder of the tributary area, and from direct deposition onto the lake surface, contributed the balance of the total load. The contributions of phosphorus and sediment from urban lands are expected to decrease as agricultural lands are progressively converted to urban uses, while heavy metals loads are expected to increase.

While some proportion of these contaminant loads may be attenuated as a consequence of the extensive wetland areas within the tributary area, the ability of these wetlands to assimilate pollutants is wholly dependent upon the maintenance of their structure and function of their ecosystems. These features can be overwhelmed by inappropriate land uses that result in the degradation of the wetlands, diminishing their ability to capture contaminants, or creating contaminant loads of such magnitude that the wetlands are overloaded. Thus, the control of nonpoint sources of water pollution at their sources is an important consideration. Properly applied, such controls can reduce the pollutant loadings to a lake by about 25 percent or more.

Appendix C presents a list of alternative nonpoint source pollution management measures that could be considered for use in the Oconomowoc Lake area to reduce loadings from nonpoint sources of pollution. Information on the cost and effectivity of the measures is also presented in Appendix C. It should be noted that appropriate public informational programming, described below, provides a means of disseminating information on various nonpoint source control measures that can be targeted to specific sectors of the community. Many of the measures are low-cost or no-cost measures that can be implemented by individual landowners. Selected measures are discussed below.

Rural Nonpoint Source Controls

Upland erosion from agricultural and other rural lands is a contributor of sediment to streams and lakes. Estimated phosphorus and sediment loadings from agricultural lands, woodlands, and wetlands in the area tributary to Oconomowoc Lake were presented in Chapter IV. These data were utilized in determining the pollutant load reduction that could be achieved, the types of practices needed, and the extent of the areas to which the practices need to be applied within the area tributary to Oconomowoc Lake.

Based upon the pollutant loading analysis set forth in Chapter IV, a total annual phosphorus load of 10,540 pounds is estimated to be contributed to Oconomowoc Lake. Of that mass, it is estimated that 7,840 pounds per year, or 75 percent of the total load, were contributed by runoff from rural land. In addition, it is estimated that about 5,415 tons of sediment, or about 90 percent of the total sediment load to Oconomowoc Lake, were contributed annually from agricultural lands in the area tributary to the Lake. As of 2000, agricultural lands comprised about 24,063 acres, or about 45 percent of the total area tributary to Oconomowoc Lake, which area is anticipated to diminish to about 20,028 acres, or less than 40 percent, of the tributary area by the year 2020.

While agricultural land uses are anticipated to be a declining form of land usage within the area tributary to Oconomowoc Lake, the agricultural operations that remain within the tributary area will continue to contribute a significant proportion of the sediment load to the waterbody. Table 15 in Chapter IV of this report suggests that, based upon estimated contaminant loadings for planned year 2035 conditions, agricultural land uses will continue to contribute about 85 percent of the total sediment load, or about 4,500 tons of sediment annually, to Oconomowoc Lake. Thus, detailed farm conservation plans are likely to continue to be required to adapt and refine erosion control and nutrient and pest management practices for individual farm units. Generally prepared with the assistance of staff from the U.S. Natural Resources Conservation Service (NRCS) or county land and water conservation departments, such plans identify desirable tillage practices, cropping patterns, and rotation cycles. The plans also consider 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.

Urban Nonpoint Source Controls

As of 2000, established urban land uses comprised about 11,321 acres, or about 21 percent, of the total area tributary to Oconomowoc Lake. The annual phosphorus loading from these urban lands was estimated to be about

2,700 pounds, or about 25 percent of the total load of phosphorus to the Lake. This is anticipated to increase to about 35 percent of the total load of phosphorus under buildout conditions. Those urban-source pollutant loadings that are most controllable include runoff from the residential lands adjacent to the Lake, and urban runoff from areas with a high proportion of impervious surface. The potential also exists within the Oconomowoc Lake tributary area for significant construction site erosion impacts if development continues in the tributary area as has been the recent trend.

Potentially applicable urban nonpoint source control measures include stormwater management measures, wet detention basins, grassed swales, and good urban "housekeeping" practices. Generally, the application of low-cost urban housekeeping practices may be expected to reduce nonpoint source loadings from urban lands by about 25 percent. Public educational programs can be developed to encourage 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 continued use of reduced quantities of street deicing salt.

Particular attention also should be given to reducing pollutant loadings from high pollutant loading areas, such as commercial sites, parking lots, and material storage areas. To the extent practicable, parking lot stormwater runoff should be diverted to areas covered by pervious soils and appropriate vegetation, rather than being directly discharged to surface waters. Material storage areas may be enclosed or periodically cleaned, and diversion of stormwater away from these sites may further reduce pollutant loadings. Street sweeping, increased catch basin cleaning, stream protection, leaf litter and vegetation debris collection, and stormwater storage and infiltration measures can enhance the control of nonpoint-source pollutants from urban and urbanizing areas, and reduce urban nonpoint source pollution loads by up to about 50 percent.

As has been noted above, as of 2000, the Village of Oconomowoc Lake and the Town of Summit had not adopted separate stormwater management ordinances applicable to developments within the areas under their jurisdiction. While such ordinances generally limit the potential impacts of new development, they do not address impacts from existing land uses nor do they address the cumulative impacts of past development. Therefore, additional measures to reduce nonpoint source pollution from existing development would appear to be warranted. Proper design and application of structural 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. These management practices are consistent with the Waukesha County stormwater ordinance provisions, which both municipalities use as guidance for stormwater management within their jurisdictions.

Developing Area Nonpoint Source Controls

Developing areas can generate significantly higher pollutant loadings, albeit for relatively short periods, than established areas of similar size. Developing areas include a wide array of activities, including urban renewal projects, individual site development within the existing urban area, and new land subdivision development. The regional land use and county development plans envision only limited new urban development within the tributary area directly adjacent to the Lake. However, as previously noted, some large-lot suburban-density development is currently taking place in the area tributary to Oconomowoc Lake, together with the redevelopment of existing, platted lakefront lots, and there is the potential for significant development of lands within the total area tributary to the Lake.

Construction sites, especially, may be expected to produce suspended solids and phosphorus loadings at rates several times higher than established urban land uses. Control of sediment loss from construction sites can be provided by measures set forth in the model ordinance developed by the WDNR in cooperation with the

Wisconsin League of Municipalities.[11] These controls are temporary measures taken to reduce pollutant loadings from construction sites during stormwater runoff events. Construction erosion controls may be expected to reduce pollutant loadings from construction sites by about 75 percent. Such practices are expected to have only a minimal impact on the total pollutant loading to the Lake due to the relatively small amount of land proposed to be developed. However, such controls are important pollution control measures that can abate localized short-term loadings of phosphorus and sediment from the tributary area and the upstream tributary area. The control measures 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 Waukesha County and Washington County construction site erosion control ordinances are administered and enforced by those counties in both the shoreland and nonshoreland areas of the unincorporated areas of the total tributary area of Oconomowoc Lake. The provisions of these ordinances apply to all development except single- and two-family residential construction. Single- and two-family construction erosion control measures are to be specified as part of the building permit process. Because of the potential for development, some of it albeit unplanned, in the area tributary to Oconomowoc Lake, it is important that adequate construction erosion control programs, including enforcement, be in place.

IN-LAKE MANAGEMENT ALTERNATIVES

The reduction of external nutrient loadings to Oconomowoc Lake by the aforedescribed measures should help to prevent further deterioration of lake water quality conditions. These measures, however, may not completely eliminate existing water quality and lake-use problems. In mesotrophic and eutrophic lakes, the nutrients previously delivered to, and retained in, such lakes can result in increased macrophyte growth that can result in restricted water use potentials, even after the implementation of tributary area-based management measures. Given that Oconomowoc Lake falls within the mesotrophic range, and benefits from contaminant retention in the upstream lakes,[12] the awareness of in-lake rehabilitation techniques may be of value.

The applicability of specific in-lake rehabilitation techniques is highly dependent on lake-specific characteristics. The success of any lake rehabilitation technique can seldom be guaranteed, and because of the relatively high cost of applying most techniques, a cautious approach to implementing in-lake rehabilitation techniques is generally recommended. Certain in-lake rehabilitation techniques should be applied only to lakes in which: 1) nutrient inputs have been reduced below the critical level; 2) there is a high probability of success in applications of the particular technology to lakes of similar size, shape, and quality; and 3) the possibility of adverse environmental impacts is minimal. Finally, it should be noted that many in-lake rehabilitation techniques require the issuance of permits from appropriate State and Federal agencies prior to implementation.

Alternative lake rehabilitation measures include in-lake water quality management, water level management, and aquatic plant and fisheries management measures. Each of these groups of management measures is described further below.

Water Quality Monitoring

As discussed in Chapter IV, water quality information for Oconomowoc Lake during the current study period has been compiled from data gathered under the auspices of the U. S. Geological Survey (USGS) trophic state index (TSI) monitoring program, within which Federal field personnel conduct a series of approximately five samplings

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[11]*Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook*, April 1994.*

[12]*See, for example, SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* A Water Quality Management Plan for Okauchee Lake, Waukesha County, Wisconsin*, October 2003.*

of the Lake beginning with the spring turnover. Samples are analyzed for an extensive array of physical and chemical parameters. The USGS also offers an array of other specialist services, including groundwater modeling and monitoring.

The University of Wisconsin-Extension (UWEX), under an agreement with the WDNR, operates a volunteer monitoring program formerly known as the Self-Help Monitoring Program and currently known as the Citizen Lake Monitoring Network (CLMN). Volunteers enrolled in this program gather data at regular intervals on water clarity using a Secchi disk. Because pollution tends to reduce water clarity, Secchi disk measurements are generally considered one of the key parameters in determining the overall quality of a lake's water as well as a lake's trophic status. Secchi disk measurement data are added to the WDNR-sponsored data base containing lake water quality information for many of the lakes in Wisconsin and is accessible on-line through the WDNR website: http://dnrmaps.wisconsin.gov/imf/imf.jsp?site=SurfaceWaterViewer.

The Expanded Self-help Monitoring Program involves the collecting of data on several key physical and chemical parameters in addition to the Secchi disk measurements. Under this program, samples of lake water are collected by volunteers at regular intervals and are analyzed by the State Laboratory of Hygiene (SLOH). Data collection is more extensive and, consequently, places more of a burden on volunteers. An alternative is the analytical services provided by the Water and Environmental Analysis Laboratory (WEAL) of the University of Wisconsin-Stevens Point (UWSP). This program also requires volunteers to obtain and transmit the water quality samples to the laboratory. In both cases, the WDNR offers Small Grant funding under the Chapter NR 190 lake management planning grant program that can be applied for to defray the costs for laboratory analysis and sampling equipment.

Continuation of the water quality monitoring conducted by the USGS is considered to be a viable option for Oconomowoc Lake. This work possibly could be supplemented by more frequent water quality monitoring by volunteer monitors working through the UWEX CLMN or utilizing the analytical services provided by the UWSP WEAL. The current water quality data base initiated during 1986 provides one of the most extensive data series extant in southeastern Wisconsin.

Water Quality Improvement Measures

This group of in-lake management practices includes a variety of measures designed to directly modify the magnitude of either a water quality determinant or biological response. Specific measures aimed at managing aquatic plants and the fisheries are separately considered below.

Phosphorus Precipitation and Inactivation

Nutrient inactivation is a restoration measure that is designed to limit the biological availability of phosphorus by chemically binding the element in the lake sediments using a variety of divalent or trivalent cations, highly positively charged elements. Aluminum sulfate (alum), ferric chloride, and ferric sulfate are commonly used cation sources. The use of these techniques to remove phosphorus from nutrient-rich lake waters is an extension of common water supply and wastewater treatment processes. Costs depend on the lake volume and type and dosage of chemical used. Approximately 100 tons of alum, costing about $150 per ton, can treat a lake area of about 40 acres. Effectiveness depends, in part, on the ability of the alum flocculent to form a stable "blanket" on the lakebed; to wit, on flushing time, turbulence, as a function of lake depth, lake water acidity (pH) and rate of continued sedimentation. Impacts can include the release of toxic quantities of free aluminum into the water. The resulting improved water clarity also can encourage the spread of rooted aquatic plants. Because of the relatively low levels of phosphorus in the Lake, consideration of nutrient inactivation through the employment of aluminum sulfate is not considered a viable option at this time.

Nutrient Load Reduction

Nutrient diversion is a restoration measure, which is designed to reduce the trophic state or degree of over-feeding of a waterbody and thereby control the growth response of the aquatic plants in the system. Control of nutrients in surface water runoff in the tributary area is generally preferable to attempting such control within a lake. Many of the techniques presented in the tributary area management section above are designed for this purpose.

In-lake control of nutrients generally involves removal of contaminated sediments or encapsulation of nutrients by chemical binding. Costs are generally high, involving an engineered design and usually some form of pumping or excavation. Effectiveness is variable, and impacts include the re-release of nutrients into the environment. While some limited deepening of specific areas within the lake basin may be warranted for navigational purposes, the widespread use of in-lake nutrient load reduction measures is not warranted in Oconomowoc Lake. As noted in Chapter IV, the good agreement between predicted and observed phosphorus concentrations in the Lake strongly suggests that the external nutrient load to the Lake accounts for the major part of the observed phosphorus concentration in the lake water column.

Hydraulic and Hydrologic Management

This group of in-lake management measures consists of actions designed to modify the depth of water in the waterbody. Generally, the objectives of such manipulation are to enhance a particular class of recreational uses, to control the types and densities of organisms within a waterbody, or to minimize high water or flooding problems. Consideration can be given to inlet and outlet control modifications, drawdown, and dredging.

Inlet/Outlet Control Operations

The inflow to Oconomowoc Lake is controlled by a dam that is owned by the Town of Oconomowoc and controlled through the Town police department; the dam is located about 0.7 miles upstream of Oconomowoc Lake on the Oconomowoc River at the outlet to Okauchee Lake.[13] Outflow from Oconomowoc Lake occurs at the northwestern end of the Lake, where the Oconomowoc River leaves the Lake. The outlet structure, reconstructed in 2005, is comprised of a dam that includes two mechanically controlled lift gates. The outlet dam is owned by the Village of Oconomowoc Lake and operated by the Village police department.

On site observation by SEWRPC staff during 2006 indicated that the outlet structure appeared to be in good physical condition and operating within its design specifications. Continued operation of these structures is recommended as a viable management measure, although improved coordination between dam operators could be considered in order to ensure maintenance of adequate minimum flows in the downstream portions of the Oconomowoc River. Implementation of a diversion structure, to enhance through flow or short circuiting of inflows to the outflows, in a manner similar to that employed at Delavan Lake,[14] is not considered practicable, despite the proximity of the inlet and outlet to the Lake.

Drawdown

Drawdown refers to the manipulation of lake water levels, especially in impounded lakes, in order to change or create specific types of habitat and thereby manage species composition within a waterbody. Drawdown may be used to control aquatic plant growth and to manage the fisheries. With regard to aquatic plant management, periodic drawdown can reduce the growth of some shoreland plants by exposing the plants to climatic extremes, while the growth of others is unaffected or enhanced. Both desirable and undesirable plants are affected by such actions. Costs are primarily associated with loss of use of the waterbody surface area during drawdown, provided there is a means of controlling water level in place, such as a dam or other outlet control structure. Effectiveness is variable with the most significant side effect being the potential for increased plant growth.

Drawdown can also affect the lake fisheries both indirectly, by reducing the numbers of food organisms, and directly, by reducing available habitat and desiccating (drying out) eggs and spawning habitat. In contrast, increasing water levels, especially during spring, can provide enhanced fish breeding habitat for some species, such as pike and muskellunge, and increase the food supply for opportunistic feeders, such as bass, by providing

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[13]*See SEWRPC Community Assistance Planning Report No. 53, 2nd Edition,* A Water Quality Management Plan for Okauchee Lake, Waukesha County, Wisconsin*, December 2003.*

[14]*See SEWRPC Community Assistance Planning Report No. 253,* A Lake Management Plan for Delavan Lake, Walworth County, Wisconsin*, May 2002.*

access to terrestrial insects, for example. Costs also are primarily associated with loss of use. Effectiveness is better than for aquatic plant control, but the potential for side effects remains high given that undesirable fish species may also benefit from water level changes.

Sediment exposure and desiccation by means of lake drawdown has been used as a means of stabilizing bottom sediments, retarding nutrient release, reducing macrophyte growth, and reducing the volume of bottom sediments. During the period of drawdown, the exposed sediments are allowed to oxidize and consolidate. It is believed that by reducing the sediment oxygen demand and increasing the oxidation state of the surface layer of the sediments, drawdown may retard the subsequent movement of phosphorus from the sediments, although there is an immediate release of soluble phosphorus reported upon re-flooding of most basins in which this technique has been applied. Sediment exposure may also curb sediment nutrient release by physically stabilizing the upper flocculent, sediment-water interface zone of the sediments which plays an important role in the exchange reaction and mixing of the sediments with the overlying water. Drawdown may thus deepen the lake by dewatering and compacting the bottom sediments. The amount of compaction depends upon the organic content of the sediment, the thickness of sediment exposed above the water table, and the timing and duration of the drawdown.

Possible improvements resulting from a lake drawdown include reduced turbidity from wind action, improved game fishing, an opportunity to collect fish more effectively in fish removal programs, an opportunity to improve docks and dams, and an opportunity to clean and repair shorelines and deepen areas using conventional earth-moving equipment. Limited, over-winter drawdowns are designed to limit shoreline damage by ice and ice movements during the winter months, and continue to be conducted in accordance with the dam operating permit, as noted in the initial report.

In contrast, depending on the timing and duration of the drawdown, drawbacks include loss of fish breeding habitat, loss of benthic food organisms, and disruption of waterfowl feeding and roosting patterns. Increased turbidity and unpleasant odors from rotting organic matter may occur during the period of the drawdown. Other adverse impacts of lake drawdown include algal blooms after re-flooding, loss of use of the lake during the drawdown, changes in species composition, and a reduction in the density of benthic organisms following drawdown and reflooding. In some drawdown projects, it has been found that several years after reflooding, flocculent sediments began to reappear because of algae and macrophyte sedimentation. Therefore, to maintain the benefits of a drawdown project, the lake may have to be drawn down every five to 10 years to recompact any new sediment.

Because of the unpredictability of the results, the impairment of recreational uses, and the temporary nature of the beneficial effects of a drawdown, drawdown is not considered a viable option for Oconomowoc Lake.

Water Level Stabilization

While water level management in a lake is a common technique for managing fish and aquatic macrophytes, the consequences of manipulating lake water levels can be both beneficial and deleterious. The major impacts from the riparian owners' standpoint is that the fluctuating water levels affect shoreline erosion, interfere with proper pier height and placement, as well as the correct placement of shoreline protection structures.

Periodic changes in precipitation and weather patterns between years often result in fluctuation of water loads to a lake. These fluctuations in turn can affect lake levels. Most plant and animal species can cope with this level of water surface fluctuation without experiencing the consequences, both positive and negative, noted above. Nevertheless, while artificial stabilization of the water surface is not considered a viable option for Oconomowoc Lake, it is desirable from the point of view of aquatic habitat that water level fluctuations be maintained within natural limits.

Dredging

Sediment removal is a restoration measure that is carried out using a variety of techniques, both land-based and water-based, depending on the extent and nature of the sediment removal to be carried out. For larger-scale applications, a barge-mounted hydraulic or cutter-head dredge is generally used. For smaller-scale operations a shore-based drag-line system is typically employed. Both methods are expensive, especially if a suitable disposal site is not located close to the dredge site. Costs for removal and disposal begin at between $10 and $15 per cubic yard, with the cost of sediment removal alone beginning at between $3.00 and $5.00 per cubic yard. Effectiveness of dredging varies with the effectiveness of tributary area controls in reducing or minimizing the sediment sources. Federal and State permits are required for use of this option.

Dredging in Oconomowoc Lake could be accomplished using several different types of equipment, including a hydraulic cutterhead dredge mounted on a floating barge in deeper water areas; bulldozer and backhoe equipment in the shoreland area, especially if the Lake is drawndown; and a clamshell, or bucket, dragline dredge from the shoreline. While the use of conventional earth-moving equipment and shore-based draglines has some advantages over hydraulic dredging, particularly since these methods may not require large disposal and dewatering sites in close proximity to the project area, these methods would be dependent, to some extent, on the drawdown of the Lake. Reducing the water level in the Lake would be especially advantageous for dragline dredging because it would limit the requirement for the removal of shoreland trees, resulting in less disturbance of the shoreline needed to provide access for trucks and equipment. Likewise, reduced water levels would allow conventional construction equipment access to the littoral portions of the waterbody.

Hydraulic cutterhead dredging is the most commonly employed method in the United States. The dredge is typically a rotating auger or cutterhead on the end of an arm that is lowered to the sediment-water interface. Sediment excavated by the cutterhead is pumped as a slurry of 10 to 20 percent solids by a centrifugal pump to the disposal site. This pumping usually limits the distance between the lake and disposal site to less than a mile, even using intermediate booster pumps. Because of the large volume of slurry produced, a relatively large disposal site is typically required. Water returned from the disposal site, whether returned to the lake or a stream, would have to meet effluent water quality standards of the State and would be subject to State permitting.

Dredging is the only restoration technique that directly removes the accumulated products of degradation and sediment from a lake system and can return a lake to a younger "age." If carried to the extreme, dredging can be used, in effect, to construct a new lake with a size and depth to suit the management objectives. Dredging has been used in other lakes to increase water depth; remove toxic materials; decrease sediment oxygen demand, prevent fish winterkills and nutrient recycling; restore fish breeding habitat; and decrease macrophyte growth. The objective of a dredging program at Oconomowoc Lake should be to increase water depth to maintain recreational boating access and increased public safety.

Even so, dredging may have serious, though generally short-term, adverse effects on the Lake. These adverse effects could include increased turbidity caused by sediment resuspension, toxicity from dissolved constituents released by the dredging, oxygen depletion as organic sediments mix with the overlying water, water temperature alterations, removal of native plant seeds, and destruction of benthic and fisheries habitats. There may also be impacts at upland spoil disposal sites, such as odor problems, restricted use of the site, and disturbances associated with heavy truck traffic. In the longer term, disruption of the lake ecosystem by dredging can encourage the colonization of disturbed portions of the lakebed by less desirable species of aquatic plants and animals, including Eurasian water milfoil, which is present in Oconomowoc Lake.

In addition, while dredging can result in an immediate increase in lake depth, such increases may be short-lived if the sources of sediment being deposited in the lake are not controlled within the area tributary to the lake. The sediment load reaching Oconomowoc Lake comes from both urban and agricultural lands within the area tributary to Oconomowoc Lake. Sediment also may be generated from streambank and shoreland erosion. Many of these sources can be effectively controlled through the adoption, implementation, and maintenance of recommended control measures within the tributary area. Such practices should be implemented in the area tributary to the Lake, as noted above, regardless of the likely conduct of any dredging project.

As noted above, dredging of lakebed material from navigable waters of the State requires a WDNR Chapter 30 permit and a U.S. Army Corps of Engineers Chapter 404 permit. In addition, current solid waste disposal regulations define dredged material as a solid waste. Chapter NR 180 of the *Wisconsin Administrative Code* requires that any dredging project of over 3,000 cubic yards submit preliminary disposal plans to the Department of Natural Resources for review and potential solid waste licensing of the disposal site. Because sodium arsenite was applied to Oconomowoc Lake during the 1950s and 1960s, as noted in Chapter V, sediment samples may need to be analyzed to determine the extent and severity of any residual arsenic contamination.

Because of the considerations noted above, and given the potential recreational use impacts of a drawdown during the summer and winter recreational seasons, extensive dredging of Oconomowoc Lake is not considered a viable alternative at this time. Limited dredging in the constructed channels serving the LaLumiere subdivision may be warranted to maintain navigability and lake access. These channels were initially constructed for boating access to Oconomowoc Lake by the riparian homeowners; maintenance of this boating access opportunity by the homeowners would be consistent with the continuity of the purpose of these waterways. Additionally, maintenance of these waterways in partnership with the Pabst Farms Joint Stormwater District may be warranted given that the north central portion of the District drains into the constructed channels.

Fisheries and Aquatic Plant Management

Fisheries Management Measures

Oconomowoc Lake provides a quality habitat for a healthy, warmwater fishery. Currently, adequate water quality, dissolved oxygen levels, bottom substrate materials along the shoreline, and a diverse aquatic plant community exist for the maintenance of a sportfish population in the Lake. Winterkill currently is not a problem. The Lake supports a gamefish-panfish fishery, with popular gamefish such as largemouth bass, smallmouth bass, walleye, northern pike, and musky being present in the Lake. In addition, the lake chubsucker and the least darter, both listed as State-designated special concern species, and the pugnose shiner, a State-designated threatened species, have been reported being present in the Lake, as noted in Chapter V.

Habitat Protection

Habitat protection refers to a range of conservation measures designed to maintain existing fish spawning habitat, including measures such as restricting recreational use and other intrusions into gravel-bottomed shoreline areas during the spawning season. For bass this is mid-April to mid-June. Use of natural vegetation in shoreland management zones and other “soft” shoreline protection options aids in habitat protection. Costs are generally low, unless the habitat is already degraded. Modification of aquatic plant harvesting operations, if being utilized, may be considered to support restoration and protection of native aquatic plant beds and maintenance of fish breeding habitat during the early summer period. Effectiveness is variable depending in part on community acceptance and enforcement. Generally, it is more effective to maintain a good habitat than to restore a habitat after it is degraded.

Loss of habitat should be a primary concern of any fisheries management program. Such environmentally valuable areas within the Lake and its tributary area are the most important areas to be protected. In addition, limiting or restricting certain activities in those areas of the Lake containing important fish habitat will prevent significant disturbance of fish activities and aquatic plant beds. Within these areas, aquatic plant management measures should be restricted, and dredging, filling, and the construction of piers and docks should be discouraged. It also should be noted that water level fluctuations other than those consequent to natural climatic variability and water quality conditions can affect fish habitat and the breeding success of fishes. In this regard, the maintenance of lake water levels within natural limits, and the maintenance of good water quality, cannot be overemphasized as fish habitat protection measures.

Shoreline Maintenance

Shoreline maintenance refers to a group of measures designed to reduce and minimize shoreline loss due to erosion by waves, ice, or related actions of the water. Most of the shoreline of Oconomowoc Lake is protected by some type of structural measure. Four shoreline erosion control techniques were in use during 2005: natural vegetative buffer strips, rock and riprap revetments, wooden and concrete bulkheads, and beach. Maintenance of a vegetated buffer strip immediately adjacent to the Lake is the simplest, least costly, and most natural method of reducing shoreline erosion. This technique employs natural vegetation, rather than maintained lawns, within five to 10 feet of the lakeshore and the establishment of emergent aquatic vegetation from two to six feet lakeward of the shoreline.

Desirable plant species that may be expected and encouraged to invade a buffer strip, or which could be planted, include arrowhead (*Sagittaria latifolia*), cattail (*Typha* spp.), common reed (*Phragmites communis*), water plantain (*Alisma plantago-aquatica*), bur-reed (*Sparganium eurycarpum*), and blue flag (*Iris versicolor*) in the wetter areas; and jewelweed (*Impatiens biflora*), elderberry (*Sambucus canadensis*), giant goldenrod (*Solidago gigantea*), marsh aster (*Aster simplex*), red-stem aster (*Aster puniceus*), and white cedar (*Thuja occidentalis*) in the drier areas. In addition, trees and shrubs such as silver maple (*Acer saccharinum*), American elm (*Ulmus americana*), black willow (*Salix nigra*), and red-osier dogwood (*Cornus stolonifera*) could become established. These plants will develop a more extensive root system than the lawn grass and the aboveground portion of the plants will protect the soil against the erosive forces of rainfall and wave action. A narrow path to the Lake can be maintained as lake access for boating, swimming, fishing, and other activities. A vegetative buffer strip would also serve to trap nutrients and sediments washing into the Lake via direct overland flow. This alternative would involve only minimal cost.

Rock revetments, or riprap, are a highly effective method of shoreline erosion control applicable to many types of erosion problems, especially in areas of low banks and shallow water. Many of these structures are already in place at Oconomowoc Lake. The technique involves the shaping of the shoreline slope, the placement of a porous filter material, such as sand, gravel, or pebbles, on the slope and the placement of rocks on top of the filter material to protect the slope against the actions of waves and ice. The advantages of rock revetments are that they are highly flexible and not readily weakened by movements caused by settling or ice expansion, they can be constructed in stages, and they require little or no maintenance. The disadvantages of rock revetments are that they limit some uses of the immediate shoreline. The rough, irregular rock surfaces are unsuitable for walking; require a relatively large amount of filter material and rocks to be transported to the lakeshore; and can cause temporary disruptions and contribute sediment to the lake. If improperly constructed, revetments may fail because of washout of the filter material. A rock revetment is estimated to cost $25 to $35 per linear foot.

Natural vegetated buffer strips and riprap, as shown in Figure 11, are considered viable options, especially in those areas subject to significant wind-wave, boat wake, and ice scour erosion. In those portions of the Lake subject to direct action of wind waves and ice scour, the use of riprap would provide a more robust means of stabilizing shorelines, while elsewhere along the lakeshore creation of vegetated buffer strips would provide not only shoreline erosion protection but also enhanced shoreland habitat for fish and wildlife. In this regard, it should be noted that the selection of appropriate shoreland protection structures is subject to the provisions of Chapter NR 328 of the *Wisconsin Administrative Code*.

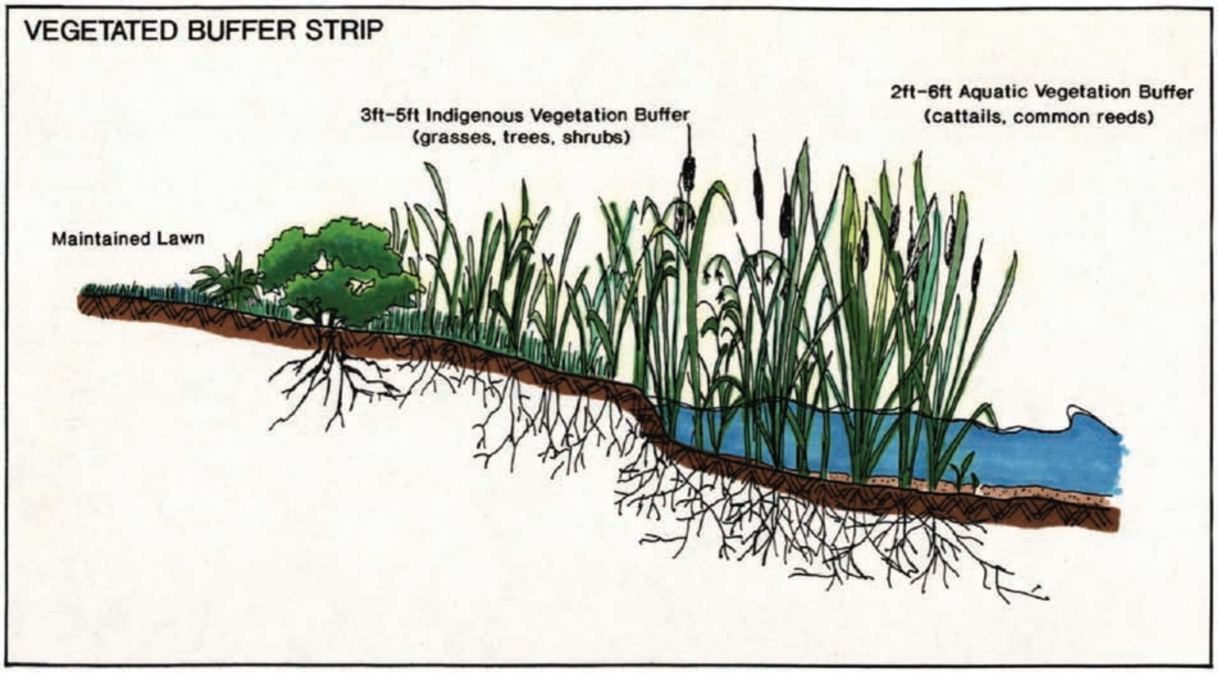
Modification of Species Composition

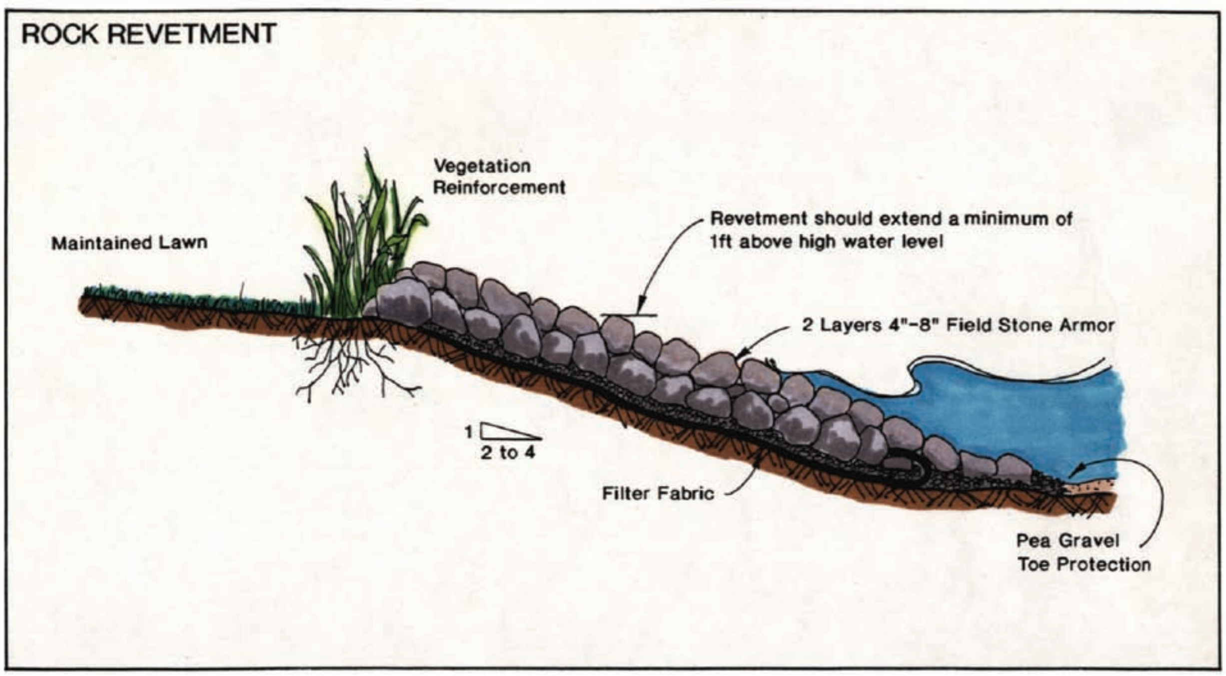
Species composition management refers to a group of conservation and restoration measures that include selective harvesting of undesirable fish species and stocking of desirable species designed to enhance the angling resource value of a lake. These measures also include water level manipulation both to aid in the breeding of desirable species, for example, increasing water levels in spring to provide additional breeding habitat for pike, and to disadvantage undesirable species, for example, drawing a lake down to concentrate forage fish and increase predation success and also to strand juveniles and desiccate the eggs of undesirable species. Costs, as with water level management above, are primarily associated with loss of use; effectiveness is good, but by no means certain; and side effects include collateral damage to desirable fish populations.

More extreme measures include organized fishing events and selective cropping of certain fish species, poisoning, and enhancement of predation by stocking. In lakes with an unbalanced fishery, dominated by carp and other rough fish, chemical eradication has been used to manage the fishery. Lake drawdown is often used along with chemical treatments to expose spawning areas and eggs and concentrate fish in shallow pools, thereby increasing their availability to anglers, commercial harvesters, or chemical eradication treatments. Fish barriers are usually used to prevent reintroduction of undesirable species from up- or downstream, and the habitat thus created will

Figure 11

RECOMMENDED ALTERNATIVES FOR SHORELINE EROSION CONTROL





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

Source: SEWRPC.

benefit the desired gamefish populations. Chemical eradication is a drastic, costly measure and the end result may be highly unpredictable. Although effectiveness is generally good, such extreme measures are not currently considered viable for Oconomowoc Lake.

As noted in Chapter V, Oconomowoc Lake is currently managed for warmwater sportfish, and selective stocking is undertaken primarily by the WDNR. Continued fish stocking by the WDNR is considered a viable option for Oconomowoc Lake, subject to monitoring and creel surveying data collected from the Lake by the WDNR. Additional fish population control measures do not appear to be warranted at this time, although rough fish populations should continue to be monitored.

Regulations and Public Information

To reduce the risk of overharvest, the WDNR has placed restrictions on the number and size of certain fish species caught by anglers. The open season, size limits, and bag limits for the fish species of Oconomowoc Lake are given in Table 21 in Chapter V of this report. Enforcement of these regulations is critical to the success of any sound fish management program.

Aquatic Plant Management Measures

Aquatic plant management refers to a group of management and restoration measures aimed at both removal of nuisance vegetation and manipulation of species composition in order to enhance and provide for recreational water use. Generally, aquatic plant management measures are classified into four groups: chemical measures, which include using aquatic herbicides; mechanical measures, which include harvesting and manual removal; biological measures, which include the use of various organisms, including insects; and physical measures, which include lake bottom coverings and water level management. All of these measures are stringently regulated and require a State permit under Chapters NR 107 or NR 109 of the *Wisconsin Administrative Code*.

The costs of aquatic plant management measures range from minimal for manual removal of plants using rakes and hand-pulling to upwards of $100,000 for the purchase of a mechanical plant harvester and ancillary equipment, the operational costs for which can approach $10,000 to $20,000 per year depending on staffing and operating policies. Harvesting is probably the measure best applicable to larger areas while chemical controls may be best suited to use in confined areas and for initial control of invasive plants. Planting of native plant species is largely experimental in lakes, but can be considered a specialized shoreland management zone at the water's edge, where it has proven to be an effective means of mitigating the effects of runoff from residential and other properties and enhancing privacy. Physical controls and mechanical harvesting may have side effects in the expansion of plant habitat and the spread of reproductive vegetative fragments. Each of these groups of aquatic plant management measures is discussed in greater detail below.

Chemical Measures

Chemical treatment with aquatic herbicides is a short-term method of controlling heavy growths of aquatic macrophytes and algae. Chemicals are applied to the growing plants in either liquid or granular form. The advantages of using chemical herbicides to control aquatic macrophyte growth are the relative ease, speed, and convenience of application. Herbicides also offer a degree of selectivity, targeting specific types of aquatic plants. However, the disadvantages associated with chemical control include the following:

1. The short-term, lethal effects of chemicals are relatively well known. However, properly applied, chemical applications should not result in such effects. Potential long-term, sublethal effects, especially on fish, fish-food organisms, and humans, are relatively unknown.

2. The elimination of macrophytes eliminates their competition with algae for light and nutrients. Algal blooms may then develop unless steps are taken simultaneously to control the sources of nutrient input.

3. Since much of the dead plant materials are left to decay in the lake, nutrients contained in them are rapidly released into the water and fuel the growth of algae. The decomposition of the dead plant material also consumes dissolved oxygen and increases the potential for fish kills. Accretion of

additional organic matter in the sediments as a result of decomposition also increases the organic content of the soils and predisposes the sediments toward reintroduction of other (or the same) nuisance plant species. Long-term deposition of plant material may result in the need for other management measures, such as dredging.

4. The elimination of macrophyte beds destroys important cover, food sources, and spawning areas for desirable fish species.

5. Adverse impacts on other aquatic organisms may be expected. At the concentrations used for macrophyte control, Diquat has been known to kill the zooplankton *Daphnia* and *Hyalella*, both important fish foods. *Daphnia* is the primary food for the young of nearly all fish species found in the Region's lakes.[15]

6. Areas generally must be treated again in the following season and weedbeds may need to be treated more than once in a summer, although certain herbicides may give relief over a period of up to three years in some lakes.

7. Many of the chemicals available often affect nontarget, desirable species, such as water lilies, as well as the target "weeds," such as Eurasian water milfoil, as both species share similar biological characteristics, being dicotyledons.

The presence of stands of hybrid water milfoil (*Myriophyllum spicatum* x *sibiricum*) in Oconomowoc Lake resulted in an experimental application of varying concentrations of the aquatic herbicide 2,4-D between 2005 and 2007.[16] The aquatic herbicide was applied in granular form during June 2005. Decreased densities of hybrid water milfoil were observed, although the treatments also resulted in decreased densities of coontail (*Ceratophyllum demersum*) and northern water milfoil (*Myriophyllum sibiricum*). In a second experimental treatment, conducted during June 2006 and with a higher dosage of herbicide, decreased abundances and frequencies of occurrence of hybrid water milfoil were observed, this time with fewer impacts on nontarget, native species. These results would suggest that further investigation of chemical-based control techniques be carried out, prior to this control technique being more widely applied in southeastern Wisconsin. Action to control the growth of milfoil, especially Eurasian water milfoil and hybrid milfoil, is warranted in order to limit the spread of these plants to other portions of the Lake. To this end, early spring treatments using targeted herbicide applications offer the opportunity to minimize milfoil growth and reproduction prior to the recreational boating season, thereby addressing one of the mechanisms that drive the spread of these plants in lakes.[17]

With respect to the control of periodic algal blooms, the advantages and disadvantages of chemical control measures used to manage aquatic macrophyte also apply to the chemical control of algae. Copper, the active

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[15]*P.A. Gilderhus, "Effects of Diquat on Bluegills and Their Food Organisms,"* The Progressive Fish-Culturist, *Vol. 2, No. 9, 1967, pp. 67-74.*

[16]*Angela L. Ortenblad, Allison M. Zappa, Abby R. Kroken, and Robert C. Anderson, "Effectiveness of Granular 2,4-D Treatment on Hybrid Watermilfoil (*Myriophyllum sibiricum *x* spicatum*) in Oconomowoc Lake, Wisconsin," Wisconsin Lutheran College Biology Department Technical Bulletin 008, March 2006; and, Allison M. Zappa and Robert C. Anderson, "Follow up Study on the Effectiveness of Granular 2,4-D Treatmnent on Hybrid Watermilfoil (*Myriophyllum sibiricum *x* spicatum*) in Oconomowoc Lake, Wisconsin," Wisconsin Lutheran College Biology Department Technical Bulletin 010, April 2007.*

[17]*Eurasian water milfoil and its hybrids reproduce through autofragmentation of plants. This can be exacerbated by boating activity which can fragment the plants through propeller action and wind-wave action which fragments the plants as a consequence of water turbulence. Of these reproduction mechanisms, only boating traffic can be controlled by humans.*

ingredient in algicides, can be an effective algicide. However, the copper may accumulate in the lake bottom sediments where excessive amounts are potentially toxic to fish and benthic animals. Fortunately, copper is rapidly eliminated from human systems and few cases of copper sensitivity among humans are known.[18]

Costs of chemical treatments vary widely. Large, organized treatments are more efficient and tend to decrease unit costs for commercial applications compared to individual treatments. Other factors, such as the type of chemical used and the number of treatments needed, are also important. Estimated costs for lakes in southeastern Wisconsin range from $240 to $480 per acre. Chemical treatments must be permitted by the State under Chapter NR 107 of the *Wisconsin Administrative Code*.

In the future, should there be a demonstrated need to control aquatic plants in selected areas of Oconomowoc Lake, chemical treatment is considered to be a viable management option only in limited, nearshore areas of the Lake, around piers and structures. Widespread use of chemical herbicides is not considered a viable option.

Manual and Mechanical Harvesting Measures
Aquatic macrophytes are mechanically harvested with specialized equipment consisting of a cutting apparatus which cuts up to five feet below the water surface and a conveyor system that picks up the cut plants and hauls them to shore. Advantages of macrophyte harvesting include the following:

1. Harvesting removes the plants from the lake. The removal of this plant biomass decreases the rate of accumulation of organic sediment. A typical harvest of submerged macrophytes from eutrophic lakes in southeastern Wisconsin can yield between 140 and 1,100 pounds of biomass per acre per year.[19]

2. Harvesting removes plant nutrients, including nitrogen and phosphorus, which would otherwise “refertilize” the lake as the plants decay. A typical harvest of submerged macrophytes from eutrophic lakes in southeastern Wisconsin can remove between four and 34 pounds of nitrogen and 0.4 to 3.4 pounds of phosphorus per acre per year. In addition to the physical removal of nutrients, plant harvesting may reduce internal nutrient recycling. Several studies have shown that aquatic macrophytes can act as nutrient pumps, recycling nutrients from the bottom sediments into the water column. Ecosystem modeling results have indicated that a harvest of 50 percent of the macrophytes in Lake Wingra, Wisconsin, could reduce instantaneous phosphorus availability by about 30 percent, with a maximum reduction of 40 to 60 percent, depending on the season.

3. Repeated macrophyte harvesting may reduce the regrowth of certain aquatic macrophytes. The regrowth of milfoil has been reported to have decreased as harvesting frequency was increased.

4. Where dense growths of filamentous algae are closely associated with macrophyte stands, they may be harvested simultaneously.

5. The macrophyte stalks remaining after harvesting provide cover for fish and fish-food organisms, and stabilize the bottom sediment against wind-wave erosion.

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[18]*J.A. Thornton, and W. Rast, “The Use of Copper and Copper Compounds as an Algicide,”* Copper Compounds Applications Handbook, *H.W. Richardson, ed., Marcel Dekker, New York, 1997.*

[19]*James E. Breck, Richard T. Prentki, and Orie L. Loucks, editors,* Aquatic Plants, Lake Management, and Ecosystem Consequences of Lake Harvesting, *Proceedings of Conference at Madison, Wisconsin, February 14-16, 1979.*

6. Selective macrophyte harvesting may reduce stunted populations of panfish in lakes where excessive cover has adversely influenced predator-prey relationships. By allowing an increase in predation on young panfish, both gamefish and the remaining panfish may show increased growth.[20]

7. The cut plant material can be used as mulch.

The disadvantages of macrophyte harvesting include the following:

1. Harvesting is most effective in water depths greater than two feet. Large harvesters cannot operate in shallow water or around docks and buoys. Operation of harvesting equipment in shallow waters can result in significant increases in turbidity and disruption of the lake bottom and lake bottom-dwelling fauna.

2. The reduction in aquatic macrophytes by harvesting reduces their competition with algae for light and nutrients. Thus, algal blooms may develop.

3. Fish, especially young-of-the-year bluegills and largemouth bass, as well as fish-food organisms, are frequently caught in the harvester. As much as 5 percent of the juvenile fish population can be removed by harvesting. A WDNR study found that four pounds of fish were removed per ton of plants harvested.[21] To protect the fish community from excessive mortality from harvesting, the WDNR generally recommends harvesting be conducted in areas 6 feet in depth or greater. Additionally, it is generally recommended that harvesting activities not begin before June 15th in order to reduce disturbing fish spawning activities.

4. The reduction in aquatic macrophyte biomass by harvesting or chemical control can reduce the diversity and productivity of macroinvertebrate fish-food organisms feeding on the epibiota. Bluegills generally move into the shoreline area after sunset, where they consume these macroinvertebrates. After sunrise they migrate to open water, where they graze, primarily on zooplankton. If harvesting or chemical control shifts the dominance of the littoral macroinvertebrate fauna to sediment dwellers, the macroinvertebrate component of the bluegill diet could be restricted.[22] This would increase predation pressure on zooplankton and reduce the growth rate of the panfish; it could eventually lead to undesirable ramifications throughout the food web in a lake.

5. Macrophyte harvesting may influence the community structure of macrophytes by favoring such plants as milfoil (*Myriophyllum* spp.) that propagate from cut fractions. This may allow these plants to spread into new areas through the rerooting of the cut fractions.

6. Certain species of plants, such as coontail, are difficult to harvest due to lack of root system.

7. The efficiency of macrophyte harvesting is greatly reduced around piers, rafts, and buoys because of the difficulty in maneuvering the harvesting equipment in those restricted areas. Manual methods have to be used in these areas.

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[20] *James E. Breck, and J.F. Kitchell, "Effects of Macrophyte Harvesting on Simulated Predator-Prey Interactions," edited by Breck et al., 1979, pp. 211-228.*

[21] *Wisconsin Department of Natural Resources,* Environmental Assessment Aquatic Nuisance Control (NR 107) Program, *3rd Edition, 1990, 213 pp.*

[22] *James E. Breck, et. al.,* op. cit.

8. High capital and labor costs may be associated with harvesting programs. Macrophyte harvesting on Oconomowoc Lake could be conducted through cooperative agreements among various municipalities in the tributary area or be contracted to a private company. These costs are largely staff costs and operating costs such as fuel, oil, and maintenance. The cost of new harvesting equipment, when needed, would be about $282,500.

Harvesting programs should be designed to provide optimal benefits and minimal adverse impacts. Small fish are common in dense macrophyte beds, but larger fish, such as largemouth bass, do not utilize these dense beds.[23] Narrow channels may be harvested to provide navigational access and "cruising lanes" for predator fish to migrate into the macrophyte beds to feed on smaller fish. "Shared access" lanes may also be cut, allowing several residents to use the same lane. Increased use of these lanes should keep them open for longer periods than would be the case if a less directed harvesting program was followed. "Clear cutting" of aquatic plants and denuding the lake bottom of flora should be avoided. However, top cutting of plans such as Eurasian water milfoil, as shown in Figure 12, is suggested.

Water depth, numbers and arrangement of docks and moored boats, and nature of bottom substrate are important factors when considering mechanical harvesting. As explained above, most harvesting equipment is large and not well-suited to close operation around docks and moored boats where precise control of movement is needed. Areas of shallow depths, two to three feet or less, containing muck or other soft, loose bottom materials are generally not considered to be well suited to harvesting as the equipment tends to churn up these bottom materials, creating turbid water conditions, affecting established benthic communities and fragmenting rooted aquatic macrophytes. Plants such as Eurasian water milfoil, which propagate through the spread of plant fragments, may actually be at an advantage as a result of the chopping action of harvesting equipment. Mechanical harvesting is best suited to areas free of docks and moored watercraft or recreational equipment, where lake bottom materials are firm and water is of sufficient depth to offer a degree of protection against potential lake bottom disruption by harvester equipment. The harvest of water lilies and emergent native plants should be avoided.

Protecting native aquatic plant communities from disturbances can help prevent Eurasian water milfoil from spreading within a lake. Recent studies show that native plants can effectively compete with Eurasian water milfoil. However, the exotic species tends to outcompete native plants when the lake's ecosystem is stressed.[24] Stress can be brought on by tributary area pollution, shoreline development, changing water levels, boating activity, carp, and aquatic nuisance controls. This maintenance of a healthy aquatic plant community has been found to be the most efficient way of managing aquatic plants, as opposed to other means of managing problems once they occur. Furthermore, native aquatic plant communities contribute most effectively to the maintenance of good water quality by providing suitable habitat for desirable fish and other aquatic organisms which promote stable or increased property values and quality of life.[25]

Because of the intermittent need for control of aquatic plants, harvesting could be considered a viable option in areas of Oconomowoc Lake that are conducive to this method of management should the need for widespread control become necessary in the future. However, use of such a control measure is not warranted at the present

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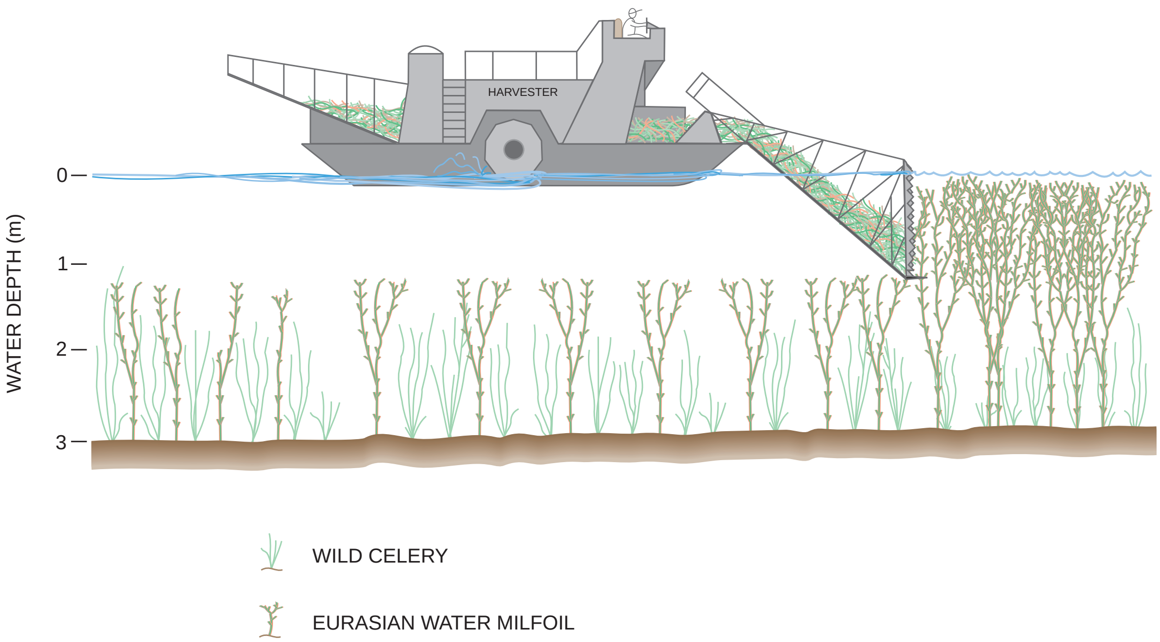
[23]*S. Nichols, Wisconsin Department of Natural Resources Technical Bulletin No. 77,* Mechanical and Habitat Manipulation for Aquatic Plant Management: A Review of Techniques*, 1974.*

[24]*Wisconsin Department of Natural Resources,* Eurasian Water Milfoil in Wisconsin: A Report to the Legislature, *1992.*

[25]*Roy Bouchard, Kevin J. Boyle, and Holly J. Michael,* Water Quality Affects Property Prices: A Case Study of Selected Maine Lakes*, Miscellaneous Report 398, February 1996.*

Figure 12

PLANT CANOPY REMOVAL WITH AN AQUATIC PLANT HARVESTER



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

Source: Wisconsin Department of Natural Resources and SEWRPC.

time Mechanical harvesting of aquatic plants must be permitted by the State under Chapter NR 109 of the *Wisconsin Administrative Code*. Due to the likelihood for the need for only intermittent use of harvesting, purchase of harvesting equipment is unlikely to be cost-effective in the long run and is, therefore, not considered a viable option at this time.

Due to water depth limitations imposed by the size and maneuverability of the harvesters, it is not always possible for harvesters to reach the shoreline of every property. Likewise, because of the cost and other concerns relating to the use of chemical herbicides, alternative measures for the control of aquatic plant growth in specific areas of the Lake should be considered. A number of specially designed rakes are available from commercial outlets to assist lakefront homeowners in manually removing aquatic plants from the shoreline area. The advantages of these rakes are that they are easy and quick to use, and result in an immediate result, in contrast to chemical treatments that involve a waiting period. This method also removes the plants from the lake, thereby avoiding the accumulation of organic matter on the lake bottom. Unfortunately, manual harvesting is feasible in only very limited areas and is not practical for large-scale use. Nevertheless, manual harvesting does offer a reasonable level of aquatic plant control in the vicinity of docks and piers, and is therefore considered a viable option. Manual harvesting beyond a 30-foot-wide recreational corridor, or within a WDNR-delineated environmentally sensitive area, must be permitted by the State under Chapter NR 109 of the *Wisconsin Administrative Code*. Pursuant to the provision of this Chapter, piers and other recreational areas must be placed within the 30-foot-wide recreational corridor.

Biological Measures

Another alternative approach to controlling nuisance weed conditions, in this particular case Eurasian water milfoil, is biological control. Classical biological control has been successfully used to control both weeds and herbivorous insects.[26] Recent documentation states that *Eurhychiopsis lecontei*, an aquatic weevil species, has the potential as a biological control agent for Eurasian water milfoil. In 1989, the weevil was discovered during a study investigating a decline of Eurasian water milfoil growth in a Vermont pond. *Eurhychiopsis* proved to have significant negative effects on Eurasian water milfoil in the field and in the lab. The adult weevil feeds on the milfoil causing lesions which make the plant more susceptible to pathogens, such as bacteria or fungi, while the weevil larvae burrows in the stem of the plant causing enough tissue damage for the plant to lose buoyancy and collapse.[27] The few studies that have been done since that time have indicated the following potential advantages to use of this weevil as a means of Eurasian water milfoil control:

1. *Eurhychiopsis lecontei* is known to cause fatal damage to the Eurasian water milfoil plant and over a period of time has the potential to cause a decrease in the milfoil population.

2. *Eurhychiopsis lecontei* larvae are easy to produce.

3. *Eurhychiopsis lecontei* are not known to cause damage to existing native aquatic plants.

The potential disadvantages of using *Eurhychiopsis lecontei* include:

1. The studies done on *Eurhychiopsis* are very recent and more tests are necessary to determine if there are significant adverse effects.[28]

2. Since the upper portion of the Eurasian water milfoil plant is preferred by the weevil, harvesting would have to be extremely limited or not used at all in conjunction with this type of aquatic plant management control.

Relatively few studies concerning the use of *Eurhychiopsis lecontei* as a means of aquatic plant management control have been completed. Such cases have resulted in variable levels of control, and, although priced competitively with aquatic herbicides, the use of *Eurhychiopsis lecontei* is not considered a viable option for Oconomowoc Lake at this time. Use of biological control agents must be permitted by the State under Chapter NR 109 of the *Wisconsin Administrative Code*. While the use of biological control agents such as the Eurasian water milfoil weevil and the beetles, *Hylobius transversovittatus*, *Galerucella pusilla*, *Galerucella calmariensis*, *Nanophyes brevis*, and *Nanophyes marmoratus,* used to control infestations of purple loosestrife in wetlands and along shorelands has been shown to be beneficial in certain circumstances, including use at Oconomowoc Lake, the use of other biological control agents is prohibited in Wisconsin; the use of the grass carp, *Ctenopharyngodon idella,* for aquatic plant control is expressly prohibited.

Physical Measures

Lake bottom covers and light screens provide limited control of rooted plants by creating a physical barrier which reduces or eliminates the sunlight available to the plants. They have been used to create swimming beaches on

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[26]*C.B. Huffacker, D.L. Dahlsen, D.H. Janzen, and G.G. Kennedy,* Insect Influences in the Regulation of Plant Population and Communities*, 1984, pp. 659-696; C.B. Huffacker and R.L. Rabb, editors,* Ecological Entomology, *John Wiley, New York, New York, USA.*

[27]*Sally P. Sheldon,* "The Potential for Biological Control of Eurasian Water Milfoil (*Myriophyllum spicatum*) 1990-1995 Final Report,*" Department of Biology, Middlebury College, February 1995.*

[28]*The use of* Eurhychiopsis *sp. on an experimental basis to control Eurasian water milfoil was monitored in selected Wisconsin lakes by the Wisconsin Department of Natural Resources and the University of Wisconsin-Stevens Point from 1995 through 1998. These results indicated mixed success, suggesting that this organism has specific habitat requirements that limit its utility as a Eurasian water milfoil control agent within Wisconsin.*

muddy shores, to improve the appearance of lakefront property, and to open channels for motorboating. Sand and gravel are usually readily available and relatively inexpensive to use as cover materials, but plants readily recolonize areas so covered in about a year. Synthetic materials, such as polyethylene, polypropylene, fiberglass, and nylon, can provide relief from rooted plants for several years. The screens are flexible and can be anchored to the lakebed in spring or draped over plants in summer.

The advantages of bottom covers and screens are that control can be confined to specific areas, the covers and screens are usually unobtrusive and create no disturbance on shore, and the covers are relatively easy to install over small areas. The disadvantages of bottom covers and screens are that they do not reduce eutrophication of the lake, they are expensive, they are difficult to spread and anchor over large areas or obstructions, they can slip on steep grades or float to the surface after trapping gases beneath them, and they may be difficult to remove or relocate.

Screens and covers should not be used in areas of strong surfs, heavy angling, or shallow waters where motor-boating occurs. They should also not be used where aquatic vegetation is desired for fish and wildlife habitat. To minimize interference with fish spawning, screens should be placed before or after spawning. A permit from the WDNR is required for use of sediment covers and light screens. Permits require inspection by the WDNR staff during the first two years, with subsequent permits issued for three-year periods. Annual removal of such barriers is generally required as a permit condition.

The estimated cost of lake bottom covers that would control plant growth along a typical shoreline property, an area of about 700 square feet, ranges from $100 for burlap to $300 for aquascreen. Placement of lake bottom screens requires a WDNR permit pursuant to Chapter 30 of the *Wisconsin Statutes*. Because of the limitations involved, placement of lake bottom covers as a method to control aquatic plant growth is not considered to be a viable option for Oconomowoc Lake.

Use of sand blankets and pea gravel deposits has also been proposed as a physical barrier to aquatic plant growth in certain situations. Placement of materials on the bed of a navigable lake or waterway also requires a WDNR permit pursuant to Chapter 30 of the *Wisconsin Statutes*, and the use of these materials is generally confined to the creation and augmentation of swimming beaches. Use of these materials for aquatic plant management purposes is not a viable option as deposition of sediments above the sand or gravel layer limits the longer term viability of this technique.

Public Informational Programming

Aquatic plant management usually centers on the eradication of nuisance aquatic plants for the improvement of recreational lake use. The majority of the public views all aquatic plants as “weeds” and residents often spend considerable time and money removing desirable plant species from a lake without considering their environ-mental impacts. As shown in Table 17 in Chapter V of this report, many aquatic plants have positive ecological value within the lake ecosystem, and most native aquatic plants rarely interfere with human water uses. Thus, public information is an important component of an aquatic plant management program and should include informational programming on:

1. The types of aquatic plants in Oconomowoc Lake and their value to water quality, fish, and wildlife.

2. The preservation of existing stands of desirable plant species.

3. The identification of nuisance species and the methods of preventing their spread.

4. Alternative methods for controlling existing nuisance plants including the positive and negative aspects of each method.

An organized aquatic plant identification/education day is one method of providing hands-on education to lake residents. Other sources of information and technical assistance include the WDNR and UWEX. The aquatic plant species lists provided in Chapter V, and the illustrations of common aquatic plants present in Oconomowoc Lake appended hereto as Appendix A, may serve as a checklist for individuals interested in identifying the plants near their residences. Residents can observe and record changes in the abundance and types of plants in their part of the lake on an annual basis.

Of the submerged floating and free-floating aquatic plant species found in Oconomowoc Lake, Eurasian water milfoil is one of the few species likely to cause lake-use problems. Eurasian water milfoil, unlike most aquatic plants, can reproduce from fragments and often forms dense, monotypic beds with little habitat value for fish or waterfowl. Lakeshore residents should be encouraged to collect fragments that wash ashore after storms and, especially, from weekend boat traffic. The plant fragments can be used as mulch on flower gardens or ornamental planting areas. Likewise, lake users should be encouraged to inspect boats and trailers both prior to launch and following recover as Eurasian water milfoil and other aquatic plants can be transported between lakes as fragments on boats and boat trailers. This effort also limits the likelihood of transporting zebra mussel, *Dreissena polymorpha*, between lakes or into new areas of lakes.

To prevent unwanted introductions of plants and invasive aquatic animals into lakes, boaters should remove all plant fragments from their boats and trailers when exiting a lake, and allow wet wells, engine water jackets, and bilges to dry thoroughly for up to one week. Alternatively, boaters can run their vessels through a car wash, where high pressure, high temperature water sprays can remove and destroy organisms such as the zebra mussel juveniles (veligers).[29] Providing the opportunity for the removal of plant fragments at the boat landing on Oconomowoc Lake, and provision of signage at the boat landing, including provision of disposal containers at the boat landing, may help motivate boaters to utilize this practice. Posters and pamphlets are available from the WDNR and UWEX that provide information and illustrations of milfoil, zebra mussel, and other nonnative aquatic species; discuss the importance of removing plant fragments from boats; and, remind boaters of their duty in this regard.

Recreational Use Management

Regulatory measures provide a basis for controlling lake use and use of the shorelands around a waterbody. On land, shoreland zoning, requiring set backs and shoreland buffers can protect and preserve views both from the water and from the land, controls development around a lake to minimize its environmental impacts and manages public and private access to a waterbody. On water, recreational use zoning can provide for safe and multiple-purpose use of lakes by various groups of lake users and protect environmentally sensitive areas of a lake. Use zoning can take the form of allocating times of use, such as the annual fishing season established by the State, or areas of use, wherein the types or rate of use is controlled, as in the case of shallow water, slow-no-wake speed limits. A key issue in zoning a waterbody for use is equity; the same rules must apply to both riparian owners/ residents and off-lake users. This condition is usually met in situations where use zoning is motivated by the protection of fish habitat, for example, as both on- and off-lake users would appreciate an enhanced fishery. Costs are relatively low, associated with creating and posting the ordinance, and effectiveness can be good with regular/consistent enforcement. Costs increase for measures requiring buoyage.

Currently, watercraft are restricted to slow-no-wake speeds within 100 feet of piers, docks, rafts, or buoyed restricted areas on any lake. These areas typically coincide with water depths of less than five feet in depth. Demarcation of Eurasian water milfoil control areas and similar environmentally valuable or sensitive areas of the Lake is recommended. It is also recommended that the Village of Oconomowoc Lake continue to enforce recreational boating ordinance appended hereto as Appendix B.

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[29]*See Wisconsin Department of Natural Resources Publication No. PUBL-WR-383 95-REV.*, Zebra Mussel Boater's Guide, *1995; Wisconsin Department of Natural Resources Publication No. PUBL-WR-463 96-REV.,* The Facts...On Eurasian Water Milfoil, *February 1996.*

Public Informational and Educational Programming

Educational and informational brochures and pamphlets of interest to homeowners and supportive of the recreational use and shoreland zoning regulations are available from UWEX, WDNR, and the Waukesha County Department of Parks and Land Use. These cover topics such as beneficial lawn care practices and household chemical use guidelines. These brochures could be provided to homeowners through local media, direct distribution, or targeted school or public library displays. Many of these ideas can be integrated into ongoing, larger-scale municipal activities such as anti-littering campaigns, recycling drives, and similar pro-environment activities.

The Village of Oconomowoc Lake regularly presents seminars and informational programs of general interest to community residents. These programs have included aquatic plant identification, lake history, lake water quality, and related topics.

In addition to public informational programming, or informal educational programming, discussed above, there are a number of school-based educational opportunities that the community can utilize at the middle school level and at the high school level. Such programming as Project WET (Water Education Training) are available from and supported by UWEX and provide youth the opportunity to experience “hands on” the aquatic environment and become better informed about current and future lake issues and concerns. Therefore, activities of this type, such as Project WET, which could be arranged through agreements involving local lake organizations, municipalities, and school districts and are considered a viable option.

Finally, reporting of water quality sampling results to the public and participation of the Village of Oconomowoc Lake in the USGS Lake Water Quality Monitoring Program should be continued. Volunteer monitoring under the auspices of the UWEX CLMN should be considered. This program involves citizens in taking Secchi-disc transparency readings in the Lake at regular intervals. The Lake Coordinator of the WDNR-Southeast Region can assist in enlisting volunteers in this program. The information gained at first hand by the public during participation in this program increases the credibility of the proposed changes in the nature and intensity of use to which the Lake is subjected.

Institutional Development

While lake management activities fall under the general powers of municipalities, other public and private organizational alternatives for the management of lakes in the State of Wisconsin exist.[30] Private lake organizations have the option to be incorporated, generally as nonstock, not-for-profit corporations under Chapter 181 of the *Wisconsin Statutes*. Public lake organizations include special-purpose units of government that are created as public inland lake protection and rehabilitation districts under Chapter 33 of the *Wisconsin Statutes*, and utility districts created pursuant to Chapter 66 of the *Wisconsin Statutes*. The specific type (or types) of organization created is based upon the decision of the community.

In the case of Oconomowoc Lake, general oversight of lake management activities currently is provided by the Village of Oconomowoc Lake. While no change in this organizational arrangement is anticipated, this section outlines those options that are available to the Oconomowoc Lake community with respect to lake management activities.

Private Lake Organizations

Private lake organizations are voluntary. Such organizations have the advantage that there are few restrictions imposed upon the types of activities in which they engage, subject to relevant permits and laws. Incorporated associations generally have a somewhat greater number of restrictions imposed upon them, but may be considered qualified associations for purposes of obtained State cost-share grants. Because of their voluntary nature, membership levels, and, therefore, income levels, of associations often fluctuate from year-to-year. Membership

[30]*See University of Wisconsin-Extension Publication No. G3216,* The Lake in Your Community*, 1986.*

in these organizations may be required under deed covenants as these organizations are generally associated with subdivisions. Thus, while these organizations tend to be geographically confined, many have broader mandates than solely lake issues, although these issues may be important to the association memberships.

Public Lake Organizations

Public inland lake protection and rehabilitation districts, or lake management districts, are public governmental units formed for the specific purpose of managing and protecting lake water quality. Inclusion in the district, once the district is created, is mandatory, and registered voters and persons owning property within the district become the electors of the district for purposes of governance. Lake management districts have the capability of raising public funds subject to majority approval of the district budget at the annual meeting of the district. For this reason, lake management districts can provide a more stable financial base from which to undertake lake management activities. Often, lake associations and lake districts operate in harmony around lakes throughout Wisconsin. Currently, the Village of Oconomowoc Lake serves as the primary lakewide association that exists with a lake focus that serves the Oconomowoc Lake community and it has generally been felt by the community that this is an effective means of addressing lake management concerns.

SUMMARY

This chapter has described options that could be employed in managing the types of problems recorded as occurring in Oconomowoc Lake and which could, singly or in combination, assist in achieving and maintaining the water quality and water use objectives set forth in Chapter VI of the lake tributary area inventory. Selected characteristics of these measures are summarized in Table 31.

An evaluation of the potential management measures for improving the Oconomowoc Lake water quality was carried out on the basis of the effectiveness, cost, and technical feasibility of the measures. Those alternative measures not considered further at this time include: phosphorus precipitation and inactivation, nutrient load reduction through sediment management, water level control by drawdown or modifications of outlet control operations, dredging, chemical eradication of rough fish, biological control of aquatic plants, lake bottom covering, development of time and/or space zone space schemes for managing surface use, and development of alternative institutions. The remaining measures are considered viable options to be considered further for incorporation in the recommended plan described in Chapter VIII.

Table 31

SELECTED CHARACTERISTICS OF ALTERNATIVE LAKE MANAGEMENT MEASURES FOR OCONOMOWOC LAKE

Plan Element	Subelement	Alternative Management Measure	Considered Viable for Inclusion in Recommended Lake Management Plan
Land Use	Zoning	Implement regional land use and county development plans within tributary area	Yes
		Maintain existing density management in lakeshore areas; consider conservation development principles	Yes
	Stormwater management	Develop and implement consistent stormwater management ordinances in all riparian communities; periodic review of stormwater ordinances	Yes
	Protecting environmentally sensitive lands	Implement regional natural areas and critical species habitat protection and management plan recommendations within tributary area; protect wetlands, woodlands, shorelands, and other environmental corridor lands and natural features	Yes
Pollution Abatement	General nonpoint source pollution abatement	Implement regional water quality management plan and county land and water resource management plan recommendations within tributary area	Yes
	Rural nonpoint source controls	Develop farm conservation plans that encourage conservation tillage, contour farming, contour strip cropping, crop rotation, grassed waterways, and pasture and streambank management in agricultural areas of the tributary area	Yes
	Urban nonpoint source controls	Promote urban housekeeping practices, public educational programming, and grassed swales	Yes
		Consider development of lawn care management and shoreland protection ordinances	Yes
	Developing area nonpoint source controls	Enforce construction site erosion control ordinances; review ordinances for consistency with NR 152	Yes
		Use conservation subdivision designs and develop integrated stormwater management systems	Yes
	Public sanitary sewerage system management	Conduct periodic review of sewer service area needs within sewered areas of the tributary area	Yes
	Onsite sewage disposal system management	Implement onsite sewage disposal system management, including inspection and maintenance	Yes
Water Quality	Water quality monitoring	Continue participation in USGS water quality monitoring program; consider participation in WDNR Citizen Lake Monitoring Network program or University of Wisconsin-Stevens Point Environmental Task Force TSI monitoring program	Yes
	Water quality improvement	Monitor internal phosphorus loading and consider periodic alum treatment to achieve phosphorus inactivation in lake sediments	No
		Promote nutrient load reduction within the lake basin through sediment management	No
		Modify outlet control operations	No
		Drawdown	No
		Water level stabilization	No
		Dredging	No[a]

Table 31 (continued)

Plan Element	Subelement	Alternative Management Measure	Considered Viable for Inclusion in Recommended Lake Management Plan
Aquatic Biota	Fisheries management	Protect fish habitat	Yes
		Maintain shoreline and littoral zone fish habitat by maintaining existing shoreline structures and repair as necessary using vegetative means insofar as practicable; reconstruction may require WDNR Chapter 30 permits	Yes
		Encourage shoreline restoration projects and creation of buffer strips, and promote consistency in application of landscaping practices in sensitive shoreline areas, through informational programming and demonstration sites	Yes
		Continue stocking of selected game fish species and monitor roughfish populations	Yes
		Chemical eradication of rough fish populations	No
		Enforce size and catch limit regulations	Yes
	Aquatic plant management	Conduct periodic aquatic plant reconnaissance surveys and update aquatic plant management plan every three to five years	Yes
		Limited use of aquatic herbicides for control of nuisance plants such as Eurasian water milfoil and purple loosestrife	Yes[a]
		Consider mechanically harvesting aquatic macrophytes to provide navigational channels and fish lanes, control nuisance plants and to promote growth of native plants	Yes[b]
		Manually harvest aquatic plants from around docks and piers where feasible	Yes
		Employ biological controls using inocula of Eurasian water milfoil weevils	No
		Consider using biological controls for management of purple loosestrife on an as-needed basis	Yes
		Use sediment covers to shade out aquatic plant growth around piers and docks	No
		Collect floating plant fragments from shoreland areas to minimize rooting of Eurasian water milfoil	Yes
Water Use	- -	Enforce boating regulations to maximize public safety; improve signage	Yes
		Develop time and/or space zoning schemes to limit surface use conflicts	No
		Maintain recreational boating access from the public access site pursuant to Chapter NR 7 guidelines	Yes
		Maintain navigational access, especially from public recreational boating access site(s) to main basin of Lake	Yes
Ancillary Management Measures	Public informational and educational programming	Conduct public informational programming and educational programming on aquatic plants, options for their management, and other topics of relevance to lake residents utilizing seminars and distribution of informational materials	Yes
		Support participation of schools in Project WET, Adopt-A-Lake, etc.	Yes
		Encourage methods of preventing unwanted intrusions of invasive biota at public recreational boat access	Yes

Table 31 (continued)

Plan Element	Subelement	Alternative Management Measure	Considered Viable for Inclusion in Recommended Lake Management Plan
Institutional Development	- -	Create a lake association for Oconomowoc Lake	No

[a] *Limited areas when necessary to control exotic, invasive species.*

[b] *In areas where water depth, bottom substrate material, and dock/moored watercraft densities are within desirable limits to promote the effectiveness of this method of aquatic plant management*.

Source: SEWRPC.

Chapter VIII

RECOMMENDED MANAGEMENT PLAN FOR OCONOMOWOC LAKE

INTRODUCTION

This chapter presents a recommended lake management plan for Oconomowoc Lake. The plan is based upon the inventories and analyses of land use and land and water management practices, pollution sources in the area tributary to Oconomowoc Lake, the physical and biological quality of the waters of the Lake, recreational use and population forecasts, and an evaluation of alternative lake management measures, as set forth in Chapters II through VII. The recommended plan sets forth means for: 1) providing water quality conditions suitable for full-body contact recreational use and the maintenance of healthy communities of warmwater fish and other aquatic life, 2) reducing the severity of existing or perceived problems which constrain or preclude desired water uses, 3) improving opportunities for water-based recreational activities, and 4) protecting environmentally sensitive areas. The elements of the recommended plan were selected from among the alternatives described in Chapter VII, and evaluated on the basis of those feasible alternatives, set forth in Table 31 in Chapter VII of this report, that may be expected to best meet the foregoing lake management objectives.

Analyses of water quality and biological conditions indicate that the general condition of the water of Oconomowoc Lake is very good. There appear to be few impediments to water-based recreation, although access by recreational watercraft is limited in some portions of the Lake by water depths and growths of aquatic macrophytes. Nevertheless, based upon a review of the inventory findings and consideration of planned developments within the area tributary to the Lake, as set forth in the adopted Waukesha County development plan,[1] measures will be required to continue to protect and maintain the high quality of the Lake for future lake users. Therefore, this plan sets forth recommendations for: land use management, including protection of the environmentally sensitive lands, in the area tributary to Oconomowoc Lake; pollution abatement; water quality monitoring and improvement; aquatic plant and fisheries management; recreational water use management; and, informational programming. These measures complement and refine the watershedwide land use controls and management measures recommended in the adopted regional water quality management plan as refined,[2] the

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[1]*SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996; see also SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035, *June 2006.*

[2]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Three,* Recommended Plan, *June 1979.*

Oconomowoc River priority watershed plan,[3] and the Waukesha County land and water resource management plan.[4]

The recommended management measures for Oconomowoc Lake are graphically summarized on Map 19, and are listed in Table 32. The recommended plan measures are more fully described in the following paragraphs. The recommended management agency responsibilities for tributary area land management are set forth in Table 33, as are the estimated capital and annual operation and maintenance costs pertaining to the recommended measures.

TRIBUTARY AREA MANAGEMENT MEASURES

Land Use Control and Management

A fundamental element of a sound management plan and program for Oconomowoc Lake is the promotion of a sound land use pattern within the area tributary to the Lake. The type and location of rural and urban land uses in the tributary area will determine, to a considerable degree, the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, various land management measures; and, ultimately, the water quality of the Lake.

The recommended land use plan for the area tributary to Oconomowoc Lake under buildout conditions is described in Chapter II. The framework for the plan is the regional land use plan as prepared and adopted by the Southeastern Wisconsin Regional Planning Commission (SEWRPC), and refined through the Waukesha County development plan.[5] The recommended land use and county development plans envision that urban land use development within the area tributary to Oconomowoc Lake will occur primarily at low densities and only in areas which are covered by soils suitable for the intended use; which are not subject to special hazards such as flooding; and, which are not environmentally sensitive, that is, not encompassed within the SEWRPC-delineated environmental corridors described in Chapter V.

Development in the Shoreland Zone

A major land use issue which has the potential to affect Oconomowoc Lake is the redevelopment of existing lakefront properties, replacing lower-density uses with higher-density, multi-family dwellings with potential for increased roof areas, parking areas, and other areas of impervious surfaces. Replacement of a pervious land surface with an impervious surface will increase the rate of stormwater runoff to the Lake, increase pollutant loadings to the Lake, and reduce groundwater recharge. While these effects can be moderated to some extent through structural stormwater management measures, there is likely to be an adverse impact on the Lake from significant redevelopment in the area tributary to the Lake involving conversion to higher-density land uses. For this reason, maintenance of the historic low- and medium-density residential character of the shoreline of Oconomowoc Lake to the maximum extent practical is recommended.

Development in the Tributary Area

Another land use issue which has the potential to affect the Lake is the potential development for urban uses of the agricultural and other open space lands in the tributary area. As previously noted, large-lot residential development is occurring in areas of the Lake tributary area in which such development was not envisioned in the adopted regional land use and county development plans. If this trend continues, much of the open space areas remaining in the tributary area will be replaced over time with large-lot urban development. This may significantly increase the pollutant loadings to the Lake, and increase the pressures for recreational use of the

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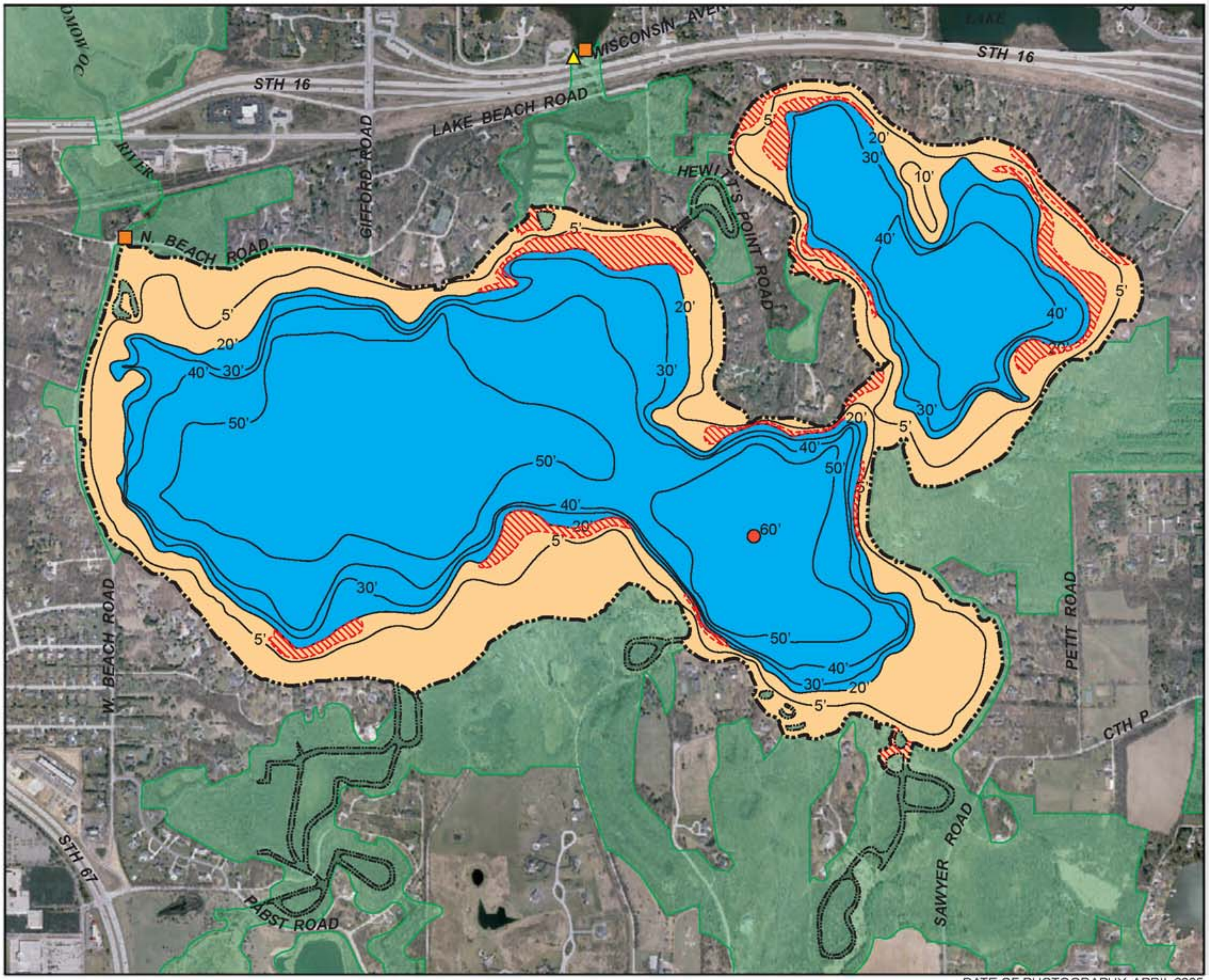
[3]*Wisconsin Department of Natural Resources Publication No. WR-194-86,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *March 1986.*

[4]*Waukesha County,* Land and Water Resource Management Plan: 1999-2002, *December 1998.*

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

Map 19

RECOMMENDED LAKE MANAGEMENT PLAN FOR OCONOMOWOC LAKE



DATE OF PHOTOGRAPHY: APRIL 2005

—20'— WATER DEPTH CONTOUR IN FEET

WATER QUALITY MONITORING

MONITORING SITE

RECREATIONAL USE MANAGEMENT

MAINTAIN PUBLIC RECREATIONAL BOATING ACCESS

WATER LEVEL MANAGEMENT

MAINTAIN WATER LEVEL CONTROL STRUCTURE -OPERATE PURSUANT TO PERMIT CONDITIONS

AQUATIC PLANT MANAGEMENT

CONTROL NONNATIVE SPECIES ESPECIALLY EURASIAN WATER MILFOIL AND HYBRIDS, CHEMICAL CONTROLS: HIGH PRIORITY MANUAL CONTROLS: AROUND PIERS AND DOCKS

OPEN WATER: NO CONTROL REQUIRED

- PERIODICALLY MONITOR AQUATIC PLANT COMMUNITIES

LAND USE MANAGEMENT

PROTECT ENVIRONMENTALLY SENSITIVE LANDS

- PROMOTE GOOD HOUSEKEEPING PRACTICES IN DRAINAGE AREA
- MAINTAIN HISTORIC LAKEFRONT DENSITIES: OBSERVE GUIDELINES IN COUNTY DEVELOPMENT PLAN
- PERIODICALLY REVIEW SEWER SERVICE AREA PLAN: MAINTAIN ONSITE SEWAGE DISPOSAL SYSTEMS IN UNSEWERED AREAS

RIPARIAN ZONE: MAINTAIN SHORELINE PROTECTION STRUCTURES, USE VEGETATED BUFFERS AS APPROPRIATE, CONTROL NONNATIVE SPECIES ESPECIALLY PURPLE LOOSESTRIFE

Source: SEWRPC.

Table 32

RECOMMENDED MANAGEMENT PLAN ELEMENTS FOR OCONOMOWOC LAKE

Plan Element	Subelement	Management Measures	Management Responsibility
Land Use	Zoning	Observe guidelines set forth in the regional land use plan and Waukesha County development plan	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
		Enforce adequate setbacks and promote environmentally friendly landscaping practices in shoreland areas	Waukesha County, Village of Oconomowoc Lake, Town of Summit, and WDNR
		Maintain historic lake front residential dwelling densities to extent practicable	Town of Summit
	Stormwater management	Develop and implement consistent stormwater management ordinances in all riparian communities; periodic review of stormwater ordinances	Town of Summit
		Restrict pollutant loading from stormwater discharges to the Lake through implementation of stormwater management practices	Waukesha County, Village of Oconomowoc Lake, Town of Summit, and WDNR
		Install construction site erosion control measures as required by local ordinance; enforce construction site erosion control and stormwater ordinance provisions	Private landowners, Waukesha County, Village of Oconomowoc Lake, Town of Summit, and WDNR
	Protection of environmentally sensitive lands	Establish adequate protection of wetlands and shorelands, and other environmental corridor lands and isolated natural features, and consider public or private acquisition of features of local or greater significance, as set forth in the regional natural areas and critical species habitat protection and management plan	Waukesha County, Village of Oconomowoc Lake, Town of Summit, and WDNR
Pollution Abatement	General nonpoint source pollution abatement	Implement regional water quality management plan and county land and water resource management plan recommendations within tributary area	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
	Rural nonpoint source controls	Promote sound rural land management practices to reduce soil loss and contaminant loadings through preparation of farm conservation plans in accordance with the county land and water resource management plans	USDA, WDATCP, and Waukesha County
	Urban nonpoint source controls	Promote sound urban housekeeping and yard care practices through informational programming	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
		Consider development of lawn care management and shoreland protection ordinances	Town of Summit and Village of Oconomowoc Lake
	Developing area nonpoint source controls	Enforce construction site erosion control and stormwater management ordinances; review ordinances for concurrency with proposed NR 152	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
		Use conservation subdivision designs and develop integrated stormwater management systems where appropriate densities exist	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
Point Source Pollution Control	Sewerage system management	Implement refined regional water quality management plan recommendations to provide sanitary sewerage services to selected urban areas of the Lake tributary area	City of Oconomowoc
		Implement onsite sewage disposal system management, including inspection and maintenance, in those portions of the watershed not served by public sanitary sewerage systems	Waukesha County and private landowners

Table 32 (continued)

Plan Element	Subelement	Management Measures	Management Responsibility
Water Quality	Water quality monitoring	Continue participation in U.S. Geological Survey TSI monitoring program	WDNR, USGS, and Village of Oconomowoc Lake
	Hydrology	Maintain outlet structure and monitor water levels	WDNR and Village of Oconomowoc Lake
Aquatic Biota	Fisheries management	Protect fish habitat	Village of Oconomowoc Lake, WDNR, and individuals
		Conduct periodic fish surveys to determine management and stocking needs; continue stocking; conduct periodic creel census; enforce size and catch limit regulations	WDNR
		Maintain existing shoreline structures and repair as necessary using vegetative means insofar as practicable; reconstruction may require WDNR Chapter 30 permits	Waukesha County, Town of Summit, Village of Oconomowoc Lake, WDNR, and private landowners
		Encourage shoreline restoration projects and creation of buffer strips, and promote consistency in application of landscaping practices in sensitive shoreland areas, through informational programming and demonstration sites	Waukesha County, Town of Summit, Village of Oconomowoc Lake, WDNR, private landowners, and UWEX
	Aquatic plant management	Conduct periodic reconnaissance surveys of aquatic plant communities and update aquatic plant management plan every three to five years	WDNR and Village of Oconomowoc Lake
		Manually harvest around piers and docks as necessary[a]	Private landowners
		Mechanically harvest boating access lands and fish cruising lanes as may become necessary	WDNR and Village of Oconomowoc Lake
		Limited use of aquatic herbicides for control of nuisance aquatic plant growth where necessary; specifically target Eurasian water milfoil[b]	WDNR and Village of Oconomowoc Lake
		Limited use of aquatic herbicides for control of invasive plant growth where necessary; specifically purple loosestrife infestations[b]	WDNR, Village of Oconomowoc Lake, and private landowners
		Use purple loosestrife beetles and weevils to control purple loosestrife infestations as appropriate	Village of Oconomowoc Lake and private landowners
		Collect floating plant fragments from shoreland areas to minimize rooting of Eurasian water milfoil and deposition of organic materials in Lake	Private landowners
Water Use	- -	Maintain recreational boating access from the public access sites pursuant to Chapter NR 7 guidelines	WDNR and Village of Oconomowoc Lake
		Maintain navigational access, especially from public recreational boating access site(s) to main basin of Lake; maintain adequate depths for navigation as required, subject to WDNR permits	WDNR and Village of Oconomowoc Lake
		Continue to enforce and periodically review, recreational boating (summer) and vehicular use (winter) ordinances	Town of Summit, Village of Oconomowoc Lake, and WDNR

Table 3 (continued)

Plan Element	Subelement	Management Measures	Management Responsibility
Ancillary Measures	Public informational and educational programming	Continue public awareness and informational programming	Waukesha County, Village of Oconomowoc Lake, Town of Summit, WDNR, and UWEX
		Encourage inclusion of lake studies in environmental curricula (e.g., Project WET, Adopt-A-Lake)	City of Oconomowoc School District, UWEX, and WDNR

[a]*Manual harvesting beyond a 30 linear foot width of shoreline harvesting is subject to WDNR permitting pursuant to Chapter NR 109 of the* Wisconsin Administrative Code*. Mechanical harvesting could be considered by the Village should the area of aquatic plant growth warrant the possible use of larger-scale aquatic plant management measures. Such a determination should be based upon the conduct of future aquatic plant surveys; use of mechanical harvesting is subject to WDNR permitting pursuant to Chapter NR 109 of the* Wisconsin Administrative Code*.*

[b]*Use of aquatic herbicides requires a WDNR permit pursuant to Chapter NR 107 of the* Wisconsin Administrative Code*.*

Source: SEWRPC.

Lake. Under the full buildout condition envisioned in the Waukesha County development plan, a significant portion of the undeveloped lands outside of the environmental corridors and other environmentally sensitive areas, could potentially be developed for low-density urban uses.

The existing zoning in the tributary area basin permits development, generally on large suburban-density lots, over much of the remaining open lands other than the environmental corridors. Control of shoreland redevelopment, and the related intensification of use, is not specifically addressed in the existing zoning codes. It is recommended that the impact of future land use development on Oconomowoc Lake be minimized through review and modification of the applicable zoning ordinance regulations and zoning district maps to address the concerns noted. Changes in zoning ordinances are recommended to minimize the areal extent of development by providing specific provisions and incentives for the clustering of residential development on smaller lots within conservation subdivisions, thus preserving significant portions of the open space within each property or group of properties considered for development, and minimizing the "footprint" of the developed area relative to the open space on and around a development site. Within the lands tributary to Oconomowoc Lake in the Village of Oconomowoc Lake, these recommendations have been incorporated into the comprehensive land use plan for the Village,[6] and/or reflected in the prevailing Village Code of ordinances.[7]

It is further recommended that development within the area tributary to the Lake, including setback and landscaping provisions, be carefully reviewed by the relevant governmental agencies and entities. Such review would address specific shoreland zoning requirements, and could consider the stormwater and urban nonpoint source pollution abatement practices proposed to be included in shoreland development activities. Provision for shoreland buffers, use of appropriate and environmentally friendly landscaping practices, and inclusion of stormwater management measures that provide water quality benefits are practices to be encouraged.

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[6]*Village of Oconomowoc Lake,* Smart Growth Plan for the Village of Oconomowoc Lake, *March 2008.*

[7]*See, for example, Chapter 17, "Zoning Code for the Village of Oconomowoc Lake," of the* Village of Oconomowoc Lake Code of Ordinances*; Ordinance No. 108, "shoreland ordinance;" Ordinance No. 130, "construction site erosion control"; Ordinance No. 197, amending Chapter 20 (Ordinance No. 114) of the* Village of Oconomowoc Lake Code of Ordinances, *"implementation of slow-no-wake provisions;" and, Ordinance No. 223, "regulating the use of lawn fertilizer,"this latter subsequently being superceded by the provisions of 2009 Wisconsin Act 9 which was adopted on April 28, 2009.*

Table 33

ESTIMATED COSTS OF RECOMMENDED LAKE MANAGEMENT MEASURES FOR OCONOMOWOC LAKE

Plan Element	Management Measure	Estimated Cost: 2000-2020[a] Capital	Estimated Cost: 2000-2020[a] Annual Operation and Maintenance	Potential Funding Sources[b]
Land Use	Observe regional and county land use plan guidelines	- -	- -	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
	Density management in the shoreland zone; enforce adequate setbacks and promote environmentally friendly landscaping practices in shoreland areas	- -	- -	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
	Develop and implement consistent stormwater management ordinances in all riparian communities; periodic review of stormwater ordinances	- -	- -	Waukesha County, Village of Oconomowoc Lake, Town of Summit, and WDNR
	Protection of environmentally sensitive lands and environmental corridors	- -	- -	WDNR Lake Protection Grant and Stewardship Grant Programs, and Village of Oconomowoc Lake
Pollution Abatement	Implement regional and county land and water resource management plans	- -[c]	- -[c]	Waukesha County, USDA EQUIP, and WDNR/ WDATCP Runoff Management Program
	Rural nonpoint source controls	- -[c]	- -[c]	Waukesha County and WDNR/WDATCP Runoff Management Program
	Urban nonpoint source controls	- -[c]	- -[c]	Waukesha County and WDNR/WDATCP Runoff Management Program
	Construction site erosion controls and stormwater management ordinances	- -[c]	$250-$500 per acre[c]	Municipalities, Waukesha County, private firms, and individuals
	Stormwater management systems developed where appropriate densities exist; use conservation subdivision designs	- -	- -	Waukesha County, Village of Oconomowoc Lake, and Town of Summit
	Public sanitary sewer system management	- -	- -	Waukesha County, Village of Oconomowoc Lake, Town of Summit, and local sanitary districts
	Onsite sewage system management	- -[c]	$100-$200[c]	Waukesha County, Village of Oconomowoc Lake, Town of Summit, and local sanitary districts
Water Quality	Continue participation in USGS monitoring program; consider participation in WDNR Self-Help Water Quality Monitoring Program, WDNR Expanded Self-Help Program, or University of Wisconsin-Stevens Point Environmental Task Force TSI monitoring program	- -	$5,500[d]	Village of Oconomowoc Lake, USGS, and WDNR
Hydrology	Maintain outlet structure and monitor water levels	- -	$1,000	WDNR and Village of Oconomowoc Lake
Aquatic Biota	Protect fish habitat	- -	- -	WDNR, Village of Oconomowoc Lake, and individuals
	Maintain shoreline and littoral zone fish habitat	- -	- -	Waukesha County, Village of Oconomowoc Lake, individuals, and WDNR

Table 33 (continued)

Plan Element	Management Measure	Estimated Cost: 2000-2020[a] Capital	Annual Operation and Maintenance	Potential Funding Sources[b]
Aquatic Biota (continued)	Conduct periodic fish surveys and continue stocking of selected gamefish	- -	- -	WDNR
	Enforce size and catch limit regulations	- -	- -	WDNR
	Encourage shoreline restoration projects through informational programming and demonstration sites	- -	- -	Waukesha County, Village of Oconomowoc Lake, Town of Summit, WDNR, private landowners, and UWEX
	Conduct periodic reconnaissance surveys of aquatic plant communities; continue to monitor invasive species	- -	$1,500[e]	WDNR Lake Management Planning Grant Program, and Village of Oconomowoc Lake
	Update aquatic plant management plan every three to five years	- -	$1,500[e]	WDNR Lake Management Planning Grant Program, and Village of Oconomowoc Lake
	Use (limited) aquatic herbicides for control of nuisance plants, such as Eurasian water milfoil and purple loosestrife	- -	$1,000 per acre[f]	Village of Oconomowoc Lake and individuals
	Consider mechanically harvesting aquatic macrophytes to provide navigational channels and fish lanes, control nuisance plants and to promote growth of native plants, if future conditions warrant this type of management	- -	$8,500[g]	WDNR Lake Management Planning Grant Program, and Village of Oconomowoc Lake
	Manually harvest aquatic plants from around docks and piers, where feasible	$100	$100	Village of Oconomowoc Lake and individuals
	Collect floating plant fragments from shoreland areas to minimize rooting of Eurasian water milfoil	- -	- -	Village of Oconomowoc Lake and individuals
Water Use	Enforce regulations governing the operation of watercraft; improve signage and materials at public recreational access site to aid in the identification and control of exotic species	$500	$100	Village of Oconomowoc Lake, Town of Summit, and WDNR
	Maintain recreational boating access from the public access sites pursuant to Chapter NR 7 guidelines	- -	- -	WDNR and Village of Oconomowoc Lake
	Maintain navigational access, especially from public recreational boating access site(s) to main basin of Lake; maintain adequate depths for navigation as required, subject to WDNR permits	- -	- -	WDNR and Village of Oconomowoc Lake
Ancillary Management Measures	Public informational and educational programming; seminars, programs, Project WET, Adopt-A-Lake	- -	$1,200	Village of Oconomowoc Lake, UWEX/WDNR/WAL Lakes partnership, and school districts
	Provide and conduct programming on aquatic plants and various management measures	- -	- -	WDNR Lake Management Planning Grant Program, and Village of Oconomowoc Lake
Total	- -	$600+	$20,750+	- -

Table 33 Footnotes

[a]*All costs expressed in January 2002 dollars.*

[b]*Unless otherwise specified, USDA is the U.S. Department of Agriculture; USGS is the U.S. Geological Survey; WDNR is the Wisconsin Department of Natural Resources; WDATCP is the Wisconsin Department of Agriculture, Trade and Consumer Protection; UWEX is the University of Wisconsin-Extension; and WAL is the Wisconsin Association of Lakes.*

[c]*Costs vary with the amount of land under development during any given year.*

[d]*Monitoring by the USGS can be cost-shared between the Federal agency and local operators; the WDNR Self-Help Monitoring Program involves no cost, but does entail a time commitment from the volunteer.*

[e]*Cost-share assistance may be available for lake management planning studies under NR 190 Lake Management Planning Grant Program.*

[f]*Cost-share assistance may be available from the Wisconsin Waterways Commission Recreational Boating Facilities Grant Program.*

[g]*Based on contract minimum in 2004 and 2005.*

Source: SEWRPC.

Stormwater Management

It is recommended that Waukesha County, the Town of Summit, and the Village of Oconomowoc Lake take an active role in promoting urban nonpoint source pollution abatement. Actions to promote urban nonpoint source pollution abatement would include the conduct of specific stormwater management planning within specific portions of the tributary area located within each municipality where further urban development or redevelopment is anticipated. Such a planning program should include a review of the stormwater management ordinances, to ensure that the ordinance provisions reflect state-of-the-art runoff and water quality management requirements, and to ensure that there is harmony between the ordinances governing urban density development in each of the municipalities draining to Oconomowoc Lake. Adoption by all riparian municipalities of common stormwater management ordinance provisions is strongly recommended.

Management of Environmentally Sensitive Lands

Wetland, woodland, and groundwater recharge area protection can be accomplished through land use regulation and public land acquisition of critical lands. Both measures are recommended for the area tributary to Oconomowoc Lake. The wetland areas within the area tributary to the Lake are currently largely protected through the existing regulatory framework provided by the U.S. Army Corps of Engineers permit program, State shoreland zoning requirements, and local zoning ordinances. Nearly all wetland areas in the Oconomowoc Lake tributary area are included in the environmental corridors delineated by the Regional Planning Commission and protected under one or more of the existing Federal, State, County, and local regulations. Consistent and effective application of the provisions of these regulations is recommended.

Nevertheless, some wetland and woodland areas have been identified for acquisition in the adopted regional natural areas and critical species habitat protection and management plan, including Oconomowoc River Marsh.[8] Implementation of the recommendations of the adopted park and open space plan for Waukesha County[9] would complement the protection and preservation of these environmentally sensitive lands.

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

[9]*SEWRPC Community Assistance Planning Report No. 137,* A Park and Open Space Plan for Waukesha County, *December 1989.*

Nonpoint Source Pollution Control

The recommended tributary area land management measures are specifically aimed at reducing the water quality impacts on Oconomowoc Lake of nonpoint sources of pollution within the tributary area. These measures are set forth in the aforereferenced regional water quality management plan and the Waukesha County land and water resource management plan. As indicated in the lake and tributary area inventory, the only significant sources of phosphorus loading to the Lake that are subject to potential controls are rural and urban nonpoint sources, and onsite sewage disposal systems in the tributary area. All of the lakeshore areas of Oconomowoc Lake currently are served by onsite sewage disposal systems, even though portions of the northern and western shorelines are within a delineated public sanitary sewerage service area.[10] Pursuant to the recommended sewer service area plan, these areas adjacent to Oconomowoc Lake will ultimately be served by waterborne sewerage systems attendant to the City of Oconomowoc wastewater treatment plant.

The planned implementation of a public wastewater conveyance system serving portions of the lakeshore, nonpoint source control measures should be considered for the areas tributary to Oconomowoc Lake. The regional water quality management plan recommended a reduction of about 25 percent in urban, and 25 percent in rural, nonpoint-source pollutants plus streambank erosion control, construction site erosion control, and onsite sewage disposal system management be achieved in the area tributary to Oconomowoc Lake. These values were further refined as a part of the Oconomowoc River Priority Watershed Pollution Abatement Program which established pollution reduction goals of between 30 and 50 percent for sediment loadings and between 28 and 76 percent for phosphorus loadings; generally, the higher phosphorus load reductions were proposed for the more urban, lower portions of the watershed, below Okauchee Lake, while the higher sediment load reductions were proposed for the upper, more rural portions of the watershed, upstream of Oconomowoc Lake.[11]

Nonpoint source pollution abatement controls in the tributary area are recommended to be achieved through a combination of rural agricultural nonpoint controls, urban stormwater management, and construction erosion controls. The implementation of the land management practices described below may be expected to result in a reduction in nonpoint-source pollutants that is considered to be the maximum practicable given the findings of the inventories and analyses compiled during the planning effort. These measures are consistent with the recommended measures set forth in the Waukesha County land and water resource management plan.

Rural Nonpoint Source Pollution Controls

The implementation of nonpoint source pollution controls in rural areas requires the cooperative efforts of the Town of Summit, Waukesha County, and private landowners. Technical assistance can be provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS); the Wisconsin Department of Agriculture, Trade and Consumer Protection; and the Waukesha County Department of Parks and Land Use. As discussed previously, it is recommended that the Town of Summit, in coordination with the WDNR, Waukesha County, and the local units of government involved, develop a strategy to address nonpoint source pollution. State and Federal soil erosion control and water quality management programs, individually or in combination, can be used to achieve pollutant reduction goals. Such programs include the USDA Environmental Quality Incentive Program (EQIP), the WDNR runoff management and lake protection programs, and various local land acquisition initiatives.

Highly localized, detailed, and site-specific measures are required to effectively reduce soil loss and contaminant runoff in rural areas. These measures are best defined and implemented at the local level through the preparation of detailed farm conservation plans. Practices which are considered most applicable within the area tributary to Oconomowoc Lake include conservation tillage, integrated nutrient and pesticide management, and pasture

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[10]*SEWRPC Community Assistance Planning Report No. 172, 2nd Edition,* Sanitary Sewer Service Area for the City of Oconomowoc and Environs, Waukesha County, Wisconsin*, September 1999, as amended.*

[11]*SEWRPC Planning Report No. 30, Volume Three*, op. cit.

management. In addition, it is recommended consideration be given to cropping patterns and crop rotation cycles, with attention to the specific topography, hydrology, and soil characteristics for each farm. A reduction of about 25 percent in the nonpoint source loading from rural lands could provide up to about a 15 percent reduction in total phosphorus loading to Oconomowoc Lake. Implementation of the recommendations and work planning activities set forth in the Waukesha County land and water resource management plan would constitute a major step toward implementation of these lake management recommendations.

The cost of the needed measures will vary depending upon the details of the recommended farm conservation plans. These costs may be expected to be incurred to a large extent for purposes of agricultural land erosion control in any case. As noted above, with the promulgation of Chapters NR 153 and NR 154 of the *Wisconsin Administrative Code*, which became effective during October 2003, cost-share funding may be available to encourage installation of appropriate land management measures. Likewise, cost-share funding may be available under the Chapter NR 120 nonpoint source pollution abatement program for the repair and maintenance of those management measures installed pursuant to the priority watershed plan.

Urban Nonpoint Source Pollution Controls

The development of urban nonpoint source pollution abatement measures for the Oconomowoc Lake areas should be the primary responsibility of the Town of Summit. In addition to the adoption of stormwater management ordinances, the most viable measures to control urban nonpoint sources of pollution appear to be good urban land management and urban housekeeping practices. Such practices consist of fertilizer and pesticide use management, litter and pet waste controls, and management of leaf litter and yard waste. The promotion of these measures requires an ongoing public informational program. It is recommended that the Village of Oconomowoc Lake, in cooperation with the Town, take the lead in sponsoring such programming for the Oconomowoc Lake community through regular public informational meetings and mailings. The agency should also ensure that relevant literature, available through the University of Wisconsin-Extension (UWEX) and the WDNR, is made available at these meetings and at the local Public Library and government offices.

As an initial step in carrying out the recommended urban practices, it is recommended that a fact sheet identifying specific residential land management measures beneficial to the water quality of Oconomowoc Lake be prepared and distributed to property owners. This fact sheet could be distributed by the Village of Oconomowoc Lake, with the assistance of the UWEX and Waukesha County Department of Parks and Land Use offices. The recommended measures may be expected to provide about a 25 percent reduction in urban nonpoint source pollution runoff and up to about a 5 percent reduction in total phosphorus loadings to the Lake.

Developing Areas and Construction Site Erosion Control

It is recommended that Waukesha County, and the Town of Summit continue efforts to control soil erosion attendant to construction activities in accordance with existing ordinances. As noted in Chapter III, Waukesha County has adopted construction erosion control ordinances. Enforcement of the ordinances is generally considered effective. The provisions of these ordinances apply to all development except single- and two-family residential construction. The single- and two-family construction erosion control is to be carried out as part of the building permit process.

Construction site erosion controls may include the use of silt fences, sedimentation basins, rapid revegetation of disturbed areas; the control of “tracking” from the site; and careful planning of the construction sequence to minimize the areas disturbed. Construction site erosion control is particularly important in minimizing the more severe localized short-term nutrient and sediment loadings to Oconomowoc Lake that can result from uncontrolled construction sites. Consideration should be given to incorporating construction site erosion control measures into a formal stormwater management system serving larger developments following construction.

Construction site erosion control measures may be expected to reduce the phosphorus loading from that source by about 75 percent. Because of the potential for development in the tributary area to Oconomowoc Lake, it is important that adequate construction erosion control programs be in place.

The cost for construction site erosion control will vary depending upon the amount of land under construction at any given time. Typical costs are $250 to $500 per acre under development.

Onsite and Public Sewage Disposal System Management

The lakeshore areas and areas tributary to Oconomowoc Lake are served by both onsite and public sanitary sewerage systems. While onsite systems have been estimated to contribute less than 2 percent of the total phosphorus load to the Lake, current County ordinance provisions requiring the regular inspection and maintenance of onsite sewage disposal systems should be enforced to minimize potential phosphorus loadings from this source. It also is recommended that Waukesha County, in cooperation with the Town of Summit, assume the lead in providing the public informational and educational programs to encourage affected property owners to have existing onsite systems inspected and any needed remedial measures undertaken, as appropriate. Homeowners should be advised of the rules and regulations governing, and the limitations of onsite sewage disposal systems, and should be encouraged to undertake preventive maintenance programs, especially of those older systems not yet subject to the inspection requirements of the County ordinance.

Typical costs for a basic inspection and maintenance service range from about $100 to $200 per year, although more extensive programs could be more expensive. The costs of the informational programming typically have been included within the operating budget of the County.

For those portions of the area tributary to Oconomowoc Lake served by public sanitary sewerage systems, it is recommended that the Town of Summit assume the lead in providing public informational and educational programs to encourage affected property owners to use their sewerage systems appropriately and wisely. In an analogous recommendation, stenciling of storm drains and related informational programming encourages residents to dispose of waste products safely, avoiding discharge directly to the surface waters or indirectly through the wastewater treatment works to the environment.

IN-LAKE MANAGEMENT MEASURES

The recommended in-lake management measures for Oconomowoc Lake are summarized in Table 32 and are graphically summarized on Map 19. The major recommendations include: water quality monitoring; fisheries management and habitat protection; nonpoint-source pollution abatement; shoreland protection; aquatic plant management; recreational use management, and informational and educational programming.

Surface Water Quality Management

Continued water quality monitoring of Oconomowoc Lake is recommended. Lake sampling protocol conducted under the current U.S. Geologic Survey (USGS) regimen is recommended with various water quality parameters being measured several times a year at a central station in the deepest portion of the main lake basin and northeast bay. It is also recommended that consideration be given to enrollment in programs such as the volunteer UWEX Citizen Lake Monitoring Network (CLMN) program, formerly the WDNR Self-Help Monitoring Program, or the University of Wisconsin-Stevens Point Environmental Task Force Laboratory lake monitoring program.

As indicated in the lake and tributary area inventory, waters flowing into and out of Oconomowoc Lake are controlled by dams located on the Oconomowoc River upstream and downstream of the Lake. Although Lake levels are not a major concern among Lake users, it is worth noting that fluctuations in lake levels can present various problems. The placement of shore protection could be more or less effective depending upon the magnitude and frequency of variations in water levels. These variations also affect fish and aquatic life habitat availability, with extreme fluctuations potentially being disadvantageous to mollusks and other less mobile life forms. It is recommended that these dams be regularly inspected for proper operation and that the Lake levels be monitored.

Fisheries Management
A baseline fishery survey, consisting of mini fyke nets and electrofishing, was recently conducted in 2004 by the WDNR; Oconomowoc Lake is scheduled for a WDNR baseline survey in 2009. Future surveys should have the following objectives:

1. To identify changes in fish species composition that may have taken place in the Lake since the previous surveys;

2. To permit any changes in fish populations, species composition and condition factors to be related to such known interventions as stocking programs, water pollution control activities, and aquatic plant management programs;

3. To refine and update information on fish spawning areas, breeding success, and survival rates;

4. To confirm the lack of disturbance by rough fish populations; and,

5. To determine the need for, and inform the timing of, any additional stocking of northern pike, walleyed pike, and/or other game fish species, as appropriate, by the WDNR, in order to maintain a continuing, viable sport fishery.

This action could provide a sound basis for the Village of Oconomowoc Lake and the WDNR to continue the stocking program and to revise, as may be found necessary, the current fishing regulations regarding the size and number of fish to be taken seasonally. Should rough fish population increases be shown to warrant intervention, conduct of "carp out" events is recommended.

Habitat Protection
The habitat protection measures recommended for Oconomowoc Lake are designed to provide for habitat protection by avoiding disturbances in fish breeding areas during spring and autumn, managing aquatic plants and maintaining stands of native aquatic plants. In particular, this recommendation extends to, and includes, any WDNR-delineated Chapter NR 107 sensitive areas that may be located in a lake, although, at the time of the printing of this document, there were no State designated sensitive areas in Oconomowoc Lake. In addition, it is recommended that environmentally sensitive lands, including wetlands along the lakeshore and in the tributary area be preserved.

Shoreland Protection
Most of the Oconomowoc Lake shoreline is protected and no major areas of erosion, which require additional protection against wind, wave, and wake erosion, were identified in the planning effort. Various protection options are described in Chapter VII for consideration in the repair or replacement of existing protection structures. Adoption of the vegetated buffer strip method is recommended to be used in lakeshore areas and on tributary waterways wherever practical in order to maintain habitat value and the natural ambience of the lakeshore. Continued maintenance of existing revetments and other protection structures is also recommended. Conversion of bulkheads to revetments or natural vegetated shoreline or combinations is recommended to be considered where potentially viable at such time as major repairs are found necessary. Natural vegetated buffer strips should also be considered for shorelines, where practical. Guidance provided in the proposed Chapter NR 328 of the *Wisconsin Administrative Code* sets forth a methodology for determining appropriate shoreline protection structures for inland lakes based upon wind wave action and fetch, substrate, and likely boat wake action.

In addition to the foregoing measures, it is also recommended that the Town of Summit continues to enforce existing shoreland setback requirements, and construction site erosion control and stormwater management ordinances. Provision of informational materials to shoreland property owners is recommended, as set forth in the informational and educational programming element of this plan.

Aquatic Plant Management

The aquatic plant management strategy set forth below recognizes the importance of recreational uses of Oconomowoc Lake. Integral to the aquatic plant management strategy is the protection and preservation of fish breeding habitat. In addition, this strategy recognizes the ecosystem values and functions provided within Oconomowoc Lake by a healthy and diverse aquatic plant community, and seeks to maximize these ecosystem level benefits necessary to ensure a balanced lake ecosystem capable of supporting a variety of diverse recreational uses and economic activities.

Alternative Methods for Aquatic Plant Control

Various aquatic plant management techniques, chemical, mechanical, biological and physical, are potentially applicable on Oconomowoc Lake. A number of these methods have been employed with varying success on Oconomowoc Lake in the past, although chemical control has been the major method utilized throughout the Lake over the years.

Chemical Controls

Chemical controls, in the form of herbicides and algicides, have been used as the primary means of aquatic plant control on Oconomowoc Lake. As noted in Chapter V of this report, the aquatic herbicides diquat, endothal, sodium arsenite, and 2,4-D have been applied to Oconomowoc Lake to control aquatic macrophyte growth; copper sulfate compounds have been used to control algae. Diquat is a nonselective herbicide that will kill many aquatic plants, such as the pondweeds, bladderwort, and naiads that provide significant habitat value for the fishes and wildlife of the Lake. Endothall primarily kills pondweeds, but does not control such nuisance species as Eurasian water milfoil, while 2,4-D and fluridone are systemic herbicides that are considered to be more selective and generally used to control Eurasian water milfoil. However, 2,4-D also will kill high-value species such as water lilies, and fluridone will also affect coontail and elodea. In addition, in some lakes the use of chemical control techniques may contribute to an ongoing aquatic plant problem by augmenting the natural rates of accumulation of decayed organic matter in the lake's sediments, releasing the nutrients contained in the plants back into the water column where they can be reused by new plants, inducing biomass production. The use of chemical control measures may also contribute to the oxygen demand that produces anoxic conditions in a lake, damaging or destroying nontarget plant species that provide needed habitat for fish and other aquatic life.

Selective use of chemical control may be a suitable technique for the control of infestations of Eurasian water milfoil and other nuisance species, especially in areas where other means are not practicable. Chemical applications in early spring have been found to be effective in controlling such infestations of milfoil and facilitating the resurgence of growth of native plant species in lakes in Southeastern Wisconsin. Chemical applications should be conducted in accordance with current administrative rules, under the authority of a State permit, and by a licensed applicator working under the supervision of WDNR staff. Records accurately delineating treated areas and the type and amount of herbicide used in each area, should be carefully documented and used as a reference in applying for permits in the following year. In addition, the use of the herbicide 2,4-D has been shown to be effective in the control of hybrid water milfoil (*Myriophyllum spicatum* x *sibiricum*) populations present in the Lake at a rate of 150 pounds per acre of granular 2,4-D.[12]

Mechanical Controls

Mechanical harvesting of aquatic plants has not been used as a means of controlling plant growth and associated filamentous algae on Oconomowoc Lake, in the past. The most significant impact of mechanical harvesting is the

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[12]*Angela L. Ortenblad, Allison M. Zappa, Abby R. Kroken, and Robert C. Anderson, "Effectiveness of Granular 2,4-D Treatment on Hybrid Watermilfoil (*Myriophyllum sibiricum *x* spicatum*) in Oconomowoc Lake, Wisconsin," Wisconsin Lutheran College Biology Department Technical Bulletin 008, March 2006; see also, Allison M. Zappa and Robert C. Anderson, "Follow up Study on the Effectiveness of Granular 2,4-D Treatment on Hybrid Watermilfoil (*Myriophyllum sibiricum *x* spicatum*) in Oconomowoc Lake, Wisconsin," Wisconsin Lutheran College Biology Department Technical Bulletin 010, April 2007.*

removal of the organic plant biomass, decreasing nutrient inputs to the Lake. Potential negative impacts of mechanical harvesting, as outlined by the U.S. Environmental Protection Agency,[13] include: the removal of small fish, limited depths of operation, propagation of plant fragments, and time needed to treat specific areas of a waterbody. However, mechanical harvesting does offer temporary relief from nuisance aquatic plant growths, especially when conducted in accordance with a management plan designed to optimize benefits and minimize adverse impacts.

In addition to controlling nuisance aquatic plant growth conditions, harvesting has been shown to promote better balance within the in-lake fishery by providing access for larger game fish, such as the largemouth bass, to smaller prey fishes and organisms which can utilize the dense plant beds. Narrow channels harvested to provide navigational access also provide "cruising lanes" for predator fish to migrate into the macrophyte beds to feed on smaller fish. Consideration of use of harvesting should future needs arise to control nuisance levels of aquatic macrophytes or invasive species such as Eurasian water milfoil is recommended.

Manual Controls

Manual methods of aquatic plant control, such as raking or hand-pulling, while environmentally sound, are difficult to employ on a large-scale. Although very effective for small-scale application, for example, in and around docks and piers, manual techniques are generally not practical for large-scale plant control methods. Manual means are recommended on Oconomowoc Lake to control nearshore plant growths, especially around piers and docks.

Shoreline Cleanup Crew

Decomposing, floating vegetation can build up along the shorelines, and, together with terrestrial leaf litter, can limit the use of shoreline areas. Not only is this material unsightly and potentially foul smelling, but it also contributes to the creation of the organic and mucky substrates favored by invasive plant species such as Eurasian water milfoil. Shoreline cleanup is a laborious job that can require substantial amounts of labor and time. To alleviate this problem, the Village of Oconomowoc Lake, in cooperation with shoreline property owners, could institute a comprehensive program of shoreline cleanup to act in conjunction with harvesting operations to remove as much floating vegetation as possible.

Informational and Educational Programming

In addition to the in-lake rehabilitation methods, an ongoing campaign of community informational programming can support the aquatic plant management program by encouraging the use of shoreland buffer strips, responsible use of household and garden chemicals, and environmentally friendly household and garden practices to minimize the input of nutrients from these riparian areas. In addition, a community information campaign should emphasize the need to clean boats and motors/propellers when removing boats from the Lake and upon launching boats into the Lake to limit the redistribution of invasive organisms. Plants removed from boats and motors should be retained onboard and/or disposed of by composting at the boat launch or homestead to avoid their being reintroduced into the water. An informational program can also remind riparian residents and others of the habitat and ecological benefits, such as shoreline stabilization, provided by the aquatic flora of the Lake, thereby promoting the preservation of a healthy aquatic flora in the Lake.

In addition to informational programming, educational programs such as Project WET, Adopt-A-Lake, and other school-based programs can help to build community awareness of the value of lake ecosystems, and the need for vigilance on the part of individual citizens and households within the area tributary to the Lake. School groups and other community service organizations also form a cadre of volunteers that can assist in shoreland management programs and in the dissemination and conduct of community informational programs.

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[13]*H. Olem and G. Flock, U.S. Environmental Protection Agency Report No. EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, Second Edition*, Washington, D.C., August 1990, p. 146.*

The Oconomowoc Lake community has consistently supported informational and educational programming within their community, have encouraged environmentally sound behaviors within the Lake, and have contributed to shoreland restoration efforts and lake monitoring as well. Thus, ongoing informational and educational programming is recommended.

Recommended Aquatic Plant Management Measures

It is recommended that continued aquatic macrophyte surveys be conducted at about five-year intervals, depending upon the observed degree of change in the aquatic plant communities. In addition, information on the aquatic plant control program should be recorded and should include descriptions of: major areas of nuisance plant growth; areas chemically treated and/or harvested; and in areas where harvesting is conducted, species harvested and amounts of plant material removed from the lake, and species and approximate numbers of fish caught in the harvest. It is further recommended that a daily harvester log, containing this information, be maintained. This information, in conjunction with the conduct of the recommended aquatic macrophyte surveys, will allow evaluation of the effectiveness of the aquatic plant control program over time and allow adjustments to be made in the program to maximize its benefit.

To enhance the use of Oconomowoc Lake while maintaining the quality and diversity of the biological communities, the following recommendations are made:

1. Reconnaissance surveys of the aquatic plant communities in Oconomowoc Lake are recommended to be conducted periodically and the approved aquatic plant management plan should be updated every three to five years.

2. It is recommended that the use of chemical herbicides be limited to controlling nuisance growth of exotic species in shallow water around docks and piers where harvesting is unable to reach. Maintenance of shoreland areas around docks and piers remains the responsibility of individual property owners. It is recommended that chemical applications, if required, be made by licensed applicators in early spring subject to State permitting requirements to maximize their effectiveness on nonnative plant species, while minimizing impacts on native plant species and acting as a preventative measure to reduce the development of nuisance conditions. Such use should be evaluated annually and the herbicide applied only on an as needed basis. Only herbicides that selectively control milfoil, such as 2,4-D and fluridone, should be used. Algicides, such as Cutrine Plus, are not recommended because there are few significant, recurring filamentous algal or planktonic algal problems in the Oconomowoc Lake and valuable macroscopic algae, such as *Chara* and *Nitella* are killed by this product.

3. Early spring treatments using targeted herbicide applications offer the opportunity to limit the spread of milfoil, especially Eurasian water milfoil and hybrid milfoil, to other portions of the Lake; consequently, the use of targeted spring herbicide treatments, with priority being given to the portion of the Oconomowoc River flowing in to Oconomowoc Lake from Okauchee Lake, is recommended. Additionally, riparian landowners should be encouraged to collect aquatic plant fragments from around their piers and docks and remove these from the Lake at regular intervals.

4. Mechanical harvesting is recommended as a possible future management method should the need arise. As indicated in Chapter V, this will, in the long-term, help to maintain good water quality conditions by removing plant materials which are currently contributing to an accumulation of decomposing vegetation and associated nutrient recycling. Due to the intermittent nature of the need for aquatic plant control on Oconomowoc Lake, the lack of well-placed adequate off-loading sites along the shoreline, and unfavorable cost-benefit comparisons, it is recommended that harvesting, if it should take place, be carried out by means of contracting with private companies rather than the Village of Oconomowoc Lake purchasing harvesting equipment. In areas where harvesting occurs, it is recommended that shared-access channels be harvested to minimize the potential detrimental effects on the fish and invertebrate communities. Directing boat traffic through these common channels would help to delay the regrowth of vegetation in these areas. Additionally, surface

harvesting is recommended, cutting to a depth to remove the surface canopy of nonnative aquatic plants, such as the Eurasian water milfoil. This should provide a competitive advantage to the low-growing native plants present in the Lake. By not disturbing the low-growing species which generally grow within one to two feet of the lake bottom and in relatively low densities, leaving the root stocks and stems of all cut plants in place, the resuspension of sediments in Oconomowoc Lake will be minimized, and some degree of cover will continue to be provided for panfish populations which support the bass population in the Lake. Further, cutting should not be broad-based, but focused on boating channels and selected navigation areas.

5. The control of rooted vegetation between adjacent piers is recommended to be left to the riparian owners concerned, as it is time consuming and costly for a mechanical harvester to maneuver between piers and boats and such maneuvering may entail liability for damage to boats and piers. The Village of Oconomowoc Lake may wish to obtain informational brochures regarding shoreline maintenance, such as information on hand-held specialty rakes made for this specific purpose, to inform residents of the control options available.

6. The collection of aquatic plant fragments and other debris along shoreline areas is recommended.

7. It is recommended that ecologically valuable areas be excluded from aquatic plant management activities, especially during fish spawning seasons in early summer and autumn. Any aquatic plant management limitations that may be set forth within a future WDNR Chapter NR 107 sensitive area determination are incorporated herein by reference.

8. It is further recommended that the Village of Oconomowoc Lake conduct public informational programming on the types of aquatic plants in Oconomowoc Lake; on the value of and the impacts of these plants on water quality, fish, and on wildlife; and on alternative methods for controlling existing nuisance plants including the positive and negative aspects of each method. This program can be incorporated into the comprehensive informational and educational programs that also would include information on related topics, such as water quality, recreational use, fisheries, and onsite sewage disposal systems.

The recommended aquatic plant control areas are shown on Map 19. The control measures in each area are designed to optimize desired recreational opportunities and to protect the aquatic resources.

The recommended aquatic plant management plan represents a continuation of the current aquatic plant management program conducted by the Village of Oconomowoc Lake.

OTHER LAKE MANAGEMENT MEASURES

Recreational Use Management

Public Recreational Boating Access

With respect to boating ordinances applicable to Oconomowoc Lake, it is recommended that current levels of enforcement be maintained. In addition, recreational boating access users should be made aware of the presence of the exotic invasive species Eurasian water milfoil within Oconomowoc Lake. Appropriate signage should be placed at the public and private (such as the yacht club) recreational boating sites, and supplemental materials on the control of invasive species should be made available to the public. These materials could be provided to riparian householders by means of mail drops or distribution of informational materials at public buildings, such as municipal buildings and the public library, and to nonriparian users by means of informational materials provided at the entrance to all municipal public recreational boating access sites. In addition, it is recommended that disposal bins be made available at the public recreational boating access sites for disposal of plant materials and other refuse removed from watercraft using the public recreational boating access sites.

Public Informational and Educational Programs
It is recommended that the Village of Oconomowoc Lake assumes the lead in the development of a public informational and educational program. Participation by the Town of Summit should be encouraged. This program should deal with various lake management-related topics, including onsite sewage disposal system management, water quality management, land management, groundwater protection, aquatic plant management, fishery management, invasive species, and recreational use. Educational and informational brochures and pamphlets of interest to homeowners and supportive of the recreational use and shoreland zoning regulations are available from the WDNR and UWEX. These cover topics such as beneficial lawn care practices and household chemical use. Such brochures are provided to riparian homeowners by the Village of Oconomowoc Lake, and should continue to be provided to homeowners through local media, direct distribution, or targeted library and civic center displays. Such distribution can also be integrated into ongoing, larger-scale activities, such as lakeside litter collections, which can reinforce anti-littering campaigns, recycling drives, and similar environmental protection activities.

Given the extent of public interest in Oconomowoc Lake, it is recommended that the Village of Oconomowoc Lake consider offering regular informational programs on the Lake and issues related thereto. Such programming can provide a mechanism to raise awareness of the Lake issues, and provide a focal point from which to distribute the informational materials referred to above.

The Village of Oconomowoc Lake and the local municipalities are also encouraged to take an active role in encouraging the local school districts to adopt and utilize lake-related educational programs, such as Project WET, as means of more closely linking students to the lake environment.

The cost for conducting this informational and educational program is estimated to be $1,200 per year.

Institutional Development
In the case of Oconomowoc Lake, general oversight of lake management activities is provided by the Village, pursuant to Section 61.34(1), *Wisconsin Statutes*. While lake management activities fall under the general powers of municipalities, as in the case of the Village of Oconomowoc Lake, other public and private organizational alternatives exist for the management of lakes in the State of Wisconsin.[14] Private lake organizations have the option to be incorporated, generally as nonstock, not-for-profit corporations under Chapter 181, *Wisconsin Statutes*. Public lake organizations include special-purpose units of government that are created as public inland lake protection and rehabilitation districts under Subchapter IV of Chapter 33, *Wisconsin Statutes*, and utility districts created pursuant to Subchapter VIII of Chapter 66, *Wisconsin Statutes*.

Public inland lake protection and rehabilitation districts can be created by petition of the property owners within the boundary of the proposed district (Section 33.25(1), *Wisconsin Statutes*) or by action of a municipality, if the municipality encompasses all of the frontage of the waterbody within its jurisdiction (Section 33.23(1), *Wisconsin Statutes*). In this latter case, the governing board of the municipality serves as the board of commissioners of the lake district (Section 33.23(1), *Wisconsin Statutes*), unless the property owners within the district petition for self-governance (Section 33.23(3), *Wisconsin Statutes*). Public inland lake protection and rehabilitation districts, with the consent of the Village, may carry out the functions of a town sanitary district (Sections 33.22(3) and 33.22(4), *Wisconsin Statutes*).

An alternative to the grant of self-governance under Section 33.23(3) of the *Wisconsin Statutes* is the formation of an interactive liaison mechanism. Such a mechanism has been adopted by several public inland lake protection and rehabilitation districts within the Southeastern Wisconsin Region, including the Big Muskego Lake Management District formed by the City of Muskego in Waukesha County and the Paddock Lake Management District formed by the Village of Paddock Lake in Kenosha County. An interactive liaison mechanism, formally

[14]*See University of Wisconsin-Extension Publication No. G3216,* The Lake in Your Community, *1986.*

created by the lake district with clear lines of authority, communication and reporting, improves the likelihood of success of District-sponsored events, activities and policies by encouraging a sense of community and partnership between the citizenry and the Lake District Board of Commissioners. This alternative also enables the municipality to focus on the broader range of concerns facing the community, while simultaneously focusing on lake protection and rehabilitation issues in an effective and meaningful way.

While the specific type (or types) of organization created is based upon the decision of the community, the Village of Oconomowoc Lake may wish to consider the formation of a public inland lake protection and rehabilitation district to serve the Oconomowoc Lake community at a future date, especially at such time as a more active program of lake management or the operation of a sanitary sewerage system may be required.

PLAN IMPLEMENTATION AND COSTS

The actions recommended in this plan largely represent an extension of ongoing actions being carried out by the Village of Oconomowoc Lake, the Town of Summit, in part, in cooperation with neighboring municipalities, and county and state agencies. The recommended plan introduces few new elements, although some of the plan recommendations represent refinements of current programs. This is particularly true in the case of the fisheries and aquatic plant management programs, where the field surveys recommended in this plan will permit more efficient management of these resources.

Generally, aquatic plant and fisheries management practices and public awareness campaigns currently implemented by the Village of Oconomowoc Lake and local municipalities, are recommended to continue with refinements as proposed herein. Some aspects of these programs lend themselves to citizen involvement through participation in the UWEX CLMN, and identification with environmentally sound owner-based land management activities. It is recommended that the Village of Oconomowoc Lake, in cooperation with the local municipalities, assume the lead in the promotion of such citizen actions, with a view toward building community commitment and involvement. Assistance is generally available from agencies such as the WDNR, the County UWEX office, and SEWRPC.

The suggested lead agency or agencies for initiating program-related activities, by plan element, are set forth in Table 32, and the estimated costs of these elements, linked to possible funding sources where such are available, are summarized in Table 33. In general, it is recommended that the Village of Oconomowoc Lake continue to provide a coordinating role for community-based lake management actions, in cooperation with the appropriate local government units.

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APPENDICES

Appendix A

ILLUSTRATIONS OF COMMON AQUATIC PLANTS FOUND IN OCONOMOWOC LAKE

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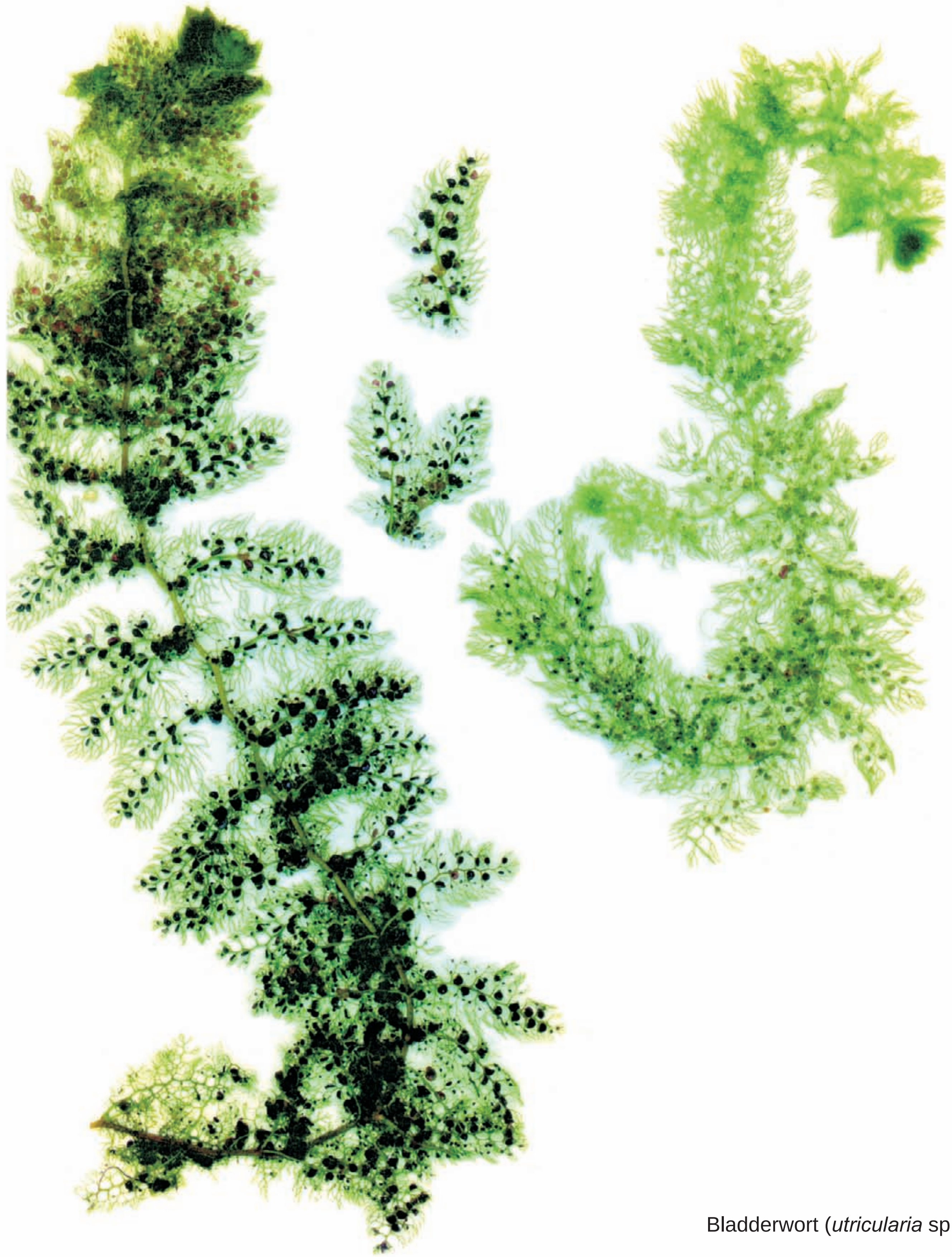


Bladderwort (*utricularia* sp.)

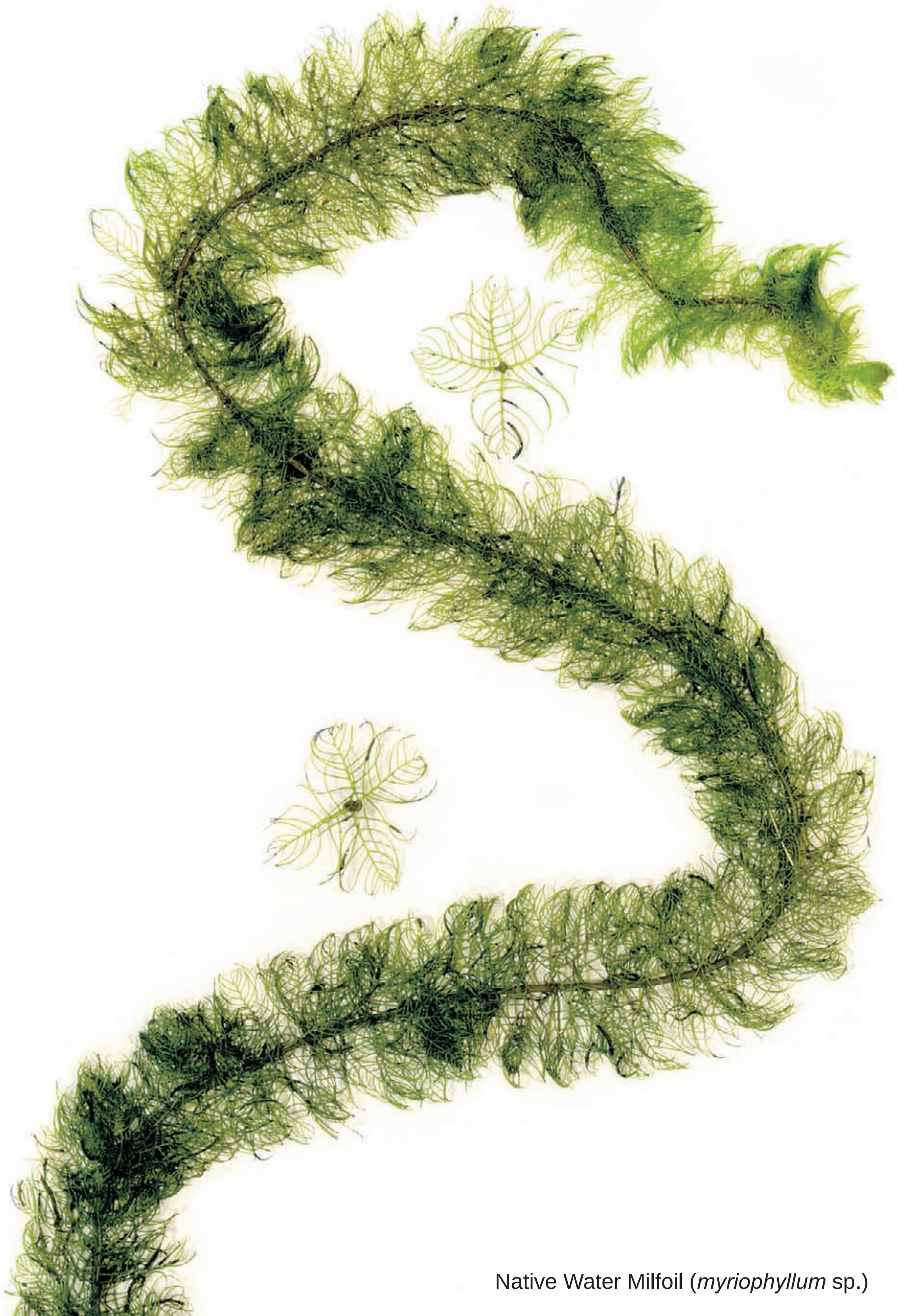
Bushy Pondweed (*najas flexilis*)

Clasping-Leaf Pondweed
(*potamogeton richardsonii*)

Coontail (*ceratophyllum demersum*)

Curly-Leaf Pondweed (*potamogeton crispus*)
Exotic Species (nonnative)

Eurasian Water Milfoil (*myriophyllum spicatum*)
Exotic Species (nonnative)



Native Water Milfoil (*myriophyllum* sp.)

Flat-Stem Pondweed (*potamogeton zosteriformis*)

Illinois Pondweed (*potamogeton illinoensis*)

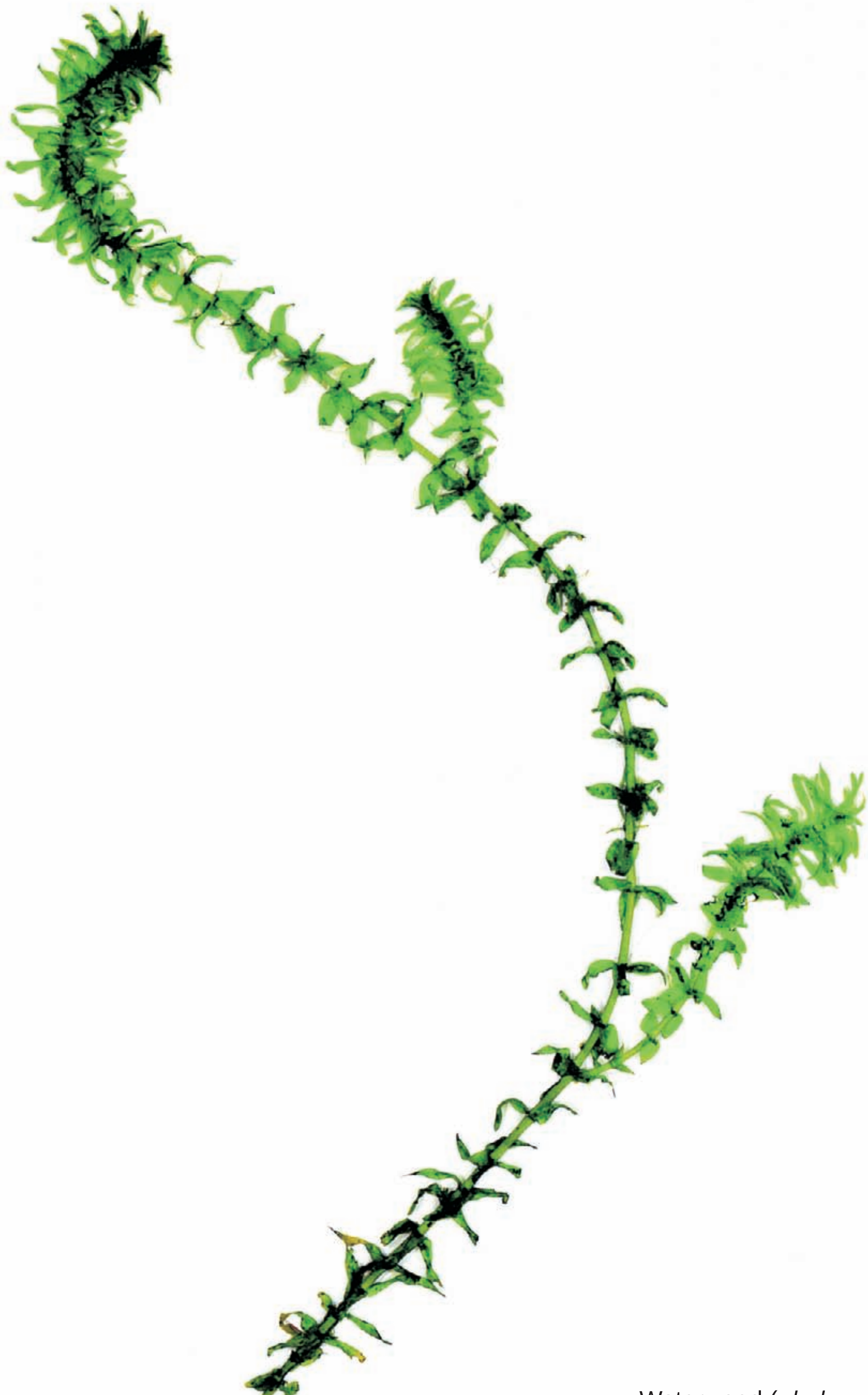
Leafy Pondweed (*potamofeton foliosus*)

Muskgrass (*chara vulgaris*)

Sago Pondweed (*potamogeton pectinatus*)

Spiny Naiad (*najas marina*)

Variable Pondweed (*potamogeton gramineus*)



Waterweed (*elodea canadensis*)

White-Stem Pondweed (*potamogeton praelongus*)

White Water Crowfoot (*ranunculus longirostris*)

Eel-Grass / Wild Celery (*valisneria americana*)

Appendix B

BOATING ORDINANCE

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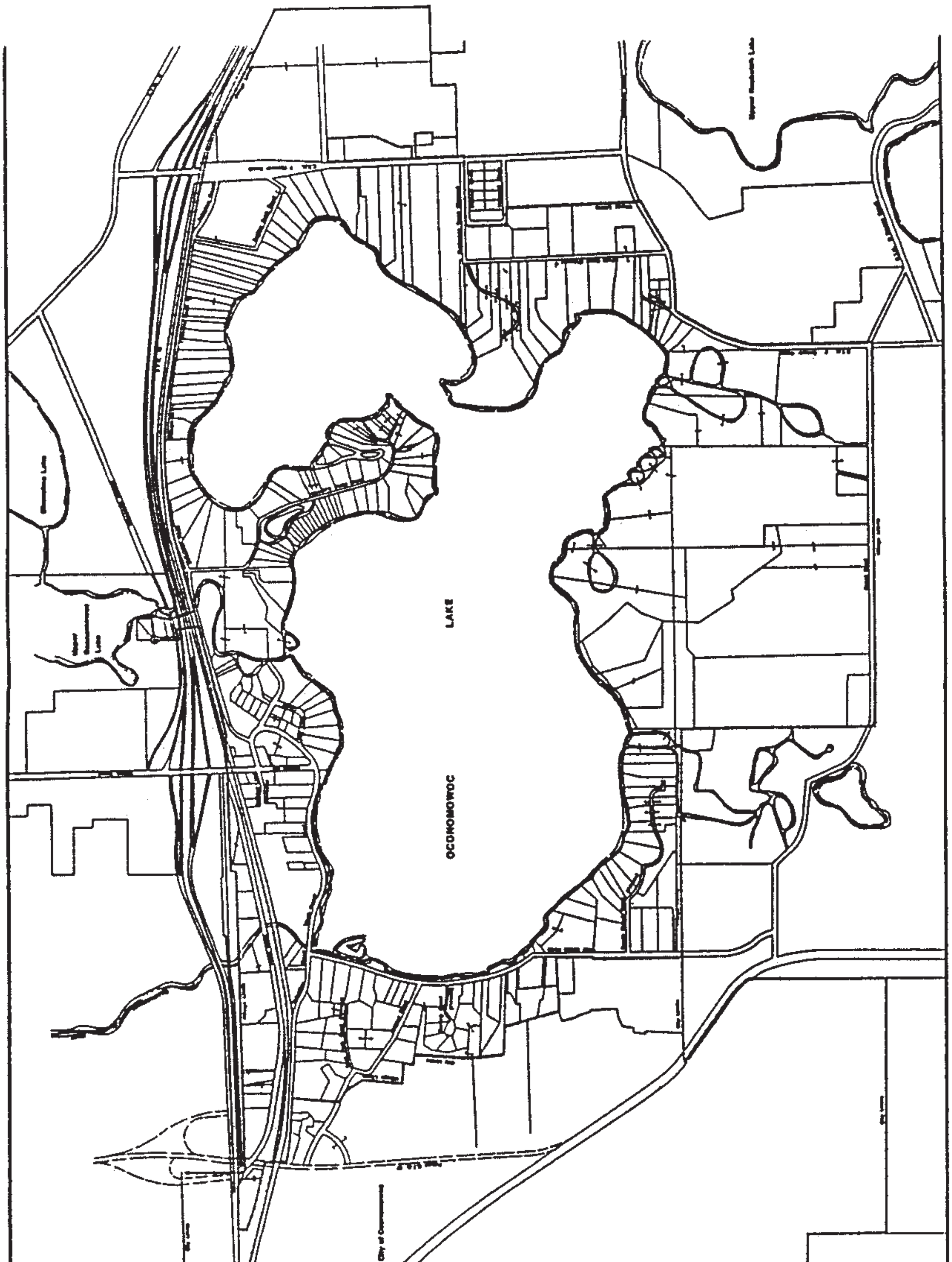
CHAPTER 20

LAKES AND BEACHES


OCONOMOWOC
LAKE

20.01 APPLICABILITY AND ENFORCEMENT. (1) APPLICABILITY. The provisions of this chapter shall apply to the waters of the Oconomowoc River and Oconomowoc Lake within the territorial jurisdiction of the Village, whether such waters are within su jurisdiction at the time of passage of this chapter or are subsequently added thereto and whether or not such waters are within its jurisdiction for other purposes.

(2) ENFORCEMENT. The provisions of this chapter shall b enforced by the Water Safety Patrol of the Village.

20.02 STATE BOATING AND WATER LAWS ADOPTED. Except as otherwise specifically provided in this Code, the current and future statutory provisions describing and defining regulation with respect to water traffic, boats, boating and related wate activities in Chapter 30 of the Wisconsin Statutes, exclusive any provision therein relating to the penalties to be imposed the punishment for violation of such statutes, are hereby adopted and by reference made part of this chapter as if fully set forth herein. Any act required to be performed or prohibited by any current or future statute incorporated herei by reference is required or prohibited by this section. Any future additions, amendments, revisions or modifications of the current or future statutes incorporated herein are intended to be made part of this Code in order to secure uniform state wid regulation of water traffic, boats, boating and related water activities.

20.03 STATE DEPARTMENT OF NATURAL RESOURCES' RULES ADOPTE Except as otherwise specifically provided in this Code, the current and future rules of the State Department of Natural Resources describing and defining regulations with respect to water traffic, boats, boating and related water activities in Section NR 5 of the Wisconsin Administrative Code are, exclusi of any provisions therein relating to penalties to be imposed the punishment for violation of such Administrative Codes, are hereby adopted and by reference made part of this chapter as i fully set forth herein. Any act required to be performed or prohibited by any current or future Administrative Code Incorporated herein by refernce is required or prohibited by this section. Any future additions, amendments, revisions or modifications of the current or future Administrative Code incorporated herein are intended to be made a part of this Cod in order to secure uniform state wide regulation of water traffic, boats, boating and related water activities.

20.04 SPEED RESTRICTIONS. (1) NIGHTTIME. No person sha operate a boat at a speed in excess of 10 mph from one hour after sunset each day until one hour before sunrise of the nex day.

(2) SPECIAL LIMITS. A person operating a motorboat shall maintain a low rate of speed when within 150 feet of any shoreline, person, raft, diving flag, seaplane, anchorage, sailboat, canoe, rowboat, stationary motorboat or bridge.

(3) EXCEPTION. This section shall not apply to boats participating in authorized races over a course laid out and clearly marked and adequately patrolled.

20.05 SAFE OPERATION REQUIRED. No person shall operate, direct or handle a boat in such manner as unreasonably to anno: unnecessarily frighten or endanger the occupants of his or oth boats.

20.06 RACING PROHIBITED. No person shall operate a motorboat in a race or speed contest with any other motorboat, except as provided in ss. 20.12 of this chapter.

20.07 ANCHORAGES AND STATIONARY OBJECTS (1) MOORING LIGHTS REQUIRED. No person shall moor or anchor any boat more than 150 feet from shoreline between one hour after sunset and one hour before sunrise, unless there is predominately display thereon a white light of sufficient size and brightness to be visible from any direction for a distance of 1,500 feet on a dark night with clear atmosphere.

(2) RAFTS AND BUOYS. No person shall erect or maintain any raft, platform or buoy more than 150 feet from the shore, unless it is so anchored that it has at least 10 inches of fre board above the waterline and either is painted white and has attached thereto not less than 12 inches from each corner or projection a red reflector in good condition not less than 3 inches in diameter or is painted with a band at least 3 inch in width of luminous paint so as to be visible from any direction.

20.08 SWIMMING REGULATIONS. It is recommended that any person swimming more that 150 feet from any shoreline be accompanied by a boat for the protection of the swimmer and as an aid to others in determining his location. Any person swimming beyond the 150 feet limit without accompanying boat does so at his own risk.

20.09 WATERSKIING. (1) DISTANCE FROM SWIMMERS, BOATS, (OTHER OBJECTS. No person on water skis, aquaplane, surfboard (similar device shall pass and no person operating a boat which is pulling or towing such skier or rider shall cause such skie: or rider to pass within 100 feet of a swimmer, diving flag, canoe, rowboat, sailboat, nonoperating motorboat, raft or pier, except in the course of the skier or rider taking off from or landing at such pier.

(2) HOURS. No person shall operate a boat while towing a person on water skis, aquaplane, surfboard or any similar devi at any time from sunset to sunrise.

(3) PERSONS IN BOAT. No person shall operate a boat whi pulling or towing any person on water skis, aquaplane, surfboard, or similar device or permit himself to be towed for such purposes, unless there are 2 persons over 12 years of age in such boat and the operator of the boat shall maintain a forward lookout.

(4) EXEMPTION FROM SPEED LIMITATIONS. The limitations contained in ss. 20.04(2) of this chapter shall not apply to boats towing a person or persons on water skis or similar devi while leaving or approaching the shoreline in a straight line as nearly as practicable at right angles to such shoreline.

20.10 LITTERING WATERS PROHIBITED. No person shall deposit, place or throw from any shore, boat raft, pier, platform or similar structure any cans, paper, bottles, debris garbage, solid or liquid waste, including human waste, into th water; into or upon the shore, rafts or piers; or onto the ice

20.11 SPEAR GUNS. No person shall have in his possessio any loaded spear gun in or on the water, ice or shoreline.

20.12 RACES, REGATTAS, SPORTING EVENTS AND EXHIBITIONS. (1) PERMIT REQUIRED. Except for formally organized sailboat races, whether on water or ice, no person shall direct or participate in any boat race, regatta, water ski meet or other water sporting event or exhibition, unless such event has been authorized and a permit issued therefor by the director of the Water Safety Patrol of the Village.

(2) PERMIT. A permit issued under this section shall specify the course or area of water to be used by participants in such events and the permittee shall be required to place markers, flags or buoy approved by the director of the Water Safety Patrol of the Village designating the specified area. Permits shall be issued only if, in the opinion of the directo: the proposed use of water can be carried out safely and withou danger to or substantial obstruction of the watercraft or persons using the water. Permits shall be valid only for the hours and areas specified therein. The fee for issuing any permit hereunder shall be $2.

(3) RIGHT-OF-WAY OF PARTICIPANTS. Boats and participant in any such permitted event shall have the right-of-way on the marked area and no other person shall obstruct such area durin the race or event or interfere therewith.

(4) INCORPORATION OF CH. 12. The provisions of ss. 12.0 and 12.11 of this Code of Ordinance shall apply to permits issued hereunder.

20.13 PATROL BOATS. (1) EXCEPTION FOR. Sections 20.0 and 20.11 of this chapter shall not apply to boats of the Wate: Safety Patrol of the Village while on patrol or rescue duty no: to members of such patrol while engaged in such duties.

(2) TRAFFIC RULES. Boats of the Water Safety Patrol shall have the right-of-way over all other boats when their siren is being sounded.

20.14 MARKERS AND NAVIGATION AIDS; POSTING ORDINANCES.

(1) DUTY OF DIRECTOR. The director of the Water Safety Patrol is authorized and directed to place and maintain suitabl markers, navigation aids and signs in such water areas or on such ice areas as he shall deem appropriate to advise the publi of the provisions of this chapter and to post prominently and maintain a copy of this chapter and all amendments hereto at al public access points within the jurisdiction of the Village.

(2) STANDARD MARKERS. The markers placed by the director or any other person upon the waters or ice shall comply with th regulations of the Department of Natural Resources.

(3) INTERFERENCE WITH MARKERS PROHIBITED. No person shall without authority remove, damage or destroy or moor or attach any boat to any buoy, beacon or marker placed in the waters or on the ice by the authority of the United States, State, Village or by any private person pursuant to the provision of this chapter.

20.15 BOAT LAUNCHING. (1) No person shall launch any boat into the waters subject to this chapter except as follows:

(a) From a public boat launching facility owned and operated by the Village and so designated and marked by the Director of the Water Safety Patrol

(b) From a commercial boat launch facility.

(c) From a private property by the owner thereof or with his express permission.

(2) All persons launching any boat at any public boat launching facility owned and operated by the Village and all persons parking any vehicle at any public boat launching owned and operated by the Village shall pay a launching/parking fee a set by the Village.

(a) The fee schedule shall be set by separate resolution of the Village Board.

(b) Residents of the Village of Oconomowoc Lake shall be exempted from fees for launching/parking at th public boat launching upon satisfactory proof of residency. The Village may issue stickers or other evidence of residency for this purpose.

(c) If an attendant is on duty at the public boat launching facility, launching/parking fees shall be paid to the attendant prior to launching.

(d) If no attendant is on duty at the public launch site, the boat launching/parking fee shall be pai pursuant to the directions at the site.

(3) Use of the public boat launching facility shall be limited to vehicles and/or vehicle-trailer combinations parked in designated parking spaces in the parking area. Launching of boats shall be prohibited if, at the time of launching, all parking stalls at the public boat launching facility are occupied. At the discretion of the Village, a public boat launching facility may be used for launching boats kept seasonally on Oconomowoc Lake without corresponding use of the parking area. Parking of vehicles and/or vehicle-trailer combinations shall be prohibited if all parking stalls at the public boat launching facility are occupied.

(4) Use of the parking area at a public boat launching facility shall be limited to vehicles and/or vehicle- trailer combinations using the launch site for the purpose of launching boats and which have paid the required boat launching fee.

(5) Failure to comply with the requirements of this section shall subject the violator to penalties as set forth in chapter 25 of this Code.

20.16 RESIDING ON BOATS. No person shall use or occupy, temporarily or permanently, any boat on the waters subject to this chapter as a dwelling or residence.

20.17 WATER SAFETY PATROL UNIT. (1) CREATION. There is hereby created as a division of the Police Department a water safety patrol unit, which shall be known as the Water Safety Patrol of the Village.

(2) DUTIES. The Water Safety Patrol shall enforce all ordinances of the Village now existing or hereafter enacted which regulate water traffic, boating, water sports, seaplanes or the use or operation of boats and other craft, including motor vehicles, on icebound waters.

(3) OFFICERS OF PATROL; DIRECTOR. The officers of the Water Safety Patrol shall be the officers of the Police Department or such of them as shall from time to time be assigned to such patrol by the Chief of Police of the Village. The director of such patrol shall be the Chief of Police.

(4) EQUIPMENT. The Water Safety Patrol shall be furnishe with and maintain a fully equipped patrol boat for the executio of its duties.

20.18 FROZEN LAKES AND RIVERS. (1) ICE FISHING. No person shall make or cause to be made any hole more than 12 inches in diameter or more than one square foot in area for the purpose of fishing through the ice on any portion of the lakes adjacent to or within the Village and under the jurisdiction of the Village.

(2) DRIVING AND PARKING VEHICLES ON THE ICE. No person shall drive or permit to be driven any automobile or truck upon the ice on any portion of the lakes or other water adjacent to or within the Village and under the jurisdiction of the Village at any time, except upon a permit issued by the Chief of Police upon application showing that there is some urgent reason or need therefor.

20.20 PENALTY. (1) Expect as otherwise provided, any person found in violation of any provision of this chapter or any order, rule or regulation made hereunder shall be subject t a penalty as provided in ss. 25.04 of this Code of Ordinances.

(2) Any officer arresting a person for violation of any provision of this chapter who is unable to bring the arrested person before the Oconomowoc Court without unnecessary delay shall permit such person to make a money deposit as provided in ss. 30.76 Wis. Stats. Such deposit shall be made to the Villag police headquarters.

Appendix C

NONPOINT SOURCE POLLUTION CONTROL MEASURES

Nonpoint, or diffuse, sources of water pollution include urban sources such as runoff from residential, commercial, industrial, transportation, and recreational land uses; construction activities; and onsite sewage disposal systems and rural sources such as runoff from cropland, pasture, and woodland, atmospheric contributions, and livestock wastes. These sources of pollutants discharge to surface waters by direct overland drainage, by drainage through natural channels, by drainage through engineered stormwater drainage systems, and by deep percolation into the ground and subsequent return flow to the surface waters.

A summary of the methods and estimated effectiveness of nonpoint source water pollution control measures is set forth in Table C-1. These measures have been grouped for planning purposes into two categories: basic practices and additional. Application of the basic practices will have a variable effectiveness in terms of control level of pollution control depending upon the subwatershed area characteristics and the pollutant considered. The additional category of nonpoint source control measures has been subdivided into four subcategories based upon the relative effectiveness and costs of the measures. The first subcategory of practices can be expected to generally result in about a 25 percent reduction in pollutant runoff. The second and third subcategory of practices, when applied in combination with the minimum and additional practices, can be expected to generally result in up to a 75 percent reduction in pollutant runoff, respectively. The fourth subcategory would consist of all of the preceding practices, plus those additional practices that would be required to achieve a reduction in ultimate runoff of more than 75 percent.

Table C-1 sets forth the diffuse source control measures applicable to general land uses and diffuse source activities, along with the estimated maximum level of pollution reduction which may be expected upon implementation of the applicable measures. The table also includes information pertaining to the costs of developing the alternatives set forth in this appendix.[1] These various individual nonpoint source control practices are summarized by group in Table C-2.

[1] *Costs are presented in more detail in the following SEWRPC Technical Reports: No. 18,* State of the Art of Water Pollution Control in Southeastern Wisconsin, *Volume Three,* Urban Storm Water Runoff, *July 1977, and Volume Four*, Rural Storm Water Runoff, *December 1976; and No. 31,* Costs of Urban Nonpoint Source Water Pollution Control Measures, *June 1991.*

Table C-1

GENERALIZED SUMMARY OF METHODS AND EFFECTIVENESS OF NONPOINT SOURCE WATER POLLUTION ABATEMENT

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Urban	Litter and pet waste control ordinance	Prevent the accumulation of litter and pet wastes on streets and residential, commercial, industrial, and recreational areas	2 to 5	Ordinance administration and enforcement costs are expected to be funded by violation penalties and related revenues
	Improved timing and efficiency of street sweeping, leaf collection and disposal, and catch basin cleaning	Improve the scheduling of these public works activities, modify work habits of personnel, and select equipment to maximize the effectiveness of these existing pollution control measures	2 to 5	No significant increase in current expenditures is expected
	Management of onsite sewage treatment systems	Regulate septic system installation, monitoring, location, and performance; replace failing systems with new septic systems or alternative treatment facilities; develop alternatives to septic systems; eliminate direct connections to drain tiles or ditches; dispose of septage at sewage treatment facility	10 to 30	Replace one-half of estimated existing failing septic systems with properly located and installed systems and replace one-half with alternative systems, such as mound systems or holding tanks; all existing and proposed onsite sewage treatment systems are assumed to be properly maintained; assume system life of 25 years. The estimated cost of a septic tank system is $5,000 to $6,000 and the cost of an alternative system is $10,000. The annual maintenance cost of a disposal system is $250. An in-ground pressure system is estimated to cost $6,000 to $10,000 with an annual operation and maintenance cost of $250. A holding tank would cost $5,500 to $6,500, with an annual operation and maintenance cost of $1,800
	Increased street sweeping	On the average, sweep all streets in urban areas an equivalent of once or twice a week with vacuum street sweepers; require parking restrictions to permit access to curb areas; sweep all streets at least eight months per year; sweep commercial and industrial areas with greater frequency than residential areas	30 to 50	Estimate curb-miles based on land use, estimated street acreage, and Commission transportation planning standards; assume one street sweeper can sweep 2,000 curb-miles per year; assume sweeper life of 10 years; assume residential areas swept once weekly, commercial and industrial areas swept twice weekly. The cost of a vacuum street sweeper is approximately $120,000. The cost of the operation and maintenance of a sweeper is about $25 per curb-mile swept
	Increased leaf and clippings collection and disposal	Increase the frequency and efficiency of leaf collection procedures in fall; use vacuum cleaners to collect leaves; implement ordinances for leaves, clippings. and other organic debris to be mulched, composted, or bagged for pickup	2 to 5	Assume one equivalent mature tree per residence, plus five trees per acre in recreational areas; 75 pounds of leaves per tree; 20 percent of leaves in urban areas not currently disposed of properly. The cost of the collection of leaves in a vacuum sweeper and disposal is estimated at $180 to $200 per ton of leaves
	Increased catch basin cleaning	Increase frequency and efficiency of catch basin cleaning; clean at least twice per year using vacuum cleaners; catch basin installation in new urban development not recommended as a cost-effective practice for water quality improvement	2 to 5	Determine curb-miles for street sweeping; vary percent of urban areas served by catch basins by watershed from Commission inventory data; assume density of 10 catch basins per curb-mile; clean each basin twice annually by vacuum cleaner. The cost of cleaning a catch basin is approximately $10
	Reduced use of deicing salt	Reduce use of deicing salt on streets; salt only intersections and problem areas; prevent excessive use of sand and other abrasives	Negligible for pollutants addressed in this plan, but helpful for reducing chlorides and associated damage to vegetation	Increased costs, such as for slower transportation movement, are expected to be offset by benefits, such as reduced automobile corrosion and damage to vegetation

Table C-1 (continued)

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Urban (continued)	Improved street maintenance and refuse collection and disposal	Increase street maintenance and repairs; increase provision of trash receptacles in public areas; improve trash collection schedules; increase cleanup of parks and commercial centers	2 to 5	Increase current expenditures by approximately 15 percent
	Parking lot stormwater temporary storage and treatment measures	Construct gravel-filled trenches, sediment basins, or similar measures to store temporarily the runoff from parking lots, rooftops, and other large impervious areas; if treatment is necessary, use a physical-chemical treatment measure, such as screens, dissolved air flotation, or a swirl concentrator	5 to 10	Design gravel-filled trenches for 24-hour, five-year recurrence interval storm; apply to off-street parking acreages. For treatment, assume four-hour detention time. The capital cost of stormwater detention and treatment facilities is estimated at $40,000 to $80,000 per acre of parking lot area, with an annual operation and maintenance cost of about $200 per acre
	Onsite storage—residential	Remove connections to sewer systems; construct onsite stormwater storage measures for subdivisions	5 to 10	Remove roof drains and other connections from sewer system wherever needed; use lawn aeration, if applicable; apply dutch drain storage facilities to 15 percent of residences. The capital cost would approximate $500 per house, with an annual operation and maintenance cost of about $25
	Stormwater Infiltration—urban	Construct gravel-filled trenches for areas of less than 10 acres or basins to collect and store temporarily stormwater runoff to reduce volume, provide groundwater recharge and augment low stream flows	45 to 90	Design gravel-filled trenches or basins to store the first 0.5 inch of runoff; provide at least a 25-foot grass buffer strip to reduce sediment loadings. The capital cost of stormwater infiltration is estimated at $12,000 for a six-foot-deep, 10-foot-wide trench, and at $70,000 for a one-acre basin, with an annual maintenance cost of about $10 to $350 for the trench and about $2,500 for the basin
	Stormwater storage—urban	Store stormwater runoff from urban land in surface storage basins or, where necessary, subsurface storage basins	10 to 35	Design all storage facilities for a 1.5-inch runoff event, which corresponds approximately to a five-year recurrence interval event, with a storm event being defined as a period of precipitation with a minimum antecedent and subsequent dry period of from 12 to 24 hours; apply subsurface storage tanks to intensively developed existing urban areas where suitable open land for surface storage is unavailable; design surface storage basins for proposed new urban land, existing urban land not storm sewered, and existing urban land where adequate open space is available at the storm sewer discharge site. The capital cost for stormwater storage would range from $35,000 to $110,000 per acre of basin, with an annual operation and maintenance cost of about $40 to $60 per acre
	Stormwater treatment	Provide physical-chemical treatment which includes screens, microstrainers, dissolved air flotation, swirl concentrator, or high-rate filtration, and/or disinfection, which may include chlorination, high-rate disinfection, or ozonation to stormwater following storage	10 to 50	To be applied only in combination with stormwater storage facilities above; general cost estimates for microstrainer treatment and ozonation were used; some costs were applied to existing urban land and proposed new urban development. Stormwater treatment has an estimated capital cost of from $900 to $7,000 per acre of tributary drainage area, with an average annual operation and maintenance cost of about $35 to $100 per acre

Table C-1 (continued)

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Rural	Conservation practices	Includes such practices as strip cropping, contour plowing, crop rotation, pasture management, critical area protection, grading and terracing, grassed waterways, diversions, woodlot management, fertilization and pesticide management, and chisel tillage	Up to 50	Cost for Natural Resources Conservation Service (NRCS) recommended practices are applied to agricultural and related rural land; the distribution and extent of the various practices were determined from an examination of 56 existing farm plan designs within the Region. The capital cost of conservation practices ranges from $3,000 to $5,000 per acre of rural land, with an average annual operation and maintenance cost of from $5.00 to $10 per rural acre
	Animal waste control system	Construct streambank fencing and crossovers to prevent access of all livestock to waterways; construct a runoff control system or a manure storage facility, as needed, for major livestock operations; prevent improper applications of manure on frozen ground, near surface drainageways, and on steep slopes; incorporate manure into soil	50 to 75	Cost estimated per animal unit; animal waste storage (liquid and slurry tank for costing purposes) facilities are recommended for all major animal operations within 500 feet of surface water and located in areas identified as having relatively high potential for severe pollution problems. Runoff control systems recommended for all other major animal operations. It is recognized that dry manure stacking facilities are significantly less expensive than liquid and slurry storage tanks and may be adequate waste storage systems in many instances. The estimated capital cost and average operation and maintenance cost of a runoff control system is $100 per animal unit and $25 per animal unit, respectively. The capital cost of a liquid and slurry storage facility is about $1,000 per animal unit, with an annual operation and maintenance cost of about $75 per unit. An animal unit is the weight equivalent of a 1,000-pound cow
	Base-of-slope detention storage	Store runoff from agricultural land to allow solids to settle out and reduce peak runoff rates. Berms could be constructed parallel to streams	50 to 75	Construct a low earthen berm at the base of agricultural fields, along the edge of a floodplain, wetland, or other sensitive area, design for 24-hour, 10-year recurrence interval storm; berm height about four feet. Apply where needed in addition to basic conservation practices; repair berm every 10 years and remove sediment and spread on land. The estimated capital cost of base-of-slope detention storage would be $500 per tributary acre, with an annual operation and maintenance cost of $25 per acre
	Bench terraces	Construct bench terraces, thereby reducing the need for many other conservation practices on sloping agricultural land	75 to 90	Apply to all appropriate agricultural lands for a maximum level of pollution control. Utilization of this practice would exclude installation of many basic conservation practices and base-of-slope detention storage. The capital cost of bench terraces is estimated at $1,500 per acre, with an annual operation and maintenance cost of $100 per acre
Urban and Rural	Public education programs	Conduct regional and county-level public education programs to inform the public and provide technical information on the need for proper land management practices on private land, the recommendations for management programs, and the effects of implemented measures; develop local awareness programs for citizens and public works officials; develop local contract and education efforts	Indeterminate	For first 10 years, includes cost of one person, materials, and support for each 25,000 population. Thereafter, the same cost can be applied for every 50,000 population. The cost of one person, materials, and support is estimated at $55,000 per year

Table C-1 (continued)

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Urban and Rural (continued)	Construction erosion control practices	Construct temporary sediment basins; install straw bale dikes; use fiber mats, mulching, and seeding; install slope drains to stabilize steep slopes; construct temporary diversion swales or berms upslope from the project	20 to 40	Assume acreage under construction is the average annual incremental increase in urban acreage; apply costs for a typical erosion control program for a construction site. The estimated capital cost and operation and maintenance cost for construction erosion control is $250 to $5,500 and $250 to $1,500 per acre under construction, respectively
	Materials storage and runoff control facilities	Enclose industrial storage sites with diversion; divert runoff to acceptable outlet or storage facility; enclose salt piles and other large storage sites in crib and dome structures	5 to 10	Assume 40 percent of industrial areas are used for storage and to be enclosed by diversions; assume existing salt storage piles enclosed by cribs and dome structures. The estimated capital cost of industrial runoff control is $2,500 per acre of industrial land. Material storage control costs are estimated at $75 per ton of material
	Stream protection measures	Provide vegetative buffer zones along streams to filter direct pollutant runoff to the stream; construct streambank protection measures, such as rock riprap, brush mats, tree revetment, jacks, and jetted willow poles, where needed	5 to 10	Apply a 50-foot-wide vegetative buffer zone on each side of 15 percent of the stream length; apply streambank protection measures to 5 percent of the stream length. Vegetative buffer zones are estimated to cost $21,200 per mile of stream and streambank protection measures cost about $37,000 per stream mile
	Pesticide and fertilizer application restrictions	Match application rate to need; eliminate excessive applications and applications near or into surface water drainageways	0 to 3	Cost included in public education program
	Critical area protection	Emphasize control of areas bordering lakes and streams; correct obvious erosion and other pollution source problems	Indeterminate	Indeterminate

[a]*Not all control measures are required for each subwatershed. The characteristics of the watershed, the estimated required level of pollution reduction needed to meet the applicable water quality standards, and other factors will influence the selection and estimation of costs of specific practices for any one subwatershed. Although the control measures costed represent the recommended practices developed at the regional level on the basis of the best available information, the local implementation process should provide more detailed data and identify more efficient and effective sets of practices to apply to local conditions.*

[b]*The approximate effectiveness refers to the estimated amount of pollution produced by the contributing category (urban or rural) that could be expected to be reduced by the implementation of the practice. The effectiveness rates would vary greatly depending on the characteristics of the watershed and individual diffuse sources. It should be further noted that practices can have only a "sequential" effect, since the percent pollution reduction of a second practice can only be applied against the residual pollutant load which is not controlled by the first practice. For example, two practices of 50 percent effectiveness in series would achieve a theoretical total effectiveness of only 75 percent control of the initial load. Further, the general levels of effectiveness reported in the table are not necessarily the same for all pollutants associated with each source. Some pollutants are transported by dissolving in water and others by attaching to solids in the water; the methods summarized here reflect typical pollutant removal levels.*

[c]*For highly urbanized areas which require retrofitting of facilities into developed areas, the costs can range from $400,000 to $1,000,000 per acre of storage.*

Source: SEWRPC.

Of the sets of practices recommended for various levels of diffuse source pollution control presented in Table C-2, not all practices are needed, applicable, or cost-effective for all watersheds, due to variations in pollutant loadings and land use and natural conditions among the watersheds. Therefore, it is recommended that the practices indicated as needed for nonpoint source pollutant control be refined by local level nonpoint source control practices planning, which would be analogous to sewerage facilities planning for point source pollution abatement. A locally prepared plan for nonpoint abatement measures should be better able to blend knowledge of current problems and practices with a quickly evolving technology to achieve a suitable, site-specific approach to pollution abatement.

Table C-2

ALTERNATIVE GROUPS OF DIFFUSE SOURCE WATER POLLUTION CONTROL MEASURES PROPOSED FOR STREAMS AND LAKE WATER QUALITY MANAGEMENT

Pollution Control Category	Level of Pollution[a] Control	Practices to Control Diffuse Source Pollution from Urban Areas[b]	Practices to Control Diffuse Source Pollution from Rural Areas[a]
Basic Practices	Variable	Construction erosion control; onsite sewage disposal system management; streambank erosion control	Streambank erosion control
	25 percent	Public education programs; litter and pet waste control; restricted use of fertilizers and pesticides; construction erosion control; critical areas protection; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; material storage facilities and runoff control	Public education programs; fertilizer and pesticide management; critical area protection; crop residue management; chisel tillage; pasture management; contour plowing; livestock waste control
Additional Diffuse Source Control Practices[c]	50 percent	Above, plus: Increased street sweeping; improved street maintenance and refuse collection and disposal; increased catch basin cleaning; stream protection; increased leaf and vegetation debris collection and disposal; stormwater storage; stormwater infiltration	Above, plus: crop rotation; contour strip-cropping; grass waterways; diversions; wind erosion controls; terraces; stream protection
	75 percent	Above, plus: An additional increase in street sweeping, stormwater storage and infiltration; additional parking lot stormwater runoff storage and treatment	Above, plus: Base-of-slope detention storage
	More than 75 percent	Above, plus: Urban stormwater treatment with physical-chemical and/or disinfection treatment measures	Bench terraces[b]

[a] *Groups of practices are presented here for general analysis purposes only. Not all practices are applicable to, or recommended for, all lake and stream tributary watersheds. For costing purposes, construction erosion control practices, public education programs, and material storage facilities and runoff controls are considered urban control measures and stream protection is considered a rural control measure.*

[b] *The provision of bench terraces would exclude most basic conservation practices and base-of-slope detention storage facilities.*

[c] *In addition to diffuse source control measures, lake rehabilitation techniques may be required to satisfy lake water quality standards.*

Source: SEWRPC.