COMMUNITY ASSISTANCE
PLANNING REPORT NO. 58
(2nd Edition)

A LAKE MANAGEMENT PLAN FOR PEWAUKEE LAKE

WAUKESHA COUNTY WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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LAKE PEWAUKEE SANITARY DISTRICT

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION STAFF

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A LAKE MANAGEMENT PLAN FOR PEWAUKEE LAKE
WAUKESHA COUNTY, WISCONSIN

Prepared by the

Southeastern Wisconsin Regional Planning Commission

In Cooperation with the

Lake Pewaukee Sanitary District

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Chapter I

INTRODUCTION

Pewaukee Lake is a 2,493-acre through-flow natural drainage lake, situated within U.S. Public Land Survey Sections 7 and 8, Township 7 North, Range 19 East, in the City, and Village of Pewaukee, and in U.S. Public Land Survey Sections 13, 14, and 15, Township 7 North, Range 18 East, Town of Delafield, all in Waukesha County. The Lake drains to the Pewaukee River, which drains to the Fox (Illinois) River and, ultimately, to the Mississippi River. The Lake offers a variety of water-based recreational opportunities and is the focus of the lake-oriented communities surrounding the Lake. For many years, the Lake has experienced various management problems, including excessive aquatic plant growth, recreational user conflicts, water quality-related use limitations, and public concerns over the aesthetic degradation. In response to these concerns, Pewaukee Lake has been the subject of numerous planning efforts including the preparation of Lake-specific plan elements within the regional water quality management plan,[1] and a water quality management plan for Pewaukee Lake that was completed by the Regional Planning Commission during 1984.[2] The regional water quality management plan identified surface water quality problems within the Upper Fox 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. In addition, the Wisconsin Department of Natural Resources prepared a nonpoint source pollution control plan for the Upper Fox River basin, which was adopted in 1994.[3]

Local concern over the state of the Lake resulted in the provision of public sanitary sewer service to the urban lands in the vicinity of the Lake, beginning in 1930 within what is now the Village of Pewaukee, and continuing through 1979 when all lakeshore properties were provided with public sanitary sewerage service. Provision of sewerage services was aided by the formation, during 1944, of the Lake Pewaukee Sanitary District, under Section 60.70 of the *Wisconsin Statutes*. Wastewater from the Lake Pewaukee Sanitary District service area is treated at the Fox River Water Pollution Control Center sewage-treatment facility and discharged to the Fox

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

[2]*SEWRPC Community Assistance Planning Report No. 58,* A Water Quality Management Plan for Pewaukee Lake, Waukesha County, Wisconsin*, March 1984.*

[3]*Wisconsin Department of Natural Resources Publication PUBL-WR-366-94,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994.*

(Illinois) River. Prior to the completion of the sewerage project, Pewaukee Lake had experienced nutrient enrichment of the Lake waters, resulting in excessive growths of algae and aquatic plants.

Seeking to improve the usability of Pewaukee Lake, and to prevent further deterioration of the natural assets and recreational use potential of the Lake, local efforts have been undertaken by the Lake Pewaukee Sanitary District,[4] the City and Village of Pewaukee, the Town of Delafield, the Southeastern Wisconsin Regional Planning Commission,[5] and the Wisconsin Department of Natural Resources[6] to help restore and maintain the Lake as a full, multiple-use waterbody. In particular, a citizen volunteer from the Pewaukee Lake community was enrolled in the WDNR Self-Help Monitoring Program between 1986 and 1992, and, since that time, the Lake Pewaukee Sanitary District staff have been independently taking Secchi disc measurements on the Lake. These measurements have been supplemented by more intensive water quality monitoring by the Wisconsin Department of Natural Resources, under the Long-Term Trend Lake Monitoring Program, from 1986 through 2000. The WDNR also conducted aquatic macrophyte surveys on the Lake under the auspices of this program during 1988, 1991, 1994, and 1997. These plans and studies have helped the Lake Pewaukee community to better understand the Lake and conduct a program of lake management that includes regular informational meetings convened by the Lake Pewaukee Sanitary District, school programs—Adopt-A-Lake and Project WET—conducted by the Asa Clark Middle School, and an extensive aquatic plant harvesting program operated by the Sanitary District and Village.

Nevertheless, concerns over the state of Pewaukee Lake continue. These concerns include the current and potential impacts of urban-density development on the water quality of the Lake, the potential loss of wetlands within the drainage area tributary to the Lake, the nature and density of aquatic plant growth in the Lake, and the maintenance and management of Lake water levels. Specifically, during the summer of 2000, Pewaukee Lake experienced one of the heaviest periods of aquatic macrophyte growths since 1990. An unusually mild winter with early ice off may in part have contributed to the nuisance levels of Eurasian water milfoil in the Lake, which were also likely to be enhanced as a consequence of both internal and external phosphorus loadings to the Lake. Likewise, concerns recently have been voiced over water levels and the operation of the control gate of the Pewaukee Lake dam. The operation of the dam gate is an important element in preserving the integrity of critical wetland and spawning areas on the Lake, and maintenance of shoreline protection structures. The construction and/or restoration of shoreline or wetland areas riparian to the Lake and adjacent to the Lake shore would be likely to benefit from water levels that mimic natural conditions.

This lake management plan forms a logical complement to the lake management actions that have been implemented on and around Pewaukee Lake, and represents an ongoing commitment by the Lake Pewaukee Sanitary District and its constituent and contracting communities to sound environmental planning. This plan was prepared by the Regional Planning Commission in cooperation with the Lake Pewaukee Sanitary District, and it incorporates the data and analyses developed in the aforementioned lake management-related studies. In addition, this plan also incorporates pertinent water quality and fishery data collected by the Wisconsin Department of

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[4]*Lake Pewaukee Sanitary District,* An Aquatic Plant Management Plan for Pewaukee Lake, Wisconsin*, January 1992.*

[5]*SEWRPC Community Assistance Planning Report No. 58,* op. cit.*; SEWRPC Memorandum Report No. 56,* A Lakefront Recreational Use and Waterway Protection Plan for the Village of Pewaukee, Waukesha County, Wisconsin*, March 1996.*

[6]*Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1986, *1986; Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1987, *1987; E. R.. Schumacher, Wisconsin Department of Natural Resources Fish Management Report No. 131,* Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County, Summer 1982, *February 1987; and Wisconsin Department of Natural Resources,* Pewaukee Lake Sensitive Area Study, *June 1994.*

Natural Resources. This report presents feasible alternative in-lake measures for enhancing the water quality conditions and for providing opportunities for the safe and enjoyable use of the Lake. More specifically, this report describes the physical, chemical, and biological characteristics of the Lake and pertinent related characteristics of the tributary watershed, as well as the feasibility of various watershed and in-lake management measures which may be applied to enhance the water quality conditions, biological communities, and recreational opportunities of the Lake.

The primary management objectives for Pewaukee 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 limited water clarity which constrain or preclude intended water uses, and 3) improving opportunities for water based recreational activities. The lake water quality management plan herein presented should constitute a practical guide for the management of the water quality of Pewaukee Lake and for the management of the land surfaces which drain directly to this important body of water.

Chapter II

PHYSICAL DESCRIPTION

INTRODUCTION

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

WATERBODY CHARACTERISTICS

Pewaukee Lake is located in the City and Village of Pewaukee, and in the Town of Delafield. Portions of the Cities of Delafield, Pewaukee, and Waukesha, the Villages of Hartland and Pewaukee, and Towns of Delafield, Lisbon, and Merton lie within the total drainage area tributary to Pewaukee Lake, as shown on Map 1.[1] Pewaukee Lake is a drainage or through flow lake—having both a defined inflow and outflow—with two connected, yet distinct basins, each with several tributary streams, and an outlet area situated at the eastern extreme of the Lake's eastern shallow basin. The Lake level is presently controlled artificially by the dam located at the outlet. There are three islands on the Lake: one in the western basin within what was the original natural Lake, and two in the eastern basin which was originally a wetland.

Pewaukee Lake lies in a preglacial erosion valley and is fed by Zion Creek, Audley Creek, and two unnamed tributaries. The Lake is drained by the Pewaukee River, which flows about 4.4 miles to its confluence with the Fox (Illinois) River. The Lake basin originally was formed by the blockage of a valley with glacial material, resulting in the impoundment of runoff and a reversal of the then-prevailing drainage pattern. The western one-half of the Lake was originally called Snail Lake, while the eastern portion was a wetland with water depths ranging between 0.5 and 1.0 foot. The lake level was naturally controlled until about 1838, when a dam was

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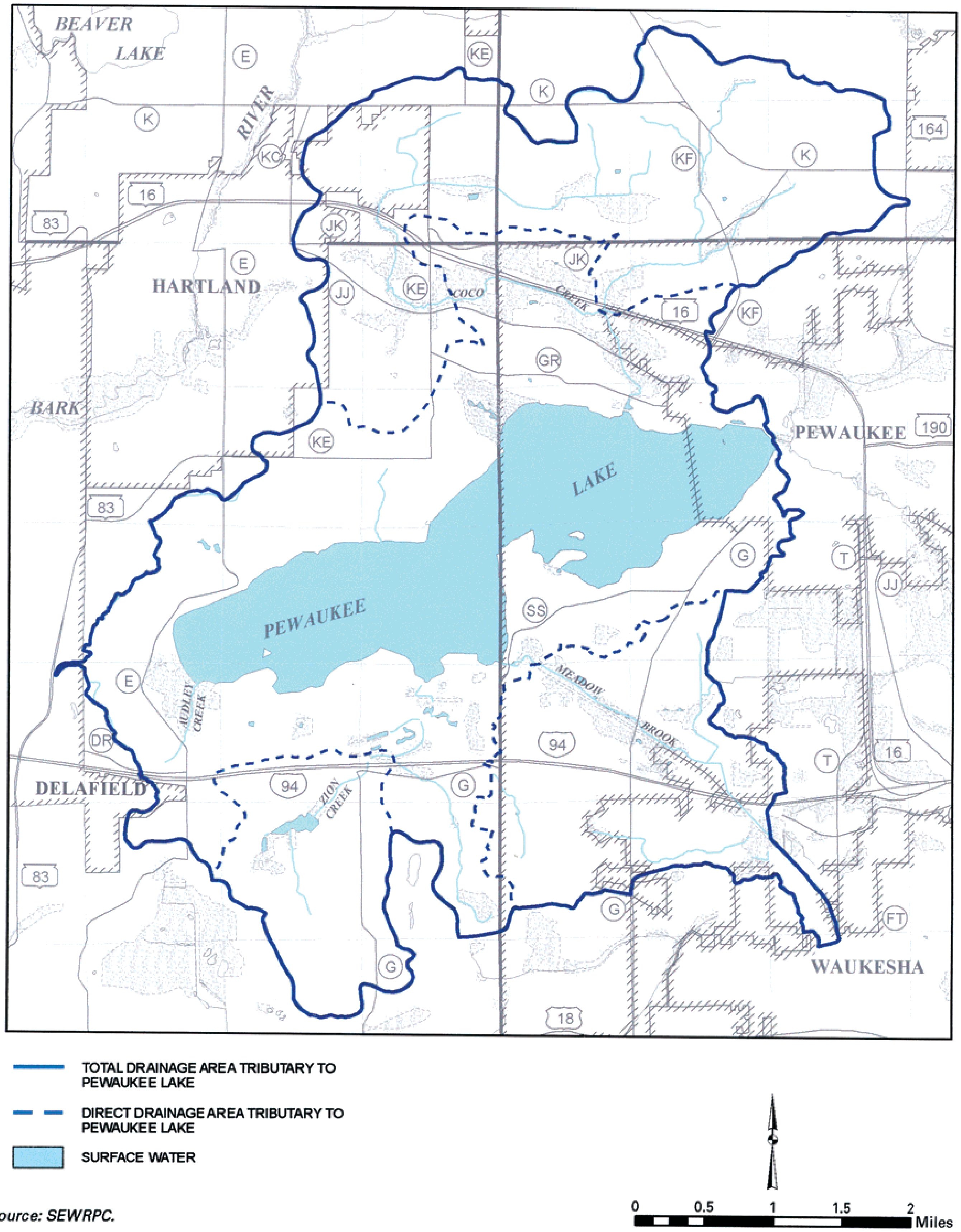
[1]*A small portion of the drainage area tributary to Pewaukee Lake extends into the City of Delafield along the former interurban railway line right-of-way and adjacent and south of IH 94. The Lake Pewaukee Sanitary District staff report that, as of 2003, a berm had been constructed across the former interurban railway line, effectively isolating this portion of the drainage area. The portion adjacent to IH 94 remains in largely open space use and is considered as unlikely to significantly influence Pewaukee Lake.*

Map 1

LOCATION MAP OF PEWAUKEE LAKE



Source: SEWRPC.

constructed at the outlet to provide power for a mill. Following the dam construction, the lake level rose by approximately six feet, which resulted in a doubling of the surface area as a consequence of the flooding of the wetland located east of the main basin of Snail Lake and along the western perimeter of the original lake. Present levels are artificially controlled by the dam at the outlet of the Lake to the Pewaukee River.

Pewaukee Lake has a surface area of 2,493-acres, with a maximum depth of 45 feet and a mean depth of about 15 feet. Approximately 15 percent of the Lake area is less than 5 feet deep, 63 percent has a water depth between five and 20 feet, and about 22 percent of the Lake has a water depth of more than 20 feet. Pewaukee Lake is 4.5 miles long and 1.4 miles wide at its widest point. The major axis of the Lake lies in a northeasterly-southwesterly direction. The Lake shoreline is 12.8 miles long, with a shoreline development factor of 1.85, indicating that the shoreline is about 1.85 times longer than a circular lake of the same area. The Lake has a total volume of approximately 37,400 acre-feet. The hydrographical and morphometric data is presented in Table 1 and the bathymetry of the Lake is shown on Map 2.

The shoreline of Pewaukee Lake is mostly developed for residential uses, with some scattered commercial uses comprised primarily of restaurants and businesses catering to lake users. Two significant wetland areas occur along the Lake's shoreline: one on the southwestern shore near the County boat landing, and the other on the northwestern shoreline of the eastern portion of the Lake. A public beach, picnic area, and fishing pier are located at the eastern end of the Lake in the vicinity of the outlet. Development of recreational facilities along the lake front at the eastern extreme of the Lake has been the subject of a recreational use plan prepared by the Regional Planning Commission.[2] This plan is currently being implemented by the Village of Pewaukee.

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 Pewaukee Lake shoreline, conducted during the summer of 2000 by Regional Planning Commission staff, identified existing shoreline protection structures around the Lake, as shown on Map 3. Most were in a good state of repair. Most of the developed shoreland of Pewaukee Lake had some form of shoreline protection in 2000. However, improperly installed and failing shoreline protection structures, and the erosion of natural shorelines on Pewaukee Lake, are a limited cause for concern.

Lake bottom sediment types are shown on Map 4. Silt and muck are the predominant lake bottom material. Other bottom sediment types primarily along the shoreline consist of combinations of sand, gravel or rock.

WATERSHED CHARACTERISTICS

The drainage area tributary to Pewaukee Lake—that is, the area which drains directly into the Lake—totals about 15,660 acres, or 24.5 square miles, in areal extent, as shown on Map 1. The Lake has a low watershed-to-lake area ratio of 6.3 to 1. Pewaukee Lake is fed by Audley Creek from the west, Coco Creek from the north, and Zion Creek and an additional unnamed tributary, locally known as Meadow Brook, from the south. The lake outlet, located on the eastern shoreline within the Village of Pewaukee, is the Pewaukee River which flows approximately 4.4 miles southeast before joining the Fox River in the City of Waukesha.

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. Soil texture and soil particle structure 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.

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[2] *SEWRPC Memorandum Report No. 56,* A Lakefront Recreational Use and Waterway Protection Plan for the Village of Pewaukee, Waukesha County, Wisconsin*, March 1996.*

Table 1

HYDROLOGY AND MORPHOMETRY CHARACTERISTICS OF PEWAUKEE LAKE: 2000

Parameter	Measurement
Size (total)	
Surface Area	2,493 acres
Total Drainage Area	15,662 acres
Direct Tributary Drainage Area	8,163 acres
Volume	37,395 acre-feet
Residence Time[a]	1.8 years
Shape	
Maximum Length of Lake	4.5 miles
Length of Shoreline	12.8 miles
Maximum Width	1.4 miles
Shoreline Development Factor[b]	1.85
Depth	
Area of Lake Less than 5 Feet	15.0 percent
Area of Lake 5 to 20 Feet	63.4 percent
Area of Lake Greater than 20 Feet	21.6 percent
Mean Depth	15 feet
Maximum Depth	45 feet

[a]*Residence Time: Time required for a volume equivalent to the full volume of the lake to enter the lake from the drainage area.*

[b]*Shoreline Development Factor: Ratio of shoreline length to that of a circular lake of the same area.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

The U.S. Natural Resources Conservation Service, formerly the U.S. Soil Conservation Service, under contract to the Southeastern Wisconsin Regional Planning Commission, completed a detailed soil survey of the Pewaukee Lake area in 1966.[3] The soil survey contained interpretations for planning and engineering applications, as well as for agricultural applications. Using the regional soil survey, an assessment was made of hydrologic characteristics of the soils in the drainage area of Pewaukee Lake. The suitability of the soils for urban residential development was assessed using three common development scenarios. These ratings reflected the requirements of Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems as it existed through the year 2000. 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 and have effectively increased the area in which onsite sewage disposal systems may be utilized. Notwithstanding, the residential lands within the drainage area tributary to Pewaukee Lake currently are served by public sanitary sewerage.[4] The existing year 2001 sanitary sewer service area for the Pewaukee Lake area, and those planned in amendments to the sanitary sewer service area served by the Lake Pewaukee Sanitary District, are delineated on Map 5.

Notwithstanding, the interpretations associated with the soil survey are such that they continue to provide insights into the potential for land-based sources of pollution to affect the Lake water quality either as a consequence of overland flows during storm events or through groundwater interflows in the Lake. Therefore, Map 6 presents the soil ratings for onsite sewage disposal systems as determined pursuant to the then-existing requirements of Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems as of early-2000. It is useful to note that about one-half of the lands within the drainage area tributary to Pewaukee Lake are covered by soils that are categorized as having few limitations for onsite sewage disposal systems. However, about one-third of the lands had severe limitations, suggesting a potential sensitivity to disturbance and likelihood of being permeable to pollutants.

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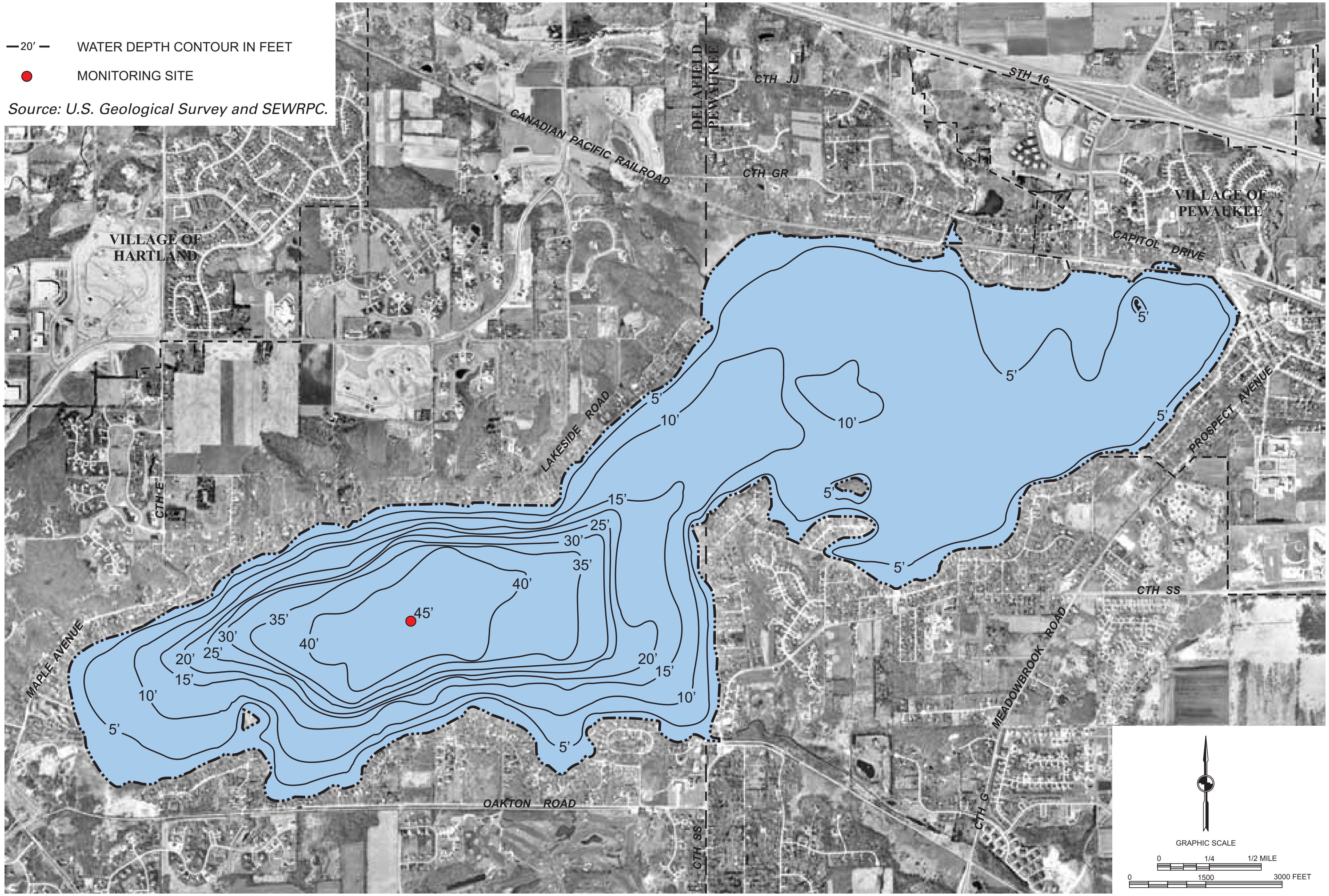
[3]*SEWRPC Planning Report No. 8,* Soils of Southeastern Wisconsin, *June 1966.*

[4]*SEWRPC Community Assistance Planning Report No. 113,* Sanitary Sewer Service Area for the Town of Pewaukee Sanitary District No. 3 Lake Pewaukee Sanitary District, and Village of Pewaukee, Waukesha County, Wisconsin, *June 1985, Amendments to the* Regional Water Quality Management Plan-2000, Town of Pewaukee Sanitary District No. 3, *March 1997, Amendment to the* Regional Water Quality Management Plan Lake Pewaukee Sanitary District, *September 1998, Amendment to the* Regional Water Quality Management Plan Village of Hartland and Lake Pewaukee Sanitary District, *June 2001.*

Map 2

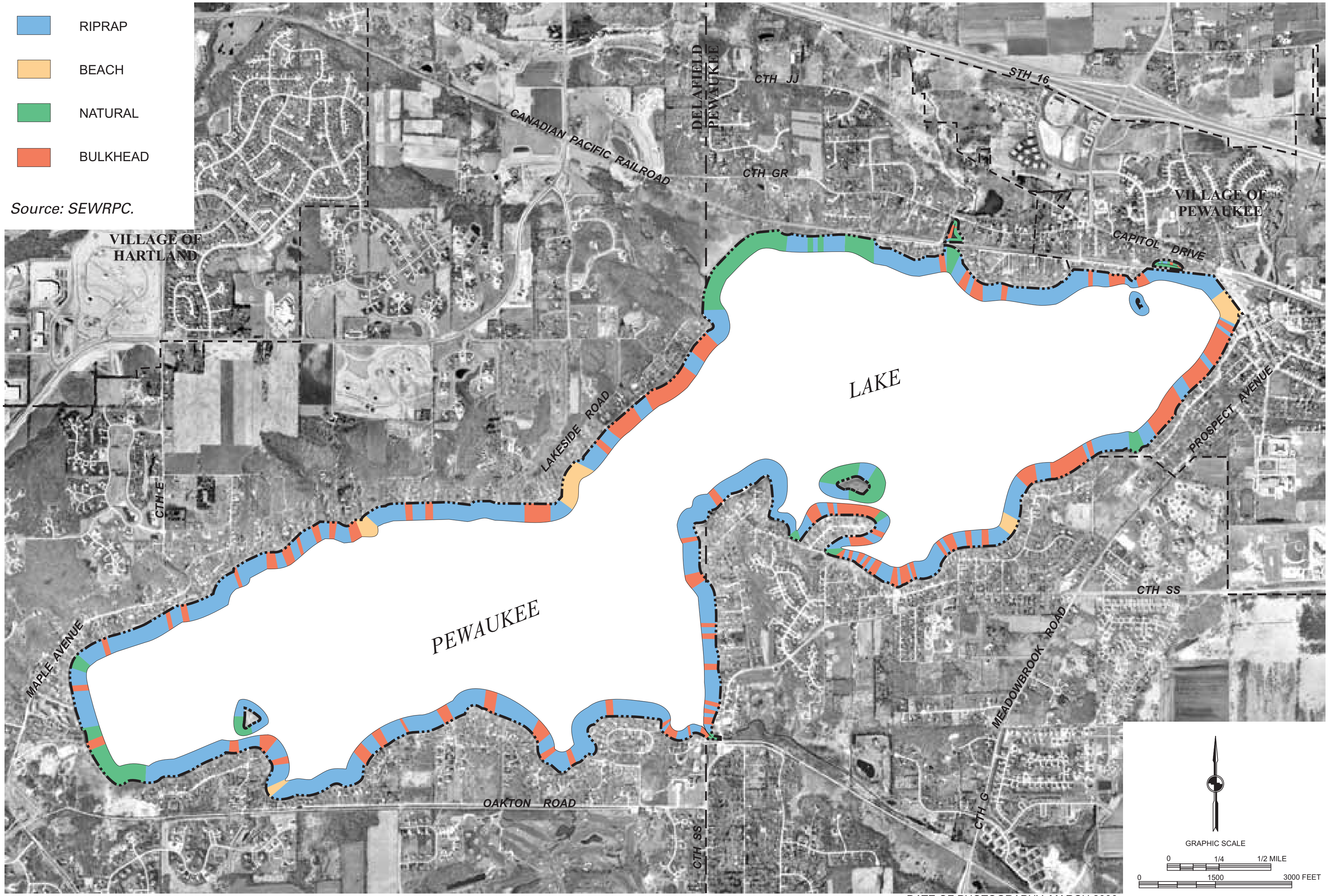
BATHYMETRIC MAP OF PEWAUKEE LAKE



DATE OF PHOTOGRAPHY: MARCH 2000

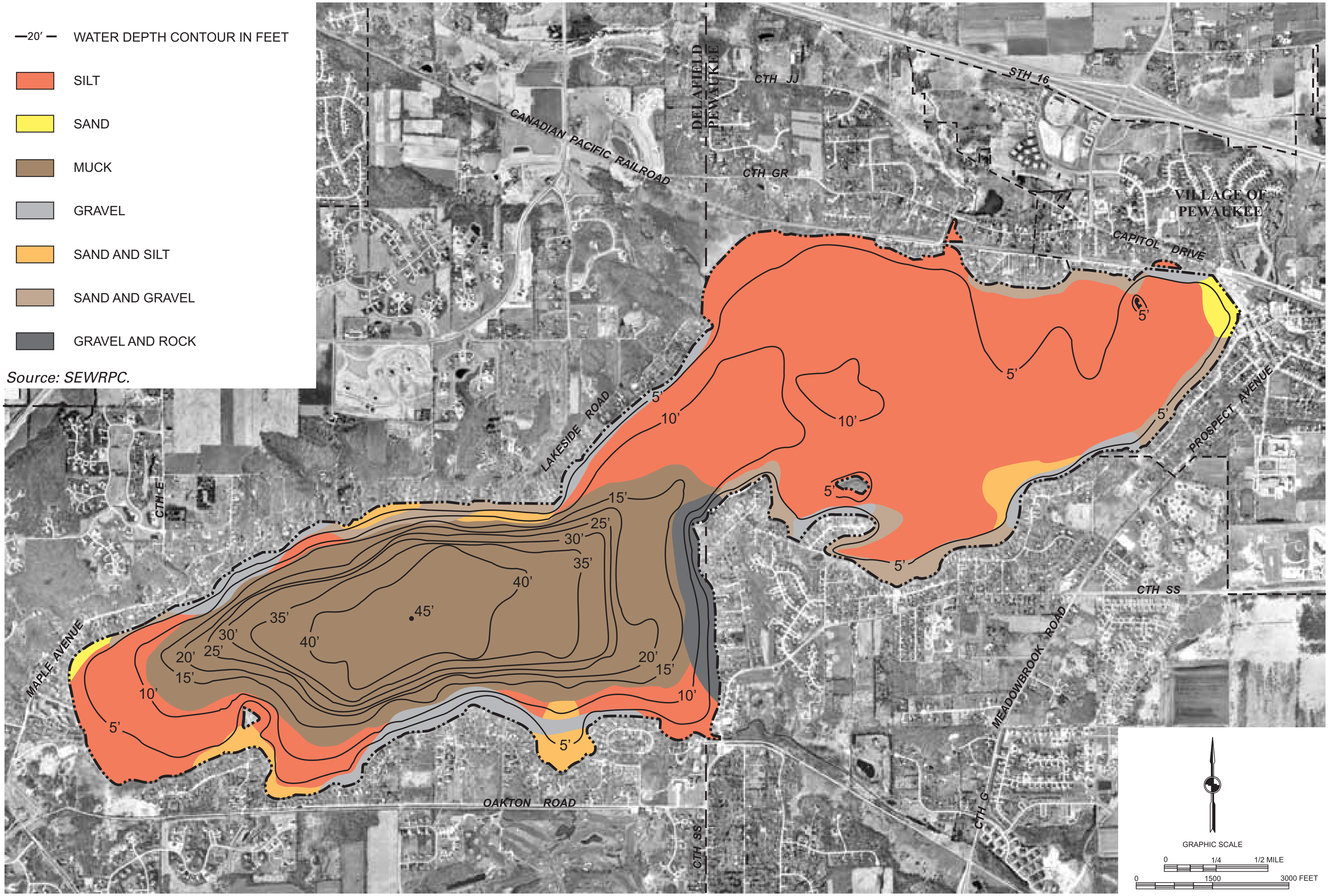
Map 3

SHORELINE PROTECTION STRUCTURES ON PEWAUKEE LAKE: 2000



Map 4

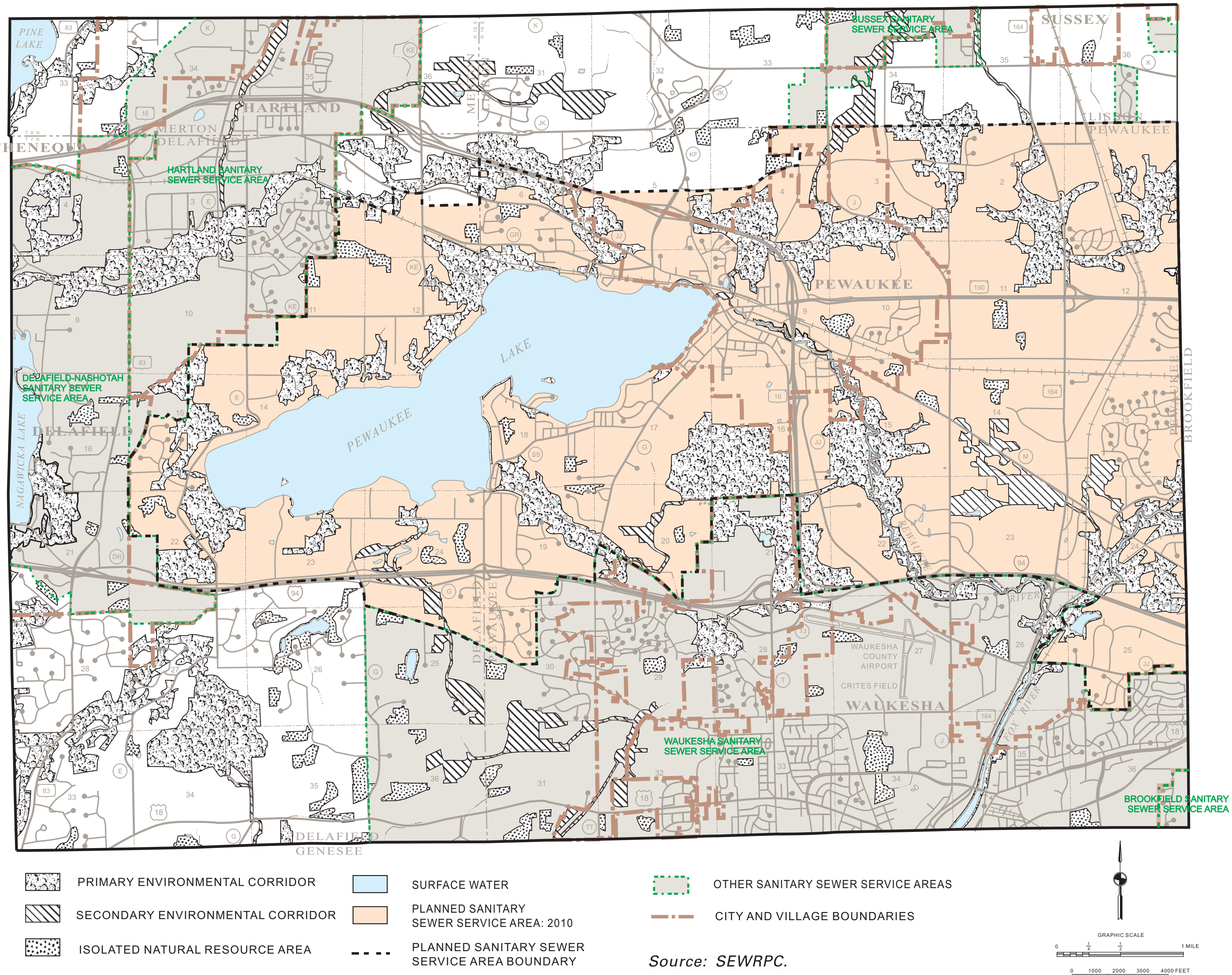
SEDIMENT SUBSTRATE DISTRIBUTION IN PEWAUKEE LAKE: 2000



Source: SEWRPC.

Map 5

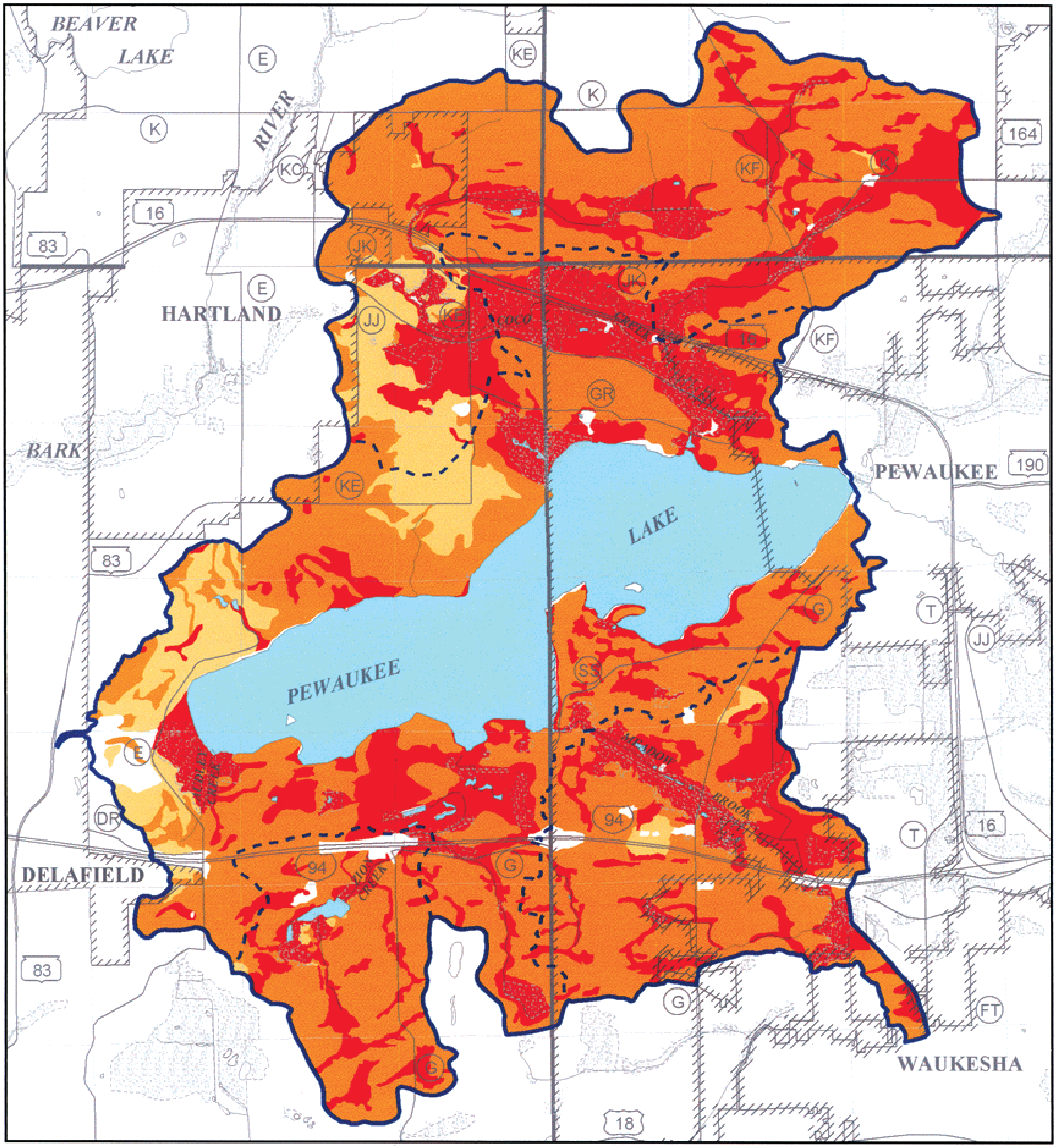
ADOPTED PEWAUKEE SANITARY SEWER SERVICE AREA: 2002



Source: SEWRPC.

Map 6

SUITABILITY OF SOILS WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE FOR CONVENTIONAL ONSITE SEWAGE DISPOSAL SYSTEMS



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

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

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

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

SURFACE WATER

Source: U.S. National Resource Conventional Service and SEWRPC.

Soils within the drainage area directly tributary to Pewaukee Lake were categorized generally into four main hydrologic groups, as indicated in Table 2. Soils that could not be categorized were included in an “other” group. About one-half of the drainage area is covered by moderately drained soils, with the balance being approximately equally covered by poorly drained and very poorly drained soils. The areal extent of these soils and their locations within the watershed are shown on Map 7.

The major soil types present within the tributary drainage area are: Fox silt loam, Theresa silt loam, Lamartine silt loam, Brookston silt loam, Hochheim loam, Palms muck, and Houghton muck.

Climate and Hydrology

Long-term average monthly air temperature and precipitation values for the Pewaukee Lake area are set forth in Table 3. These averages were taken from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Waukesha, Wisconsin. The records of this station may be considered typical of the lake area. Table 3 also sets forth storm water runoff values derived from the U.S. Geological Survey (USGS) flow records for the Fox River at Waukesha. The mean annual temperature of 47.0°F at Waukesha is similar to that reported from other recording locations in southeastern Wisconsin. The mean annual precipitation at Waukesha is about 32.55 inches. 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, the approximately 45 percent of the annual precipitation occurs during the winter or early spring when the ground is frozen, and may result in high surface runoff during those seasons.

The 12-month period over which the Pewaukee Lake water quality sampling study was carried out—January 1999 through December 1999—was a period of variable temperatures and rainfall in southeastern Wisconsin, as indicated in Table 3. Temperatures were generally normal to above normal during the early winter of 1999, and generally above normal in the spring, summer, and fall of 1999. Precipitation at Waukesha during the sampling period was about 37.26 inches, or 13 percent, above normal, with the greatest increase from the average—6.48 inches—occurring during July 1999. Seven of the 12 months of the study period—January, February, May, June, July, and September, 1999—experienced above normal amounts of precipitation.

Lake Stage

The water level of Pewaukee Lake is primarily determined by the dam located at the outlet of the Lake to the Pewaukee River. As established by the Wisconsin Department of Natural Resources, the level of the Lake is to be maintained at an elevation ranging from 852.20 to 852.80 feet National Geodetic Vertical Datum of 1929 (NGVD-29).

Water Budget

A water budget for Pewaukee Lake was computed from inflow and outflow data collected during 1976 and 1977. During the initial planning project, flow data were obtained from three of the tributary streams flowing into Pewaukee Lake, and the outflow from the Pewaukee River; additional data on precipitation and evaporation rates and lake levels were also acquired. Data were not collected from Audley Creek during that study, since lower than normal precipitation resulted in flows that were too low to be measured reliably. During that study year, approximately 12,586 acre-feet of water entered the lake. Of this total, about 5,893 acre-feet, or 47 percent, were contributed from tributary streams. Direct precipitation onto the lake surface contributed approximately 4,415 acre-feet, or 35 percent, of the total water entering the lake. The remaining 2,278 acre-feet, or 18 percent, were contributed by overland flow. About 13,259 acre-feet were lost from Pewaukee Lake during the study year: about 6,520 acre-feet evaporated from the lake surface and about 6,172 acre-feet were discharged through the Pewaukee River.

In addition to the surface water quantity measurements conducted during 1976 and 1977, groundwater flows were also estimated using ten pairs of groundwater sampling wells. These wells were used to measure the direction and

Table 2

GENERAL HYDROLOGIC SOIL TYPES WITHIN THE TOTAL AND DIRECT DRAINAGE AREAS TRIBUTARY TO PEWAUKEE LAKE

Group	Soil Characteristics	Direct Tributary Drainage Area (acres)	Percent of Total	Total Tributary Drainage Area (acres)	Percent of Total
A	Well drained; very rapidly to rapid permeability; low shrink-swell potential	- -	- -	- -	- -
B	Moderately well drained; texture intermediate between coarse and fine; moderately rapid to moderate permeability; low to moderate shrink-swell potential	3,650	45	8,456	54
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	812	10	2,259	15
D	Very poorly drained; high water table for most of the year; organic or clay soils; clay soils having high shrink-swell potential	966	12	2,069	13
Other	Group not determined	262	3	373	2
Water	- -	2,473	30	2,511	16
- -	Total	8,163	100	15,662	100

Source: SEWRPC.

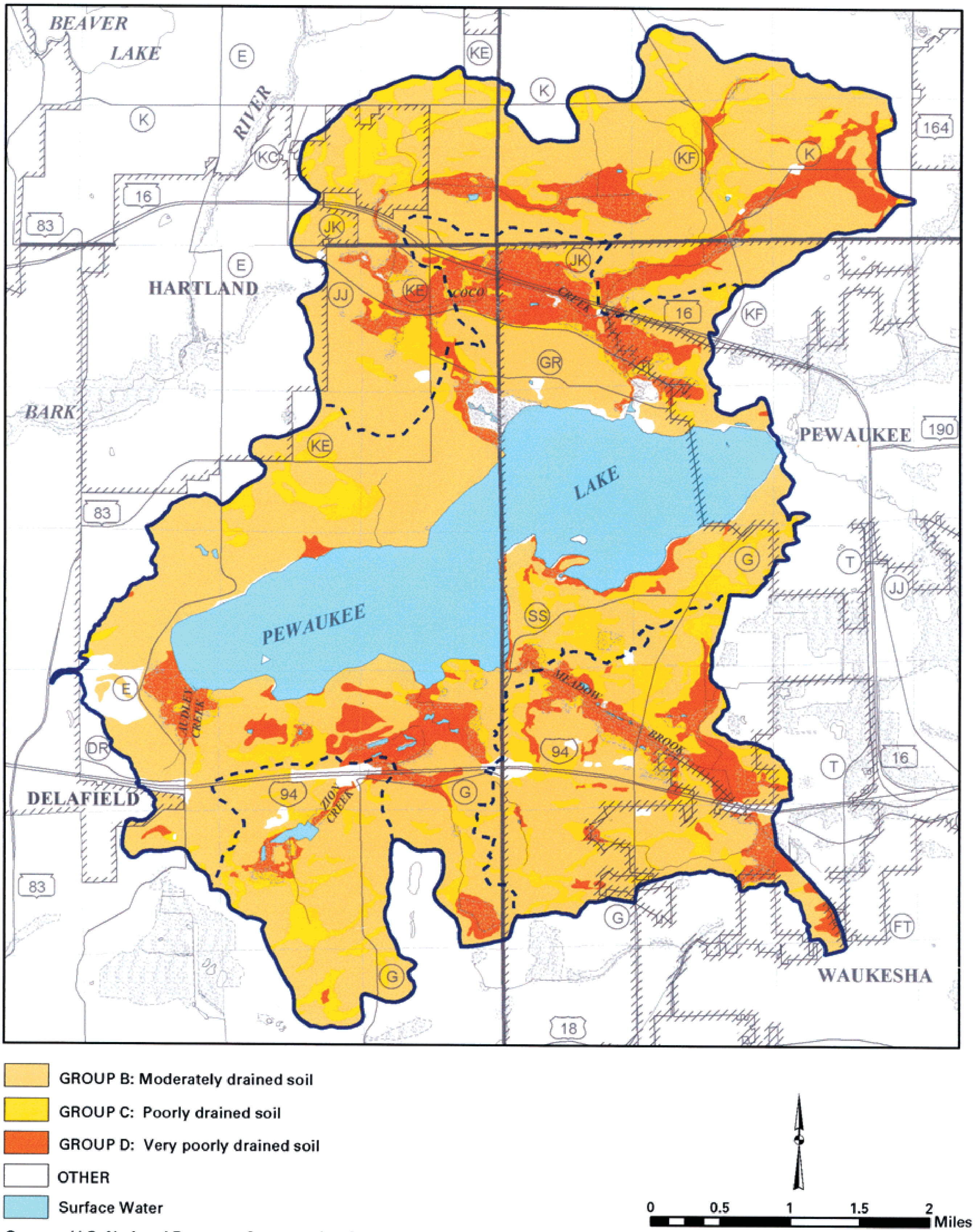
flow of groundwater in the vicinity of Pewaukee Lake. Inflows of groundwater occurred at nine of the paired-well sites, but the paired wells in the vicinity of the lake outlet showed a net outflow of groundwater from the waterbody. The net outflow was estimated at 567 acre-feet. Consequently, there was a net reduction of 673 acre-feet in the volume of water stored in the Lake during the study period.

A long-term budget for Pewaukee Lake was computed from estimated precipitation and inflow volumes from the tributary streams, and estimated outflows through the Pewaukee River, based upon data collected by the U.S. Geological Survey at Waukesha, Wisconsin, between 1963 and 2001, and is set forth in Figure 1. An average of about 14,232 acre-feet, or about 70 percent of the water entering the Lake, is contributed by surface runoff, and about 6,378 acre-feet, or about 30 percent, is contributed by precipitation directly onto the Lake surface. Of this total long-term annual inflow, it is estimated that about 8,102 acre-feet, or about 40 percent of the inflow volume, is lost to evaporation from the Lake surface; about 567 acre-feet, or about 3 percent—estimated as the net groundwater loss from the Lake measured in the initial plan—is lost as groundwater outflow from the Lake, and about 11,941 acre-feet, 57 percent, is discharged from the Lake to the Pewaukee River. The long-term water balance for Pewaukee Lake assumes no significant net change in Lake water level.

The hydraulic residence time is important in determining the expected response time of a lake to increased or reduced nutrient and other pollutant loadings. The hydraulic residence time for Pewaukee Lake during the initial study period of May 1976 through April 1977—a year of significantly below-average precipitation—was estimated to be about 2.9 years. During years of average climatological conditions, the hydraulic residence time is estimated to be about 1.8 years, as suggested by the long-term average water balance for the Lake.

Map 7

HYDROLOGIC SOIL GROUPS WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE



Source: U.S. National Resource Conservation Service and SEWRPC.

Table 3

LONG-TERM AND 1999 STUDY YEAR TEMPERATURE, PRECIPITATION, AND RUNOFF DATA FOR THE PEWAUKEE LAKE AREA

Temperature													
Air Temperature Data (°F)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	18.6	23.1	33.9	46.2	57.7	67.4	72.3	70.1	62.2	50.8	37.8	24.1	47.0
1999 Mean Monthly	17.8	32.2	35.1	49.1	60.7	69.0	76.3	68.9	62.3	50.4	44.7	27.6	49.5
Departure from Long-Term Mean	-0.8	9.1	1.2	2.9	3.0	1.6	4.0	-1.2	0.1	-0.4	6.9	3.5	2.5

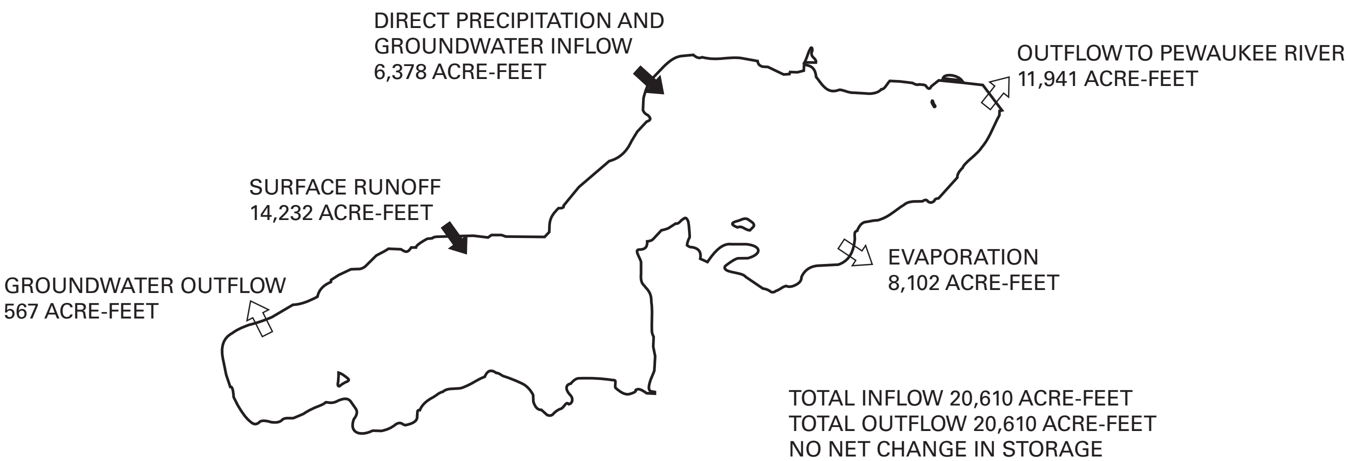
Precipitation														
Precipitation Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Total
Long-Term Mean Monthly	1.34	1.09	2.36	3.35	2.99	3.47	3.33	4.10	3.68	2.48	2.40	1.96	2.71	32.55
1999 Mean Monthly	4.27	1.22	0.83	5.45	3.82	6.14	6.48	1.86	3.87	0.77	0.78	1.77	3.11	37.26
Departure from Long-Term Mean	2.93	0.13	-1.53	2.10	0.83	2.67	3.15	-2.24	0.19	-1.71	-1.62	-0.19	0.39	4.71

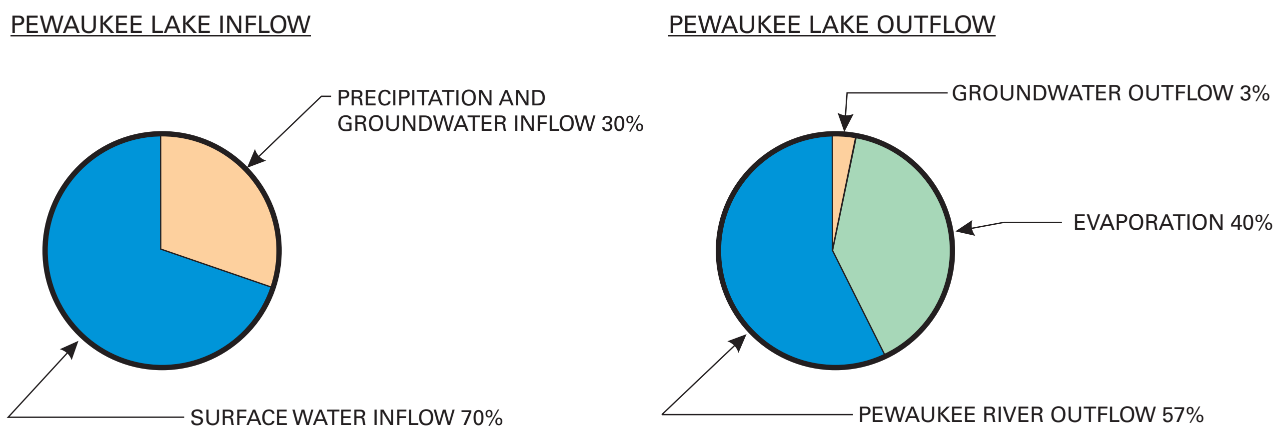
Runoff													
Runoff Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	0.61	0.78	1.75	1.87	1.14	0.86	0.72	0.58	0.65	0.68	0.72	0.75	0.93
1999 Mean Monthly	0.96	1.91	1.19	2.57	2.05	1.88	1.28	0.48	0.44	0.45	0.29	0.41	1.16
Departure from Mean Monthly	0.35	1.13	-0.56	0.70	0.91	1.02	0.56	-0.10	-0.21	-0.23	-0.43	-0.34	0.23

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

Figure 1

HYDROLOGIC BUDGET FOR PEWAUKEE LAKE: 1963-2001





Source: U.S. Geological Survey and SEWRPC.

Chapter III

HISTORICAL, EXISTING, AND FORECAST LAND USE AND POPULATION

INTRODUCTION

Water pollution problems, recreational use conflicts, and deterioration of the natural environment are all primarily a function of the human activities within the drainage area of a waterbody, as are the ultimate solutions to these problems. This is especially true with respect to lakes, which are highly susceptible to deterioration from human activities because of relatively long pollutant retention times, and because of the variety of often conflicting uses to which lakes are subjected. Furthermore, urban development is often concentrated in the direct drainage areas, around the shorelines of lakes, where there are no intermediate stream segments to attenuate pollutant runoff and loadings. This type of lake degradation is more likely to interfere with desired water uses and is often more difficult and costly to correct than degradation arising from clearly identifiable point sources of pollution in the watershed. Accordingly, the land uses and attendant population levels in the drainage area directly tributary to a lake must be important considerations in any lake management planning effort. In the case of Pewaukee Lake, which is situated at the headwaters of a larger drainage system, the importance of nonpoint-sourced pollutants in determining lake water quality and in influencing downstream water quality is paramount. For this reason, land usage and population distributions are summarized in this Chapter, together with a review of jurisdictional issues relevant to water quality and lake management.

CIVIL DIVISIONS

The geographic extent and functional responsibilities of civil divisions and special-purpose units of government are important factors related to land use and management, since these local units of government provide the basic structure of the decision-making framework within which land use development and redevelopment must be addressed. Superimposed on the Pewaukee Lake drainage area are the local civil division boundaries shown on Map 8.

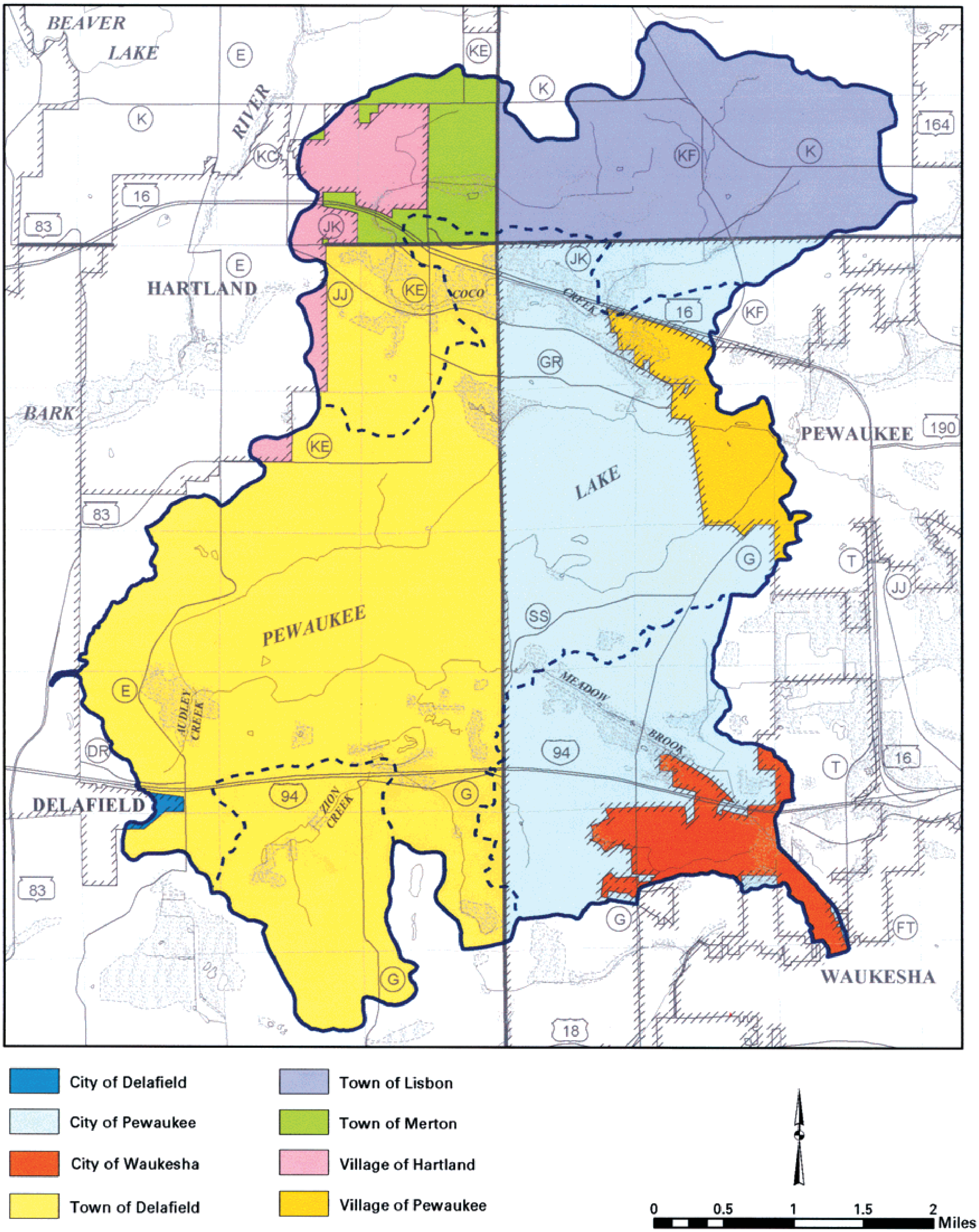
The drainage area directly tributary to Pewaukee Lake includes portions of the Towns of Delafield, Lisbon, and Merton; the Villages of Hartland and Pewaukee; and the Cities of Delafield, Pewaukee, and Waukesha, all of which are located in Waukesha County. The area and proportion of the drainage area lying within the jurisdiction of each civil division, as of 1995, are set forth in Table 4.

POPULATION

In the drainage area tributary to Pewaukee Lake, significant urban development began during the 1920s and continued to surge with major land use development occurring in the years following World War II. The resident

Map 8

CIVIL DIVISION BOUNDARIES IN THE PEWAUKEE LAKE TRIBUTARY DRAINAGE AREA



Source: SEWRPC.

Table 4

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

Civil Division	Civil Division Area within Total Drainage Area (acres)	Percent of Total Drainage Area within Civil Division	Percent of Civil Division within Total Drainage Area
City of Delafield	28	1	2
City of Pewaukee	4,448	28	27
City of Waukesha	562	4	5
Village of Hartland	549	3	26
Village of Pewaukee	553	4	20
Town of Merton	548	3	3
Town of Lisbon	2,057	13	10
Town of Delafield	6,917	44	50
Total	15,662	100	- -

Source: SEWRPC.

population approximated 4,500 persons in 1950 and has increased relatively steadily since that time. The 2000 resident population was estimated at about 22,500 persons, or about five times that of the estimated 1950 population, as indicated in Table 5. The number of resident households in the drainage area tributary to Pewaukee Lake also increased steadily since 1950. An estimated 2,000 household were present within the drainage area tributary to Pewaukee Lake in 1963, which number had increased to about 5,000 households by 1990. This number is also expected to increase to about 7,400 households by the year 2010, based upon the recommendations set forth in the adopted regional land use plan,[1] as refined by the county development plan.[2] This increased population and the number of resident households in the drainage area tributary to Pewaukee Lake is expected to be accommodated as agricultural lands in the drainage area are converted to urban residential uses. Residential land uses are anticipated to continue to be the dominant urban land use, as shown in Table 5. This population growth, and associated demand for housing and recreational opportunities, will place a continued and increasing stress on the natural resource base of the Pewaukee Lake drainage area. For this reason, also, demands on the water resources, and associated use and user conflicts, may be expected to increase.

LAND USE

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

The movement of European settlers into the Southeastern Wisconsin Region began about 1830. Completion, within Southeastern Wisconsin, of the U.S. Public Land Survey in 1836, and the subsequent sale of public lands in Wisconsin, brought a rapid influx of settlers into the area. Map 9 shows the original plat of the U.S. Public Land Survey for the Pewaukee Lake area. The Village of Pewaukee was subsequently incorporated in 1848.

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

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

Table 5

HISTORIC AND FORECAST RESIDENT POPULATION AND HOUSEHOLD LEVELS WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1950-2010[a]

Year	Number of Residents	Number of Households
1950	4,350	- -
1960	6,290	- -
1963	7,530	1,960
1970	8,330	2,470
1980	11,920	3,960
1985	14,000	4,400
1990	14,500	4,990
2010 Recommended Plan	20,400	7,360

[a]*Study area approximated using whole U.S. Public Land Survey one-quarter sections and U.S. Bureau of Census data.*

Source: SEWRPC

Significant urban development began to occur in the drainage area tributary to Pewaukee Lake in the early 1900s. Map 10 and Table 6 indicate the historic urban growth patterns in the tributary drainage area since 1850. The most significant urban development occurred between 1920 and 1940, and from 1960 to 1990. During these periods, almost 3,500 acres of the drainage area were converted from rural to urban land uses. Although the shoreline of the Lake is generally fully developed, the rate of urban development in the drainage area tributary to Pewaukee Lake has continued to increase significantly in the last decade, culminating in the incorporation of the City of Pewaukee during 1999.

The existing land use pattern in the Pewaukee Lake tributary drainage area, as of 1995, is shown on Maps 11 and 12, and is quantified in Tables 7 and 8. As indicated in Table 7, as of 1995, about 2,600 acres, or 32 percent, of the drainage area directly tributary to Pewaukee Lake were devoted to urban land uses. The dominant urban land use was residential, encompassing about 1,600 acres, or 60 percent of the area in urban use. As of 1995, about 5,500 acres, or 68 percent of the drainage area tributary to Pewaukee Lake, were still devoted to rural land uses. About 1,900 acres, or about 35 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface waters, including the surface area of Pewaukee Lake, accounted for approximately 3,600 acres, or 44 percent, of the area in rural uses.

Within the total drainage area tributary to Pewaukee Lake, as of 1995, about 5,300 acres, or 34 percent, of the total drainage area tributary to Pewaukee Lake were devoted to urban land uses, as shown in Table 8. The dominant urban land use was residential, encompassing about 3,400 acres, or 64 percent, of the area in urban use. As of 1995, about 10,400 acres, or 66 percent of the drainage area tributary to Pewaukee Lake, were still devoted to rural land uses. About 5,800 acres, or about 55 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface waters, including the surface area of Pewaukee Lake, accounted for approximately 4,600 acres, or 44 percent, of the area in rural uses.

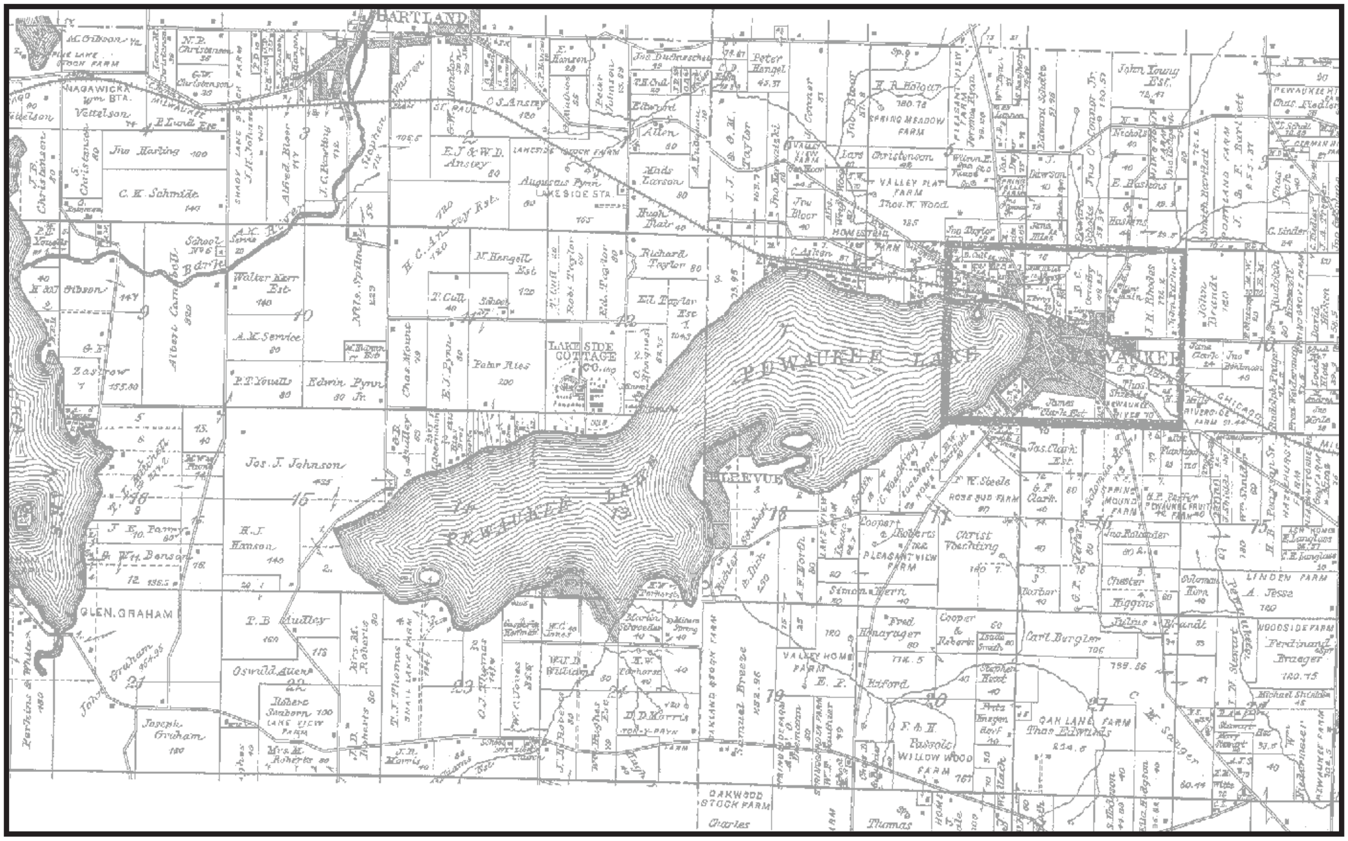
Under 2020 conditions, the trend toward more intense urban land usage is also expected to be reflected in the drainage area tributary to the Lake.[3] As noted above, much of this development is expected to occur as agricultural lands are converted to urban lands, primarily for residential use, as shown on Maps 13 and 14. However, some redevelopment of existing properties and the reconstruction of existing single-family homes may be expected, especially on lakeshore properties. By 2020, urban land uses within the drainage area directly tributary to Pewaukee Lake are expected to increase in areal extent to about 4,100 acres, or 50 percent of the drainage area directly tributary to the Lake, as shown in Table 7. Urban residential uses are expected to increase from about 1,600 acres, as of 1995, to about 2,700 acres in the year 2020. Agricultural lands in the drainage area, consequently, are expected to decrease in areal extent from about 1,900 acres, as of 1995, to less than 500 acres in the year 2020.

In the total drainage area tributary to Pewaukee Lake, urban land uses are expected to increase in areal extent to about 8,900 acres, or 57 percent of the drainage area by the year 2020, as shown in Table 8. Urban residential uses are expected to increase from about 3,400 acres, as of 1995, to about 5,800 acres in the year 2020. Agricultural lands in the drainage area, consequently, are expected to decrease in areal extent from about 5,800 acres, as of

[3]*SEWRPC Planning Report No. 45,* op cit.; *SEWRPC Community Assistance Planning Report No. 209,* op. cit.

Map 9

HISTORIC PLAT MAP FOR THE PEWAUKEE LAKE AREA: 1873



Source: Harrison and Warner, Combination Atlas Map of Waukesha County, Wisconsin*, 1873.*

1995, to about 2,200 acres in the year 2020. Recent surveillance indicates that such changes in land usage appear to be due to large-lot residential development. If this trend continues, some of the open space areas remaining in the drainage 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]

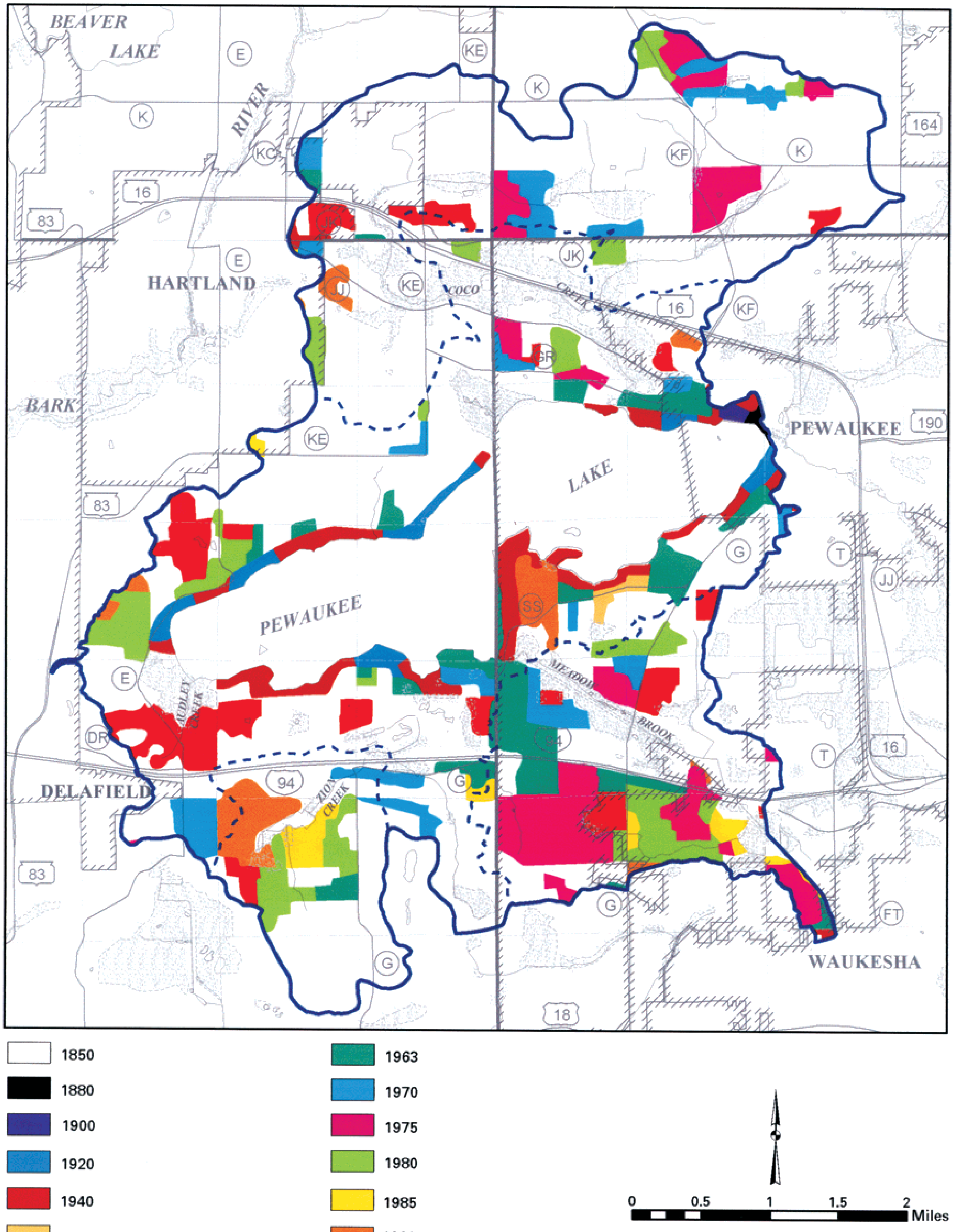
LAND USE REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. Local zoning regulations include general, or comprehensive, zoning regulations and special-purpose regulations governing floodland and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land uses must take into consideration the provisions of both general and special-purpose zoning. As already noted, the drainage area tributary to Pewaukee Lake includes portions of the Cities of Delafield, Pewaukee, and

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

Map 10

HISTORIC URBAN GROWTH WITHIN THE PEWAUKEE LAKE TRIBUTARY DRAINAGE AREA



Source: SEWRPC.

Table 6

EXTENT OF URBAN GROWTH WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1850-1995

	Direct Drainage Area		Total Tributary Drainage Area	
Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]
1850	- -	- -	- -	- -
1880	- -	11	- -	11
1900	14	25	14	25
1920	164	189	164	189
1940	380	569	399	588
1950	33	602	33	621
1963	371	973	652	1,273
1970	260	1,233	558	1,831
1975	99	1,332	819	2,650
1980	258	1,590	719	3,369
1985	33	1,623	170	3,539
1990	154	1,777	325	3,864
1995	432	2,209	689	4,553

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

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

Waukesha; the Villages of Hartland, and Pewaukee; and the Towns of Delafield, Lisbon, and Merton, all in Waukesha County. The ordinances administered by these units of government are summarized in Table 9.

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, *Wisconsin Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.69 of the *Statutes*. However, 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 city and village zoning authority conferred in Section 62.23, subject, however, to county board approval where a general-purpose county zoning ordinance exists. Alternatively, a town may adopt a zoning ordinance under Section 60.61 of the *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.

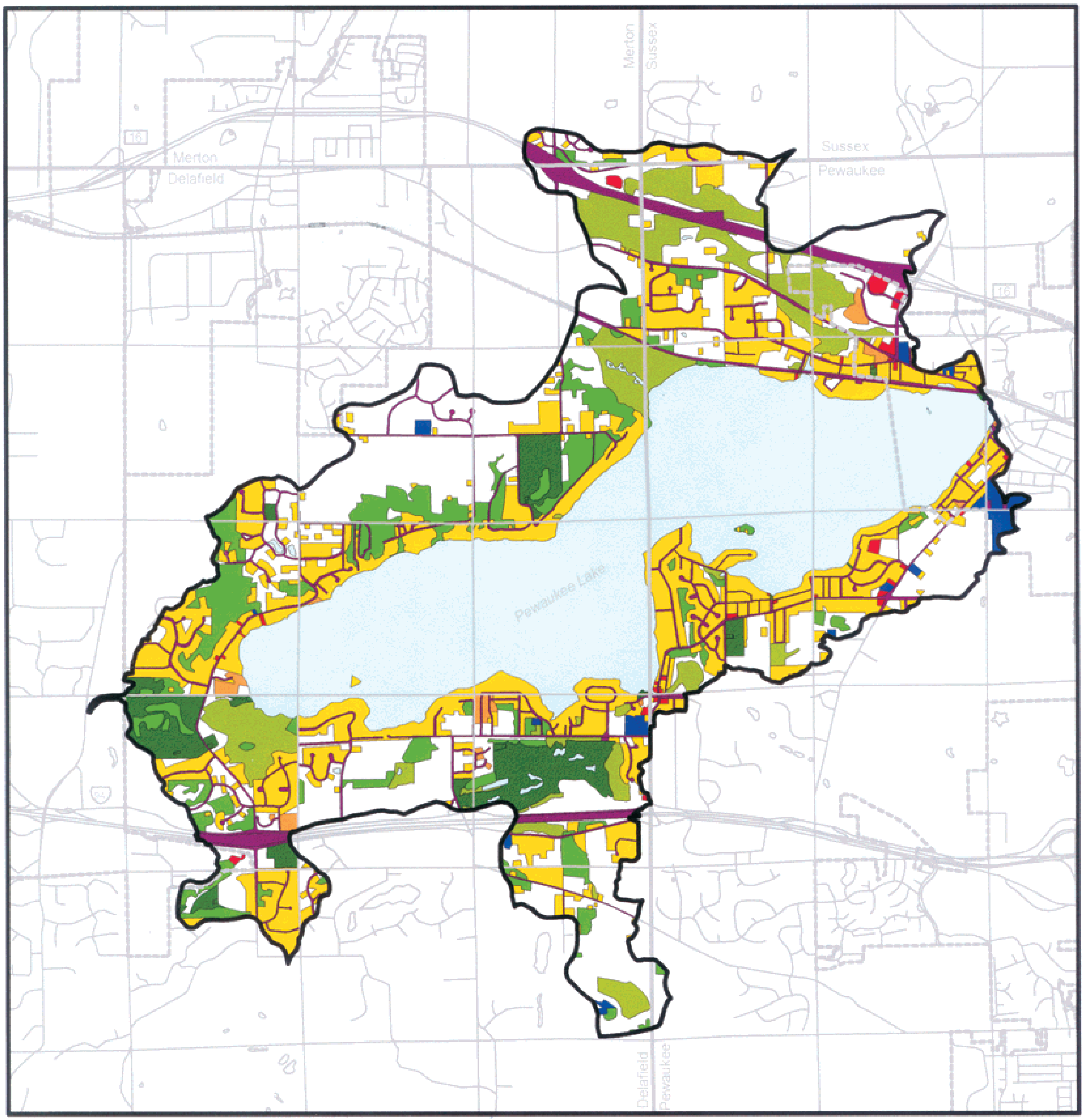
General zoning is in effect in all communities in Waukesha County. All three towns within the drainage area tributary to Pewaukee Lake have adopted their own zoning ordinances under village powers.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that cities, villages, and counties, with respect to their unincorporated areas, adopt floodland zoning to preserve the floodwater conveyance and storage capacity of floodplain areas and to prevent the location of new flood damage-prone development in flood hazard areas. The minimum standards which such ordinances must meet are set forth in Chapter NR 116 of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain,

Map 11

EXISTING LAND USE WITHIN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO PEWAUKEE LAKE: 1995



SINGLE-FAMILY RESIDENTIAL
MULTI-FAMILY RESIDENTIAL
COMMERCIAL
NONE MANUFACTURING, WHOLESALE, AND STORAGE
TRANSPORTATION, COMMUNICATION, AND UTILITIES
GOVERNMENTAL AND INSTITUTIONAL

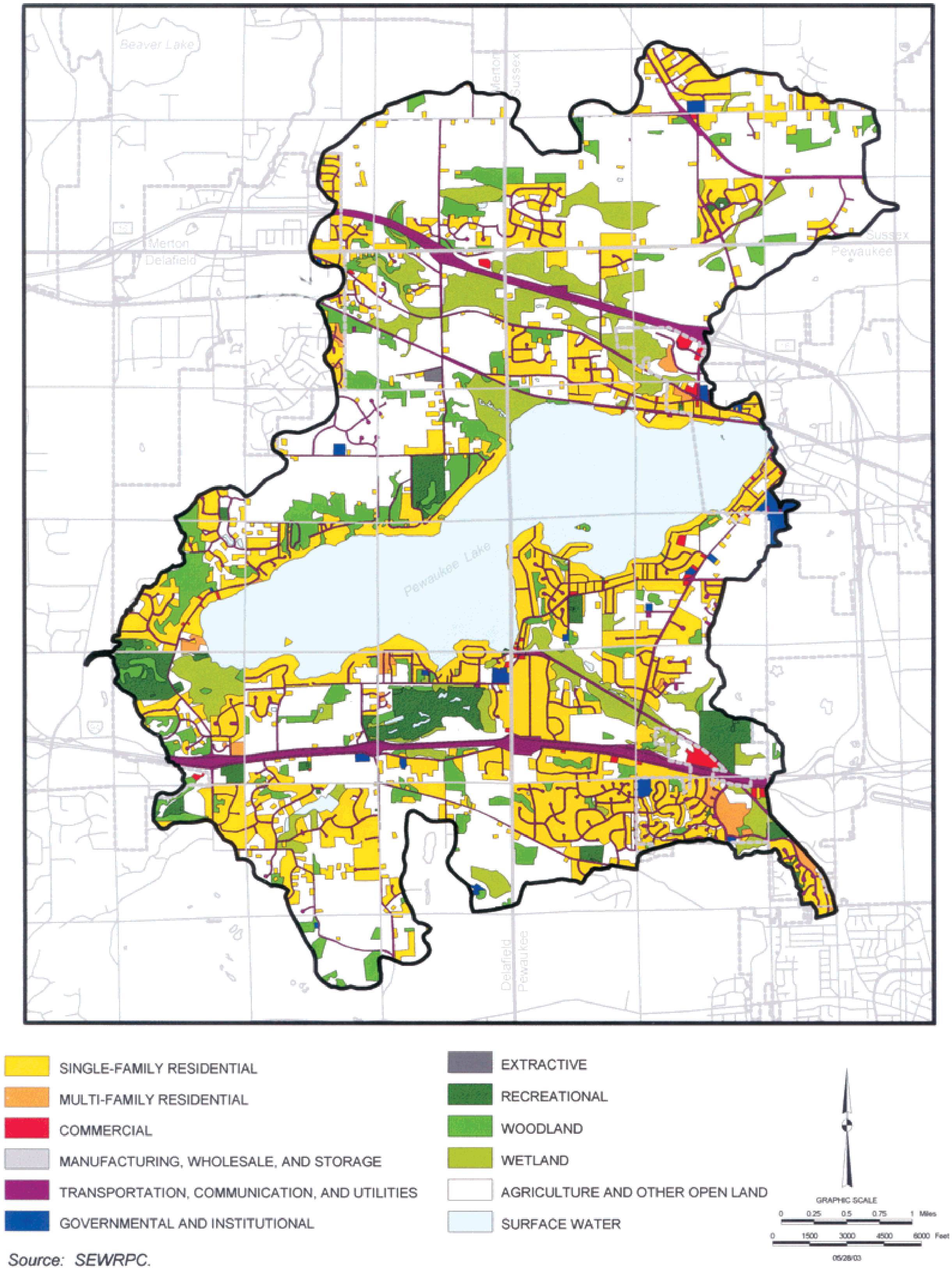
NONE EXTRACTIVE
RECREATIONAL
WOODLAND
WETLAND
AGRICULTURE AND OTHER OPEN LAND
SURFACE WATER

GRAPHIC SCALE
0 0.25 0.5 0.75 1 Miles
0 1500 3000 4500 6000 Feet
05/28/03

Source: SEWRPC.

Map 12

EXISTING LAND USE WITHIN THE TOTAL DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1995



Source: SEWRPC.

Table 7

EXISTING AND PLANNED LAND USE WITHIN THE DIRECT DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1995 AND 2020

Land Use Categories[a]	1995		2020	
	Acres	Percent of Direct Tributary Drainage Area	Acres	Percent of Direct Tributary Drainage Area
Urban				
Residential	1,619	19.8	2,680	32.8
Commercial	39	0.5	161	2.0
Industrial	- -	- -	- -	- -
Governmental and Institutional	67	0.8	99	1.2
Transportation, Communication, and Utilities	569	7.0	865	10.6
Recreation	327	4.0	290	3.6
Subtotal	2,621	32.1	4,095	50.2
Rural				
Agricultural	1,940	23.8	466	5.7
Wetlands	576	7.1	576	7.1
Woodlands	574	7.0	574	7.0
Water	2,452	30.0	2,452	30.0
Extractive	- -	- -	- -	- -
Subtotal	5,542	67.9	4,068	49.8
Total	8,163	100.0	8,163	100.0

[a]*Parking included in associated use.*

Source: SEWRPC.

which is defined as the area subject to inundation by the 100-year recurrence interval flood event, the event which has a 1 percent probability of occurring in any given year. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 100-year recurrence peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the 100-year recurrence flood. Permitting the filling and development of the flood fringe area, however, reduces the floodwater storage capacity of the natural floodplain, and may thereby increase downstream flood flows and stages. It should be noted that towns may enact floodland zoning regulations which may be more restrictive than those in the County Shoreland and Floodland Protection Zoning Ordinance. However, all of the towns within the drainage area tributary to Pewaukee Lake currently are regulated only by the county ordinance for floodplain zoning. Floodland zoning ordinances are in effect within all parts of the total drainage area tributary to Pewaukee Lake.

Shoreland Zoning

Under Section 59.692 of the *Wisconsin Statutes*, counties in Wisconsin are required to adopt zoning regulations within statutorily defined shoreland areas, those lands within 1,000 feet of a navigable lake, pond, or flowage, or 300 feet of a navigable stream, or to the landward side of the floodplain, whichever distance is greater, within their unincorporated areas. Minimum standards for county shoreland zoning ordinances are set forth in Chapter NR 115 of the *Wisconsin Administrative Code*. Chapter NR 115 sets forth minimum requirements regarding lot sizes and building setbacks; restrictions on cutting of trees and shrubbery; and restrictions on filling, grading, lagooning, dredging, ditching, and excavating that must be incorporated into county shoreland zoning regulations. In addition, Chapter NR 115 requires that counties place all wetlands five acres or larger and within the statutory

Table 8

EXISTING AND PLANNED LAND USE WITHIN THE TOTAL DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1995 AND 2020

Land Use Categories[a]	1995 Acres	1995 Percent of Total Tributary Drainage Area	2020 Acres	2020 Percent of Total Tributary Drainage Area
Urban				
Residential	3,373	21.6	5,846	37.3
Commercial	65	0.4	276	1.8
Industrial	1	- -	1	- -
Governmental and Institutional	93	0.6	136	0.9
Transportation, Communication, and Utilities	1,304	8.3	1,975	12.6
Recreation	456	2.9	634	4.0
Subtotal	5,292	33.8	8,868	56.6
Rural				
Agricultural	5,772	36.8	2,196	14.0
Wetlands	1,081	6.9	1,081	6.9
Woodlands	1,031	6.6	1,031	6.6
Water	2,478	15.8	2,478	15.8
Extractive	8	0.1	8	0.1
Subtotal	10,370	66.2	6,794	43.4
Total	15,662	100.0	15,662	100.0

[a]*Parking included in associated use.*

Source: SEWRPC.

shoreland zoning jurisdiction area into a wetland conservancy zoning district to ensure their preservation after completion of appropriate wetland inventories by the Wisconsin Department of Natural Resources.

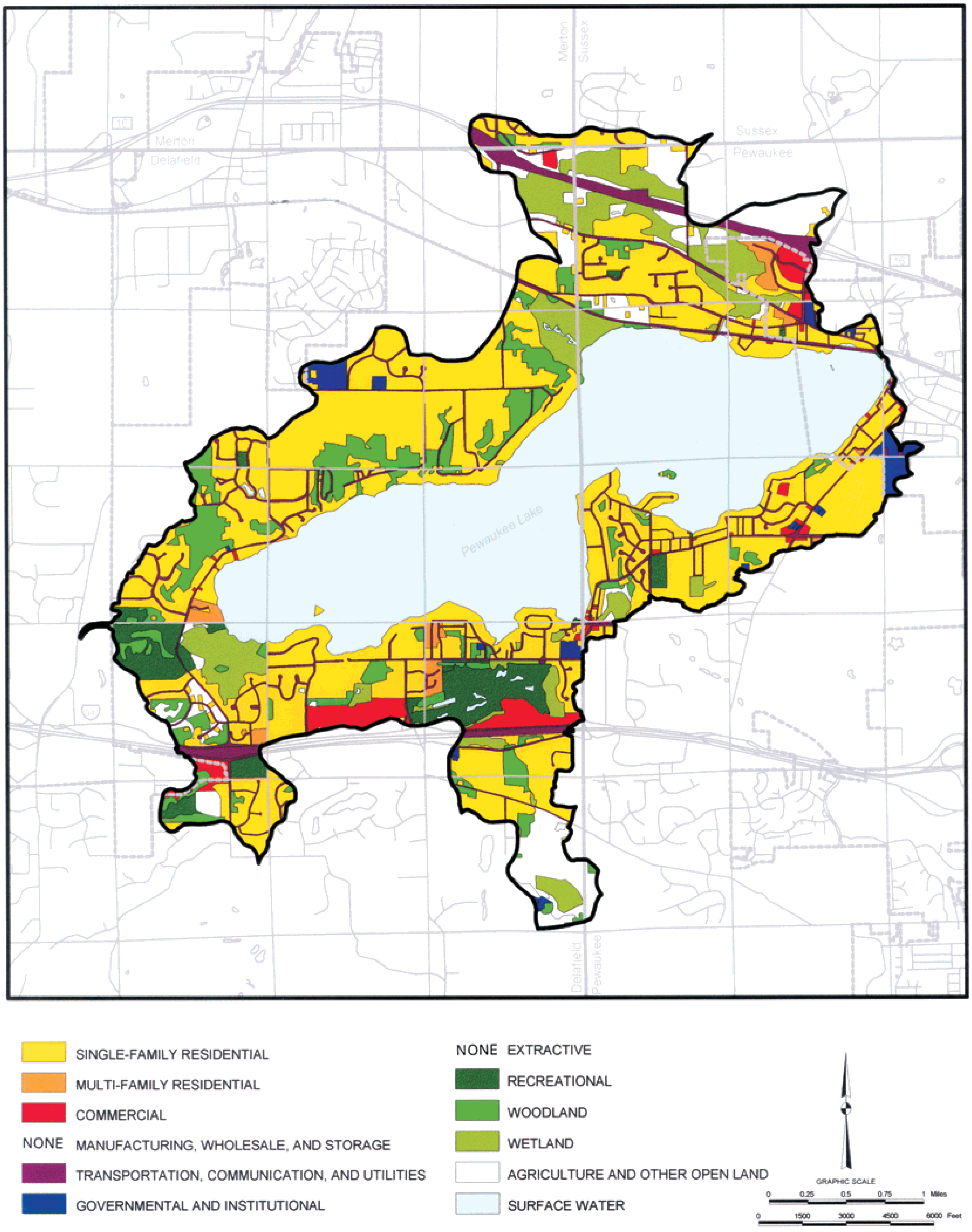
In 1982, the State Legislature extended shoreland-wetland zoning requirements to cities and villages in Wisconsin. Under Sections 62.231 and 61.351, respectively, of the *Wisconsin Statutes*, cities and villages in Wisconsin are required to place wetlands five acres or larger and located in statutory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

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

County shoreland zoning ordinances are in effect in all unincorporated areas of Waukesha County. All of the incorporated municipalities within the total drainage area tributary to Pewaukee Lake have adopted shoreland-wetland zoning ordinances.

Map 13

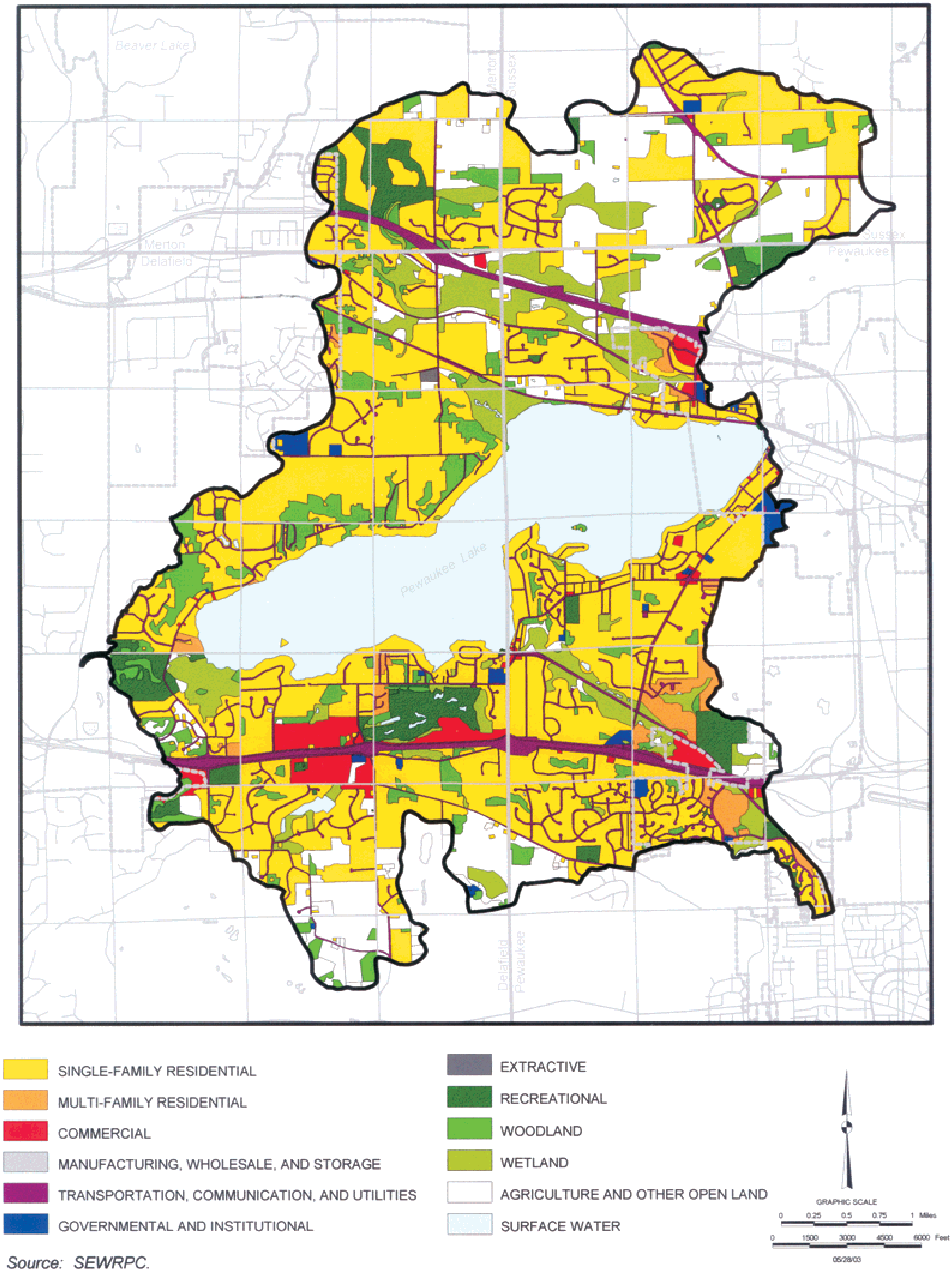
PLANNED LAND USE WITHIN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO PEWAUKEE LAKE: 2020



Source: SEWRPC.

Map 14

PLANNED LAND USE WITHIN THE TOTAL DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 2020



Source: SEWRPC.

Table 9

LAND USE REGULATIONS WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE IN WAUKESHA COUNTY BY CIVIL DIVISION: 2001

Community	Type of Ordinance				
	General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Waukesha County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
City of Delafield	Adopted	Adopted	Adopted	Adopted	Adopted
City of Pewaukee	Adopted	Adopted	Adopted	Adopted	Other[a]
City of Waukesha	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Hartland	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Pewaukee	Adopted	Adopted	Adopted	Adopted	County ordinance
Town of Delafield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Lisbon	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Merton	Adopted	County ordinance	County ordinance	Adopted	County ordinance

[a]*Erosion control and stormwater management standards are built into other ordinances.*

Source: SEWRPC.

Subdivision Regulations

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

The subdivision regulatory powers of towns and counties are confined to unincorporated areas. City and village subdivision control ordinances may be applied to extraterritorial areas, as well as to the incorporated areas.[5] It is possible for both a county and a town to have concurrent jurisdiction over land divisions in unincorporated areas, or for a city or village to have concurrent jurisdiction with a town or county in the city or village extraterritorial plat approval area. In the case of overlapping jurisdiction, the most restrictive requirements apply. Each of the incorporated communities within the tributary drainage area to Pewaukee Lake has adopted its own subdivision ordinance. The subdivision control ordinances adopted and administered by Waukesha County apply only to the unincorporated statutory shoreland areas of the County.

Construction Site Erosion Control and Stormwater Management Regulations

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

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

Construction site erosion control and stormwater management ordinances were in effect in all communities within the tributary drainage area to Pewaukee Lake in 2001. The Cities of Delafield and Waukesha, and the Village of Hartland, have adopted both construction site erosion control regulations and stormwater management regulations. The Towns of Delafield, Lisbon, and Merton, and the Village of Pewaukee, have adopted construction site erosion control and stormwater management ordinances by reference to the County ordinances. With the exception of the City of Pewaukee which addresses construction site erosion control standards in its ordinance, stormwater management standards are built into other development policies. The City of Delafield and the Village of Hartland have adopted similar ordinance language in an effort to better protect the water resources shared by these neighboring communities. These ordinances differ from that of the County only in that they are applicable to sites of 4,000 square feet or more in areal extent, rather than sites of 3,000 square feet or more.

Waukesha County has adopted construction erosion control and stormwater management ordinances. These ordinances apply to the unincorporated town lands in the county. The Waukesha County construction site erosion control ordinance applies to all lands requiring a subdivision plat or certified survey, to sites upon which construction activities will disturb 3,000 square feet or more and/or 400 cubic yards or more of material, and to sites where pipeline placement operations disturb 300 linear feet or more of land surface. These ordinances require persons engaging in land disturbing activities to employ soil erosion control practices on affected sites that are consistent with those set forth in the *Wisconsin Construction Site Best Management Practice Handbook*[6] or equivalent practices. In general, these practices are designed to minimize soil 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 and five acres in areal extent where there is at least 1.5 acres of impervious surface, nonresidential lands of 1.5 acres in areal extent where there is at least 0.5 acre of impervious surface, or other lands on which development activities may result in stormwater runoff likely to harm public property or safety. Lands within an area covered by an approved stormwater management plan are specifically exempted from the Waukesha County ordinance. The 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*.[7]

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

Chapter IV

WATER QUALITY

INTRODUCTION

The earliest data on water quality conditions in Pewaukee Lake date back to the early 1900s, when E.A. Birge and C. Juday, widely-recognized pioneering lake researchers from the University of Wisconsin, collected basic information on the Lake.[1] However, most water quality information is relatively recent. Water chemistry data for Pewaukee Lake were collected by the Wisconsin Conservation Department, now the Wisconsin Department of Natural Resources, in 1944, 1946, and 1950, and between 1963 and 1966. Additional data were included in the 1963 Wisconsin Department of Natural Resources Report, *Surface Water Resources of Waukesha County*,[2] and other data are included in miscellaneous Wisconsin Department of Natural Resources file data and reports. More recently, the Wisconsin Department of Natural Resources has monitored the water quality of Pewaukee Lake periodically from 1972 through 1981, and, under the auspices of their Long-Term Trend Monitoring Program, from 1986 through 2000.[3] These latter studies involved the determination of the physical and chemical characteristics of the Lake's water, including dissolved oxygen concentration and water temperature profiles, pH, specific conductance, water clarity, and nutrient and chlorophyll-*a* concentrations.

EXISTING WATER QUALITY CONDITIONS

Water quality data gathered under the auspices of the aforementioned Wisconsin Department of Natural Resources monitoring programs were used to assess Lake water quality in Pewaukee Lake. For purposes of the initial lake management plan for Pewaukee Lake, data for the period from 1972 through 1979 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 are supplemented with more recent data, collected during

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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]*R.J. Poff and C.W. Threinen,* Surface Water Resources of Waukesha County*, Wisconsin Conservation Department, 1963, p. 69.*

[3]*Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1986, *1986; Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County: Long-Term Trend Lake, 1987, *1987; E. R.. Schumacher, Wisconsin Department of Natural Resources Fish Management Report No. 131,* Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County, Summer 1982, *February 1987; and Wisconsin Department of Natural Resources,* Pewaukee Lake Sensitive Area Study, *June 1994.*

the period from 1981 through 2000, to determine and evaluate current water quality conditions in the Lake.[4] Water quality samples generally were taken seasonally from the main basin of the Lake. The primary sampling station used for the various sampling studies was located at the deepest portion of Pewaukee Lake, as shown on Map 1.

Thermal Stratification

Thermal and dissolved oxygen profiles for Pewaukee Lake are shown in Figures 2 and 3. Between 1973 and 2000, water temperatures in Pewaukee Lake ranged from a minimum of 32°F during the winter to 83.5°F during the summer, as shown in Table 10. In recent years, the range in water temperatures was approximately 10°F warmer than that measured during the previous water quality study which indicated a maximum water temperature of approximately 75°F during July 1976, as shown in Figure 2.

The Lake was dimictic, which means that it mixes completely two times per year, and is subject to thermal stratification during summer and winter. This process is illustrated diagrammatically in Figure 4. Thermal stratification is a result of the differential heating of the 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 Pewaukee 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 4. This "barrier" is marked by a sharp temperature gradient known as the thermocline and is characterized by a 1°C drop in temperature per 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 5. 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.

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

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

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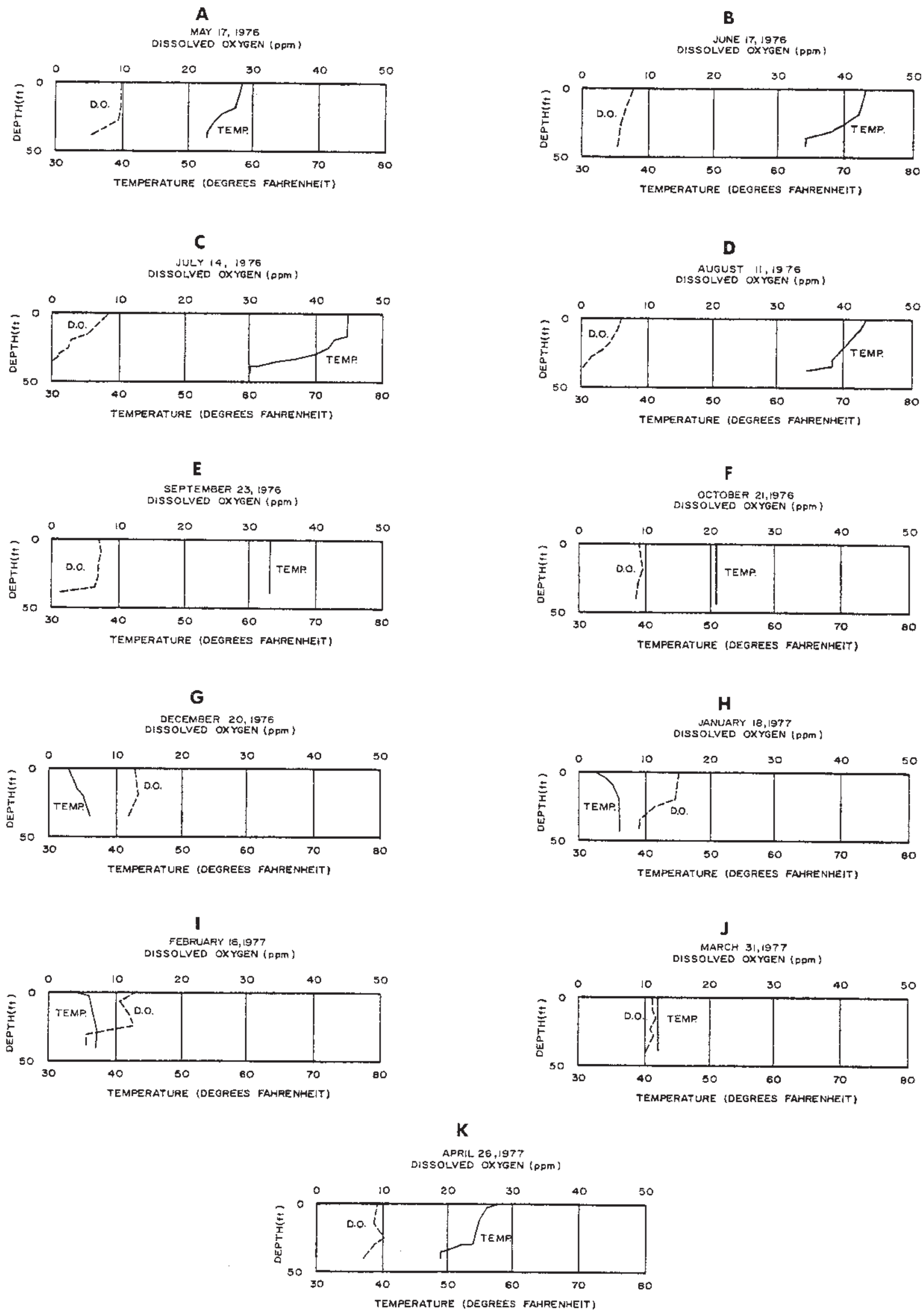
[4]*See for example, Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County Long Term Trend Lake, 1986; *and Wisconsin Department of Natural Resources,* Pewaukee Lake, Waukesha County Long Term Trend Lake, 1987.

Figure 2

DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR PEWAUKEE LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 3

DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR PEWAUKEE LAKE: 1994-2001

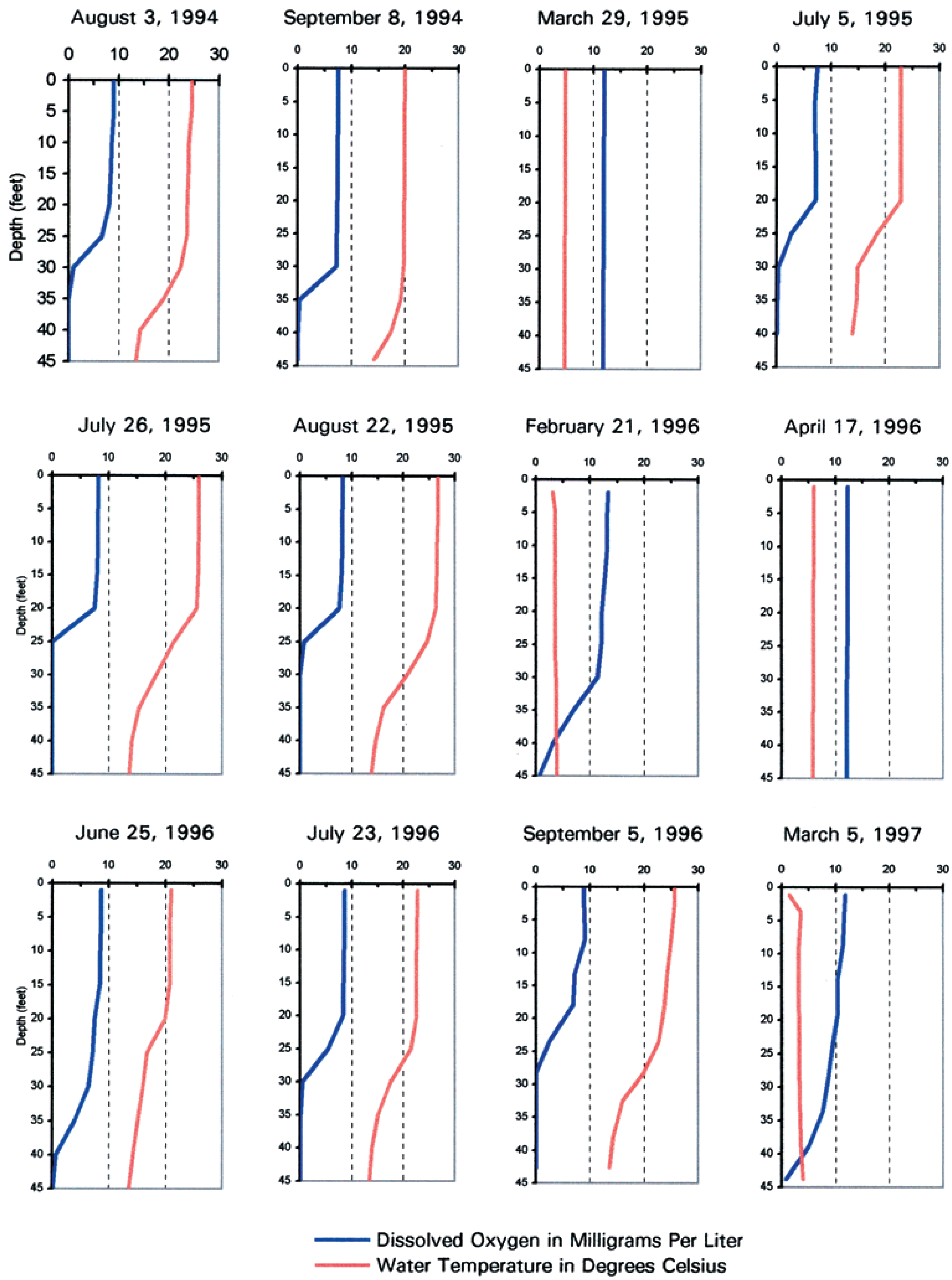
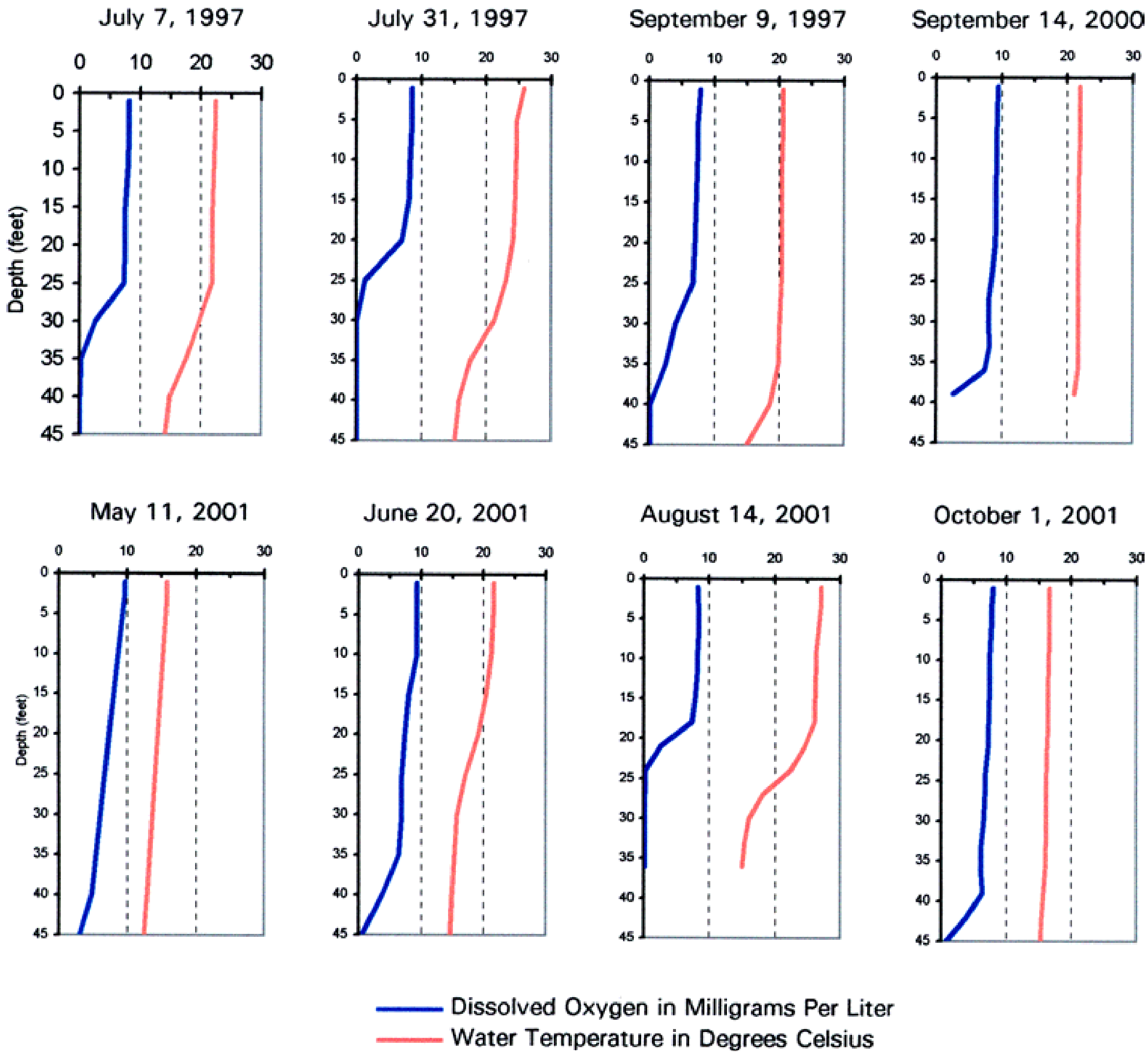


Figure 3 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

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

Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake ecosystem. As shown in Figures 2 and 3, dissolved oxygen levels were generally higher at the surface of Pewaukee Lake, where there was an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis. Dissolved oxygen levels were lowest on the bottom of the Lake, where decomposer

Table 10

SEASONAL WATER QUALITY CONDITIONS IN PEWAUKEE LAKE: 1973-2000

Parameter[a]	Fall (mid-September to mid-December) Shallow[b]	Fall Deep[c]	Winter (mid-December to mid-March) Shallow[b]	Winter Deep[c]	Spring (mid-March to mid-June) Shallow[b]	Spring Deep[c]	Summer (mid-June to mid-September) Shallow[b]	Summer Deep[c]
Physical Properties								
Alkalinity, as $CaCO_3$								
Range	174-202	172-202	148-216	200-258	188-207	196-218	179-184	196-204
Mean	188	185.6	197	228	199.07	203.09	181.67	201.33
Standard Deviation	10.8	10.7	32.8	23.7	5.09	6.24	2.52	4.62
Number of Samples	5	5	4	4	15	11	3	3
Color								
Range	5	- -	- -	- -	5-15	5-15	15	- -
Mean	5	- -	- -	- -	10.45	12.14	15	- -
Standard Deviation	- -	- -	- -	- -	3.50	3.93	0	- -
Number of Samples	1	- -	- -	- -	11	7	2	- -
Dissolved Oxygen								
Range	5.8-11	4.5-12.3	8.5-17.6	0-12.9	0.1-14.5	0.1-14.3	0.1-15.7	0-2.64
Mean	9.38	8.85	12.66	4.51	11.3	8.94	8.57	0.45
Standard Deviation	1.89	3.26	2.50	4.16	2.78	4.49	2.02	0.67
Number of Samples	6	4	14	14	20	16	40	36
pH (units)								
Range	7.8-8.3	8-8.3	7.55-8.4	8-8.3	7.2-8.4	7.2-8.4	7.3-8.8	6.8-8.5
Mean	8.08	8.15	8.04	7.79	8.02	7.995	8.38	7.61
Standard Deviation	0.17	0.105	0.26	0.307	0.32	0.366	0.32	0.36
Number of Samples	6	6	14	15	19	16	40	37
Secchi Depth (feet)								
Range	1.22-2.3	- -	0.85-10.6	- -	1.32-6.25	- -	0.91-5.6	- -
Mean	1.79	- -	4.98	- -	2.55	- -	2.05	- -
Standard Deviation	0.36	- -	2.90	- -	1.24	- -	0.86	- -
Number of Samples	7	- -	14	- -	20	- -	42	- -
Specific Conductance (µS/cm)								
Range	415-590	448-610	319-645	345-701	360-648	372-730	342-650	420-731
Mean	491.3	502.5	466.8	508.9	502.73	524.64	552	601.86
Standard Deviation	62.56	60.85	119.7	116.3	93.12	101.59	74.58	77.67
Number of Samples	6	6	11	12	15	14	36	35
Temperature (°F)								
Range	42-68.72	42-59	32-44.96	37-43.16	37.22-66.92	37.4-57.74	58.28-83.50	44.6-71.24
Mean	54.22	49.36	48.42	38.95	48.42	44.72	72.78	55.76
Standard Deviation	5.47	6.9	3.45	1.68	8.35	5.48	5.47	5.87
Number of Samples	6	5	15	15	20	17	39	38
Turbidity (NTU)								
Range	1.4-4.5	3.2-4.9	1.3-3.4	1.7-2.5	0.7-4.8	1.2-7.5	0.6-6.3	2.3-2.9
Mean	3.35	3.92	2.28	2.15	2.24	2.94	3.6	2.67
Standard Deviation	1.06	0.65	0.90	0.41	1.42	2.02	2.52	0.32
Number of Samples	6	5	4	4	15	11	4	3
Metals/Salts								
Dissolved Calcium								
Range	39-63.6	37-65.1	30-49	47-66	38-48	32-52	23-43	26-47
Mean	45.32	43.46	42.5	56.25	42.8	43.23	35.25	38.33
Standard Deviation	10.4	12.14	8.74	7.80	2.83	5.42	8.58	10.97
Number of Samples	5	5	4	4	15	13	4	3
Dissolved Chloride								
Range	33-44	33-46	28-50	35-66	35-75	35-75	24-45	35-45
Mean	36.6	37	40.5	47.5	47.8	49.8	35.33	38.67
Standard Deviation	4.34	5.2	10.38	14.15	15.90	16.24	10.60	5.51
Number of Samples	5	5	4	4	5	5	3	3
Dissolved Iron (µg/l)								
Range	0.11	0.16	- -	- -	0.01-0.1	0.01-0.11	0.35	0.47
Mean	0.11	0.16	- -	- -	0.053	0.056	0.35	0.47
Standard Deviation	- -	- -	- -	- -	0.030	0.031	- -	- -
Number of Samples	1	1	- -	- -	9	9	1	1
Dissolved Magnesium								
Range	32.9-44	33.6-44	34-45	45-51	26-43	25-46	20-44	22-44
Mean	38.32	37.5	40.75	48.6	34.67	36.23	34	35.33
Standard Deviation	4.21	4.0	4.79	3.2	4.13	5.34	10.36	11.72
Number of Samples	5	5	4	3	15	13	4	3
Dissolved Manganese (µg/l)								
Range	0.05	0.06	0.03	0.21-0.24	0.1-40	0.1-40	0.06	0.36
Mean	0.05	0.06	0.03	0.225	27.01	22.72	0.06	0.36
Standard Deviation	- -	- -	- -	0.021	18.10	18.58	- -	- -
Number of Samples	1	1	1	2	11	10	1	1

Table 10 (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 Potassium								
Range	1.2-11.4	1.2-11.2	1.8-4.2	2-4.4	1-2.5	1-3.7	1.4-2.9	1.8-3.1
Mean	4.4	4.38	2.55	3	2.03	2.23	2.37	2.6
Standard Deviation	4.00	3.93	1.14	1.03	0.35	0.65	0.84	0.7
Number of Samples	5	5	4	4	15	13	3	3
Dissolved Silica								
Range	- -	- -	- -	- -	0.09-2.1	0.2-2	- -	- -
Mean	- -	- -	- -	- -	0.64	0.6	- -	- -
Standard Deviation	- -	- -	- -	- -	0.74	0.57	- -	- -
Number of Samples	- -	- -	- -	- -	11	9	- -	- -
Dissolved Sodium								
Range	8.9-26	3-25	17-23	20-35	15-39	15-35	10-19	15-21
Mean	15.46	13.96	19	26.25	26.87	26.62	14	17
Standard Deviation	7.06	8.72	2.82	7.09	7.17	6.32	4.58	3.46
Number of Samples	5	5	4	4	15	13	3	3
Dissolved Sulfate SO_4								
Range	20-38	22-33	25-36	33-36	25-34	25-34	32-35	30-34
Mean	29.25	27.5	30.5	34.5	29	29.5	33.5	32
Standard Deviation	8.22	4.93	7.78	2.12	2.91	3.03	2.12	2.83
Number of Samples	4	4	2	2	13	10	2	2
Nutrients								
Dissolved Nitrogen, Ammonia								
Range	0.08-0.27	0.03-0.23	0.12-0.39	0.15-1.19	0.013-0.562	0.021-0.251	0.05-0.15	0.26-0.93
Mean	0.168	0.172	0.24	0.502	0.105	0.11	0.09	0.683
Standard Deviation	0.078	0.084	0.11	0.47	0.127	0.069	0.053	0.368
Number of Samples	5	5	4	4	17	13	3	3
Dissolved Nitrogen, NO_2+NO_3								
Range	0.053-0.183	0.044-0.195	0.11-0.29	0.059-0.258	0.007-0.335	0.08-0.378	0.151-0.215	0.796
Mean	0.114	0.105	0.23	0.17	0.16	0.19	0.183	0.796
Standard Deviation	0.055	0.068	0.82	0.086	0.083	0.091	0.045	- -
Number of Samples	5	4	4	4	17	13	2	1
Total Nitrogen, Organic								
Range	0.75-1.43	0.78-1.18	0.55-0.75	0.46-0.84	0.6-1.2	0.6-0.9	0.65-1.02	0.58-0.99
Mean	1.01	0.942	0.66	0.59	0.72	0.75	0.85	0.81
Standard Deviation	0.26	0.15	0.10	0.17	0.16	0.113	0.17	0.21
Number of Samples	5	5	4	4	15	12	4	3
Dissolved Orthophosphorus								
Range	0.034-0.061	0.039-0.08	0.007-0.068	0.023-0.067	0.002-0.084	0.002-0.114	0.006-0.048	0.036-0.149
Mean	0.045	0.0528	.029	0.042	0.019	0.0239	0.029	0.085
Standard Deviation	0.012	0.017	0.023	0.017	0.026	0.0326	0.018	0.047
Number of Samples	5	5	5	5	17	14	4	4
Total Phosphorus								
Range	0.02-0.09	0.06-0.113	0.005-0.08	0.011-0.115	0.006-0.08	0.016-0.1	0.01-0.089	0.017-0.36
Mean	0.062	0.0755	0.029	0.052	0.029	0.038	0.025	0.19
Standard Deviation	0.025	0.0208	0.021	0.030	0.023	0.028	0.018	0.095
Number of Samples	6	6	14	14	19	15	38	36
Biological								
Chlorophyll-*a* (µg/l)								
Range	4-10.2	- -	0.32-16	- -	2-25.5	- -	0.58-15	- -
Mean	7.1	- -	3.74	- -	9.78	- -	8.54	- -
Standard Deviation	4.38	- -	5.49	- -	6.00	- -	3.02	- -
Number of Samples	2	- -	7	- -	16	- -	37	- -

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

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

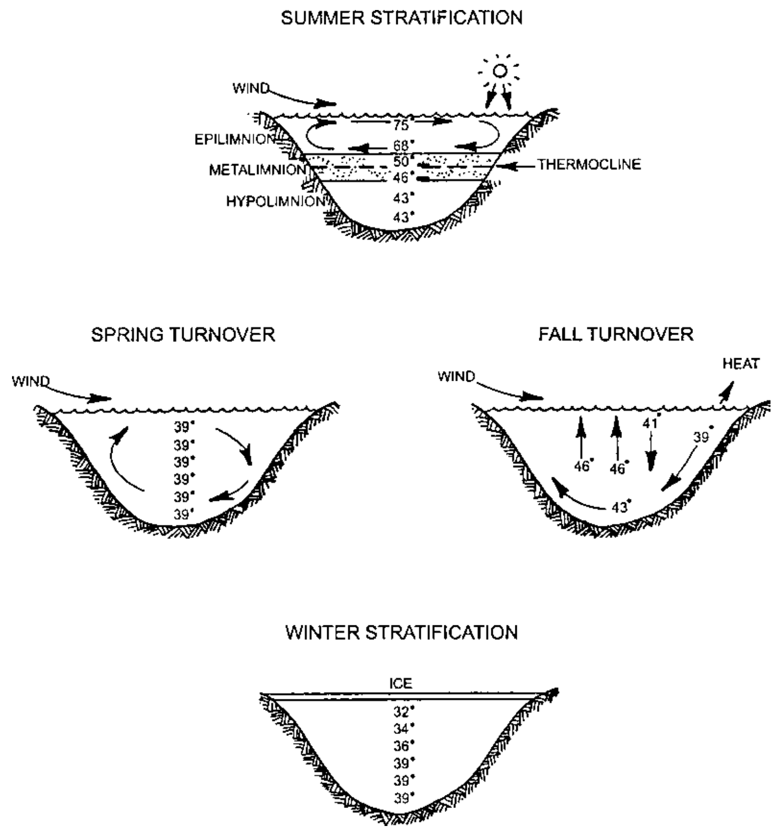
[c]*Depth of sample greater than 30 feet.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

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

Figure 4

THERMAL STRATIFICATION OF LAKES



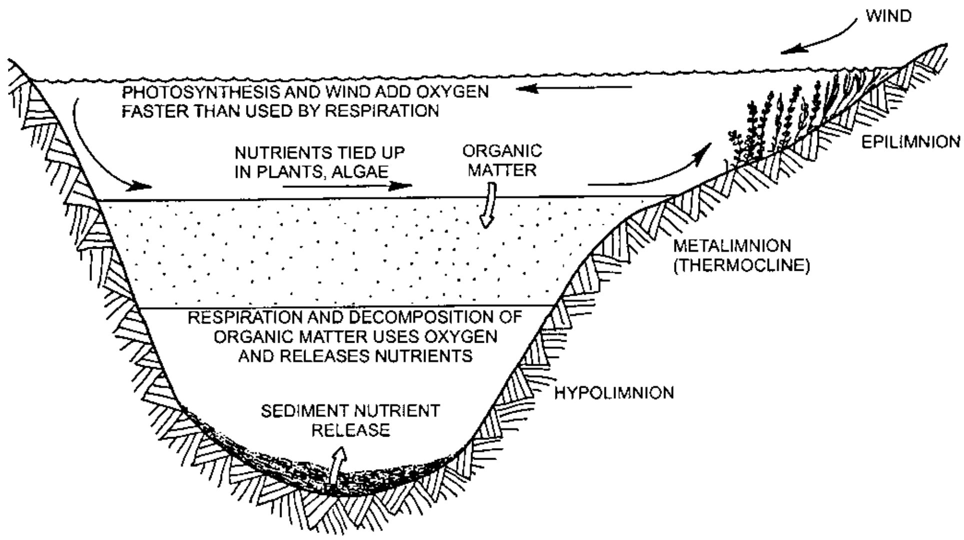
Source: University of Wisconsin-Extension and SEWRPC.

Dissolved oxygen concentrations in the surface waters of Pewaukee Lake ranged from about 17.6 milligrams per liter (mg/l) during winter to about 0.1 mg/l during summer. Hypolimnetic dissolved oxygen concentrations dropped to zero during late summer. This pattern continues to be observed, with the hypolimnion of Pewaukee Lake becoming anoxic during summer stratification. Dissolved oxygen concentrations at the bottom of the Lake fall to zero by mid- to late-June, as shown in Figure 3. Even at a depth of approximately 30 feet, oxygen concentrations were at or below the recommended concentration of 5 mg/l, the minimum level necessary to support many species of fish during most years studied.

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

Figure 5

LAKE PROCESSES DURING SUMMER STRATIFICATION



Source: University of Wisconsin-Extension and SEWRPC.

can contribute to the winter-kill of fish. Although dissolved oxygen levels in the hypolimnion of Pewaukee Lake were found to be below the 5 mg/l level during winter, a relatively large volume of the Lake retained adequate dissolved oxygen concentrations to sustain fish populations throughout the winter. At the end of winter, dissolved oxygen concentrations in the bottom waters of the Lake were restored during the period of spring turnover, which generally occurs between March and May.

Hypolimnetic anoxia is common in many of the lakes in Southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion cause fish to move upward, nearer to the surface of the lakes, where higher dissolved oxygen concentration exist. This migration, when combined with temperature, can select against some fish species 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. The likely import of internal loading to the nutrient budget of Pewaukee Lake is discussed further below.

Specific Conductance

Specific conductance is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. During periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion.

This is a consequence of the "internal loading" phenomenon noted above. As shown in Table 10, the specific conductance of Pewaukee Lake during summer of 1973 through 2000 ranged from 340 to 731 microSiemens per centimeter (μS/cm) at 25°C. During the initial planning study, conductivity ranged from 420 to 624 μS/cm. Significant surface to bottom conductivity gradients were observed, especially during the summer period when specific conductance increased with depth from between 342 and 650 μS/cm at the surface to between 420 and 731 μS/cm at depth. These ranges are within the normal range for lakes in Southeastern Wisconsin.[5]

Chloride

During the initial planning study, chloride concentrations ranged from 32 to 54 milligrams per liter (mg/l), with an average of 38 mg/l. These concentrations have continued to increase, with chloride concentrations in Pewaukee Lake during the 1980 through 1999 study ranging from 24 to 75 mg/l, as shown in Tables 10 and 11. The most important anthropogenic source of chlorides to Pewaukee Lake is believed to be the salts used on streets and highways for winter snow and ice control.[6] These values are somewhat higher than the concentrations found in many other lakes in southeastern Wisconsin,[7] although an increasing trend in chloride concentrations has been observed within the Southeastern Wisconsin Region, as shown in Figure 6.

Alkalinity and Hardness

Alkalinity is an index of the buffering capacity of a lake, or the capacity of a lake to absorb and neutralize acids. The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity because of the types of soils and underlying bedrock in the Region's watersheds. In contrast, water hardness is a measure of the multivalent metallic ion concentrations, such as those of calcium and magnesium, present in a lake. Hardness is usually reported as an equivalent concentration of calcium carbonate ($CaCO_3$). Applying these measures to the study lake, Pewaukee Lake may be classified as a hard-water alkaline lake. During the initial study period, the spring alkalinity averaged about 201 mg/l, while hardness averaged about 249 mg/l, as shown in Table 10. During the current study period, alkalinity ranged from 148 to 218 mg/l, with an average of 198 mg/l, as shown in Table 11. These values were within the normal range of lakes in Southeastern Wisconsin.[8]

Hydrogen Ion Concentration (pH)

The pH is a logarithmic measure of hydrogen ion concentration on a scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, and a pH below 7 indicates acidic water. In Pewaukee Lake, the pH was found to range between 7.4 and 8.4 standard units during the initial study period, and between 7.2 and about 8.8 standard units during the current study period, as shown in Tables 10 and 11. Since Pewaukee 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.

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

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

[6]*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. This latter is of lesser importance to Pewaukee Lake, as such waters are conveyed to the public sewage treatment facility and the effluent therefrom is discharged to the Fox River downstream of the Lake.*

[7]*R.A. Lillie and J.W. Mason,* op. cit.

[8]Ibid.

Table 11

PEWAUKEE LAKE SPRING OVERTURN WATER QUALITY: 1986-2000

Water Quality Parameter	April 21, 1986		April 7, 1987			April 14, 1988		April 27, 1989		April 10, 1990		May 9, 1991		April 13, 1992	
	Shallow	Middle	Shallow	Middle	Deep	Shallow	Middle	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Depth of Sample (feet)	0	35	0	20	42	0	35	0	45	0	45	0	48	0	45
Specific Conductance (μS/cm)	360	- -	380	370	372	490	490	425	410	405	405	480	500	495	495
pH	8.0	8.0	8.20	8.20	8.20	8.1	8.1	7.70	7.55	8.25	8.30	7.20	7.20	8.40	8.40
Water Temperature (°F)	48.2	48.2	42.8	42.1	41.9	48.2	48.2	50.4	46.4	41.9	41.9	54.5	50.0	37.2	37.4
Color (platinum-cobalt scale)	15	10	15	- -	- -	5	10	10	10	10	- -	10	15	10	10
Turbidity (Nephelometric turbidity units)	1.2	1.3	4.0	- -	- -	1.2	1.2	0.7	1.3	0.9	- -	3.1	5.0	1.5	1.6
Secchi Disk (feet)	10.5	- -	6.9	- -	- -	9.8	- -	20.5	- -	13.1	- -	6.5	- -	6.9	- -
Dissolved Oxygen	13.4	10.8	12.4	12.2	12.0	11.6	11.6	10.7	9.6	12.5	12.5	11.5	8.5	14.5	14.3
Hardness, as $CaCO_3$	- -	- -	250	280	260	240	240	250	250	250	250	260	260	260	260
Calcium	44.0	45.0	44.0	45.0	32.0	41.0	41.0	40.0	40.0	40.0	40.0	46.0	47.0	45.0	46.0
Magnesium	33.0	32.0	35.0	40.0	43.0	33.0	33.0	36.0	36.0	38.0	37.0	36.0	36.0	37.0	37.0
Sodium	24.0	24.0	24.0	24.0	20.0	25.0	25.0	27.0	27.0	28.0	29.0	29.0	29.0	30.0	30.0
Potassium	2.0	1.0	1.0	1.0	1.0	1.90	2.10	1.90	1.90	2.00	2.00	1.88	2.15	1.93	1.89
Alkalinity, as $CaCO_3$	200	200	202	- -	- -	196	198	197	198	200	- -	206	208	203	203
Chloride	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Sulfate	32	32	25	25	25	27	27	27	27	26	- -	32	32	34	34
Dissolved Solids	- -	- -	328	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Nitrate/Nitrite Nitrogen	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10	0.08	0.08	0.20	0.20
Ammonia Nitrogen	0.0008	0.0006	0.001	0.001	0.001	0.001	0.002	0.0004	0.0005	0.0009	0.001	0.0002	0.0003	0.001	0.001
Kdeldahl Nitrogen	- -	0.600	0.700	0.700	0.700	0.600	0.600	0.600	0.700	- -	- -	0.900	0.900	0.800	0.700
Total Phosphorus	- -	0.020	0.017	0.025	0.018	0.014	0.014	0.017	0.022	0.017	0.016	0.030	0.040	0.02	0.02
Orthophosphorus	0.005	0.005	0.006	0.006	0.008	0.003	0.005	0.006	0.014	0.005	0.007	0.005	0.004	0.007	0.006
Iron (μg/l)	- -	- -	- -	- -	- -	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.11
Manganese (μg/l)	- -	- -	- -	- -	- -	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Chlorophyll-*a* (μg/l)	5.00	- -	14.00	- -	- -	5.00	- -	2.00	- -	6.00	- -	14.00	- -	16.00	- -

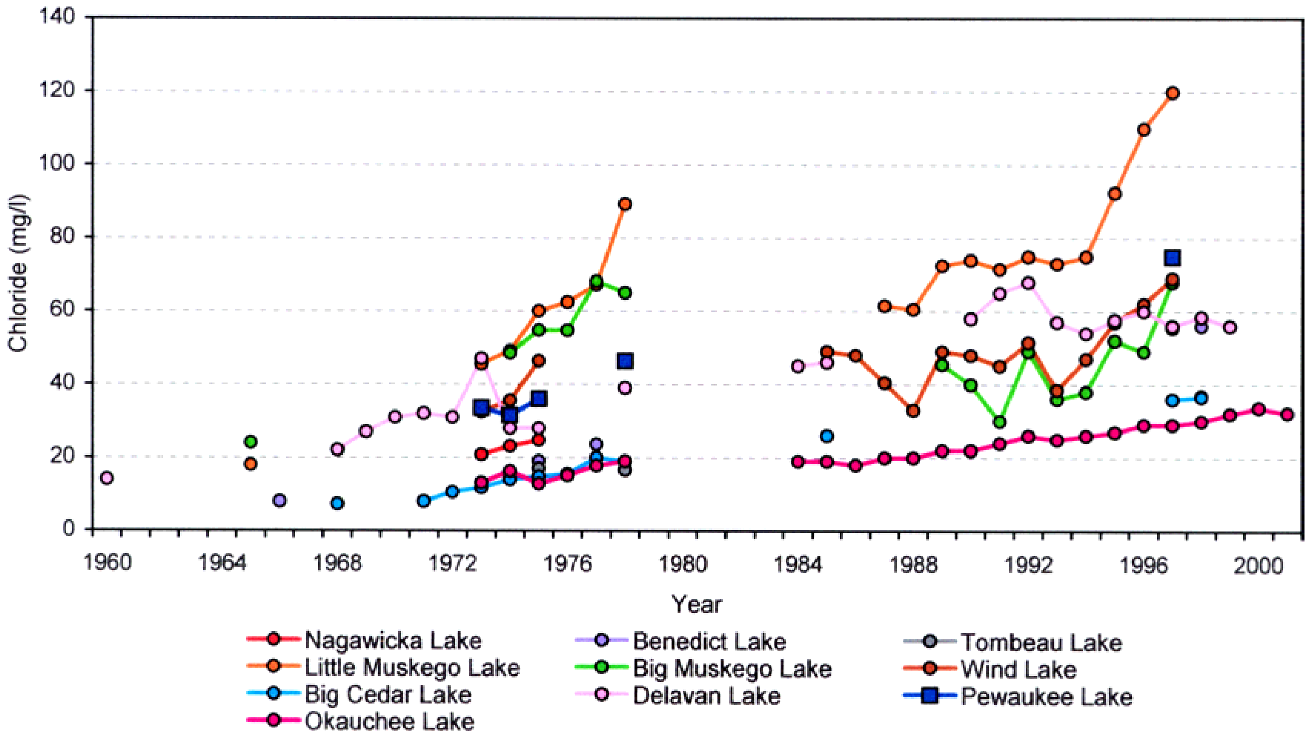
Table 11 (continued)

Water Quality Parameter	May 6, 1993		April 19, 1994		March 29,1995		April 17,1996		April 29,1997		March 30, 1998		April 7, 1999	
	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Depth of Sample (feet)	1	42	0	45	0	45	0	45	1	45	0	45	0	43
Specific Conductance (µS/cm)	618	626	- -	- -	626	626	- -	- -	648	647	599	598	550	550
pH	8.20	7.40	- -	- -	8.25	8.30	8.10	8.20	8.40	8.30	8.00	7.90	8.16	8.17
Water Temperature (°F)	59.0	46.0	49.8	48.6	40.6	40.5	43.0	46.8	47.7	46.8	45.0	43.2	47.1	46.8
Color (platinum-cobalt scale)	- -	- -	15	15	10	15	5	5	10	15	- -	- -	- -	- -
Turbidity (Nephelometric turbidity units)	- -	- -	1.7	2.0	2.4	2.8	1.2	1.2	0.8	1.3	- -	- -	- -	- -
Secchi Disk (feet)	13.9	- -	6.9	- -	6.9	- -	9.8	- -	11.8	- -	5.2	- -	8.2	- -
Dissolved Oxygen	11.1	7.2	11.5	10.8	12.1	11.9	12.4	12.2	11.3	11.0	13.0	12.9	11.86	11.29
Hardness, as $CaCO_3$	- -	- -	210	190	260	260	- -	- -	260	250	- -	- -	- -	- -
Calcium	- -	- -	38.0	36.0	44.0	45.0	43.0	43.0	45.0	45.0	- -	- -	- -	- -
Magnesium	- -	- -	27.0	25.0	37.0	37.0	35.0	35.0	35.0	34.0	- -	- -	- -	- -
Sodium	- -	- -	24.0	23.0	33.0	33.0	34.0	35.0	37.0	35.0	- -	- -	- -	- -
Potassium	- -	- -	1.86	1.79	2.30	2.30	2.30	2.20	2.00	2.10	- -	- -	- -	- -
Alkalinity, as $CaCO_3$	- -	- -	207	208	201	201	198	198	202	202	- -	- -	- -	- -
Chloride	- -	- -	- -	- -	- -	- -	- -	- -	75	75	- -	- -	- -	- -
Sulfate	- -	- -	27	28	28	29	30	30	29	29	- -	- -	- -	- -
Dissolved Solids	- -	- -	- -	- -	- -	- -	- -	- -	0.415	0.415	0.383	0.383	0.3	0.3
Nitrate/Nitrite Nitrogen	0.2	0.2	0.1	0.1	0.1	- -	0.1	0.1	0.2	0.2	- -	- -	- -	- -
Ammonia Nitrogen	0.002	0.0008	0.0005	0.0008	0.0005	- -	0.0004	0.0008	0.003	0.003	- -	- -	- -	- -
Kdeldahl Nitrogen	0.600	0.900	0.600	0.600	0.700	- -	0.600	0.600	0.700	0.700	- -	- -	- -	- -
Total Phosphorus	0.006	0.025	0.03	0.025	0.016	- -	0.014	0.017	0.015	0.016	- -	- -	- -	- -
Orthophosphorus	0.004	0.012	0.004	0.003	0.005	0.005	0.002	0.002	0.003	0.003	- -	- -	- -	- -
Iron (µg/l)	- -	- -	0.05	0.08	0.01	0.01	0.02	0.02	0.10	0.04	- -	- -	- -	- -
Manganese (µg/l)	- -	- -	40.0	40.0	7.0	8.0	5.0	6.0	5.0	13.0	- -	- -	- -	- -
Chlorophyll-*a* (µg/l)	3.26	- -	25.50	- -	14.10	- -	9.12	- -	4.54	- -	- -	- -	- -	- -

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 6

CHLORIDE CONCENTRATION TRENDS FOR ASSORTED LAKES IN SOUTHEASTERN WISCONSIN: 1960-1999



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

zooplankton, and suspended sediment, and/or because of color caused by high concentrations of dissolved organic substances. Water clarity is measured with a Secchi-disc, 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-disc reading." Such measurements comprise an important part of the Wisconsin Department of Natural Resources Self-Help Monitoring Program in which citizen volunteers assist in lake water quality monitoring efforts.

Water clarity generally varies throughout the year as algal populations increase and decrease in response to changes in weather conditions and nutrient loadings. Secchi-disc depth measurements for the period of 1972 to 1979 for Pewaukee Lake ranged from a low of 2.8 feet in February 1975 to a high of 22.0 feet in March 1977, with an average of 5.5 feet. The lower readings were usually recorded during July and August, primarily because of excessive growth of free-floating algae. During the current study period, Secchi-disc readings for Pewaukee Lake were between 3.6 and 34.8 feet, with an average of about 9.0 feet. As shown in Figure 7, during recent years, these values indicate poor to good water quality compared to other lakes in Southeastern Wisconsin.[9] In part, however, this improved water clarity may be related to the presence of zebra mussel, *Dreissena polymorpha*, in the Lake, which mollusc is an invasive, nonnative filter feeding shellfish known to impact water clarity in inland lakes.

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[9]Ibid.

Figure 7

PRIMARY WATER QUALITY INDICATORS FOR PEWAUKEE LAKE: 1973-2001

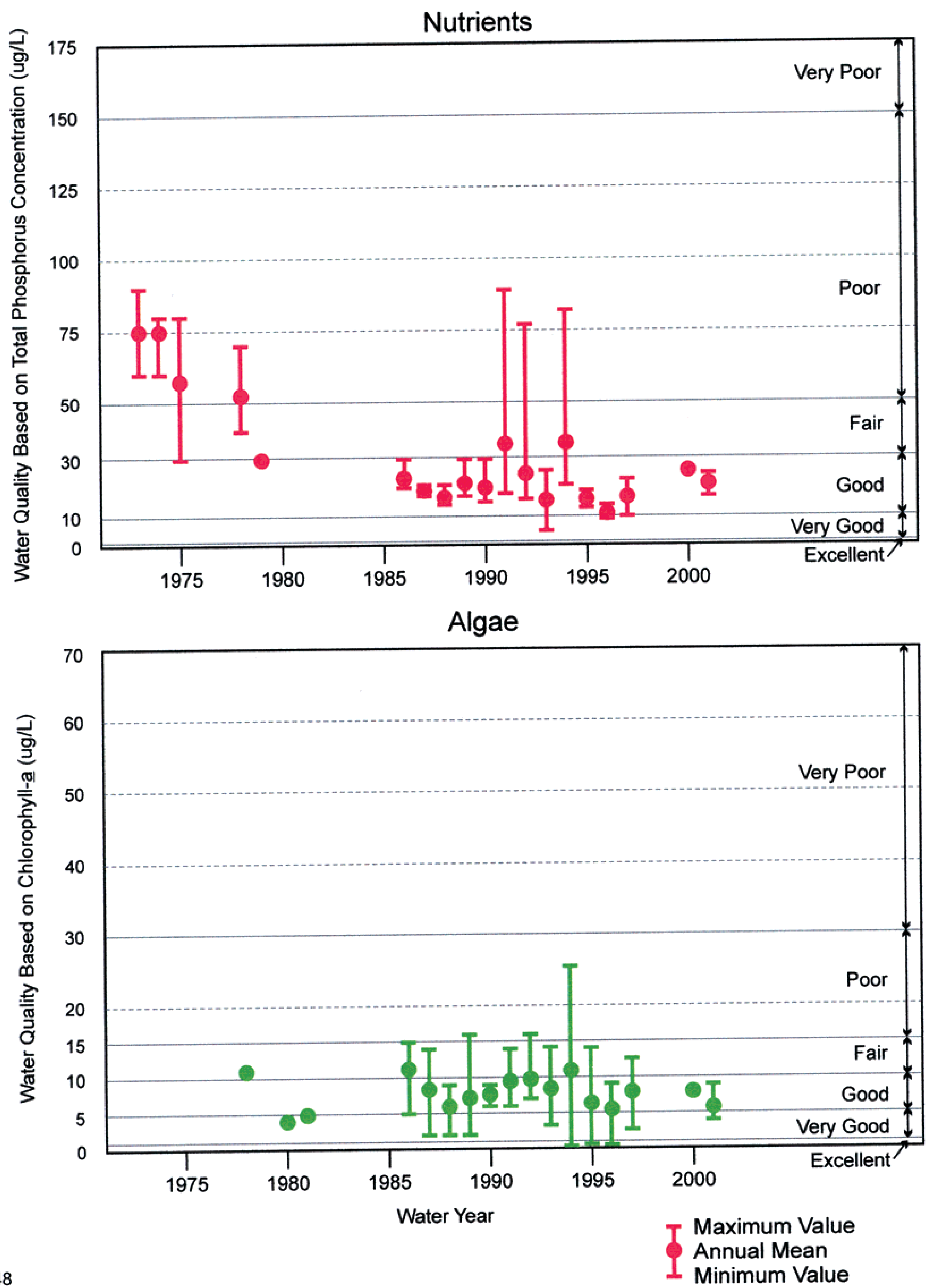
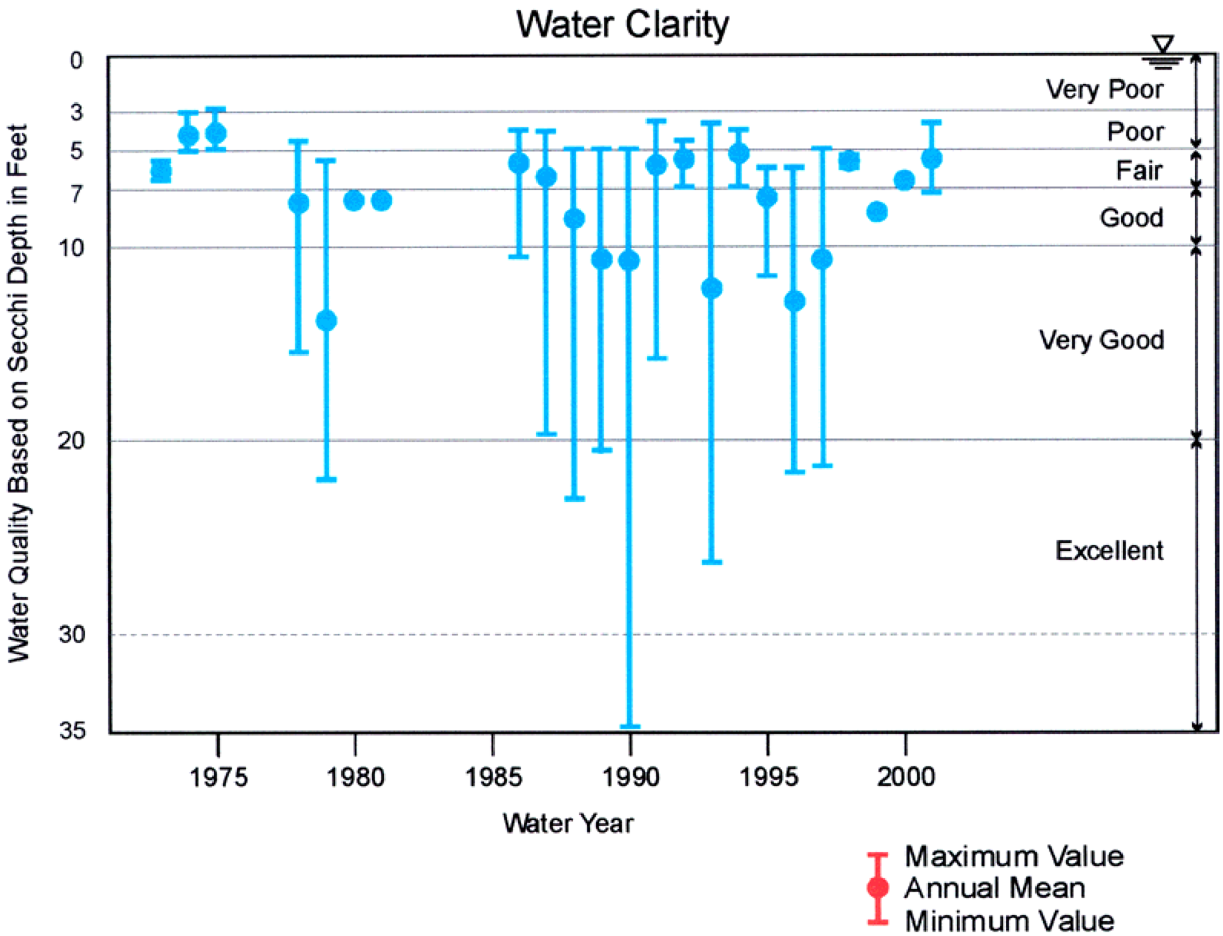


Figure 7 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

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 biomass or amount of algae in the water. As shown in Figure 7, chlorophyll-*a* concentrations determined from Pewaukee Lake during the initial study ranged from a low of 0.8 micrograms per liter (µg/l) in January 1977, to a high of 18.5 µg/l in July 1976, with an average of 7.5 µg/l. In July and August 1976, chlorophyll-*a* values were above 15 µg/l. During the current study period, chlorophyll-*a* concentrations in Pewaukee Lake ranged from 0.3 to 25.5 µg/l. 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[10] and indicate fair to very 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.[11]

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[10]Ibid.

[11]*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.*

Nutrient Characteristics

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.[12] 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. As shown in Table 12, the nitrogen-to-phosphorus ratios in samples collected from Pewaukee Lake in recent years, following the completion of the public sanitary sewerage system, were always greater than 10:1. This indicates that plant production was most likely consistently limited by phosphorus. In fact, the summer N:P ratio was frequently equal to or greater than 14:1. This indicates that summer aquatic plant growth in Pewaukee Lake is generally limited by phosphorus.

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

Total phosphorus concentrations in Pewaukee Lake were found to exceed the levels necessary to support periodic nuisance algae blooms. The recommended water quality standard for phosphorus, which is set forth in the Commission's adopted regional water quality management plan for lakes, is 0.02 milligram 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 algae and aquatic plant growth to levels consistent with the recreational and warmwater fishery and other aquatic life water use objectives.

In Pewaukee Lake, during the period 1973 through 1977, the mean concentration of total phosphorus was 0.07 mg/l during the spring turnover, and 0.06 mg/l on an average annual basis. Total phosphorus concentrations were found to be higher in the bottom waters, ranging from about 0.02 to 0.36 mg/l, as shown in Table 10. The average bottom water total phosphorus concentration in Pewaukee Lake during the study period was 0.19 mg/l. Following the provision of public sanitary sewerage service to the riparian communities, and during the current study, the total spring phosphorus concentrations in Pewaukee Lake were generally found to be less than 0.02 mg/l, as shown in Tables 11 and 12. Throughout the study period, total phosphorus in the surface waters of Pewaukee Lake generally averaged 0.02 mg/l, indicating good water quality, as illustrated in Figure 7. Dissolved phosphorus concentrations ranged from 0.002 mg/l to 0.084 mg/l in the surface waters, and from 0.023 mg/l to 0.149 mg/l in the hypolimnion during periods of summer stratification.

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

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[12] *M.0. 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.*

Table 12

NITROGEN-PHOSPHORUS RATIOS FOR PEWAUKEE LAKE: 1974-1997

Date	Nutrient Levels		
	Nitrogen (mg/l)	Phosphorus (mg/l)	N:P Ratio (mg/l)
April 2, 1974	0.71	0.080	8.9
April 22, 1975	0.81	0.070	11.6
April 7, 1987	0.70	0.017	41.2
April 14, 1988	0.60	0.014	42.9
April 27, 1989	0.60	0.017	35.3
May 9, 1991	0.90	0.030	30.0
April 13, 1992	0.80	0.020	40.0
April 19, 1994	0.60	0.030	20.0
March 29, 1995	0.70	0.016	43.8
April 17, 1996	0.60	0.014	42.9
April 29, 1997	0.70	0.015	46.7

Source: Wisconsin Department of Natural Resources and SEWRPC.

The data indicated that there was internal loading of phosphorus from the bottom sediments of Pewaukee Lake. As shown in Tables 10 and 11, the dissolved phosphorus concentrations in the bottom waters were relatively high, ranging from about 0.02 mg/l to 0.36 mg/l for samples collected during the summer when such releases of phosphorus are most likely to occur. While the magnitude of the this release and its concomitant effects in contributing to algal growth in the surface waters of the Lake may be moderated by a number of circumstance, including the rate of mixing during the spring and fall overturn events, the contribution of phosphorus from the bottom waters of Pewaukee Lake should be considered in terms of the total phosphorus load.

POLLUTION LOADINGS AND SOURCES

Pollutant loads to a lake are generated by various natural processes and human activities that take place in the drainage area tributary to a lake. These loads are transported to the lake through the atmosphere, across the land surface, and by way of inflowing streams. Pollutants transported by the atmosphere are deposited onto the surface of the lake as dry fallout and direct precipitation. Pollutants transported across the land surface enter the lake as direct runoff and, indirectly, as groundwater inflows, including drainage from onsite wastewater treatment systems. Pollutants transported by streams enter a lake as surface water inflows. In drained lakes, like Pewaukee Lake, pollutant loadings transported across the land surface directly tributary to a lake, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities, comprise the principal route by which contaminants enter a waterbody.[13] For this reason, the discussion that follows is based upon nonpoint source pollutant loadings to Pewaukee Lake.

Currently, there are no significant point source discharges of pollutants to Pewaukee Lake or to the surface waters tributary to Pewaukee Lake. Nonpoint sources of water pollution include urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities; and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems. The tributary drainage area of Pewaukee Lake is about 15,729 acres in areal extent, including about 8,248 acres that drain to the Lake without passing through any

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[13]*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.*

upstream waterbodies. As already noted, inflow to Pewaukee Lake is primarily through a series of local drainageways, including Coco Creek and Zion Creek.

Nonpoint-sourced phosphorus, suspended solids, and urban-derived metals input to and output from Pewaukee Lake were estimated using the Wisconsin Lake Model Spreadsheet (WILMS version 3.0), and unit area load-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 adopted lake management plan, which were based upon drainage basin runoff, atmospheric fallout and washout, groundwater inflow and outflow, and flow through the lake outlet.

During the 1977 study period, measured concentrations were used to develop annual loading budgets for nitrogen, phosphorus, and sediment as shown in Table 13. Inputs to the lake were calculated from flow and water quality data collected at Zion Creek, Coco Creek, and the unnamed tributary, and upon groundwater samples. Outputs were based on flow and water quality data collected at the lake outlet. Further, estimates of the amount of nitrogen and phosphorus removed as a consequence of macrophyte and fish harvesting were also calculated. Ranges and mean values for water quality parameters measured at these sites are set forth in Table 14. Atmospheric contributions of nitrogen, phosphorus and suspended solids were calculated based on precipitation records and literature values which are considered representative of these different constituents for the Pewaukee Lake region.[14] During that year, it was estimated that 14 and 13 percent, respectively, of the nitrogen and phosphorus entering the Lake came from direct drainage; 35 and 34 percent, respectively, from the inlets; 14 and 7 percent, respectively, from precipitation; and 37 and 46 percent, respectively, from dry fallout on the lake surface. Of the total mass of nutrients and sediment entering Pewaukee Lake, 72 percent of the nitrogen, 26 percent of the phosphorus, and 61 percent of the sediment was estimated to have remained in the Lake.

Phosphorus Loadings

Phosphorus has been identified as the factor generally limiting aquatic plant growth in Pewaukee Lake. Thus, excessive levels of phosphorus in the lake are likely to result in conditions that interfere with the desired use of the lake. During the initial study, existing 1980 and forecast year 2000 phosphorus sources to the lake were identified and quantified using Commission 1975 land use inventory data; Commission planned year 2000 land use data, derived from the adopted regional land use plan; and the Commission water quality simulation model.

Table 15 sets forth the estimated phosphorus loads to Pewaukee Lake under existing 1980 conditions. It was estimated that, under 1980 existing conditions, the total phosphorus load to Pewaukee Lake was 16,000 pounds. Of this total, about 4,800 pounds, or 30 percent, were estimated to be contributed by runoff from livestock operations. In addition, runoff from recreational lands was estimated to contribute 2,360 pounds, or 15 percent, of the total. Malfunctioning septic tank systems were estimated to contribute 1,180 pounds, or 7 percent, of the total phosphorus load to the Lake. Woodlands, residential lands, and agricultural lands were estimated to contribute 1,870 pounds, or 12 percent; 1,600 pounds, or 10 percent; and 1,190 pounds, or 7 percent, respectively, of the phosphorus entering the Lake. The remaining land uses in the Pewaukee Lake direct tributary drainage area—commercial, industrial, governmental and institutional, transportation, direct atmospheric fallout, and other open lands—contributed an estimated 3,000 pounds, or 19 percent of the phosphorus load to the Lake.

Without the implementation of remedial measures, the Commission estimated that, under year 2000 conditions, the total phosphorus load to the Lake would increase to approximately 17,870 pounds per year, or by about 12 percent over the estimated 1980 loadings. It was assumed that, while the recommended sewerage services would be provided, other nonpoint source pollution abatement measures would not be implemented. Under the then-forecast year 2000 scenario, increased urban-density development was envisioned to occur without appropriate

[14] *J.W. Kluesner,* Nutrient Transport and Transformation in Lake Wingra, Wisconsin*, Ph.D. Thesis, University of Wisconsin at Madison, 1972; T.J. Hurphy and P.V. Doskey, "Inputs of Phosphorus From Precipitation to Lake Michigan,"* Journal of Great Lakes Research*, Volume 2, No. 1, 1976, pp. 66-70.*

Table 13

ANNUAL LOADING BUDGETS TO PEWAUKEE LAKE FOR NITROGEN, PHOSPHORUS, AND SEDIMENT BASED ON MEASURED DATA: 1976-1977

Source	Nitrogen		Phosphorus		Sediment	
	Amount (pounds)	Percent	Amount (pounds)	Percent	Amount (pounds)	Percent
Inputs						
Inlets						
Coco Creek	19,818	21	706	19	95,696	26
Zion Creek	5,499	6	312	8	29,879	8
Unnamed Tributary No. 2	7,603	8	276	7	67,759	18
Subtotal Inlets	32,920	35	1,294	34	193,334	52
Direct Drainage	12,704	14	501	13	74,650	20
Precipitation	13,057	14	276	7	- -	- -
Dry Fallout	33,905	37	1,745	46	106,451	28
Total Inputs	92,586	100	3,816[a]	100	374,435	100
Outputs						
Pewaukee River Outlet	18,170	20	1,029	27	145,427	39
Macrophyte Harvest[b]	5,760	6	904	24	- -	- -
Fish Harvest	1,994	2	875	23	- -	- -
Net Accumulation to Lake System	66,662	72	1,008	26	229,008	61
Total Outputs	92,586	100	3,816	100	374,435	100

[a]*Phosphorus loading rate to Pewaukee Lake, as presented here, would be approximately 5,230 pounds per year if adjusted only for the volumetric differences in stormwater runoff to the lake during a year of normal precipitation. This adjustment would not account for patterns in storm intensity and storm duration.*

[b]*Assumes a macrophyte harvest rate of approximately 800 tons per year.*

Source: Wisconsin Department of Natural Resources.

construction site erosion controls and other similar practices, while rural agriculture was anticipated to continue as an active land use.

Subsequent to these studies, the changes envisioned in land usage have occurred throughout the drainage area to Pewaukee Lake, as noted in Chapter 3. However, remedial actions such as the provision of a public sanitary sewerage system and extensive nonpoint source pollution controls have been fully implemented, as recommended in the adopted regional water quality management plan. Thus, changes in the nutrient, sediment, and metal loadings to Pewaukee Lake may be anticipated. The WILMS and unit area loading models were used to evaluate the potential impacts of these changes. Forecast nutrient, sediment, and metals loads for Pewaukee Lake based upon current 1995 land use and planned 2020 land use are set forth in Tables 16 and 17, respectively, and show significant reductions in loadings compared with those initially forecast. The forecast data compared relatively well with the range of observed phosphorus levels within the Lake.

The resulting estimated phosphorus budget for Pewaukee Lake under existing 1995 land use conditions is shown in Table 16. A total annual phosphorus loading of between about 6,300 and 13,500 pounds, with a most likely total phosphorus loading of about 6,500 pounds, was estimated to be contributed to Pewaukee Lake. Of the most likely annual total phosphorus load, it was estimated that 6,000 pounds per year, or 80 percent of the total loading, was contributed by runoff from rural land; 470 pounds per year, or 15 percent, was contributed by runoff from urban land; and about 325 pounds, or about 5 percent, by direct precipitation onto the Lake surface.

Table 14

WATER QUALITY VALUES FOR PEWAUKEE LAKE INLETS, OUTLET, AND GROUNDWATER WELLS: 1976-1977

Water Quality Parameter[a]	Lake Inlet (Unnamed Tributary No. 1)		Lake Inlet (Unnamed Tributary No. 2)		Lake Inlet (Zion Creek)		Lake Outlet (Pewaukee River)		Groundwater Wells[b]	
	Range	Mean[c]	Range	Mean[c]	Range	Mean[c]	Range	Mean[c]	Range	Mean[c]
Nitrite Nitrogen	0.003-0.089	0.023(39)	0.020-0.215	0.034(27)	0.001-0.112	0.042(35)	0.003-0.184	0.045(11)	0.13-2.62	0.88(16)[d]
Nitrate Nitrogen	0.37-291.0	1.28	0.03-1.10	0.28	0.23-4.74	1.42	<0.02-0.81	0.22		
Ammonia Nitrogen	<0.03-0.28	0.07	<0.03-1.56	0.13	<0.03-0.77	0.08	<0.03-0.22	0.04	<0.04-1.64	0.33
Organic Nitrogen	0.12-3.40	0.78	<0.03-1.83	0.75	<0.06-1.63	0.07	0.51-1.19	0.81	<0.04-0.93	0.40
Total Nitrogen	0.75-4.48	2.14	0.04-3.50	1.19	0.85-4.71	2.24	0.63-1.60	1.12	0.44-3.56	1.59
Reactive Phosphorus	<0.006-0.273	0.056	0.015-0.241	0.052	0.014-0.386	0.081	0.029-0.079	0.045	<0.004-0.072	0.028(17)
Total Phosphorus	0.01-0.45	0.12	<0.01-0.37	0.11	0.02-0.67	0.15	0.05-0.12	0.08	<0.01-0.13	0.05
Chloride	21-69	40(34)	23-96	70(23)	26-89	58(30)	37-46	40(9)	6-446	132(16)
Conductivity (micromhos/cm)	482-845	672	530-919	706	405-879	689	459-602	506	613-2,325	1,286
pH (standard units)	7.0-8.1	7.8	7.4-8.0	7.7	7.4-8.2	7.8	7.5-8.3	7.9	7.4-8.1	7.8(15)
Total Suspended Solids	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Biochemical Oxygen Demand	6.0-14.6	5.1(18)	6.7-7.0	2.6(10)	0.8-12.4	4.7(14)	1.4-11.8	4.6(7)	- -	- -
Chemical Oxygen Demand	1-85	21(19)	14-27	23(10)	1-29	19(16)	19-29	25(8)	- -	- -
Calcium	- -	- -	- -	- -	- -	- -	- -	- -	59-121	93(9)
Magnesium	- -	- -	- -	- -	- -	- -	- -	- -	46-68	56
Sodium	- -	- -	- -	- -	- -	- -	- -	- -	9-93	42
Potassium	- -	- -	- -	- -	- -	- -	- -	- -	<0.5-4.5	1.8
Sulfate	- -	- -	- -	- -	- -	- -	- -	- -	20-57	34(3)
Iron	- -	- -	- -	- -	- -	- -	- -	- -	<0.06-1.57	0.40(9)
Manganese	- -	- -	- -	- -	- -	- -	- -	- -	0.03-2.19	1.27
Fecal Coliform Count (no./100 ml)	<10-60,000	- -(30)	10-3,000	- -(18)	<10-40,000	- -(25)	<10-900	- -(10)	<10-1,000	100(15)
Turbidity (Formazin units)	- -	- -	- -	- -	- -	- -	- -	- -	0.3-4.5	1.9(15)

[a] *All values in mg/l, unless otherwise specified.*

[b] *Samples taken at six sites.*

[c] *Number of samples in parentheses.*

[d] *Nitrite and nitrate nitrogen are measured together.*

Source: Wisconsin Department of Natural Resources.

Table 15

ESTIMATED TOTAL PHOSPHORUS LOADS TO PEWAUKEE LAKE: 1980 AND 2000

	Existing 1980			Anticipated 2000[a]		
Source	Extent	Total Loading (pounds per year)	Percent Distribution	Extent	Total Loading (pounds per year)	Percent Distribution
Residential Land (acres)	2,936	1,604	9.9	4,140	2,338	13.1
Commercial Land (acres)[b]	57	247	1.5	64	53	0.3
Industrial Land (acres)	87	70	0.4	87	70	0.4
Governmental and Institutional Land (acres)	177	144	0.7	229	190	1.1
Transportation Land (acres)	1,313	1,247	7.7	1,605	1,589	8.9
Construction Activities (acres)	- -	- -	- -	83	1,822	10.2
Recreational Land (acres)[b]	482	2,362	14.6	501	2,383	13.3
Onsite Sewage Disposal Systems[c]	279	1,176	7.4	154	445	2.5
Urban Subtotal	- -	6,850	42.2	- -	8,890	49.8
Agricultural Land (acres)	6,582	1,191	7.5	5,280	1,077	6.0
Atmospheric Contribution (acres of receiving surface water)[d]	2,516	1,258	8.1	2,516	1,258	7.0
Woodlands (acres)	1,033	1,867	11.9	1,033	1,829	10.2
Wetlands (acres)	1,638	- -	- -	1,638	- -	- -
Open Land (acres)	442	37	0.2	170	19	0.1
Livestock (animal units)[e]	1,488	4,797	30.1	1,488	4,797	26.9
Rural Subtotal	- -	9,150	57.8	- -	8,980	50.2
Total[f]	- -	16,000	100.0	- -	17,870	100.0

[a]*Assumes provision of sanitary sever service as recommended in the regional water quality management plan, assumes no nonpoint source control.*

[b]*Phosphorus loads under year 2000 conditions reflect abandonment, as recommended, of the private sewage treatment plants at the Steeplechase Inn and the Oakton Manor-Tumblebrook Golf Course.*

[c]*Includes only those systems on soils having severe or very severe limitations for disposal of septic tank effluent.*

[d]*Includes the surface area of Pewaukee Lake.*

[e]*An animal unit is the equivalent in waste production of a 1,000-pound dairy cow.*

[f]*The dry (27 percent below normal) study year precipitation patterns and the fixed-Interval water sampling procedures combined to interfere with the accurate reflection or the wet-weather increases in nonpoint source pollutant loads which are a result of the flushing action of more intense storm events. Consequently, the "measured phosphorus loads reported In Table 13—3,816 pounds per year—are not considered directly comparable to the estimated normal year phosphorus loads presented here.*

Source: SEWRPC.

Phosphorus release from the lake bottom sediments—internal loading—may also contribute phosphorus to the Lake. However, this loading was assumed to be negligible given the good agreement between predicted and observed phosphorus concentrations. Notwithstanding, Figure 8 suggests that the potential for internal loading to occur has been significant in recent years. As shown in Figure 8, hypolimnetic phosphorus concentrations during the period from 1986 through 1997 were significantly higher than measured during the period from 1973 through 1979, despite a substantial reduction in surface water phosphorus concentrations. While it is likely that overturn events generally occurred at rates such that little of this hypolimnetic phosphorus was mixed into the epilimnion

Table 16

ESTIMATED EXTERNAL SOURCES OF PHOSPHORUS TO PEWAUKEE LAKE

Source	1995		2020	
	Pounds[a]	Percentage[a]	Pounds[a]	Percentage[a]
Urban[b]				
High-Density (Commercial and Industrial Uses and Multi-family Residential Uses)	185	3	2,290	40
Low-Density (Single Family and Suburban Density Residential Uses)	375	6	503	9
Subtotal	560	9	2,793	49
Rural				
Mixed Agricultural	5,150	79	1,992	35
Pasture/Grass	121	2	170	3
Wetlands	97	<1	97	1
Woodlands	80	<1	80	1
Water	600	9	600	11
Subtotal	6,048	91	2,939	51
Total	6,608	100	5,732	100

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

[b]*Includes the contribution from onsite sewage disposal systems that remain in use outside of the portion of the tributary drainage area to Pewaukee Lake served by public sanitary sewerage systems, estimated within the WILMS model as ranging from approximately 50 pounds per year to as much as 1,300 pounds per year, depending upon soil type, system condition, and system location. For purposes of this analysis, 50 pounds per year were used as the contribution from onsite sewage disposal systems as that value provided the loading that was best correlated to the measured in-lake phosphorus concentrations.*

Source: SEWRPC.

of the Lake—i.e., at rates on the order of days,[15] the elevated surface water phosphorus concentrations shown in the figure for specific dates within 1991, 1992, and 1994 indicate that, portions of this internal load, at times, can be mixed into the surface waters of the Lake during high intensity storm events—i.e., when mixing occurs at rates on the order of hours.[16] More recent data, obtained during 2001, do not indicate a continuation of this trend, but continued monitoring would be indicated (see Chapter VIII).

Under 2020 conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual total phosphorus load to the Lake is anticipated to continue to diminish slightly as agricultural activities within the drainage area tributary to Pewaukee Lake are replaced by urban residential land uses. The most likely annual total phosphorus load to the Lake under buildout conditions is estimated to be 5,700 pounds.

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

[16]*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),"* Hydrobiologia*, Volume 97, 1982, pp. 209-224.*

Table 17

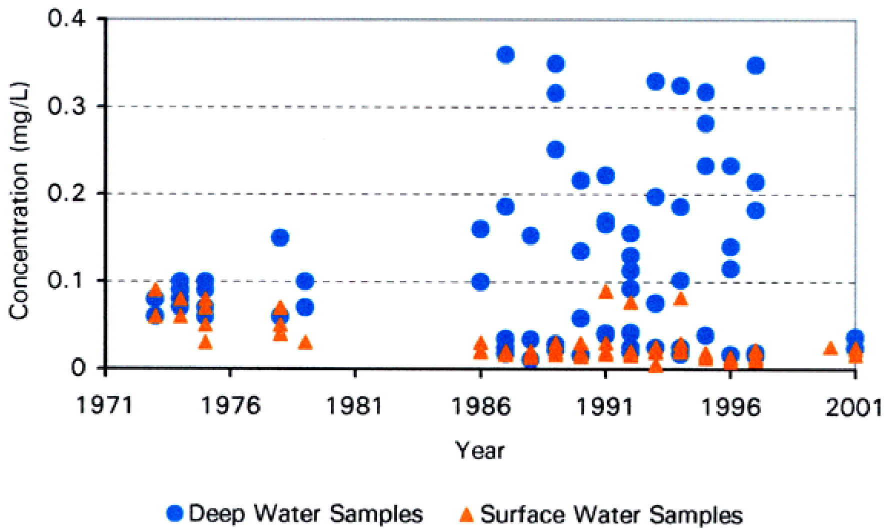
ESTIMATED CONTAMINANT LOADS TO PEWAUKEE LAKE: 1995 AND 2020

Land Use	1995						2020					
	Area (acres)	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)	Area (acres)	Sediment (tons)	Phosphorus (pounds)	Copper (pounds)	Zinc (pounds)	Cadmium (pounds)
Residential	3,373	168.7	911	68	472	0.0	5,846	292.3	1,578	117	819	0.0
Commercial	65	25.5	78	14	97	0.7	276	100.2	331	60	411	3.0
Industrial	9	3.4	10	2	13	0.1	9	3.4	10	2	13	0.1
Communications and Utilities	1,304	6.2	143	- -	- -	- -	1,975	9.4	217	- -	- -	- -
Governmental	93	23.8	128	7	74	0.0	136	34.7	184	10	109	0.0
Recreational	456	5.5	123	- -	- -	- -	634	7.7	171	- -	- -	- -
Water	2,478	233.0	322	- -	- -	- -	2,478	233.0	322	- -	- -	- -
Wetlands	1,081	2.0	43	- -	- -	- -	1,081	2.0	43	- -	- -	- -
Woodlands	1,031	1.8	42	- -	- -	- -	1,031	1.9	42	- -	- -	- -
Agricultural	5,772	1298.7	4,963	- -	- -	- -	2,196	494.1	1,888	- -	- -	- -
Total	15,662	1,768.6	6,673	91	656	0.8	15,662	1,186.7	4,786	189	1,352	3.1

Source: SEWRPC.

Figure 8

TOTAL PHOSPHORUS CONCENTRATION AMONG SURFACE VERSUS DEEP WATER SAMPLES WITHIN PEWAUKEE LAKE: 1973–2001



Source: Wisconsin Department of Natural Resources and SEWRPC.

However, this trend may be offset by the increasing utilization of agro-chemicals in urban landscaping.[17] 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.[18] Thus, it may be anticipated that the distribution of the sources of the phosphorus load to the Lake may change, with approximately equal masses of phosphorus being contributed from urban—estimated to be 2,800 pounds of phosphorus per year—and rural—estimated to be 2,300 pounds of phosphorus per year—sources. An estimated 600 pounds of phosphorus per year are estimated to be contributed by direct precipitation onto the Lake surface.

Sediment Loadings

The estimated sediment budget for Pewaukee Lake under existing 1995 land use conditions is shown in Table 17. A total annual sediment loading of between about 1,770 tons of sediment was estimated to be contributed to Pewaukee Lake. Of the likely annual sediment load, it was estimated that 1,300 tons per year, or 74 percent of the total loading, was contributed by runoff from rural land, with approximately equal masses of sediment—about 230 tons, each—being contributed from urban lands and by direct precipitation onto the Lake surface. Of the sediment load generated from rural land uses, almost all of the load, about 99 percent, was indicated as being of agricultural origin.

Under 2020 conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual sediment load to the Lake is anticipated to remain about the same. The most likely annual

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[17] *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.*

[18] Ibid.

sediment load to the Lake under buildout conditions is estimated to be 1,190 tons. However, the distribution of the sources of the sediment load to the Lake may be expected to change, with an increased mass of sediment being contributed from urban—estimated to be 450 tons of sediment per year—and rural—estimated to be 500 tons of sediment per year—sources. An estimated 235 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.[19] Table 17 sets forth the estimated loadings of copper, zinc, and cadmium likely to be contributed to Pewaukee Lake from urban development surrounding the Lake. The majority of these metals become associated with sediment particles[20] and are likely to be encapsulated into the bottom sediments of the Lake.

The estimated heavy metal budget for Pewaukee Lake under existing 1995 land use conditions is shown in Table 17. About 90 pounds of copper, 660 pounds of zinc, and 0.8 pound of cadmium were estimated to be contributed annually to Pewaukee Lake from urban lands.

Under 2020 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 increase by approximately two-fold. The most likely annual loads to the Lake under buildout conditions are estimated to be 190 pounds of copper, 1,350 pounds of zinc, and three pounds of cadmium.

Groundwater Quality

During the 1977 planning program, groundwater quality was monitored in 10 paired observation wells around Pewaukee Lake. Groundwater contributions of inorganic nitrogen ranged between 0.13 and 2.62 mg/l for both nitrite (NO_2) and nitrate (NO_3) nitrogen, and between 0.04 and 1.64 mg/l for ammonia nitrogen (NH_3), with mean values of 0.88 mg/l and 0.33 mg/l, respectively. Total phosphorus values ranged from 0.01 to 0.13 mg/l, with a mean value of 0.05 mg/l. Nutrient concentrations were not considered to be excessive in the well waters examined, and no bacterial contamination of significance was found. Other groundwater quality parameters are given in Table 14.

In-Lake Sinks

Of the annual total phosphorus load entering Pewaukee Lake, it is estimated that 80 percent of the total phosphorus load, or about 5,300 pounds of phosphorus, is retained within the Lake. This mass of phosphorus is either used by the biomass within the Lake or deposited in the lake sediments.[21] The balance of the phosphorus entering the Lake is transported downstream. The phosphorus mass retained in the Lake is typically reduced by the Lake Pewaukee Sanitary District aquatic plant harvesting program, which removes phosphorus from the Lake as a component of the aquatic plant biomass.[22]

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

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

[21] *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.*

[22] *T.M. Burton, D.L. King, and J.L. Ervin, U.S. Environmental Protection Agency Report No. EPA 440/5-79-OD1, "Aquatic Plant Harvesting As A Lake Restoration Technique,"* Proceedings of the U.S. Environmental Protection Agency National Lake Restoration Conference*, 1979; see also 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.*

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,[23] and the Carlson Trophic State Index (TSI).[24] In addition, the Wisconsin Trophic State Index value (WTSI) is presented.[25] 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 Wisconsin Department of Natural Resources for use in lake management investigations.

Vollenweider Trophic State Classification

Using the Vollenweider trophic system and applying the data in Table 10, Pewaukee Lake would be classified as having about a 60 percent probability of being mesotrophic based upon phosphorus levels, as shown in Figure 9. The Lake would have about a 35 percent probability of being eutrophic, and less than a 5 percent probability of being oligotrophic, based upon mean annual phosphorus concentrations. Based upon chlorophyll-*a* levels, the Lake would be classified as having a 55 percent probability of being mesotrophic, with about a 35 percent probability of being eutrophic and about a 5 percent probability of being oligotrophic or hypertrophic, as shown in Figure 9. Based upon Secchi-disc readings, the Lake would be classified as having a 50 percent probability of being eutrophic, with a 30 percent probability of being mesotrophic and a 15 percent probability of being hypertrophic, as shown in Figure 9. While these indicators result in slightly differing lake trophic state classifications, it may be concluded that Pewaukee Lake should be classified as a mesotrophic lake, or a lake with acceptable water quality for most uses.

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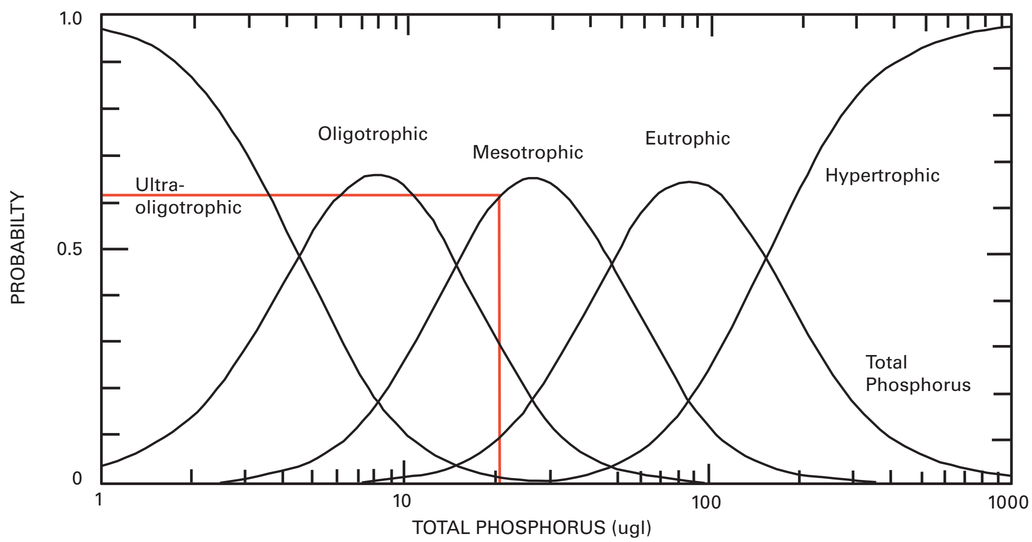
[23]*H. Olem and G. Flock, U.S. Environmental Protection Agency Report EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, Second Edition*, Washington, D.C., August 1990.*

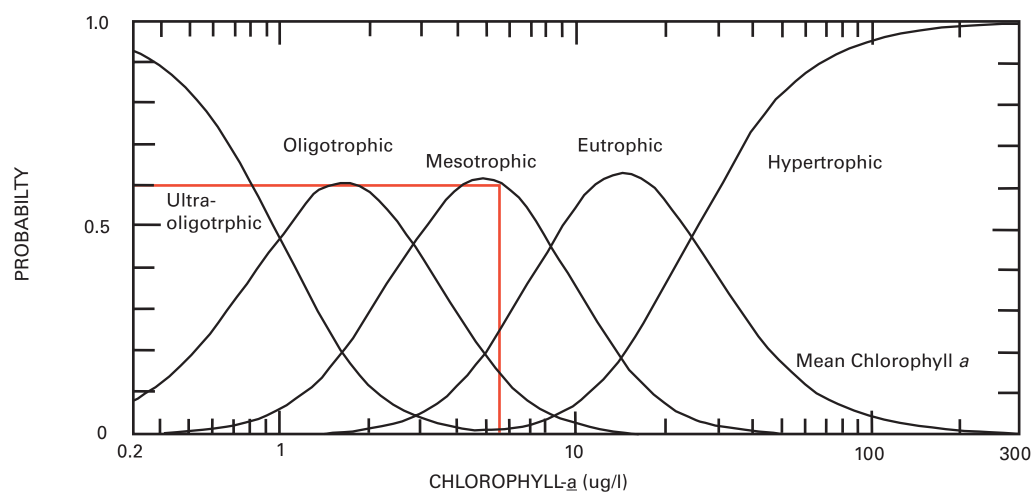
[24]*R.E. Carlson, "A Trophic State Index for Lakes,"* Limnology and Oceanography*, Vol. 22, No. 2, 1977.*

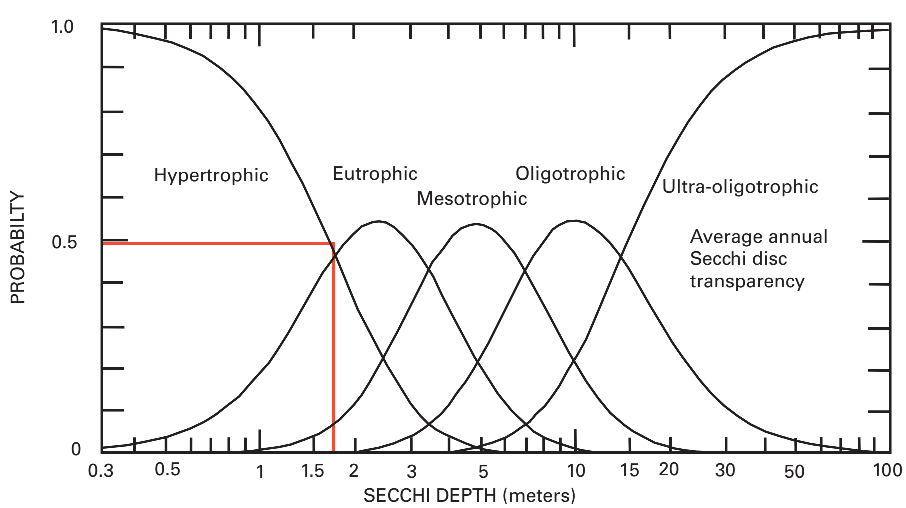
[25]*See R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings*, Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

Figure 9

TROPHIC STATE CLASSIFICATION OF PEWAUKEE LAKE BASED UPON THE VOLLENWEIDER MODEL: 2001







Source: U.S. Geological Survey and SEWRPC.

Trophic State Index
The Trophic State Index (TSI) assigns a numerical trophic condition rating based on Secchi-disc transparency, and total phosphorus and chlorophyll-*a* concentrations. The original Trophic State Index developed by Carlson has been modified for Wisconsin lakes by the Wisconsin Department of Natural Resources using data on 184 lakes throughout the State.[26] The Wisconsin Trophic State Index (WTSI) ratings for Pewaukee Lake are shown in Figure 10 as a function of sampling date. Based on the Wisconsin Trophic State Index rating of between 45 and 55, Pewaukee Lake may be classified as meso-eutrophic. Figure 10 clearly shows an improvement in lake trophic status between the 1970s and 1990s, with the WTSI decreasing from about 60 to about 55. 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 Pewaukee Lake. Nonetheless, slightly increased WTSI values in recent years may indicate some cause for concern during this period.

SUMMARY

Pewaukee Lake represents a typical hard-water, alkaline lake that is considered to have relatively good water quality, especially since the implementation of public sewage treatment measures during the 1970s. Physical and chemical parameters measured during the study period indicated that the water quality was within the “poor” to “good” range, depending upon the parameters considered. Total phosphorus levels were found to be generally at the level considered to cause nuisance algal and macrophytic growths. Summer stratification was commonly observed in Pewaukee Lake. Nevertheless, the surface waters of the Lake remained well oxygenated and supported a healthy fish population. Winterkill was not a problem in Pewaukee 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 Pewaukee Lake.

There were no significant point sources of pollutants in the Pewaukee Lake watershed. Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. In 1995, the total annual phosphorus load to Pewaukee Lake was estimated to be 6,500 pounds. Runoff from the rural lands contributed the largest amount of phosphorus, about 76 percent of the total phosphorus load, with the runoff from urban lands contributing about 19 percent of the total phosphorus load. In addition, direct precipitation onto the Lake surface contributed about 5 percent of the total phosphorus load, or relatively minor amounts of phosphorus, to the Lake. Agricultural lands constituted the primary source of phosphorus to the Lake under current land use conditions within the drainage area tributary to the Lake. Under forecast buildout conditions, both rural and urban lands are anticipated to contribute approximately equal masses of phosphorus to Pewaukee Lake.

Approximately 80 percent, or 5,300 pounds, of the total phosphorus loading is estimated to remain in the Lake by conversion to biomass or through sedimentation, resulting in a net transfer of about 1,200 pounds of phosphorus downstream.

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

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

Figure 17

WISCONSIN TROPHIC STATE INDEX FOR PEWAUKEE LAKE: 1973-2001

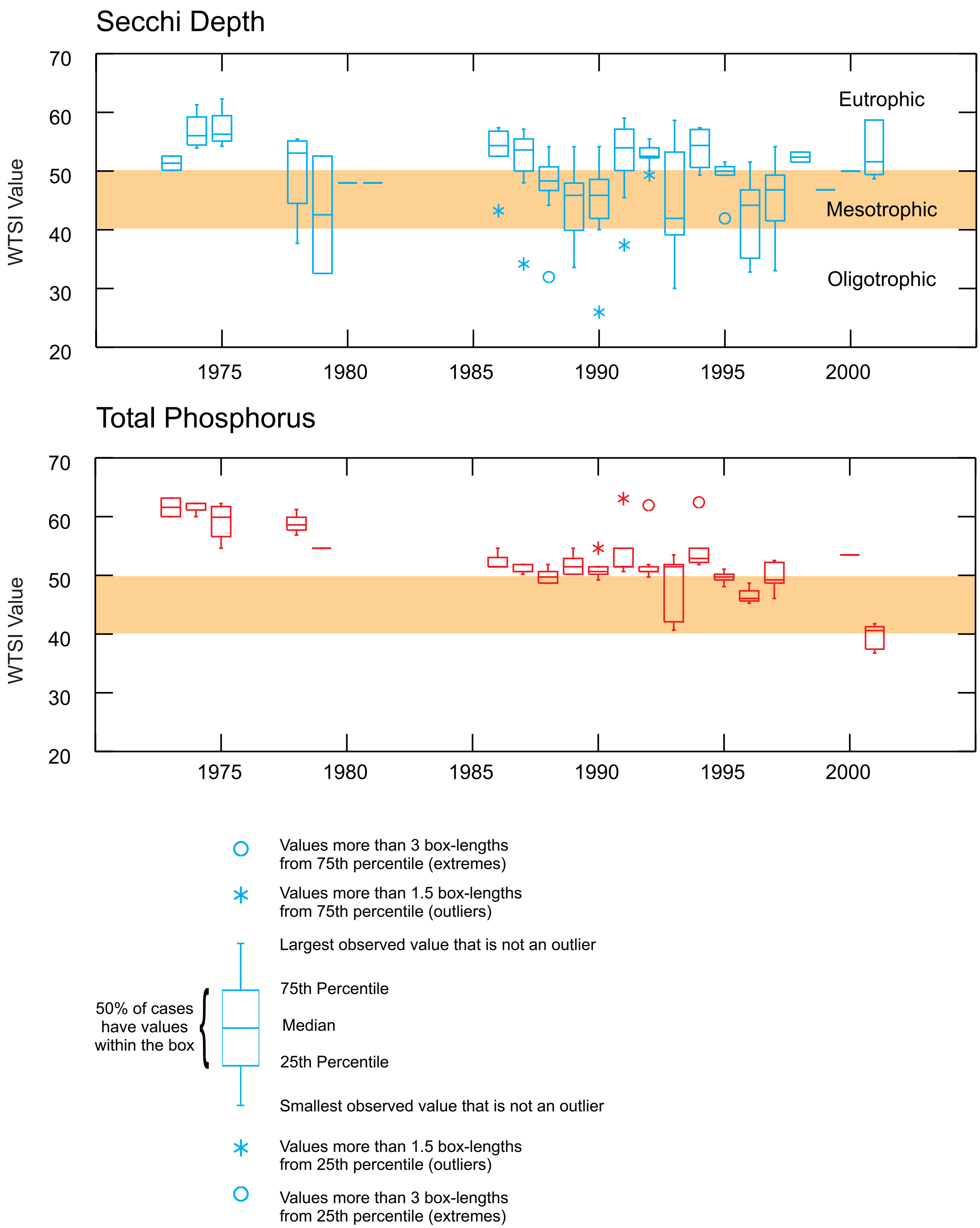
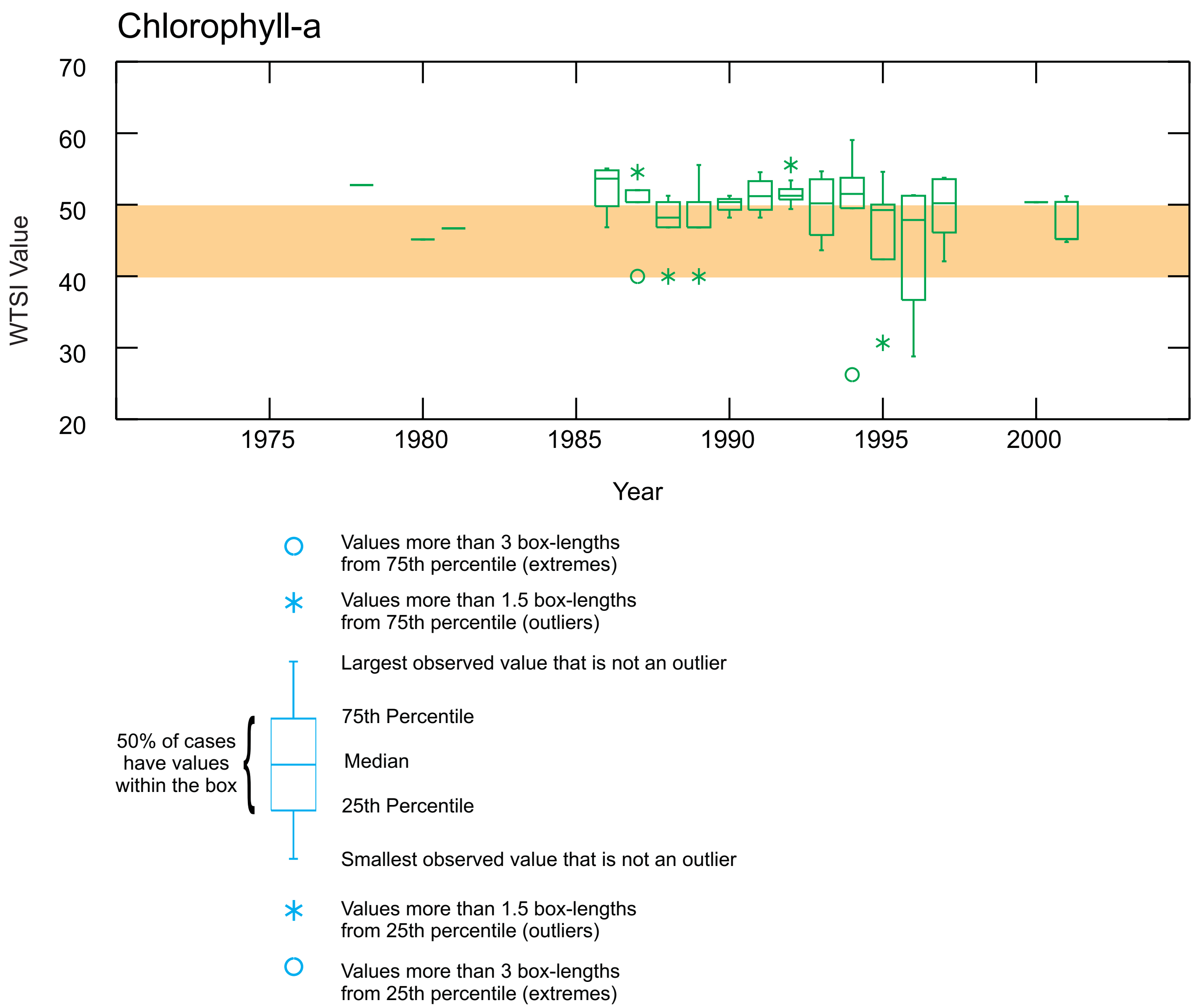


Figure 17 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

Chapter V

AQUATIC BIOTA AND ECOLOGICALLY VALUABLE AREAS

INTRODUCTION

Pewaukee Lake is an important element of the natural resource base of the City and Village of Pewaukee and the Town of Delafield. The Lake, its biota, and the adjacent park and residential lands combine to contribute to the quality of life in the area. When located in urban settings, resource features such as lakes and wetlands are typically subject to extensive recreational use and high levels of pollutant discharges, common forms of stress to aquatic systems, and these may result in the deterioration of these natural resource features. For this reason, the formulation of sound management strategies must be based on a thorough knowledge of the pertinent characteristics of the individual resource features, as well as of the urban development in the area concerned. Accordingly, this chapter provides information concerning the natural resource features of the Pewaukee Lake watershed, including data on aquatic macrophytes, fish, wildlife, wetlands and woodlands, and environmental corridors. 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 to other aquatic organisms. In this process, known as photosynthesis, plants utilize energy from sunlight and release oxygen required by other aquatic life forms.

To document the types, distribution, and relative abundance of aquatic macrophytes and phytoplankton in Pewaukee Lake, a number of surveys were conducted as part of both the initial planning program and the current planning effort. In addition, data on aquatic plant communities were collected by the Wisconsin Department of Natural Resources (WDNR) as part of the Long-Term Trend or Ambient Lake Monitoring Program. These aquatic plant surveys were conducted during the summers of 1986, 1988, 1991, 1994, and 1997. Subsequently, an aquatic plant survey was conducted by the Commission staff during the summer of 2000 and a reconnaissance conducted during 2001. Phytoplankton populations were sampled only during the 1986 survey. These data are summarized below.

Phytoplankton

Phytoplankton, or algae, are small, generally microscopic plants that are found in all lakes and streams. They occur in a wide variety of forms, in single cells or colonies, and can be either attached or free-floating. Phytoplankton abundance varies seasonally with fluctuations in solar irradiance, turbulence due to prevailing winds, and nutrient availability. In lakes with high nutrient levels, heavy growths of phytoplankton, or algal blooms, may occur. Algal blooms have been occasionally perceived as a problem in Pewaukee Lake, most recently, during the summer of 2002.

Green algae (Chlorophyta) are the most important source 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 of grazing by zooplankton.

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 along shorelines, where they die and decompose, causing noxious odors and unsightly conditions. The decay process consumes oxygen, sometimes depleting available supplies and resulting in fish kills. Also, certain species of blue-green algae may release toxic materials into the water.

The concentrations and types of algae present in Pewaukee Lake during the initial planning project period are shown in Figures 11 and 12, respectively. Algal populations were highest during mid-July 1976. Seasonally, algal populations were greatest during the summer months, through September 1976. Concentrations greater than 10 million cells per liter are generally considered to result in “bloom” conditions in a lake. The lowest populations, approximately 100,000 cells per liter, occurred during December 1976. Algal populations remained low, fewer than 300,000 cells per liter, from December 1976 through mid-February 1977.

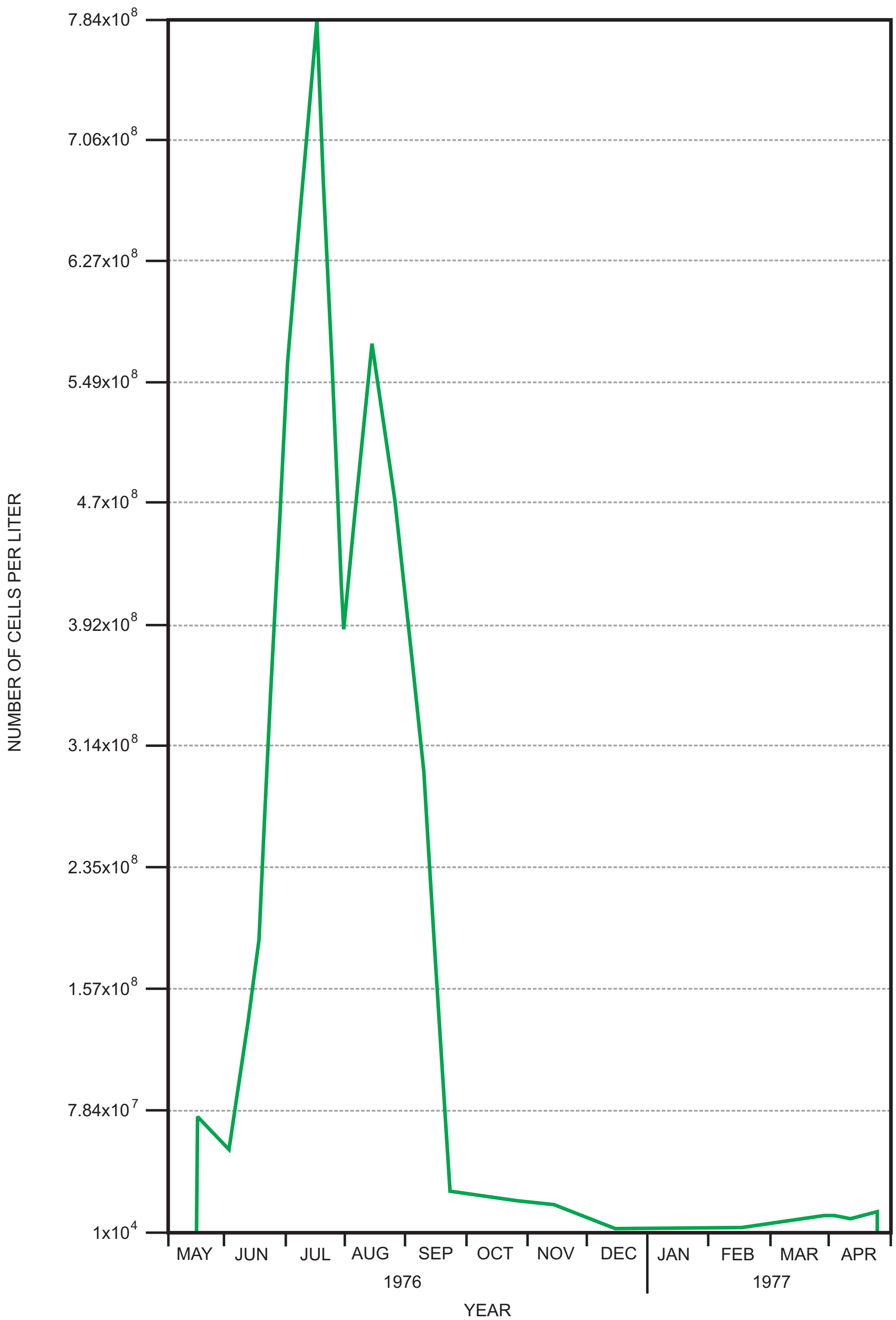
Blue-green algae (Cyanophyta) were the dominant group of algae in Pewaukee Lake throughout much of the year, comprising over 90 percent of the total numbers of algae in the Lake from mid-May through September 1976, and during November 1976. Blooms of blue-green algae in excess of 100 million cells per liter occurred from mid-June through early September. *Anacystis* sp. (= *Microcystis* sp.), a small, spherical, bloom-forming alga that occurs as a floating film on the water, was the most numerous species present during the entire period. Other dominant blue-green algae included: *Merismopedia tenuissima*, a flat, plate-like colony of round cells that occur in multiples of four; *Coelospharium naeglianum* and *C. pallidum*, hollow spheres of numerous coccoid algae; *Aphanocapsa delicattisrima*, a solid sphere of hundreds of shiny blue-green algae evenly spaced throughout the sphere; and, *Aphanazomenon* sp., a long thread-like group of rod-shaped cells which often clump together to form flakes which resemble grass clippings floating on the water. During these blooms, and the ensuing decomposition period, wind-concentrated accumulations of these algae resulted in odors and other undesirable conditions that occasionally curtailed swimming activities in the Lake.

During late-winter, February through mid-April 1977, diatoms (Bacillariophyceae) became the most numerous group of algae. Fluctuations in diatom cell counts ranged from 800,000 to more than eight million cells per liter. This seasonal increase or pulse in diatom growth is common to lakes in the Region, and is known as the spring diatom bloom. Diatoms are adapted to grow well under low light and cool temperature conditions and can, in some instances, form a brownish, slippery covering over submerged objects. The dominant diatom species included: *Stephanodiscus hantzii*, a disk-shaped cell with spines along the margin of the cell; *Astrionella formosa*, a star-shaped colony of match stick-shaped cells commonly found in cool waters of moderate to poor quality; and, *Synedra* sp., a needle-shaped cell. After the subsidence of the spring diatom bloom, warmer water temperatures and greater light intensities resulted in renewed growth and dominance of blue-green algae.

More recent observations of the algal community of Pewaukee Lake have been made by the Wisconsin Lutheran College during the summer of 2002. These observations indicated the presence of green and blue-green algae, and diatoms, as had been observed during the initial studies in 1976, albeit at lower densities than were reported in that study. As noted above, however, the summer of 2002 was unusual in that lake users reported the presence of algal blooms in the Lake for the first time in many years. This situation reflects the changing dynamics between rooted aquatic plants and algae that are characteristic of shallow lakes, waterbodies with depths similar to those of

Figure 11

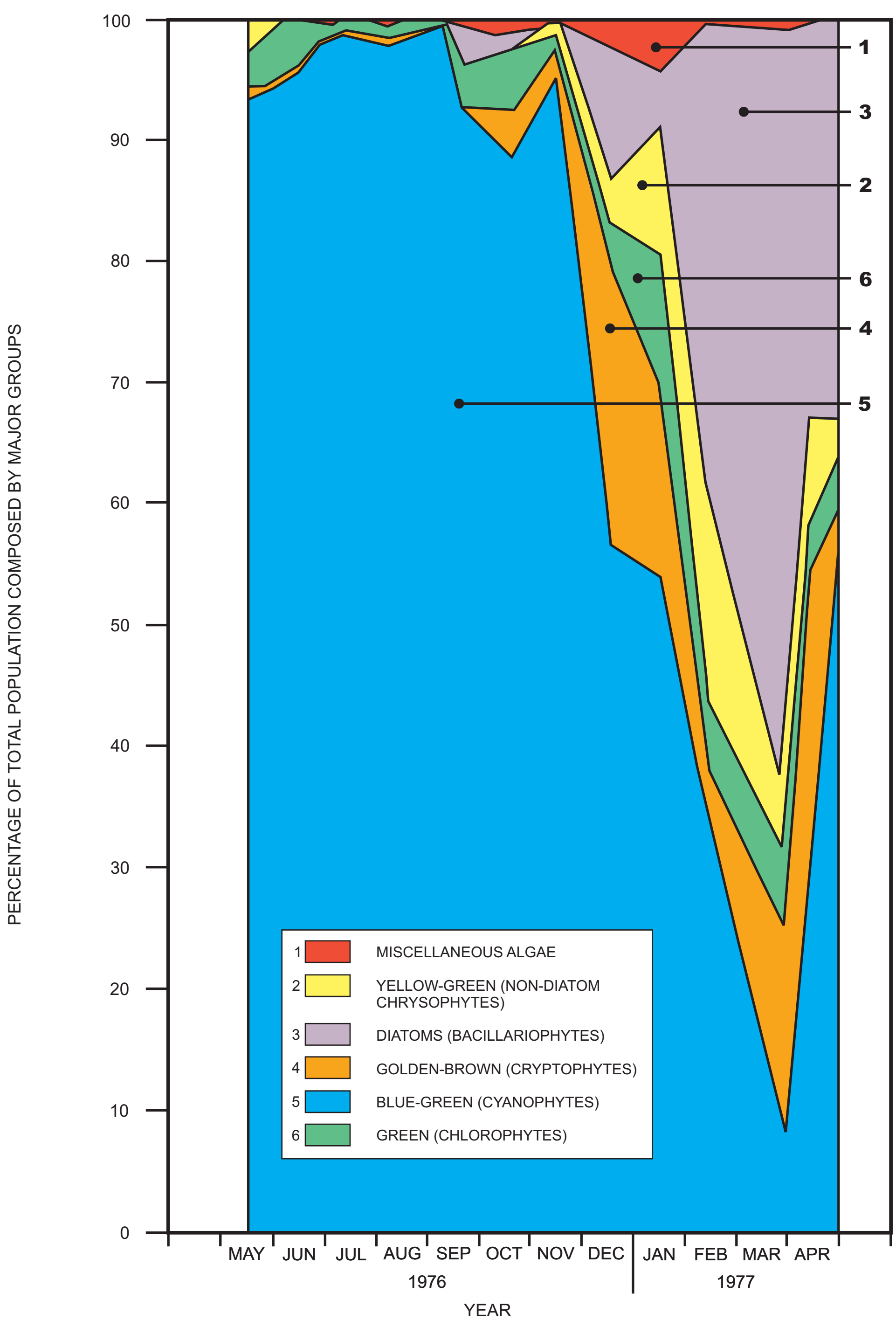
MONTHLY ALGAL POPULATIONS IN PEWAUKEE LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 12

TYPES OF ALGAE PRESENT IN PEWAUKEE LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

the easternmost embayment of Pewaukee Lake, as well as interannual climatic variability that forms a driving force for aquatic plant production in inland lakes.

Aquatic Macrophytes

Aquatic macrophytes—including emergent species such as rushes and cattails, floating-leaves species such as lily pads, and submergent species such as pondweeds, coontail and water milfoil—play an important role in the ecology of Southeastern Wisconsin lakes. Depending on their types, distribution and abundance, they can be either beneficial or a nuisance. Macrophytes growing in the proper locations and in reasonable densities in lakes are beneficial in maintaining lake fisheries and wildlife populations, providing habitat for a variety of aquatic organisms. They also may remove nutrients from the water that otherwise would contribute to excessive algal growth. Aquatic plants can become a nuisance 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. Many factors—including lake configuration, depth, water clarity, nutrient availability, bottom substrate, wave action, and type and size of fish populations present—determine the distribution and abundance of aquatic macrophytes in lakes, with most waterbodies within the Southeastern Wisconsin Region naturally supporting abundant and diverse aquatic plant communities. Illustrations of representative macrophyte species observed in Pewaukee Lake are set forth in Appendix A.

The initial aquatic plant survey of Pewaukee Lake was conducted on August 9, 1976. Table 18 sets forth the vegetation that was identified, the frequency of occurrence, and the relative abundance of each species noted for the 15 distinct areas surveyed. A comparison of the macrophyte communities surveyed during 1976 with those noted to have been present within the Lake during 1967 is also presented in Table 18. These data indicated that macrophyte growth in Pewaukee Lake was moderate to excessive at the time of the 1976 survey. The dominant submerged macrophyte identified during that survey was Eurasian water milfoil (*Myriophyllum spicatum*), a nonnative, invasive species introduced from Europe, which exhibited moderate to heavy growth throughout the Lake, as shown on Map 15.[1] Other common macrophytes included Sago pondweed (*Potamogeton pectinatus*), curly-leaf pondweed (*Potamogeton crispus*), pondweed (*Potamogeton vaginatus*), and stonewort (*Chara* sp.). Both Eurasian water milfoil and curly-leaf pondweed are designated as invasive, nonnative plants pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*. Both of these species can outcompete important native aquatic plant communities which can lead to the loss of plant diversity, degradation of water quality, and reduction in habitat value for fish, invertebrates and wildlife. The dominant emergent species observed during the 1976 survey included broadleaf cattail (*Typha latifolia*), soft-stem bulrush (*Scirpus validus*), and bur reed (*Sparganium eurycarpum*).

Aquatic plant surveys completed during the period from 1988 through 1997, summarized on Maps 16 through 19, show changing conditions within the Lake. Notably, curly-leaf pondweed (*Potamogeton crispus*) and Eurasian water milfoil (*Myriophyllum spicatum*) populations, which were widespread and abundant during the 1988 survey, as shown on Maps 20 and 21, diminished in areal extent during the 1990s, as shown on Maps 22 through 24. Curly-leaf pondweed (*Potamogeton crispus*) became a minor part of the aquatic plant community during the 1990s. Native aquatic plant communities experienced a resurgence during these years, as shown on Maps 16 through 19.

Most recently, an aquatic plant survey was conducted by staff of the Southeastern Wisconsin Regional Planning Commission, in association with staff from the Lake Pewaukee Sanitary District, during July and August 2000, and August 2001. During these surveys, 17 species of submergent aquatic plants were identified in Pewaukee Lake, as shown in Table 19. Species that interfere with the recreational and aesthetic use of the Lake, such as *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Potamogeton crispus*, were all found to be present in the Lake. Plant growth occurred throughout most of the Lake where the water depth was less than 15 feet. Eurasian

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

Table 18

AQUATIC PLANT SPECIES PRESENT IN PEWAUKEE LAKE: 1967 AND 1976

Area	Common Name	Scientific Name	Relative Abundance	
			1967 (lakewide)	1976 (area)
1	Stonewort	*Chara* sp.	Sparse	Moderate
	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Moderate
	Bassweed	*Potamogeton amplifolius*	- -	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Sparse
	Soft-stem bulrush	*Scirpus validus*	Very sparse	Very sparse
	Bur reed	*Sparganium eurycarpum*	Very sparse	Very sparse
	Broadleaf cat-tail	*Typha latifolia*	Very sparse	Very sparse
	Bladderwort	*Utricularia purpurea*	Very sparse	Sparse
2	Stonewort	*Chara* sp.	Sparse	Abundant
	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Abundant
	Clasping leaf pondweed	*Potamogeton richardsonii*	- -	Very sparse
	Pondweed	*Potamogeton vaginatus*	- -	Very sparse
3	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Abundant
	Curly-leaf pondweed	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Sparse
	Pondweed	*Potamogeton vaginatus*	- -	Very sparse
4	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Abundant
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
5	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Very abundant
	Yellow water lily	*Nuphar* sp.	Very sparse	Very sparse
	Curly-leaf pondweed[a]	*Potamogeton crispus*	Sparse	Moderate
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
6	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Very abundant
	Curly-leaf pondweed[a]	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Sparse
	Pondweed	*Potamogeton vaginatus*	- -	Very sparse
7	Water weed	*Anacharis* sp.	Very sparse	Very sparse
	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Abundant
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
8	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Moderate
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
	Pondweed	*Potamogeton vaginatus*	- -	Very sparse
9	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Very abundant
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
	Curly-leaf pondweed[a]	*Potamogeton crispus*	Sparse	Moderate
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
	Pondweed	*Potamogeton vaginatus*	- -	Very sparse
10	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Very abundant
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
	Curly-leaf pondweed	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
11	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Abundant
	Curly-leaf pondweed	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
	Pondweed	*Potamogeton vaginatus*	- -	Sparse

Table 18 (continued)

Area	Common Name	Scientific Name	Relative Abundance	
			1967 (lakewide)	1976 (area)
12	Stonewort	*Chara* sp.	Sparse	Very sparse
	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Moderate
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
13	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Very abundant
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
	Yellow water lily	*Nuphar* sp.	Very sparse	Very sparse
	Water lily	*Nymphaea* sp.	Sparse	Very sparse
	Curly-leaf pondweed	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Moderate
	Pondweed	*Potamogeton vaginatus*	- -	Sparse
	Soft-stem bulrush	*Scirpus validus*	Very sparse	Very sparse
	Bur reed	*Sparganium eurycarpum*	Very sparse	Very sparse
	Broadleaf cat-tail	*Typha latifolia*	Very sparse	Very sparse
14	Water weed	*Anacharis* sp.	Very sparse	Very sparse
	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Abundant
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
	Curly-leaf pondweed	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
15	Eurasian water milfoil[a]	*Myriophyllum spicatum*	Abundant	Very abundant
	Bushy pondweed	*Najas flexilis*	- -	Very sparse
	Curly-leaf pondweed	*Potamogeton crispus*	Sparse	Very sparse
	Sago pondweed	*Potamogeton pectinatus*	Sparse	Very sparse
	Soft-stem bulrush	*Scirpus validus*	Very sparse	Very sparse
	Bur reed	*Sparganium eurycarpum*	Very sparse	Very sparse
	Broadleaf cat-tail	*Typha latifolia*	Very sparse	Very sparse

[a]*Nonnative or alien species.*

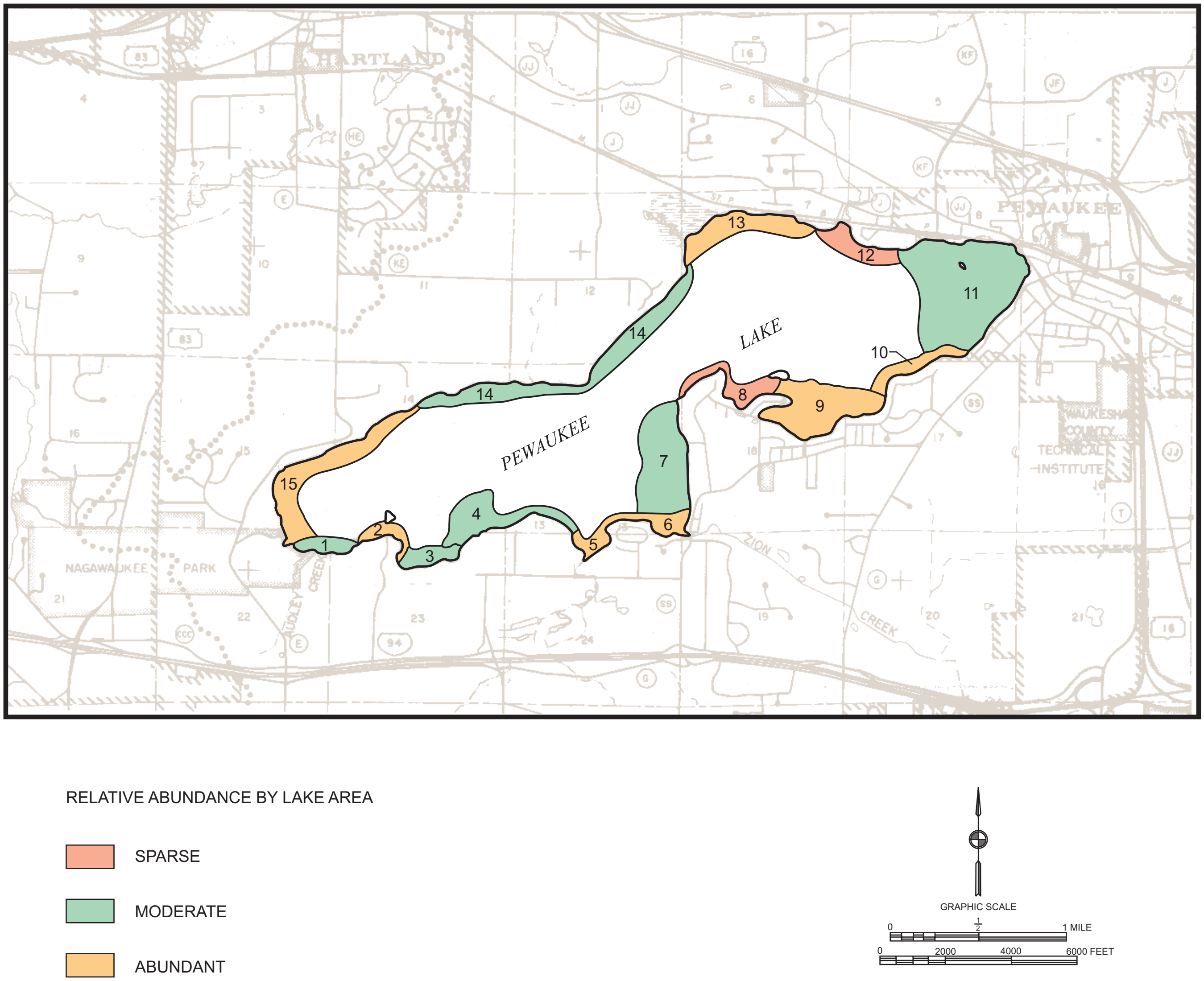
Source: Wisconsin Department of Natural Resources and SEWRPC.

water milfoil (*Myriophyllum spicatum)*, coontail (*Ceratophyllum demersum*), wild celery (*Vallisneria americana*), and muskgrass (*Chara* spp.) appeared to be the dominant species, while healthy populations of pondweeds (*Potamogeton* spp.) appeared to be scattered throughout the Lake. Pondweeds were most commonly found at depths of between five and 10 feet, as shown on Map 25. Eurasian water milfoil was dominant throughout the Lake, but largely confined to areas of the Lake with depths of between five and 15 feet—growths of this plant reached an areal extent that was not dissimilar to that reported from the Lake during 1988, as can be seen by comparing Maps 21 and 26.

In general, Pewaukee Lake supports a healthy and diverse aquatic macrophyte community. Changes in the aquatic macrophyte species distribution and abundance in Pewaukee Lake, between 1988 and 2000, are summarized in Table 19. The growths of Eurasian water milfoil (*Myriophyllum spicatum*) in the Lake during the year 2000 were among the heaviest growths of Eurasian water milfoil in recent years. These growths created nuisance conditions in much of the eastern basin of the Lake and in the western basin of the Lake where depths were less than about 12 feet. Only during 1990 did the Lake Pewaukee Sanitary District's aquatic plant harvesting program exceed the amount of aquatic macrophytes harvested during 2000, as shown on Figure 13. The resurgence of Eurasian water milfoil within the Lake during recent years may reflect the cyclical nature of the climatic regime within the Region, and the tolerance of the Eurasian water milfoil to colder water temperatures than those generally tolerated by native aquatic plant species.

Map 15

AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 1976



Source: SEWRPC.

Aquatic Plant Management

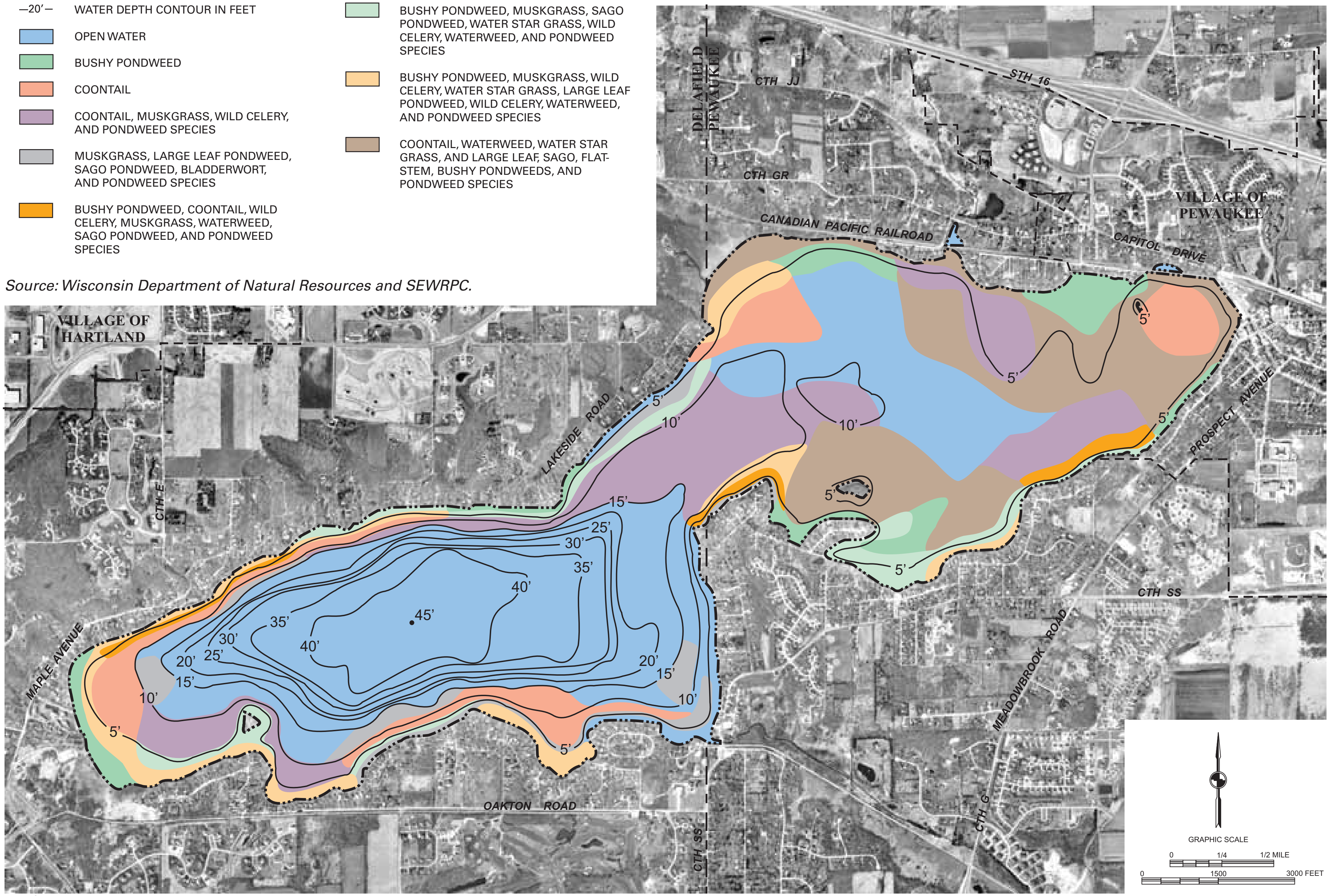
Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the WDNR prior to 1950. Thus, while previous interventions were likely, the first recorded efforts to manage the aquatic plants in Pewaukee Lake have taken place since 1950. Aquatic plant management activities in Pewaukee Lake can be categorized as chemical macrophyte and algal control, and macrophyte harvesting. 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 macrophyte growths on Pewaukee Lake have historically resulted in the application of a chemical control program. Although the use of chemicals to control aquatic plants has been regulated in

Map 16

NATIVE AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 1988

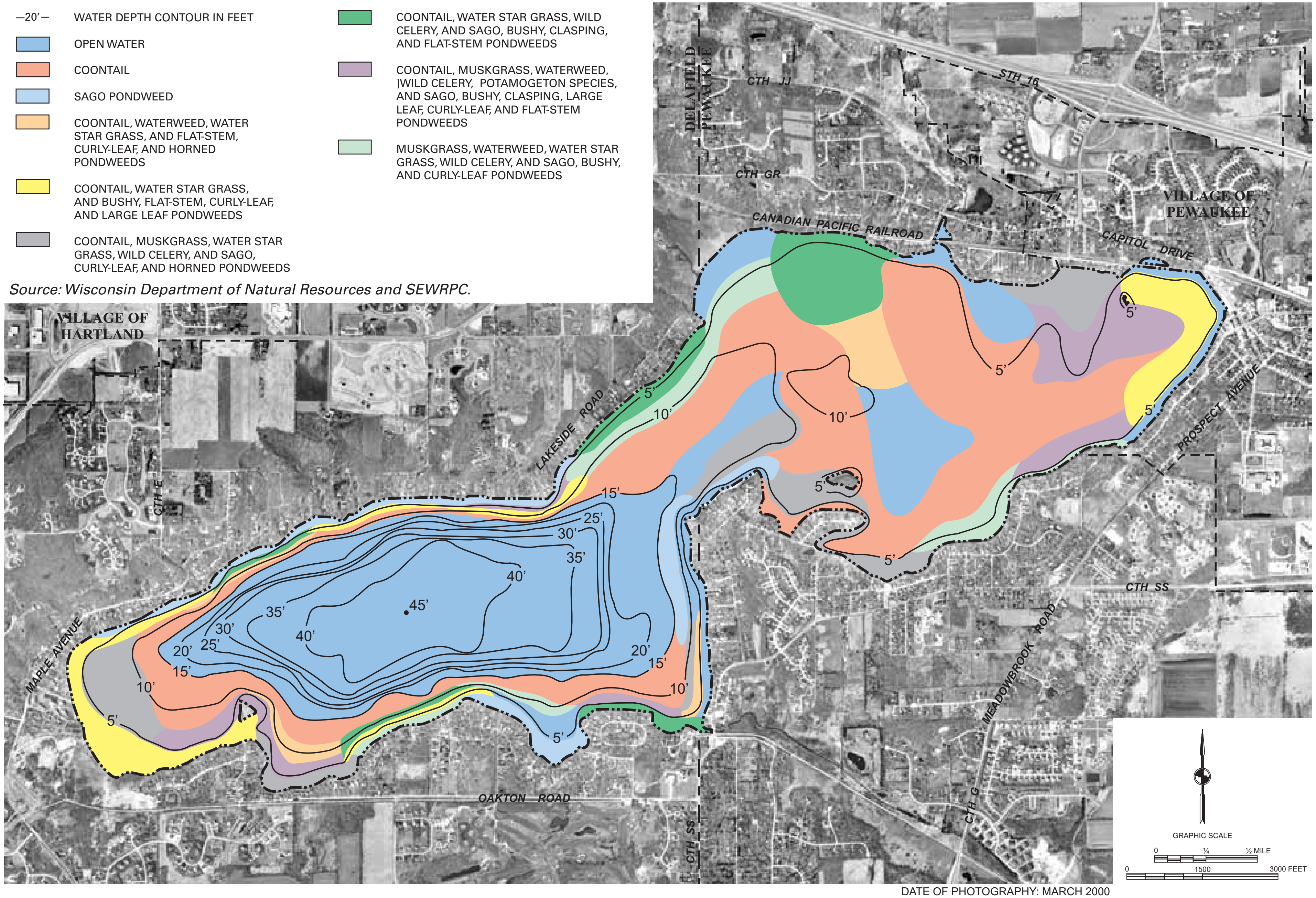


Source: Wisconsin Department of Natural Resources and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

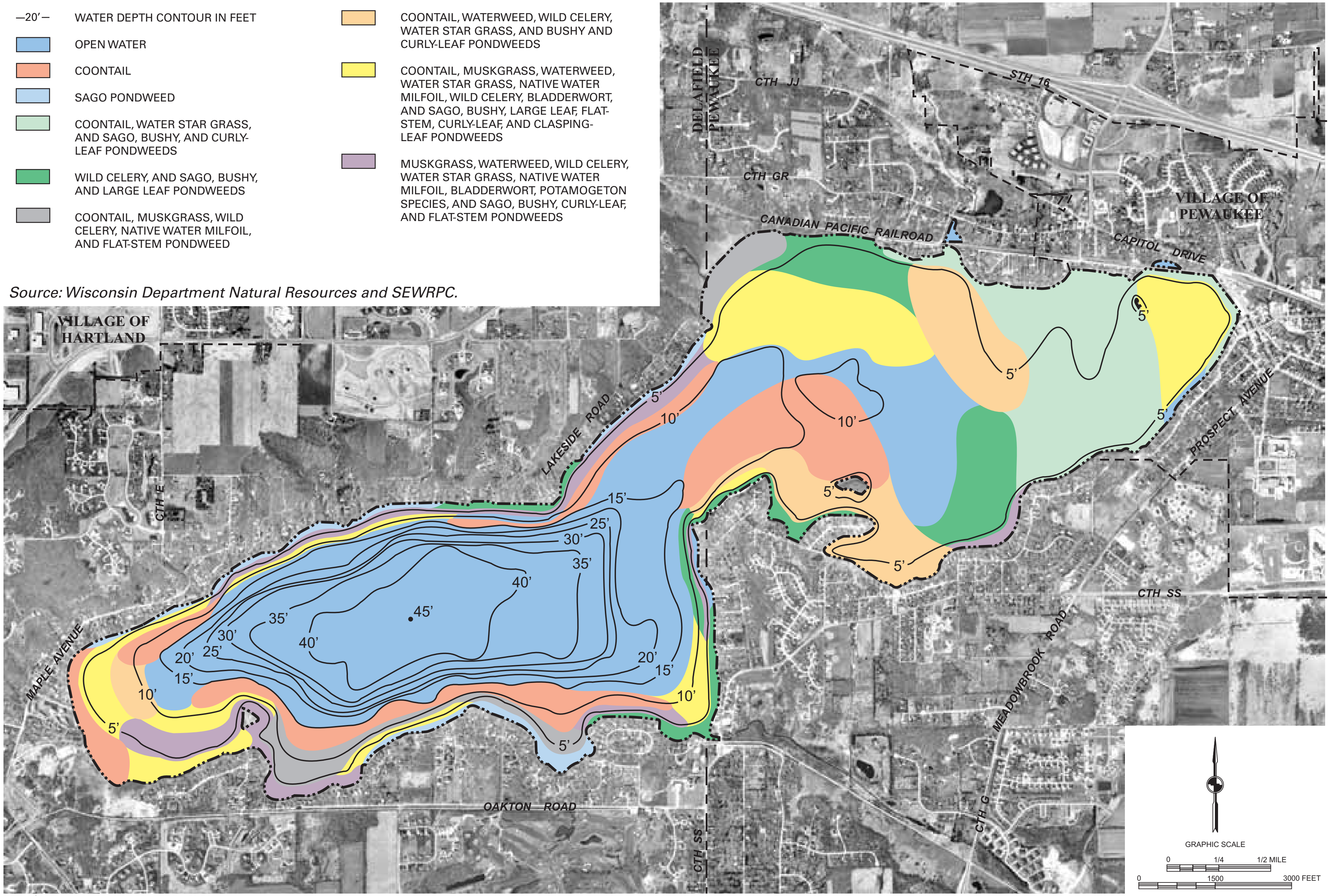
Map 17

NATIVE AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 1991



Map 18

NATIVE AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 1994

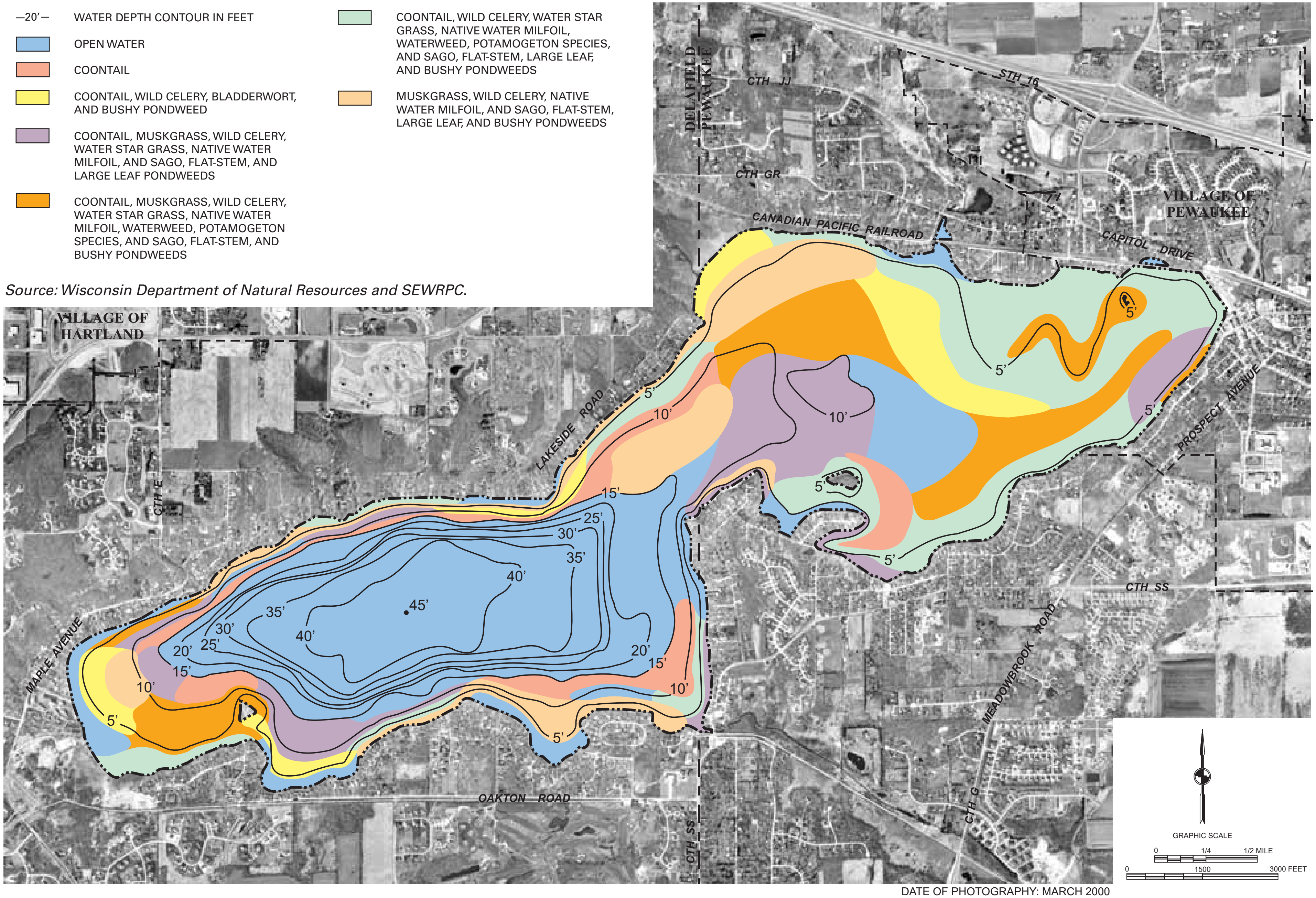


Source: Wisconsin Department Natural Resources and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Map 19

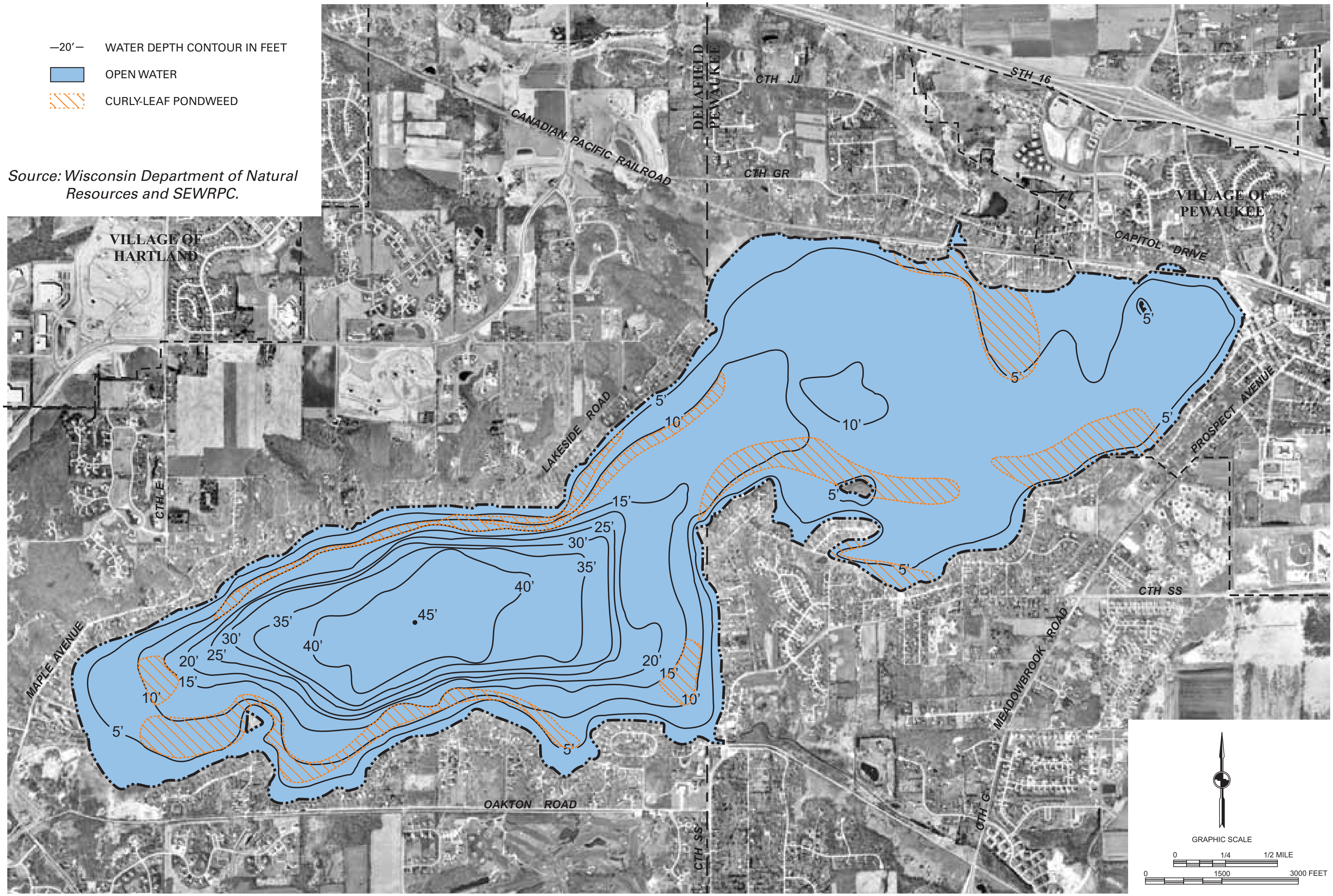
NATIVE AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

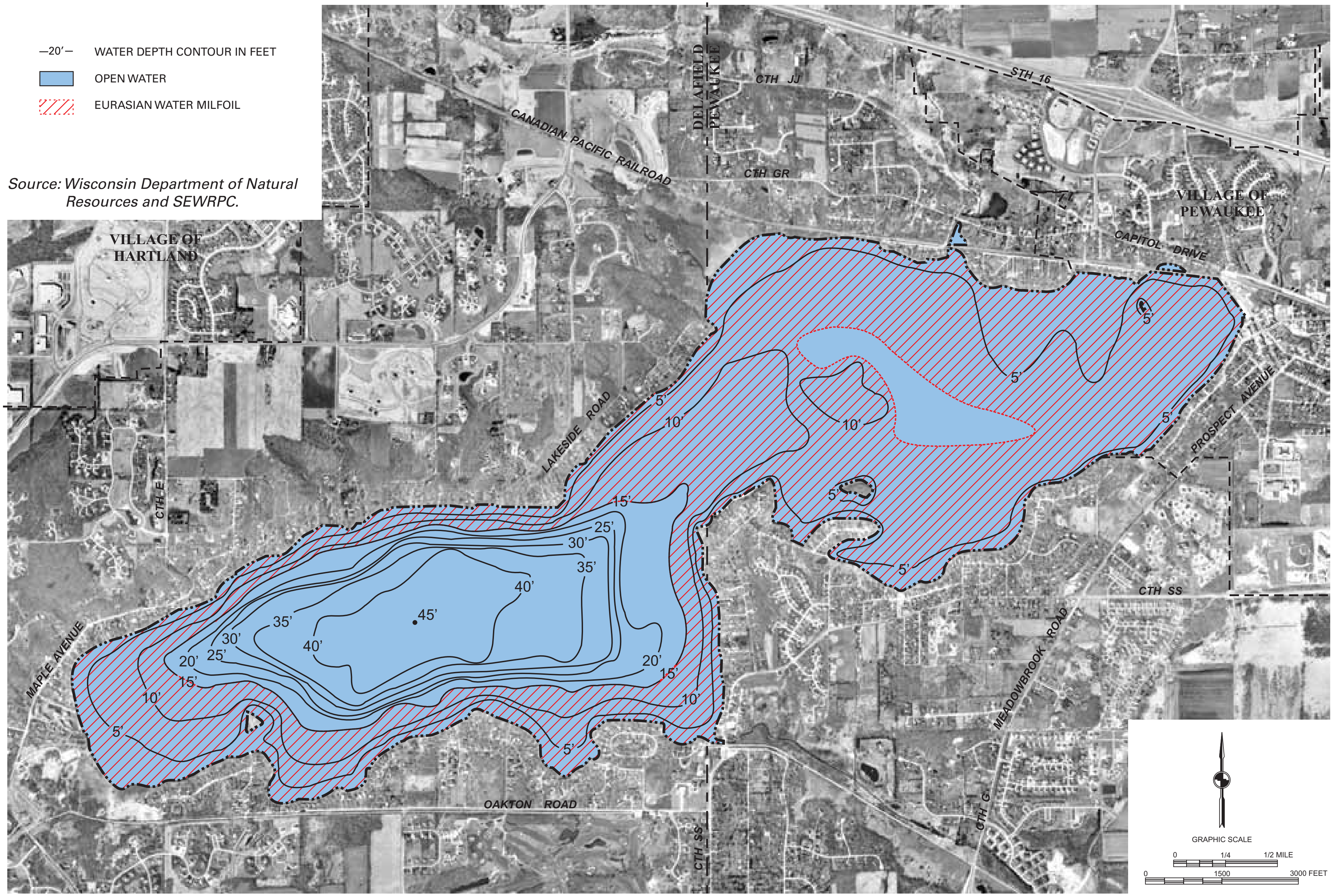
Map 20

DISTRIBUTION OF CURLY-LEAF PONDWEED IN PEWAUKEE LAKE: 1988



Map 21

DISTRIBUTION OF EURASIAN WATER MILFOIL IN PEWAUKEE LAKE: 1988

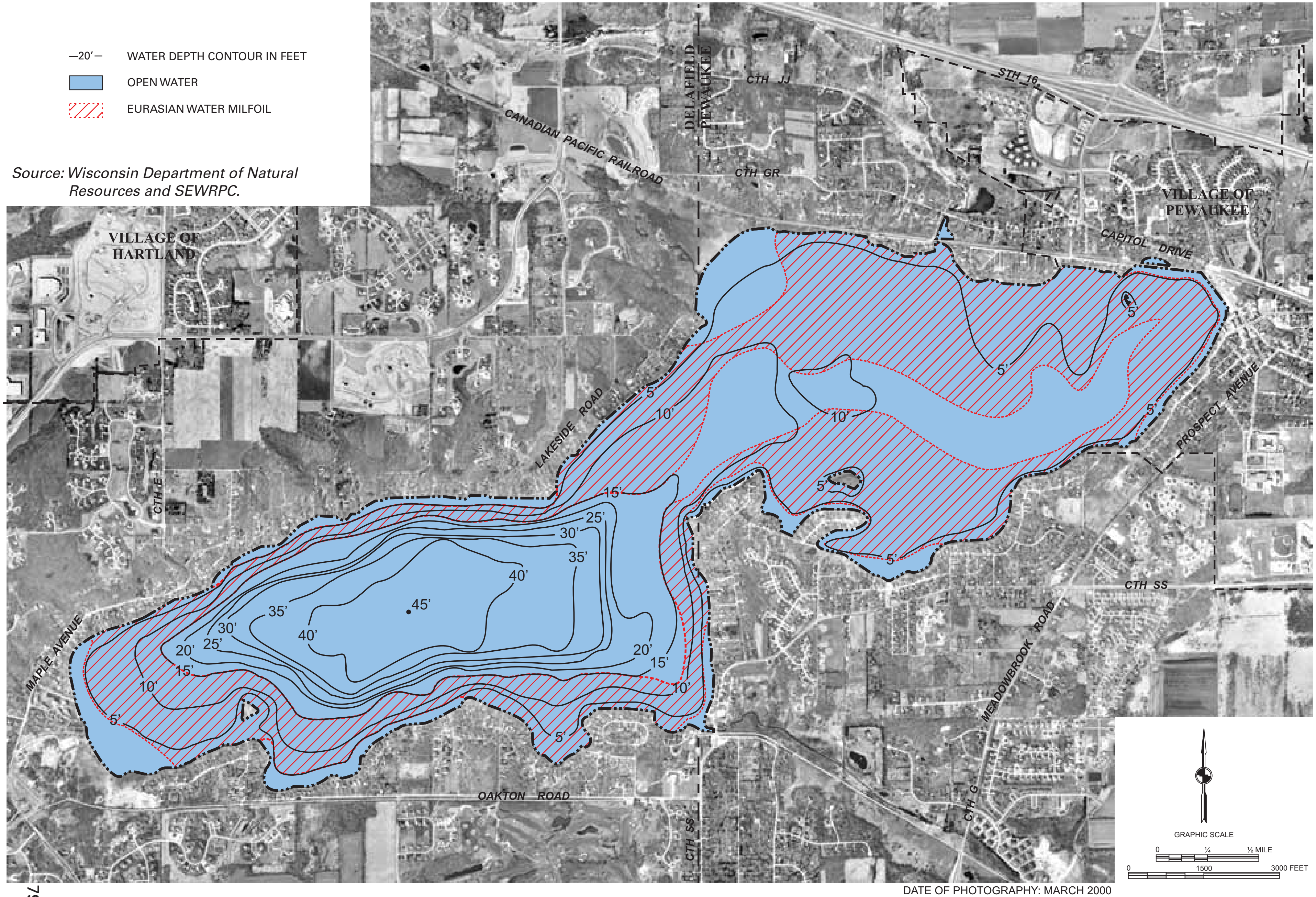


Source: Wisconsin Department of Natural Resources and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Map 22

DISTRIBUTION OF EURASIAN WATER MILFOIL IN PEWAUKEE LAKE: 1991



Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 23

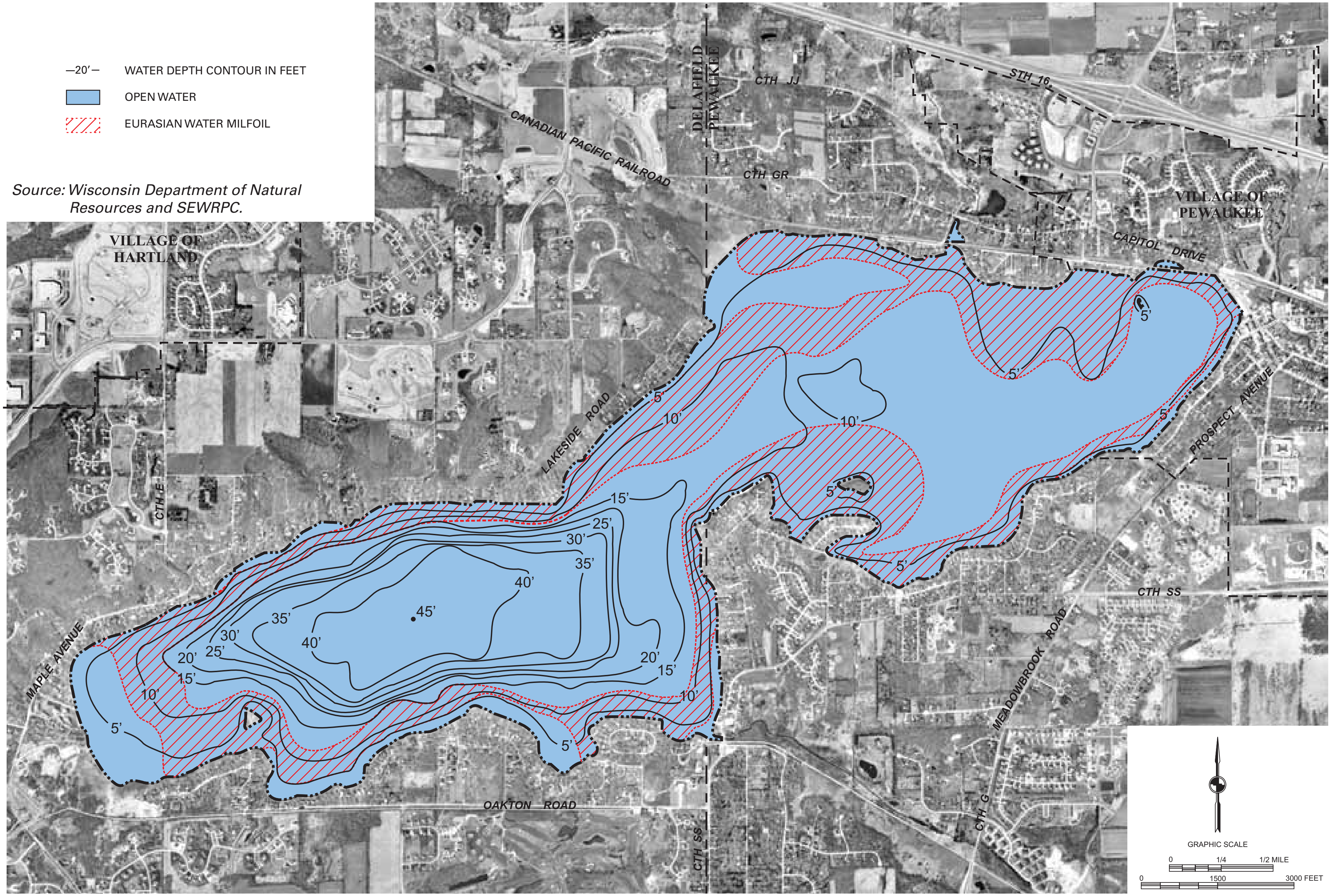
DISTRIBUTION OF EURASIAN WATER MILFOIL IN PEWAUKEE LAKE: 1994

—20'— WATER DEPTH CONTOUR IN FEET

OPEN WATER

EURASIAN WATER MILFOIL

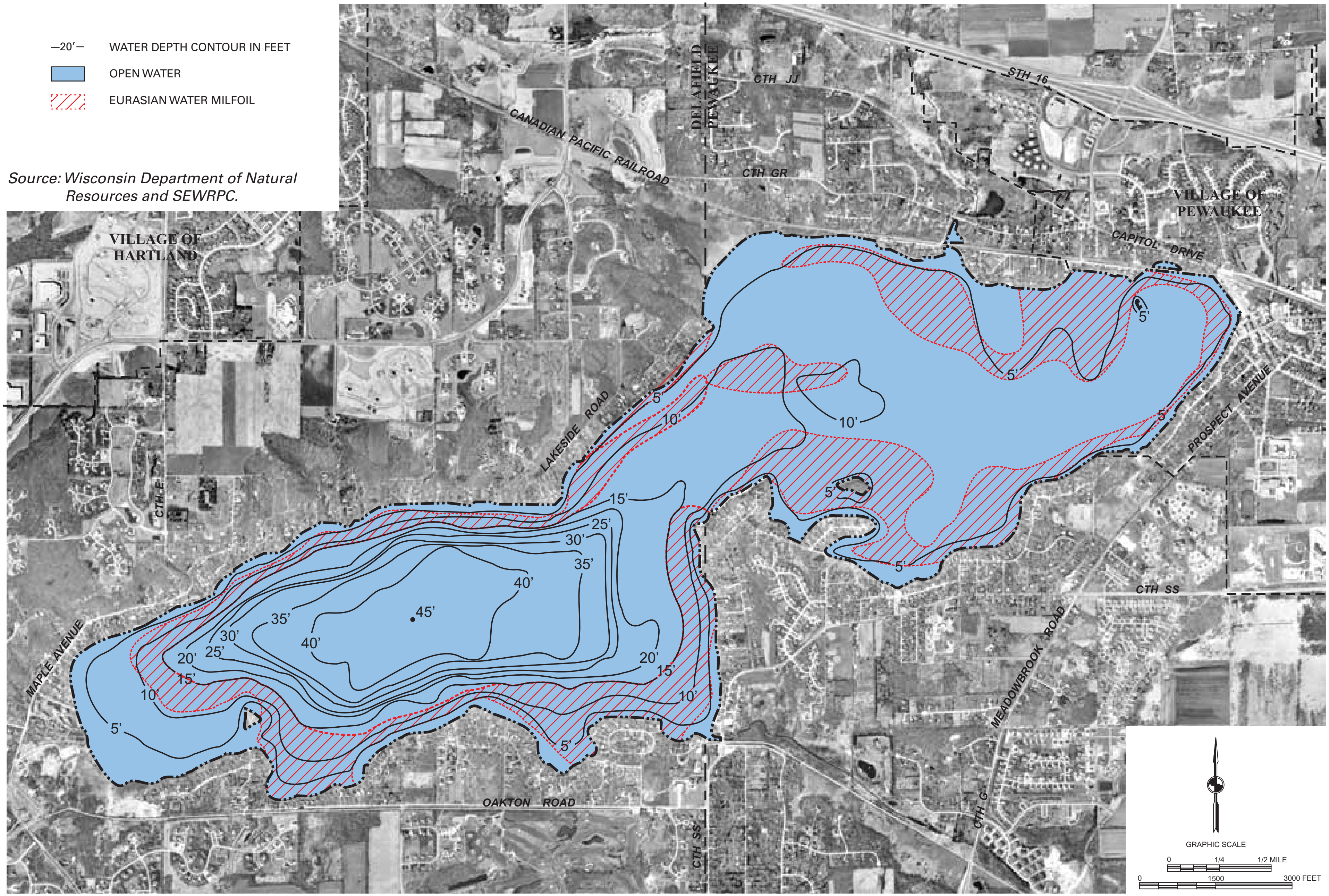
Source: Wisconsin Department of Natural Resources and SEWRPC.



DATE OF PHOTOGRAPHY: MARCH 2000

Map 24

DISTRIBUTION OF EURASIAN WATER MILFOIL IN PEWAUKEE LAKE: 1997



Source: Wisconsin Department of Natural Resources and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Table 19

PEWAUKEE LAKE AQUATIC PLANT SPECIES PRESENT IN PEWAUKEE LAKE: 1988-2000

Aquatic Plant Species	1988 Survey Density[a,b]	1991 Survey Density[a,b]	1994 Survey Density[a,b]	1997 Survey Density[a,b]	2000 Survey Density[b]
Ceratophyllum demersum (coontail)	2.75	2.97	2.22	2.40	2.57
Chara vulgaris (muskgrass)	1.77	1.03	1.50	1.13	2.15
Elodea canadensis (waterweed)	0.56	0.65	1.25	1.65	1.86
Myriophyllum sp. (native water milfoil)	- -	- -	1.20	1.91	1.00
Myriophyllum spicatum (Eurasian water milfoil)[c]	3.62	2.96	2.76	2.47	3.27
Najas flexilis (bushy pondweed)	2.07	1.47	1.79	0.63	2.61
Najas guadalupensis (southern naiad)	- -	- -	- -	1.72	- -
Potamogeton amplifolius (large-leaf pondweed)[d]	1.50	0.50	0.40	1.17	1.50
Potamogeton crispus (curly-leaf pondweed)[c]	1.82	1.58	0.88	- -	1.00
Potamogeton filiformis (thread-leaf pondweed)	- -	0.75	- -	- -	- -
Potamogeton illinoensis (Illinois pondweed)[d]	- -	- -	- -	- -	0.60
Potamogeton natans (floating-leaf pondweed)	- -	- -	- -	- -	0.60
Potamogeton pectinatus (Sago pondweed)[d]	0.94	1.56	1.24	1.13	1.56
Potamogeton praelongus (white-stem pondweed)[d]	- -	- -	- -	- -	1.20
Potamogeton richardsonii (clasping-leaf pondweed)[d]	- -	0.42	0.25	- -	1.00
Potamogeton zosteriformis (flat-stemmed pondweed)	0.75	0.80	1.05	1.48	1.60
Potamogeton spp. (pondweed)	1.90	0.25	0.25	0.63	- -
Utricularia sp. (bladderwort)	0.25	- -	0.88	0.75	1.00
Vallisneria americana (water celery)[c]	0.77	0.79	1.16	1.50	2.51
Zosterella dubia (water stargrass)	0.75	0.75	0.63	0.67	2.00
Shannon-Weaver Diversity Index Value[e]	66.7	57.9	63.9	70.7	110.3

NOTE: Species mean density for all sample points including sample points where a particular species did not occur in Pewaukee Lake: Abundant (density rating equals 4 to 5), Common (density rating equals 2 to 3), Scarce (density rating equals 1), and Absent (density rating equals 0).

[a]*Survey conducted by Wisconsin Department of Natural Resources as part of the Long-Term Trend Monitoring Program.*

[b]*Maximum density equals 5.0.*

[c]*Designated as invasive and nonnative aquatic plant species pursuant to section NR 109.07 of the* Wisconsin Administrative Code.

[d]*Considered a high-value aquatic plant species known to offer important values in specific aquatic ecosystems under Section NR 107.08 (4) of the* Wisconsin Administrative Code.

[e]*The Shannon-Weaver index indicates the "evenness" of the community distribution within the lake basin; the higher the number, the more diverse the plant community.*

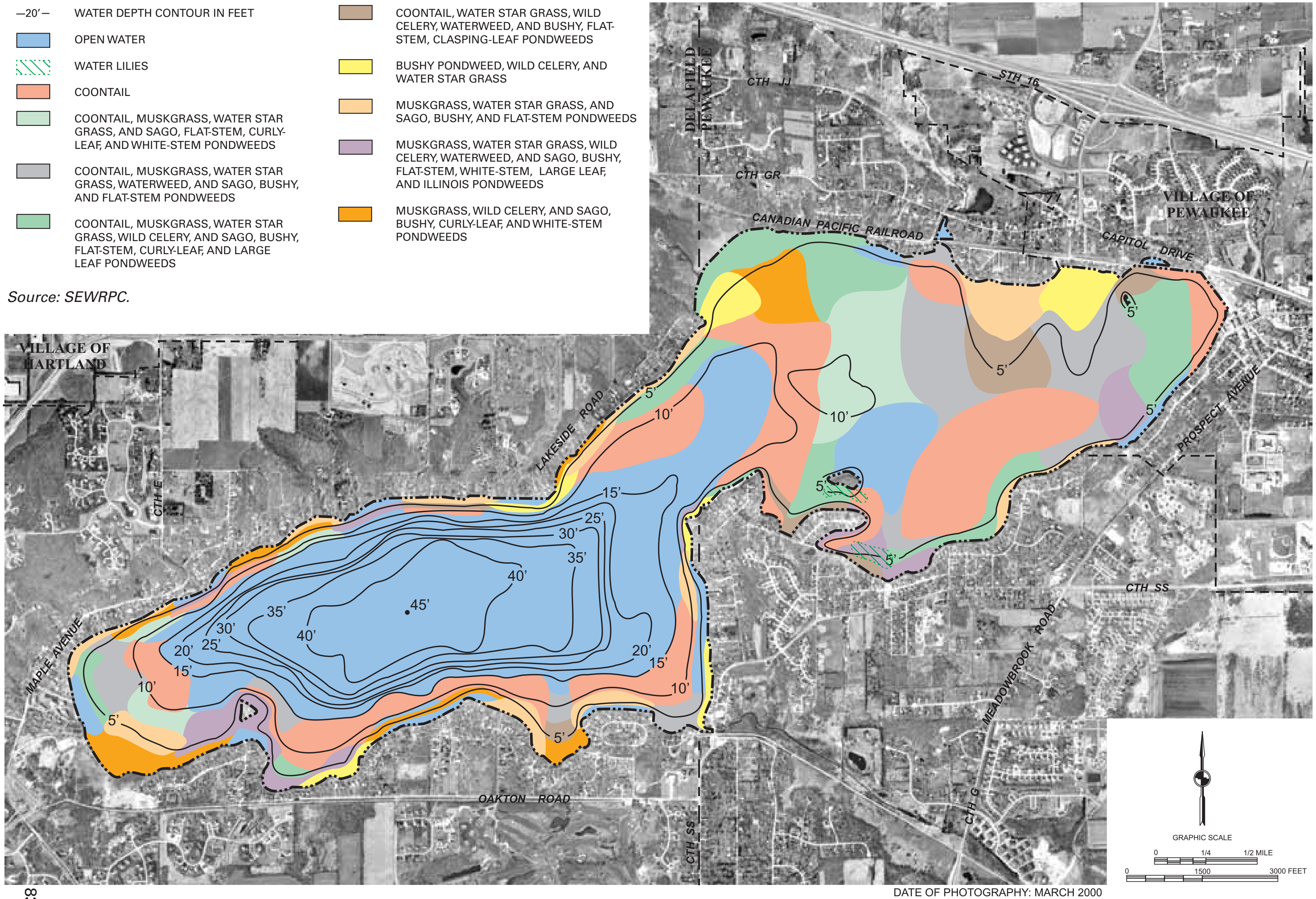
Source: Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and SEWRPC.

Wisconsin since 1941, records of aquatic herbicide applications have only been maintained by the Wisconsin Department of Natural Resources beginning in 1950. Recorded chemical herbicide treatments that have been applied to Pewaukee Lake from 1950 through 1989 are set forth in Table 20.

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 Pewaukee Lake, and years of application during the period 1950 through 1967, are listed in Table 20. The total amount of sodium arsenite applied over this 17-year period was about 334,232 pounds, which is the largest mass of this chemical herbicide applied to any lake in Wisconsin.

Map 25

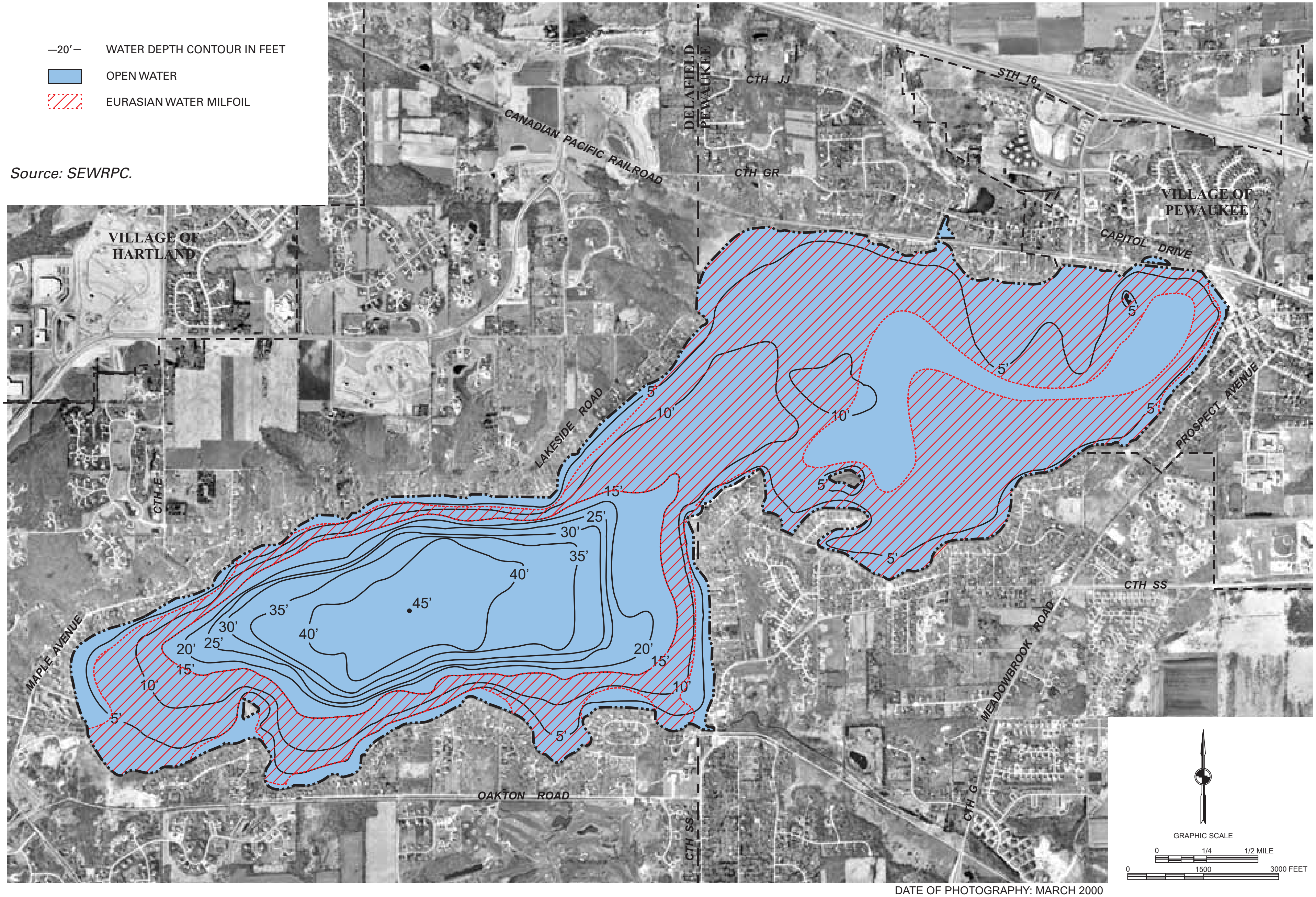
NATIVE AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 2000



Source: SEWRPC.

Map 26

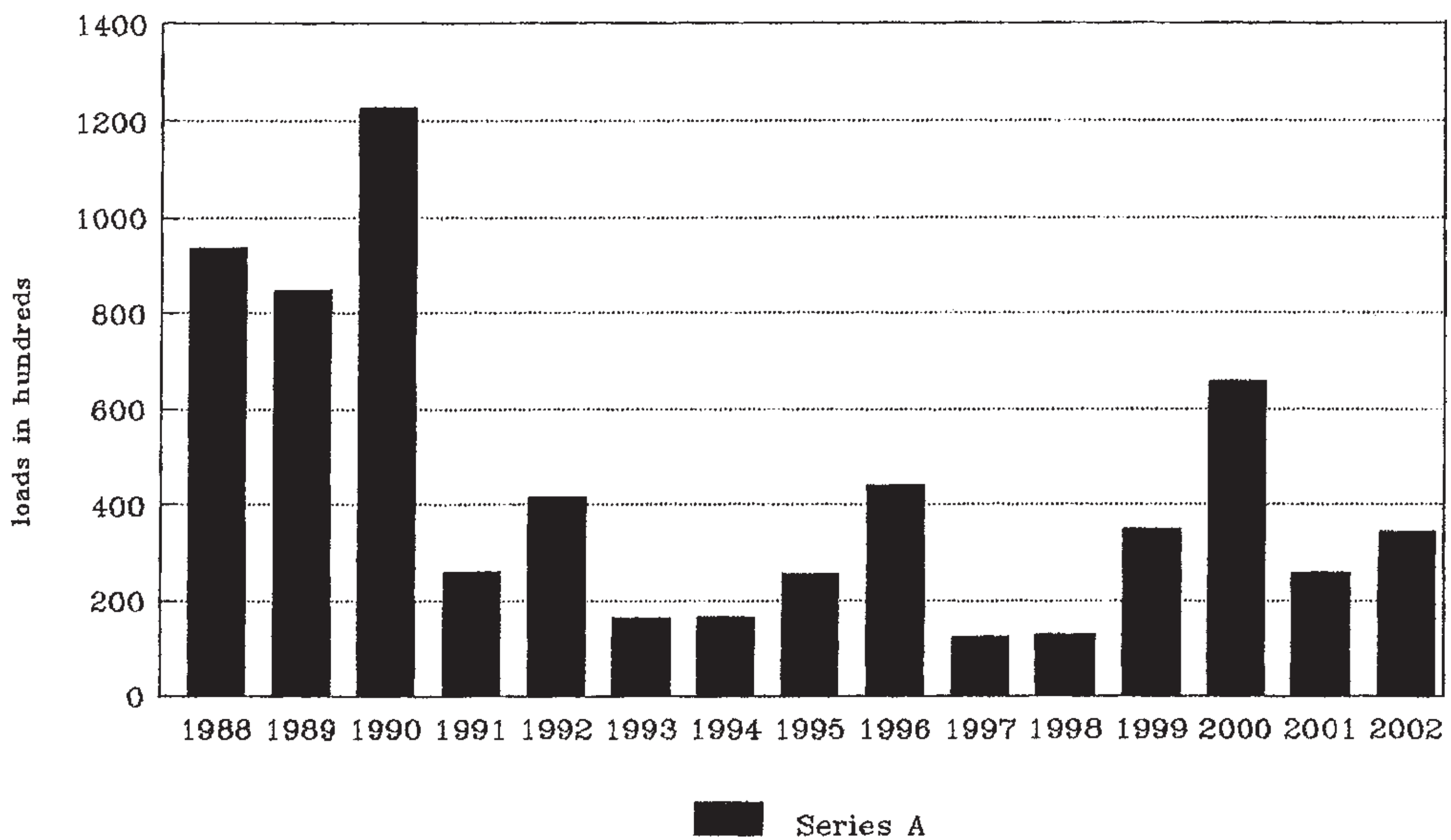
DISTRIBUTION OF EURASIAN WATER MILFOIL IN PEWAUKEE LAKE: 2000



Source: SEWRPC.

Figure 13

TOTAL BIOMASS OF AQUATIC PLANTS HARVESTED FROM PEWAUKEE LAKE: 1988-2002



Source: Lake Pewaukee Sanitary District and SEWRPC.

Table 20

CHEMICAL CONTROL OF AQUATIC PLANTS IN PEWAUKEE LAKE: 1950-2000

Year	Total Acres Treated	Algae Control			Macrophyte Control				
		Copper Sulfate (pounds)	Blue Vitriol (pounds)	Cultrine or Cutrine-+	Sodium Arsenite (pounds)	2, 4-D (gallons)	Diquat (gallons)	Endothal (gallons)	Aquathol (gallons)
1950-1969	882.9	66,105	16,680	2,525.0 gallons	217,040	- -	- -	- -	- -
1960	375.8	- -	6,600	1,500.0 pounds	19,680	- -	- -	- -	- -
1961	364.4	- -	6,750	- -	21,600	- -	- -	- -	- -
1962	257.0	7,600	- -	322.6 pounds	5,124	53.0	- -	- -	- -
1963	361.0	6,215	- -	4,665.0 pounds	23,334	- -	- -	- -	- -
1964	413.0	5,450	- -	- -	21,792	- -	- -	- -	- -
1965	1,282.6	6,150	- -	- -	17,982	- -	- -	- -	- -
1966	240.4	2,464	- -	- -	2,280	- -	48.4	- -	52.4
1967	104.0	200	- -	- -	5,400	15.0	- -	- -	11.0
1968	404.8	1,250	- -	- -	- -	465.0	- -	- -	700.0
1969	127.0	200	- -	- -	- -	90.0	- -	- -	100.0
1970[a]	129.5	1,805	- -	- -	- -	15.0	- -	5	240.0
1971	56.6	240	- -	- -	- -	45.0	5.0	- -	- -
1972	59.3	140	- -	- -	- -	- -	10.0	- -	25.0
1973	168.4	- -	- -	- -	- -	578.0	- -	- -	135.0
1974	32.1	- -	- -	- -	- -	175.0	- -	- -	- -
1975	25.8	- -	- -	- -	- -	124.0	- -	- -	- -
1976	2.0	- -	- -	- -	- -	8.0 5.0 pounds	- -	- -	- -
1977	56.9	- -	- -	- -	- -	227.2	- -	- -	- -
1978	- -	- -	- -	- -	- -	- -	- -	- -	- -
1979	- -	- -	- -	- -	- -	- -	- -	- -	- -
1980	33.7	- -	- -	- -	- -	163.0	- -	- -	- -
1981	49.7	- -	- -	- -	- -	303.0	- -	- -	- -
1982	1.4	- -	- -	- -	- -	9.0	- -	- -	- -
1983	- -	- -	- -	- -	- -	- -	- -	- -	- -
1984	16.2	- -	- -	- -	- -	45.0	- -	- -	- -
1985	37.8	- -	- -	- -	- -	70.0	- -	- -	- -
1986	2.8	10	- -	5.0 gallons	- -	5.0	- -	- -	- -
1987	0.4	- -	- -	2.0 gallons[b]	- -	- -	- -	- -	- -
1988	0.5	- -	- -	- -	- -	10 pounds[b]	- -	- -	30.0 pounds[b]
1989	0.1	- -	- -	- -	- -	30 pounds[b]	- -	- -	- -
1990-2000	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total	- -	97,829	30,030	6,492.6 pounds, 2,532.0 gallons	334,232	2,390.2 gallons, 45.0 pounds	63.4	5	1,163.4 gallons, 30.0 pounds

[a]120 pounds of lime were applied in 1970.

[b]Private chemical treatments of aquatic plants.

Source: Wisconsin Department of Natural Resources and SEWRPC.

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

When it became apparent that arsenic was accumulating in the sediments of treated lakes and that the accumulations of arsenic were found to present potential health hazards to both humans and aquatic life, the use of sodium arsenite was discontinued in the State in 1969. Consequent to the application of sodium arsenite to Pewaukee Lake, the concentrations of arsenic within the lake sediments of Pewaukee Lake have been reported by the WDNR to exceed the draft sediment quality criteria limits set forth by the Wisconsin Department of Natural Resources, and shown in Table 21. During their 1978 investigation, the WDNR reported sediment arsenic concentrations of 160 milligrams per kilogram (mg/kg) in surfacial sediments in the Lake. Such concentrations may continue to pose a potential environmental hazard, and may necessitate to disposal of dredged lake sediments within a secure waste disposal site, thereby significantly increasing the costs associated with sediment removal from Pewaukee Lake. Notwithstanding, data on dissolved arsenic concentrations in Pewaukee Lake, reported by the WDNR between 1964 and 1978, suggested that, while arsenic was being mobilized from the sediments during anaerobic periods, it was being flushed from the Lake through the outlet structure—observed concentrations of dissolved arsenic decreased from about 0.33 milligrams per liter (mg/l) to between 0.01 mg/l and 0.05 mg/l during the period of observation.

As shown in Table 20, the aquatic herbicides diquat, endothall, and 2,4-D have also been applied to Pewaukee Lake to control aquatic macrophyte growth. Diquat and endothall (Aquathol) are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Endothall primarily kills pondweeds, but does not control such nuisance species as Eurasian water milfoil (*Myriophyllum spicatum*). The herbicide 2,4-D is a systemic herbicide that is absorbed by the leaves and translocated to other parts of the plant; it is more selective than the other herbicides listed above and is generally used to control Eurasian water milfoil. However, it will also kill species such as water lilies (*Nymphaea* sp. and *Nuphar* sp.). The present restrictions on water use after application of these herbicides are given in Table 22.

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to Pewaukee Lake. As shown in Table 20, copper sulfate (Cutrine Plus) has been applied to Pewaukee Lake, on occasion. Like arsenic, copper, the active ingredient in many algicides including Cutrine Plus, may accumulate in the bottom sediments. Excessive levels of copper may be toxic to fish and benthic organisms, but, generally, have not been found to be harmful to humans.[2] Restrictions on water uses after application of Cutrine Plus are also given in Table 22.

Macrophyte Harvesting

Excessive macrophyte growth on Pewaukee Lake has historically resulted in a control program that used both harvesting and chemicals. The existing macrophyte control program follows an aquatic management plan developed for the Lake in 1992.[3] The harvesting program emphasizes removal of nuisance plants necessary to facilitate recreational use, rather than 100 percent plant removal. Under this program, the City of Pewaukee contracts with the Lake Pewaukee Sanitary District to conduct the harvesting. In addition, the Village of Pewaukee also operates an aquatic plant harvesting program on the Lake. The harvesting operations conducted by the Lake Pewaukee Sanitary District and the Village of Pewaukee are carried out using three Aquarius Systems harvesters, two being the H-620 model and one being the H-420 model, and three high-speed transport barges. One shore conveyer is used by the Sanitary District for off-loading and another by the Village.

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

[3]*Lake Pewaukee Sanitary District,* An Aquatic Plant Management Plan for Pewaukee Lake, Pewaukee, Wisconsin, *January 1992*

Table 21

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

Table 22

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.

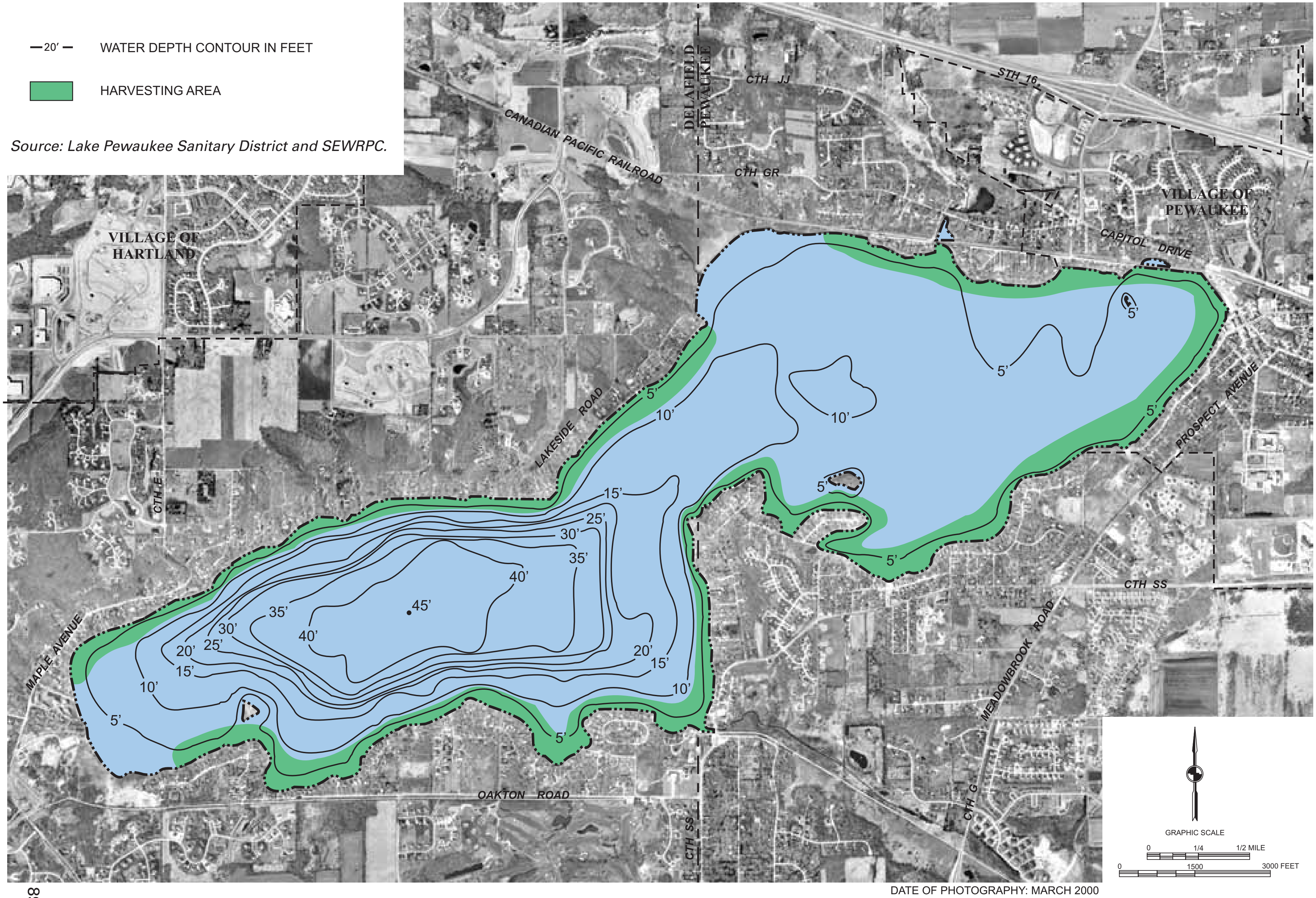
[e]According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the drinking water tolerance of fluridone (Sonar®) is 0.15 parts per million (ppm).

Source: Wisconsin Department of Natural Resources.

Typically, harvesting prior to June 15 is limited to cutting access channels to facilitate navigation to piers and channels. After mid-June, the harvesting operation is expanded within the areas of the Lake that experience nuisance plant conditions, within the slow-no-wake zone, up to approximately 200 feet from pierheads. During periods of exceptionally heavy aquatic plant growth, the aquatic plant harvesting operations may be expanded to two shifts, operating between 5 a.m. and 7 p.m. The biomass of aquatic plants harvested is shown in Figure 13, and the general location of the harvesting operations is shown on Map 27. Permits are required pursuant to

Map 27

GENERALIZED LOCATIONS OF AQUATIC PLANT HARVESTING OPERATIONS ON PEWAUKEE LAKE: 2002



Source: Lake Pewaukee Sanitary District and SEWRPC.

Chapter NR 109 of the *Wisconsin Administrative Code* to cut vegetation in lakes. The harvested plant material must be removed from the water.

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 food web.

Zooplankton

Zooplankton are microscopic animals which inhabit the same environment as phytoplankton, the microscopic plants. An important link in the food chain, zooplankton feed mostly on algae and, in turn, are a good food source for fish. Crustacean zooplankton were found in varying abundances in Pewaukee Lake during the 1976 study year, as shown in Table 23. Populations of most zooplankton species peaked during spring and fall, as shown in Figure 14. The dominant zooplankter during the fall pulse was *Eubosmina coregoni*, while *Daphnia galeata mendotae* and *Diaphanosoma leuchtenbergianum* dominated during the summer. Nauplii and copepodids, immature copepods, were found throughout most of the year, as shown in Figure 15. These animals may provide an abundant source of food for young fish. Larger zooplankters, such as *Daphnia pulicaria*, *D. schodleri*, and *Leptodora kindtii*, were present, but in small numbers. This may indicate selective cropping of the zooplankton by fish. However, a large pulse of *Eubosmina coregoni* occurred during the fall of 1976, and coincided with a period when there were relatively small numbers of *Bosmina longirostris*. Since *E. coregoni* is the larger of the two species, and should be most likely to be subjected to greater predation by the fish population, the dominance of *E. coregoni* appears to run counter to indications of selective fish predation. The amount of habitat provided by the abundant macrophyte growth in Pewaukee Lake at that time, however, may have provided adequate cover for *E. coregoni* and limited predation.

Additional sampling of zooplankton was done at three sites on Pewaukee Lake by the Wisconsin Lutheran College, during July and August 2000.[4] Fourteen different types of zooplankton were identified as shown in Table 23. The greatest density of zooplankton was observed at the eastern site in both July and August. The total number of zooplankton was greatest in July at all sites. The western and middle sites had the highest diversity. Copepod densities were higher than cladoceran densities for the entire sampling season at all three sites.

Benthic Invertebrates

The benthic, or bottom dwelling, faunal communities of lakes include such organisms as sludge worms, midges, and caddisfly larvae. These organisms are an important part of the food chain, acting as processors of organic material that accumulates on the lake bottom. Some benthic fauna are opportunistic in their feeding habits, while others are predaceous. The diversity of benthic faunal communities can be used as an indicator of lake trophic status. In general, a reduced or limited diversity of organisms present is indicative of an eutrophic lake; however, there is no single "indicator organism." Rather, the entire community must be assessed to determine trophic status as populations can fluctuate widely through the year and between years as a consequence of season, climatic variability, and localized water quality changes.

The benthic fauna population of Pewaukee Lake was sampled during the early spring of 1976 and 1977 prior to metamorphosis and emergence of adult benthic organisms.[5] The results of these surveys are set forth in Table 24.

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[4]*Angela L. Schmoldt and Robert C. Anderson,* Southeast Wisconsin's Pewaukee Lake Biological Evaluation 2000, *Wisconsin Lutheran College, Biology Department, Technical Bulletin 002, May 2001.*

[5]*Samples were collected in the deep basin in the western portion of the Lake, and processed by sieving through a 60-mesh sieve; samples were preserved in 95 percent ethyl alcohol. The larvae were picked from the debris, counted, and classified. Chironomid larvae, however, were not reared to adult stages and, therefore, species identification must be considered tentative.*

Table 23

CRUSTACEAN ZOOPLANKTON FOUND IN PEWAUKEE LAKE: 1976-G2000

Type	1976-1977 Survey	2000 Survey
Acanthocyclops vernalis	X	- -
Allona costa	X	X
Bosmina longirostris	X	X
Camptocerus sp.	X	- -
Ceriodaphnia sp.	X	X
Chydorus sphaericus	X	X
Cyclops bicuspidatus thomasi	X	- -
Daphnia galeata mendotae	X	- -
Daphnia longiremis	- -	X
Daphnia longispina	- -	X
Daphnia magna	- -	X
Daphnia pulex	- -	X
Daphnia pulicaria	X	X
Daphnia retrocurva	X	- -
Daphnia schodleri	X	- -
Diaphanosoma birgei	- -	X
Diaphanosoma leuchtenbergianum	X	- -
Eubosmina coregoni	X	X
Leptodora kindtii	X	- -
Mesocyclops edax	X	- -
Skistodiaptomus oregonensis	X	- -

Source: Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and SEWRPC.

At those times, the community was dominated by the phantom midge (*Chaoborus punctipennis*) and the midge (*Chiranomus plumosus*). In addition, several other species were present in small numbers: *Procladius* sp., *Chironomus attenuatus*, *Cryptocladopelma* sp., *Glypototendipes* sp., and *Paratendipes* sp. Both *Chironomus plumosus* and *Chaoborus punctipennis* are forms typically found in eutrophic waters, while the remaining five species are typical of a mesotrophic lake system. At the time of the 1976 and 1977 surveys, Pewaukee Lake had a relatively diverse benthic fauna. However, a lengthening of the anoxic period was considered at that time to potentially favor *C. punctipennis* and *C. plumosus* over the other species.

The benthic fauna of Pewaukee Lake also were sampled by the Wisconsin Lutheran College during June, July and August of 2000. This study found 18 types of macroinvertebrates including mayfly nymphs, scuds, and midge and phantom midge larvae. These data also are shown in Table 24, and suggest an improved trophic condition within the Lake. Notwithstanding, the WDNR has reported the presence of the nonnative, invasive mollusk, *Dreissena polymorpha* (zebra mussel), in Pewaukee Lake during 2002.

Fishes of Pewaukee Lake

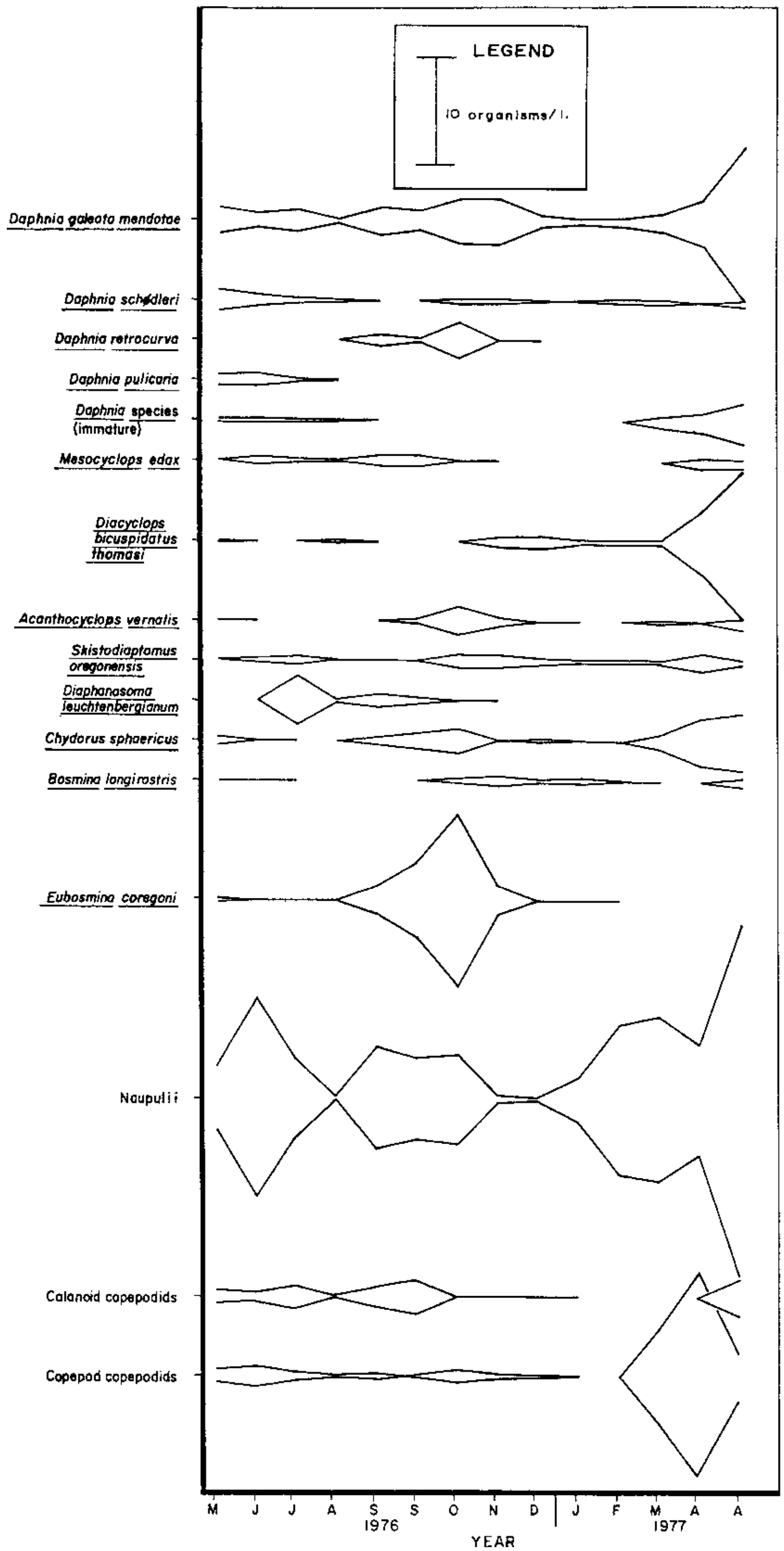
Pewaukee Lake supports a relatively large and diverse fish community, as shown in Table 25. WDNR survey reports indicated that, from 1964 through 1982, 45 different fish species have been captured in the Lake.[6]

A survey conducted in the fall of 1977 by the WDNR indicated that Pewaukee Lake had an outstanding fish population. Twenty-two species of fish were captured during this census. Game fish captured during the 1977

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

Figure 14

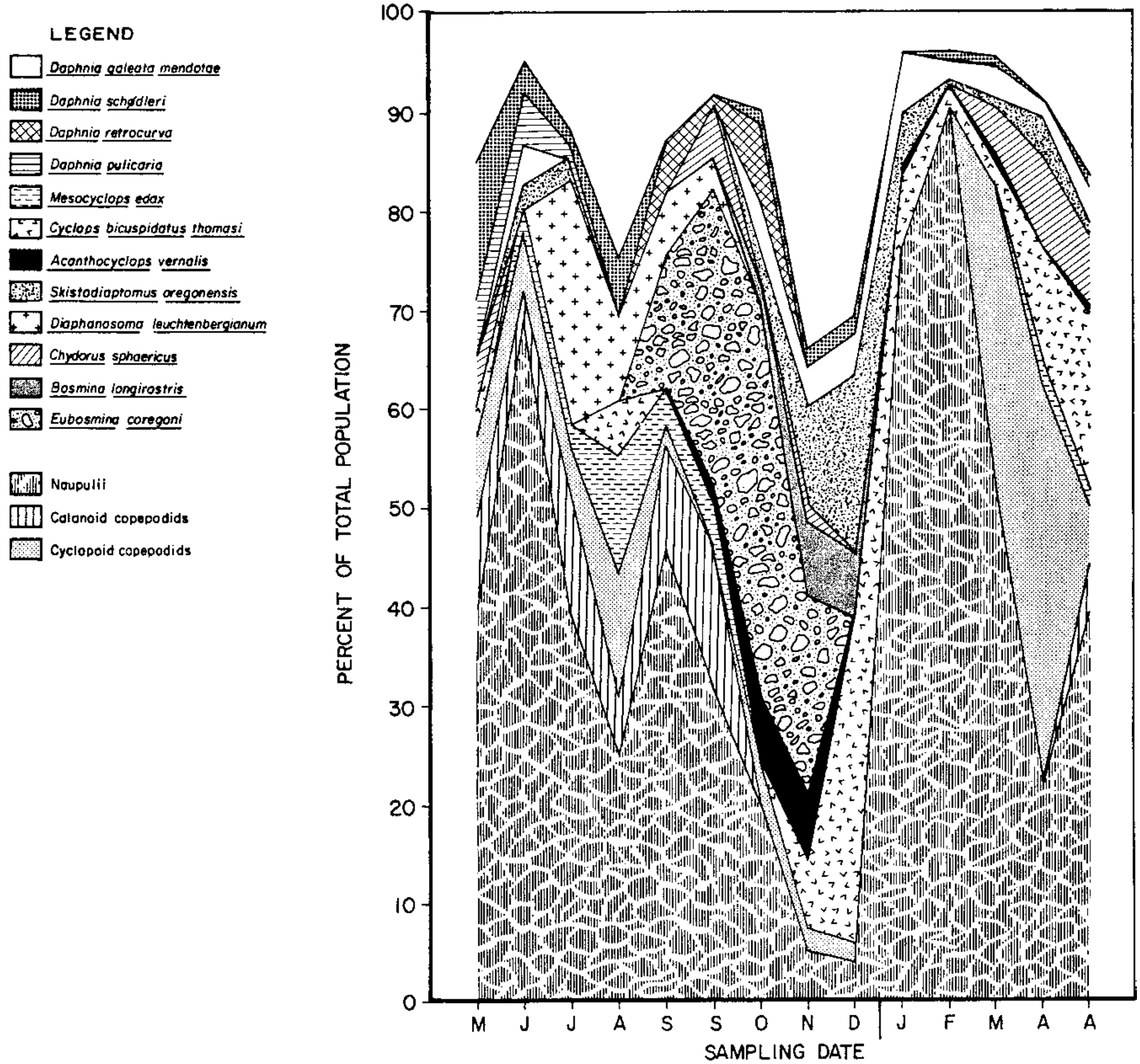
ZOOPLANKTON SPECIES AND ABUNDANCE IN PEWAUKEE LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 15

TYPES OF ZOOPLANKTON IN PEWAUKEE LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 24

BENTHIC FAUNA FOUND IN PEWAUKEE LAKE: 1976-2000

Type		1976-1977 Survey	2000 Survey
Amphipoda	Gammaridae Haustoriidae	- - - -	X X
Emphemenoptera	Caenidae Ephemeridae	- - - -	X X
Megaloptera	Sialidae Ceratopogonidae	- - - -	X X
Chironomidae	*Prodiamesa* sp. *Chironomus attenuatus* *Chironomus plumosus* *Chironomus* sp. *Cryoptocladopelma* sp. *Glypototendipes* sp. *Procladius* sp. *Paratendipes* sp. *Corynoneura* sp. *Pentaneura* sp. *Anatopynia* sp. *Trissocladius* sp. *Coeloanypus* sp.	- - X X - - X X X X - - - - - - - - - -	X - - - - X - - - - X X X X X X X
Hirudinea	- -	- -	X
Oligochaete	Tubificidae	- -	X
Culicidae	*Chaoborus punctipennis* *Chaoborus* sp.	X - -	X X

Source: Wisconsin Department of Natural Resources, Wisconsin Lutheran College, and SEWRPC.

survey included, but were not limited to, northern pike (*Esox lucius*), muskellunge (*Esox masquinongy*), largemouth bass (*Micropterus salmoides*), and walleyed pike (*Stizostedion vitreum vitreum*). Large numbers of panfish were also caught, including more than 1,000 bluegill (*Lepomis macrochirus*), 1,200 yellow perch (*Perca flavescens*), and 500 pumpkinseed (*Lepomis gibbosus*). Some rough fish, including carp (*Cyprinus carpio*) and sheepshead (*Aplodinotus grunniens*), were also collected during the 1977 survey, although they were not present in large numbers. No fish species captured were classified as rare, endangered, or threatened during this survey.

As of 1998, Pewaukee Lake continues to support a relatively large and diverse fish community.[7] During the 1998 comprehensive fisheries survey and creel survey, the WDNR recorded 21 species of fish that had been captured from the Lake. The pugnose shiner, a State Threatened Species, and the lake chubsucker, a State Special Concern Species were reported from Pewaukee Lake during that survey.

Important predator fish in Pewaukee Lake include smallmouth and largemouth bass, northern pike and muskellunge. These fish species are considered to be common. All of these species are carnivorous, feeding primarily on other fish, crayfish, and frogs. These species also are among the largest and most prized game fish sought by Pewaukee Lake anglers.

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[7] *Sue Beyler, and Steve Gospodarek,* Pewaukee Lake 1998 Comprehensive Survey (WBIC 0772000), *Wisconsin Department of Natural Resources, Internal Report File Ref: 3600, 2000.*

Table 25

FISH SPECIES OCCURRING IN PEWAUKEE LAKE

Species	Family	Scientific Name	Relative Abundance
Bowfin	Amiidae	*Amia calva*	Present
Brook Silverside	Atherinidae	*Labidesthes sicculus*	Common
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*	Present
White Sucker	Catostomidae	*Catostomus commersoni*	Common
Lake Chubsucker	Catostomidae	*Erimyon sucetta*	Present
Rock Bass	Centrarchidae	*Ambloplites ruperstris*	Common
Green Sunfish	Centrarchidae	*Lepomis cyanellus*	Common
Pumpkinseed	Centrarchidae	*Lepomis gibbosus*	Common
Warmouth	Centrarchidae	*Lepomis gulosus*	Common
Bluegill	Centrarchidae	*Lepomis macrochirus*	Abundant
Smallmouth Bass	Centrarchidae	*Micropterus dolomieui*	Common
Largemouth Bass	Centrarchidae	*Micropterus salmoides*	Common
White Crappie	Centrarchidae	*Pomoxia annularis*	Present
Black Crappie	Centrarchidae	*Pomoxis nigromaculatus*	Common
Goldfish	Cyprinidae	*Carassius auratus*	Present
Common Carp	Cyprinidae	*Cyprinus carpio*	Common
Pugnose Shiner	Cyprinidae	*Notropis anogenus*	Present
Emerald Shiner	Cyprinidae	*Notropis atherinoides*	Present
Common Shiner	Cyprinidae	*Notropis cornutus*	Present
Golden Shiner	Cyprinidae	*Notemigonus crysoleucas*	Present
Bigmouth Shiner	Cyprinidae	*Notropis dorsalis*	Present
Blackchin Shiner	Cyprinidae	*Notropis heterodon*	Present
Blacknose Shiner	Cyprinidae	*Notropis heterolepis*	Present
Spottail Shiner	Cyprinidae	*Notropis hudsonius*	Present
Spotfin Shiner	Cyprinidae	*Notropis spilopterus*	Present
Mimic Shiner	Cyprinidae	*Notropis volucellus*	Present
Bluntnose Minnow	Cyprinidae	*Pimephales notatus*	Common
Fathead Minnow	Cyprinidae	*Pimephales promelas*	Present
Creek Chub	Cyprinidae	*Semotilus atromaculatus*	Present
Banded Killifish	Cyprinodontidae	*Fundulus diaphanus*	Present
Grass Pickerel	Esocidae	*Esox americanus vermiculatus*	Present
Northern Pike	Esocidae	*Esox lucius*	Present
Muskellunge	Esocidae	*Esox masquinongy*	Common
Hybrid Muskellunge	Esocidae	*Esox* sp.	Present
Brook Stickleback	Gasterosteidae	*Culaea inconstans*	Present
Brown Bullhead	Ictaluridae	*Ictalurus nebulosus*	Common
Black Bullhead	Ictaluridae	*Ictalurus melas*	Common
Yellow Bullhead	Ictaluridae	*Ictalurus natalis*	Common
Tadpole Madtom	Ictaluridae	*Noturus gyrinus*	Present
White Bass	Percichthyidae	*Morone chrysops*	Common
Johnny Darter	Percidae	*Etheostoma nigrum*	Present
Yellow Perch	Percidae	*Perca flavescens*	Abundant
Walleyed Pike	Percidae	*Stizotedion vitreum vitreum*	Present
Freshwater Drum	Sciaenidae	*Aplodinotus grunniens*	Common
Central Mudminnow	Umbridae	*Umbra limi*	Present

Source: Claggett (1981); Fago (1982); Becker (1964); Wisconsin Department of Natural Resources and SEWRPC.

Historically, numerous types of fish have been stocked in Pewaukee Lake. The fish stocking record for the period of 1937 through 1980 is presented Table 26. All life stages—eggs, fry, fingerlings, and adults—of the 10 species of fish were stocked. In order to enhance and maintain sport fishing opportunities for anglers using Pewaukee Lake, the WDNR has recently stocked the Lake with walleyed pike, northern pike, muskellunge, and largemouth

Table 26

FISH STOCKED INTO PEWAUKEE LAKE: 1937-1980

	Bluegill		Bullhead		Crappie		Largemouth Bass		Muskellunge		Muskellunge Hybrid	
Year	Number	Size[a]	Number	Size[a]	Number	Size[a]	Number	Size[a]	Number	Size[a]	Number	Size[a]
1937	21,750	Fingerling	5,000	Fingerling	3,750	Fingerling	24,500	Fingerling	145,400	Fry	- -	
1938	90	Adult	- -	- -	10,000	Fingerling	32,000	Fingerling	115	Fingerling	- -	- -
	44,000	Fingerling										
1939	24,000	Fingerling	- -	- -	- -	- -	20,702	Fingerling	50	Fingerling	- -	- -
									60,000	Fry		
1940	- -	- -	- -	- -	- -	- -	20,700	Fingerling	60,000	Fry	- -	- -
1941	2,000	Fingerling	- -	- -	- -	- -	25,000	Fingerling	- -	- -	- -	- -
							600	Yearling				
1942	10,000	Fingerling	6,000	Fingerling	- -	- -	16,000	Fingerling	- -	- -	- -	- -
	350	Yearling					350	Yearling				
1943	- -	- -	50,000	Fingerling	- -	- -	15,000	Fingerling	- -	- -	- -	- -
1944	200	Adult	10,000	Fingerling	- -	- -	10,000	Fingerling	- -	- -	- -	- -
	10,000	Fingerling										
1945	6,000	Fingerling	- -	- -	- -	- -	7,000	Fingerling	- -	- -	- -	- -
1946	5,000	Fingerling	- -	- -	- -	- -	8,000	Fingerling	- -	- -	- -	- -
1947	- -	- -	- -	- -	- -	- -	13,000	Fingerling	- -	- -	- -	- -
1948	- -	- -	- -	- -	- -	- -	10,000	Fingerling	- -	- -	- -	- -
1949	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1950	- -	- -	- -	- -	- -	- -	15,325	Fingerling	- -	- -	- -	- -
1951	- -	- -	- -	- -	- -	- -	2,000	Fingerling	- -	- -	- -	- -
1952	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1953	- -	- -	- -	- -	- -	- -	9,192	Fingerling	- -	- -	- -	- -
1954-1955	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	
1956	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1957-1966	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1967	- -	- -	- -	- -	- -	- -	- -	- -	2,400	Fingerling	- -	- -
1968	- -	- -	- -	- -	- -	- -	- -	- -	1,250	Fingerling	- -	- -
1969	- -	- -	- -	- -	- -	- -	- -	- -	1,200	Fingerling	- -	- -
1970	- -	- -	- -	- -	- -	- -	- -	- -	1,200	Fingerling	- -	- -
1971	- -	- -	- -	- -	- -	- -	- -	- -	2,000	Fingerling	- -	- -
1972	- -	- -	- -	- -	- -	- -	- -	- -	1,942	Fingerling	- -	- -
1973	- -	- -	- -	- -	- -	- -	- -	- -	2,864	Fingerling	- -	- -
1974	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1975	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	1,850	Fingerling
1976	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	3,678	Fingerling
1977	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	4,272	Fingerling
1978-1979	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1980	- -	- -	- -	- -	- -	- -	- -	- -	1,410	Fingerling	850	Fingerling

bass, as shown in Table 27. The Department plans to continue to stock Pewaukee Lake with northern pike, walleyed pike and muskellunge, depending on their availability from the Department's fish hatcheries.[8]

A muskellunge management program, consisting of the stocking of muskellunge and hybrid—or tiger—muskellunge, and subsequent creel censi and surveys, was initiated during 1967. Since then, the lake has been stocked annually, with the exception of 1974, 1978, and 1979, with fingerlings of either one or both of the above species. The program has generated a great deal of enthusiasm among anglers in Southeastern Wisconsin, as Pewaukee Lake has been proven by the Wisconsin Department of Natural Resources to have a productive muskellunge fishery. A creel census conducted between 1973 and 1975 indicated a successful stocking program, with muskellunge being caught in good numbers and exhibiting excellent growth rates.[9] This survey led to the

[8]*Sue Beyler, and Steve Gospodarek,* Pewaukee Lake 1998 Comprehensive Survey (WBIC 0772000), *and* Fall 1999 Electrofishing Survey to Assess Young-of-Year Walleye Production on Pewaukee Lake (WBIC 0772000), *Wisconsin Department of Natural Resources, Internal Report File Ref: 3600, 2000.*

[9]*S.A. Holzer,* "Report on Muskellunge Stocking Program in Pewaukee Lake, Waukesha County," *Wisconsin Department of Natural Resources, Intra-Department Memorandum, 1975.*

Table 26 (continued)

Year	Northern Pike		Perch		Smallmouth Bass		Walleyed Pike		White Bass	
	Number	Size[a]	Number	Size[a]	Number	Size[a]	Number	Size[a]	Number	Size[a]
1937	2,250	Fingerling	18,375,000	Fry	65	Adult	7,071,300	Fry	- -	- -
			19,975	Fingerling						
			9,000	Adult						
1938	233,824	Fry	15,482,880	Eggs	- -	- -	5,835,000	Fry	- -	- -
	5,000	Fingerling	148,000	Fingerling						
1939	143,000	Fry	- -	- -	- -	- -	6,944,800	Fry	- -	- -
1940	219,210	Fry	- -	- -	- -	- -	6,432,760	Fry	- -	- -
1941	- -	- -	- -	- -	- -	- -	6,400,000	Fry	-.-	- -
1942	- -	- -	- -	- -	- -	- -	3,500,000	Fry	- -	- -
1943	- -	- -	4,000	Fingerling	- -	- -	5,000,000	Fry	12,000	Fingerling
1944	- -	- -	- -	- -	- -	- -	1,500,000	Fry	- -	- -
1995	- -	- -	- -	- -	- -	- -	2,000	Fingerling	- -	- -
							1,150,000	Fry		
1946	- -	- -	- -	- -	- -	- -	2,000	Fingerling	- -	- -
							5,200,000	Fry		
1947	- -	- -	- -	- -	- -	- -	5,200,000	Fry	- -	- -
1948	- -	- -	- -	- -	- -	- -	5,200,000	Fry	- -	- -
1949	- -	- -	- -	- -	- -	- -	5,250	Fingerling	- -	- -
1950	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1951	- -	- -	- -	- -	- -	- -	7,250	Fingerling	- -	- -
1952	500	Fingerling	- -	- -	- -	- -	41,064	Fingerling	- -	- -
1953	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1954-1955	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1956	- -	- -	- -	- -	- -	- -	9,400	Fingerling	- -	- -
1957-1966	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1967	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1968	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1969	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1970	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1971	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1972	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1973	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1974	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1975	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1976	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1977	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1978-1979	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
1980	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

[a]A fry is a newly hatched fish, a fingerling is a fish in its first year, a yearling is an immature fish.

Source: Wisconsin Department of Natural Resources.

continuation and expansion of the muskellunge management program by the Wisconsin Department of Natural Resources. In 1980, approximately 850 fingerling tiger muskellunge and 1,470 muskellunge were stocked into the Lake.

A wide range of panfish are also present in the Lake, as shown in Table 25. “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. Panfish species known to exist in Pewaukee Lake include bluegills, pumpkinseeds, yellow perch, and black crappies. The habitats of panfish vary widely among the different species, but their cropping of the plentiful supply of insects and plants, coupled with prolific breeding rates, leads to large populations with a rapid turnover. Some lakes within Southeastern Wisconsin have stunted, or slow-growing, panfish populations because their numbers are not controlled by predator fishes. Panfish frequently feed on the fry of predator fish and, if the panfish population is overabundant, they may quickly deplete the predator fry population. Figure 16 illustrates the importance of a balanced predator-prey relationship, using walleyed pike and perch as an example.

“Rough fish” is a broad term applied to species, such as carp, that do not readily bite on hook and line, but feed on game fish, destroy habitat needed by more desirable species, and are commonly considered in Southeastern Wisconsin as undesirable for human consumption. Rough fish species which have been found in Pewaukee Lake include carp, lake chubsucker, white sucker, and bowfin. Of these, the lake chubsucker is a State-listed species of special concern.

Table 27

FISH STOCKED INTO PEWAUKEE LAKE: 1980-2000

Year	Channel Catfish (number and size)	Largemouth Bass (number and size)	Muskellunge (number and size)	Muskellunge Hybrid (number and size)	Northern Pike (number and size)	Walleyed Pike (number and size)
1980	- -	- -	1,470 fingerlings	850 fingerlings	- -	37,473 fingerlings
1981	- -	- -	487 fingerlings	2,550 fingerlings	- -	3,000,000 fry
1982	- -	- -	1,250 fingerlings	1,963 fingerlings	- -	101,925 fingerlings
1983	- -	- -	- -	3,500 fingerlings	- -	89,124 fingerlings
1984	- -	- -	1,550 fingerlings	1,280 fingerlings	1,970 fingerlings	2,500,000 fry
1985	- -	- -	1,253 fingerlings	3,528 fingerlings	- -	103,643 fingerlings
1986	- -	- -	2,090 fingerlings	1,250 fingerlings	- -	66,488 fingerlings
1987	- -	- -	2,137 fingerlings	1,000 fingerlings	- -	10,080 fingerlings
1988		- -	3,000 fingerlings	1,000 fingerlings	- -	- -
1989		- -	2,450 fingerlings	1,000 fingerlings	- -	38,185 fingerlings
1990	4,000 fingerlings	- -	1,033 fingerlings	- -	- -	100,000 fingerlings
1991	- -	3,200 fingerlings	2,966 fingerlings	- -	2,500 fingerlings	70,000 fingerlings
1992	- -	- -	6,236 fingerlings	- -	2,500 fingerlings	106,886 fingerlings
1993	- -	- -	2,935 fingerlings	- -	2,500 fingerlings	- -
1994	- -	- -	893 fingerlings	- -	1,560 fingerlings	98,296 fingerlings
1995	- -	- -	100 fingerlings	- -	- -	- -
1996	- -	- -	5,381 fingerlings	- -	2,105 fingerlings	100,000 fingerlings
1997	- -	- -	425 fingerlings	- -	- -	- -
1998	- -	- -	2,484 fingerlings	- -	4,754 fingerlings	235,468 fingerlings
1999	- -	- -	4,628 yearlings	- -	2,360 fingerlings	- -
2000	- -	- -	1,430 fingerlings	4 yearlings	5,000 fingerlings	249,300 fingerlings
Total	4,000 fingerlings	3,200 fingerlings	44,198 fingerlings	17,921 fingerlings, and 4 yearlings	25,249 fingerlings	5,500,000 fry, and 1,406,868 fingerlings

Source: Wisconsin Department of Natural Resources and SEWRPC.

Pewaukee Lake is currently passively managed for the production of bluegills, yellow perch, black crappie and largemouth and smallmouth bass which regulates the harvest of fishes from the Lake under current state fishing regulations. The 2001-02 regulations governing the harvest of fishes from the waters of the State are summarized in Table 28.

Other Wildlife

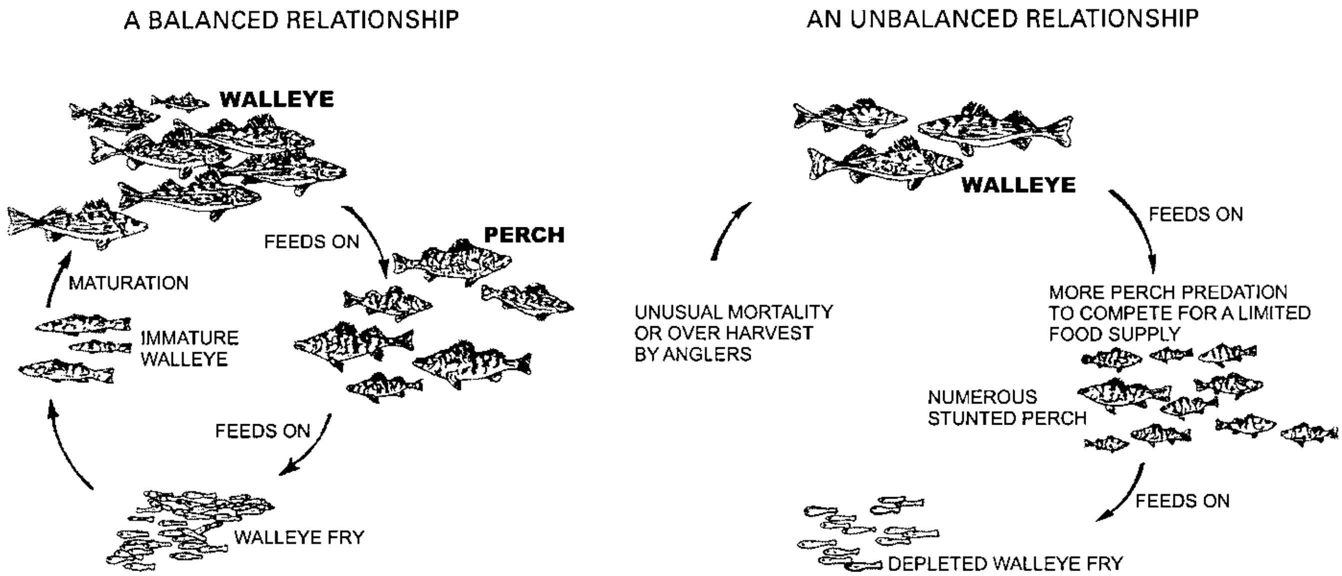
Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the Pewaukee Lake study, it is possible, by polling naturalists and wildlife managers familiar with the area, to complete a list of amphibians, reptiles, birds, and mammals which may be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

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 Pewaukee 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 29 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 Pewaukee Lake area. Table 30 lists those birds that normally occur in the drainage area. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits

Figure 16

THE PREDATOR-PREY RELATIONSHIP



Source: Wisconsin Department of Natural Resources and SEWRPC.

the area only on rare occasions. The Pewaukee Lake drainage area supports a significant population of waterfowl, including mallard and teal. Larger numbers of birds move through the drainage 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 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 Pewaukee Lake include the Cerulean warblers, the Acadian flycatcher, great egret, and the Osprey. Endangered species migrating in the vicinity of Pewaukee Lake include the common tern, Caspian tern, Forster's tern, and the loggerhead shrike.

Amphibians and reptiles are vital components of the ecosystem in an environmental unit like the Pewaukee Lake drainage area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Pewaukee Lake area. Table 31 lists the 14 amphibian and 15 reptile species normally expected to be present in the Pewaukee Lake area under present conditions and identifies those species most sensitive to urbanization.

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 is the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

Table 28

FISHING REGULATIONS APPLICABLE TO PEWAUKEE LAKE: 2002-2003

Species	Open Season	Daily Limit	Minimum Size
Northern Pike	May 5 to March 1	2	26 inches
Walleyed Pike	May 5 to March 1	5	15 inches
Largemouth and Smallmouth Bass	May 5 to March 1	5 in total	14 inches
Muskellunge	May 5 to November 30 (Southern Zone)	1	34 inches
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 2002, Guide to Wisconsin Hook and Line Fishing Regulations 2002-2003*, January 2002; and SEWRPC.*

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

WILDLIFE HABITAT AND RESOURCES

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

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

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

3. <u>Vegetative Composition and Structure</u>
   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. <u>Location with Respect to Other Wildlife Habitat Areas</u>
   It is very desirable that wildlife habitat maintains its proximity to other wildlife habitat areas.

5. <u>Disturbance</u>
   Minimum levels of disturbance from human activities are necessary for good wildlife habitat, other than those activities of a wildlife management nature.

Table 29

MAMMALS OF THE PEWAUKEE 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*
Stiped 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.*

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

As shown on Map 28, about 3,533 acres, or about 22 percent of the drainage area tributary to Pewaukee Lake, were classified in the 1985 inventory as wildlife habitat. This area is somewhat larger than the area reported in the initial planning study, which indicated about 3,092 acres of the drainage area tributary to Pewaukee Lake to be wildlife habitat. This increase reflects, in part, the results of the wetland acquisition and restoration program of the Lake Pewaukee Sanitary District and the prairie restoration program of the Pewaukee School District. Of the current area of wildlife habitat, about 1,151 acres, or about 7 percent of the drainage area, were classified as Class I habitat; 1,633 acres, or 10 percent, were classified as Class II habitat; and 749 acres, or 5 percent, were classified as Class III habitat.

In 1980, woodlands, scattered throughout the drainage area provided approximately 796 acres of small mammal habitat, and about 28 acres of low-value deer habitat. Wetlands adjacent to the lake, and scattered shallow water areas and marshes in the tributary drainage area, provided about 157 acres of waterfowl habitat, and 46 acres of muskrat habitat.

WETLANDS

Wetlands are defined by the Regional Planning Commission as, “areas that have a predominance of

Table 30

BIRDS KNOWN OR LIKELY TO OCCUR IN THE PEWAUKEE 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 30 (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
Strigidae			
Eastern Screech Owl	X	X	- -
Great Horned Owl	X	X	- -
Snowy Owl	- -	R	- -
Barred Owl	X	X	- -

Table 30 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Strigidae (continued)			
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
Sittidae			
Red-Breasted Nuthatch	R	X	X
White-Breasted Nuthatch	X	X	- -

Table 30 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
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
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

Table 30 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Parulidae (continued)			
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
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

Table 30 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
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 Bird Life, 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.*

hydric soils and that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions." This definition, which is also used by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency, is essentially the same as the definition used by the U.S. Natural Resource Conservation Service.[10]

Another definition, which is applied by the State of Wisconsin Department of Natural Resources and which is set forth in Chapter 23 of the *Wisconsin Statutes*, defines a wetland as "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which has soils

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

Table 31

AMPHIBIANS AND REPTILES OF THE PEWAUKEE 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.*

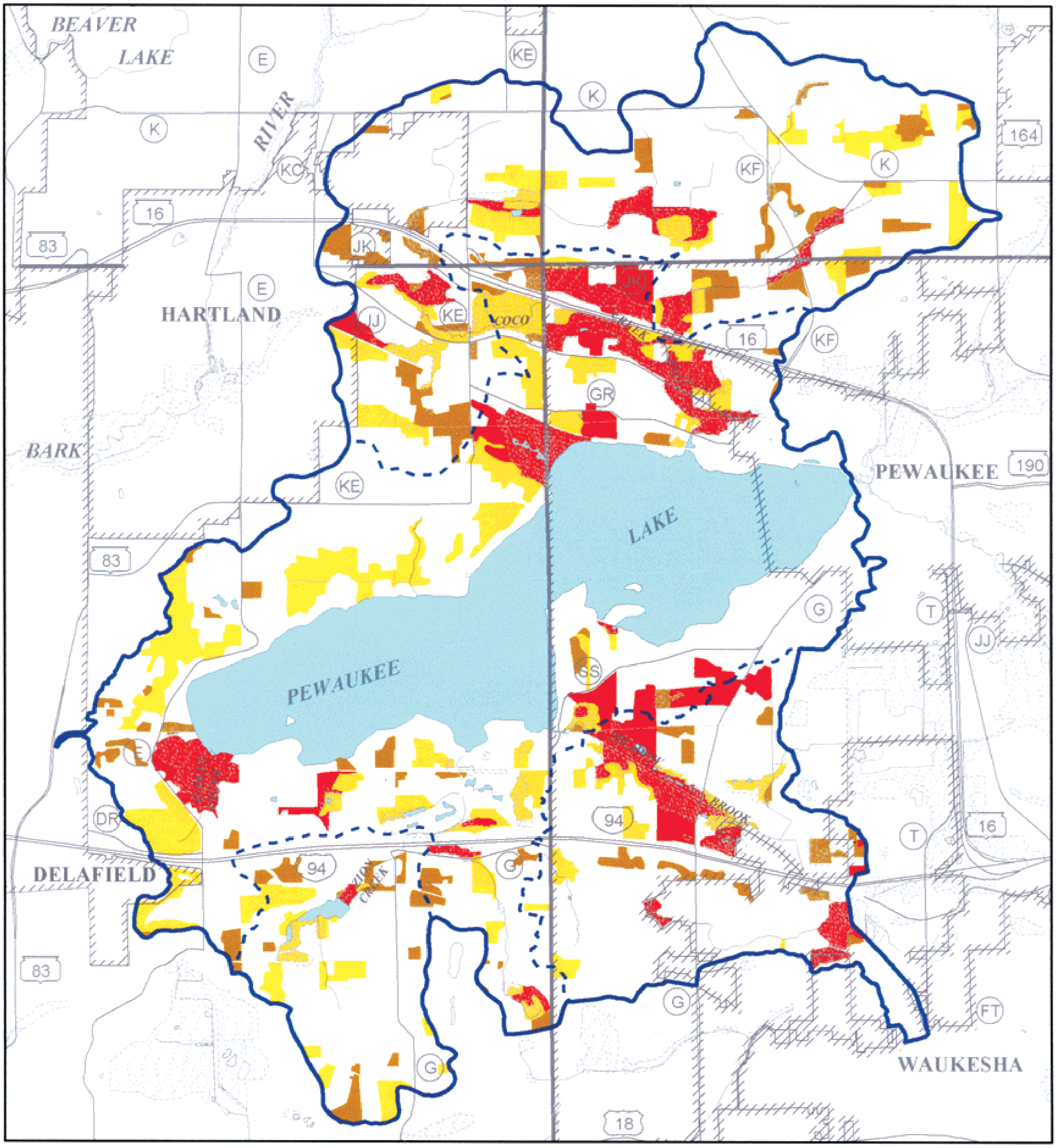
[c]*State-designated special concern species.*

[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.

Map 28

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



Class I, High-Value Habitat

Class II, Medium-Value Habitat

Class III, Good-Value Habitat

Surface Water

Source: SEWRPC.

indicative of wet conditions.” In practice, the Department definition differs from the Regional Planning Commission definition in that the Department considers very poorly drained, poorly drained, and some of the somewhat poorly drained soils as wetland soils meeting the Department “wet condition” criterion. The Commission definition only considers the very poorly drained and poorly drained soils as meeting the “hydric soil” criterion. Thus, the State definition as actually applied is more inclusive than the Federal and Commission definitions in that the Department may include some soils that do not show hydric field characteristics as wet soils capable of supporting wetland vegetation, a condition that may occur in some floodlands.[11]

As a practical matter, experience has shown that application of the Wisconsin Department of Natural Resources, the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, and the Regional Planning Commission definitions produce reasonably consistent wetland identifications and delineations in the majority of situations within the Southeastern Wisconsin Region. That consistency is due in large part to the provision in the Federal wetland delineation manual 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, southern sedge meadow, fresh (wet) meadow, shrub carr, alder thickets, low prairie, fens, bogs, southern wet- and wet-mesic hardwood forest, and coniferous swamp. Wetlands form an important part of the landscape in and adjacent to Pewaukee Lake in that they perform an important set of natural functions that make them ecologically and environmentally invaluable resources. Wetlands affect the quality of water by acting as a filter or a buffer zone allowing silt and sediments, and their associated pollutants, to settle out and by absorbing potential contaminants within the plant biomass. They also influence the quantity of water by providing water during periods of drought and holding it back during periods of flood. When located along shorelines of lakes and streams, wetlands help protect those shorelines from erosion. Wetlands also may serve as groundwater discharge and recharge areas in addition to being important resources for overall ecological health and diversity by providing essential breeding and feeding grounds, shelter, and cover or refugia for many forms of fish and wildlife.

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

Table 32 characterizes the wetland plant species typically found in the drainage basin. As shown on Map 29, in 1995, wetlands covered about 1,075 acres, or 7 percent, of the drainage area tributary to Pewaukee Lake. The major wetland communities located in the drainage area tributary to Pewaukee Lake included deep and shallow marsh, sedge meadow, fresh (wet) meadow, shrub carr, southern wet to wet-mesic hardwoods, and a fen. The amount and distribution of wetlands in the area should remain relatively constant if the recommendations contained in the adopted regional land use plan are followed.

Lowland forests in the Pewaukee Lake drainage basin include southern wet to wet-mesic hardwood forests, and are scattered throughout the drainage basin, but tend to be concentrated in the southern portions of the drainage basin. These wetlands are characterized by black willow, cottonwood, green ash, and American elm.

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[11] *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.*

Table 32

EMERGENT WETLAND PLANT SPECIES IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO PEWAUKEE LAKE

Scientific Name: Family, Genus, and Species	Common Name
Polypodiaceae	
Thelypteris palustris	Marsh fern
Cypressaceae	
Thuja occidentalis	White cedar
Typhaceae	
Typha latifolia	Broadleaf cat-tail
Typha angustifolia	Narrowleaf cat-tail
Sparganiaceae	
Sparganium eurycarpum	Bur-reed
Alismataceae	
Alisma plantago-aquatica	Water plantain
Sagittaria latifolia	Arrow-head
Gramineae	
Bromus ciliatus	Ciliated brome grass
Glyceria striata	Fowl manna grass
Phramites communis	Reed grass
Calamagrostis canadensis	Canada bluojoint grass
Agrostis stolonifera[a]	Redtop grass
Muhlenbergia glomerata[b]	Muhly grass
Muhlenbergia mexicana-racemosa[b]	Muhly grass
Spartina pectinata	Prairie cord grass
Phalaris arundinacea[a]	Reed canary grass
Leersia oryzoides	Cut grass
Andropogon gerardi[b]	Big Bluestem grass
Cyperaceae	
Eleocharis rostellata[a,b]	Beaked spike rush
Scirpus validus	Softstem bulrush
Scirpus acutus	Hardstem bulrush
Scirpus fluviatilis	River bulrush
Scirpus atrovirens	Green bulrush
Eriophorum sp.	Cotton grass
Carex sterilis[b]	Sedge
Carex stricta	Tussock sedge
Carex lacustris	Lake sedge
Carex spp.	Sedges
Araceae	
Sumplocarpus foetidus	Skunk cabbage
Acorus calamus	Sweet flag
Amaryllidaceae	
Hypoxix hirsuta	Star-grass
Iridaceae	
Iris versicolor	Blue flag
Orchidaceae	
Habenaria hyperborea	Northern fringed orchid
Salicaceae	
Populus deltoides	Cottonwood
Salix serissima	Autumn willow
Salix candida	Sage-leaved willow
Salix nigra	Black willow
Salix interior	Sandbar willow
Salix discolor	Pussy willow
Betulaceae	
Betula papyrifera	Paper birch
Betula pumila	Bog birch
Ulmaceae	
Ulmus americana	American elm
Urticaceae	
Urtica dioica	Stinging nettle
Polygonaceae	
Rumex orbiculatus	Water dock
Polygonum natans	Smartweed
Ranunculaceae	
Caltha palustris	Marsh marigold
Thailictrum dasycarpum	Meadow rue
Aquifoliaceae	
Ilex verticillata	Winterberry
Aceraceae	
Acer negundo	Boxelder
Balsaminaceae	
Impatiens biflora	Jewel weed
Rhamnaceae	
Rhamnus cathartica[a]	Common buckthorn
Rhamnus alnifolius[b]	Alderleaf buckthorn
Hypericaceae	
Triadenum fraseri	Marsh St. John's wort
Lythraceae	
Decodon verticillatus	Water-willow
Lythrum salicaria[a]	Purple loosestrife
Onagraceae	
Epilobium coloratum	Willow-herb
Umbelliferae	
Zizia aurea	Golden alexanders
Cicuta bulbifera	Water-hemlock
Angelica atropurpurea	Angelica
Oxypolis rigidior	Cowbane
Cornaceae	
Cornsus amomum	Silky dogwood
Cornsus stolonifera	Red osier dogwood
Oleaceae	
Fraxinus pennsylvanic	Green ash
Gentianaceae	
Gentiana procera[b,d]	Lesser fringed gentian
Asclepiadaceae	
Asclipias incarnata	Marsh milkweed
Verbenaceae	
Verbena hastata	Blue vervain
Labiatae	
Pycnanthemum virginianum	Mountain mint
Lycopus virginicus	Bugle weed
Lycopus americanus	Common water horehound
Mentha arvensis	Wild mint
Mentha piperita[a]	Peppermint
Scrophulariaceae	
Chelone glabra	Turtlehead
Pedicularis lanceolata	Swamp lousewort
Caprifoliceae	
Viburnum trilobum	Highbush cranberry
Viburnum lentago	Nannyberry
Sambucus canadensis	Elderberry
Cucurbitaceae	
Echinocystis lobata	Wild cucumber
Valerianaceae	
Valeriana edulis	Marsh valerlan
Lobeliaceae	
Lobelia siphilitica	Great blue lobelia
Lobelia kalmii[b]	Brook lobelia
Compositae	
Helenium autumnale	Sneezeveed
Bidens cernua	Bur marigold
Bidens frondosa	Beggar's ticks
Ambrosia trifida	Giant ragweed
Solidago uliginosa	Bog goldenrod
Solidago patula	Swamp goldenrod
Solidago gigantea	Giant goldenrod
Solidago ohioensis[b,d]	Ohio goldenrod
Solidago riddellii[b]	Riddell's goldenrod
Solidago graminifolia	grass-leaved goldenrod
Aster novae-angliae	New England aster

Table 32 (continued)

Scientific Name Family, Genus, and Species	Common Name
Cruciferae	
Cardamine bulbosa	Bitter cress
Nasturtium officinale[a]	Water-cress
Saxifragaceae	
Parnassia glauca[b]	Grass of Parnassus
Ribes hirtellum	Northern gooseberry
Rosaceae	
Physocarpus opulifolius	Ninebark
Potentilla fruticosa	Shrubby cinquefoil
Potentilla palustris	Bog cicquefoil

Scientific Name Family, Genus, and Species	Common Name
Compositae (continued)	
Aster puniceus	Redstem aster
Aster ludiculus	Swamp aster
Aster junciformis	Rush aster
Aster umbellatus	Flat-top aster
Aster Simplex	Marsh aster
Eupatorium maculatum	Joe-pys weed
Eupatorium perfoliatum	Boneset
Liatris pycnostachya	Gayfeather
Cirsium miticum[b]	Swamp thistle

NOTE: This table is presented in taxonomic order.

[a]*Alien or nonnative plant species.*

[b]*Plant species located in the fen.*

[c]*Identified as a Wisconsin endangered plant species in DNR Technical Bulletin No. 92, Endangered and Threatened Vascular Plants in Wisconsin, by Robert H. Reed.*

[d]*Identiried as a Wisconsin threatened plant species, Ibid.*

Source: Waukesha County Park and Planning Commission and SEWRPC.

Sedge meadows are considered to be 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. Sedge meadows in the drainage area directly tributary to the lake are located primary along the northern and western portions of the lake.

Shrub carrs, in addition to the sedges and grasses found in the sedge meadows, contain an abundance of shrubs such as willows (*Salix* spp.) and red osier dogwood (*Cornus stolonifera*). In extremely disturbed shrub carrs, the willows, red osier dogwood, and sedges are replaced by such exotic plants as honeysuckle (*Lonicera* sp.), buckthorn (*Rhamnus* sp.), and the very aggressive reed canary grass (*Phalaris arundinacea*). Shrub carrs are concentrated along the western and northern shores of the lake with smaller areas, usually associated with larger wetland complexes, scattered throughout the watershed.

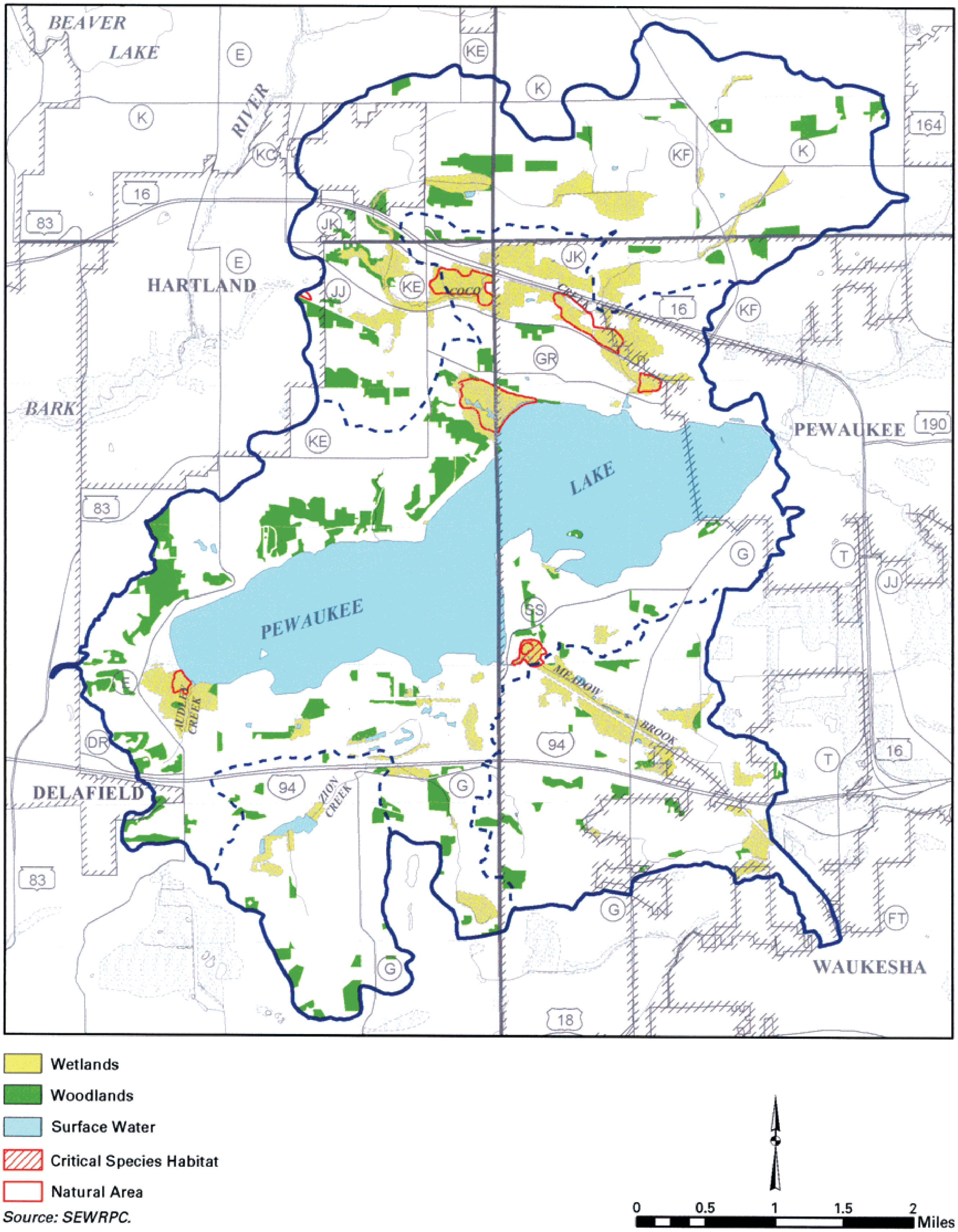
Fresh (wet) meadows, which are concentrated primarily in the northern and southeastern portions of the drainage basin, are essentially lowland meadows which are dominated by forbes such as the marsh (*Aster simplex*), swamp (*Aster lucidulus*), and New England (*Aster novae-angliae*) asters, and giant goldenrod (*Solidago gigantea*).

A high-quality fen, located at the west end of the lake, is associated with a 22-acre wetland complex composed of shrub carr, deep and shallow marsh, and sedge meadow. Fens are very rare and specialized plant communities growing on water-logged organic soils associated with alkaline springs and seepages. Characteristic plants include shrubby cinquefoil (*Potentilla fruticosa*), Riddell's goldenrod (*Solidago riddellii*), and other species known as calciphiles or calcium tolerant plants.

Deep and shallow marsh areas tend to be concentrated at the northern and western ends of the lake, with smaller shallow marshes scattered through the drainage basin. The deep and shallow marsh plant communities are dominated by cattails (*Typha* spp.). Other emergent plant species commonly occurring in the deep and shallow marshes within the Pewaukee Lake drainage basin include bur-reed (*Sparganium eurycarpum*), Arrow-head (*Sagittaria latifolia*), reed grass (*Phragmites communis*), bulrushes (*Scirpus* spp.), lake sedge (*Carex lacustris*), and water-willow (*Decodon verticillatus*).

Map 29

WETLANDS AND WOODLANDS WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1995



Source: SEWRPC.

Of the wetlands within the drainage area tributary to Pewaukee Lake, the Regional Planning Commission has identified two as natural areas of countywide or regional significance. A 22-acre wetland complex, which includes the Pewaukee Lake Access nature study area comprised of southern sedge meadow, fen, shrub carr, and deep and shallow marsh, is located at the west end of the Lake. A 40-acre wetland, the north Pewaukee Lake wetland complex comprised of shallow marsh, southern sedge meadow, and shrub carr, is located on the northern side of the Lake. In addition, the 11-acre shallow marsh located in the northwest one-quarter of U.S. Public Land Survey Section 8, Township 7 North, Range 19 East, City of Pewaukee, has been identified by the Commission as a natural of area of local significance.

As of 2000, the Lake Pewaukee Sanitary District had purchased and acquired approximately 245 acres of wetland tributary to Pewaukee Lake, shown on Map 30. The goal of the District is to acquire a total of approximately 350 acres of wetlands within the drainage area tributary to the Lake. The focus of wetland acquisition program is mainly in the Taylor's Bay area, in the Coco Creek area, and in the area to the northwest of the Lake within the Commission-delineated environmental corridor lands, as shown of Map 31.

WOODLANDS

Woodlands are defined by the Regional Planning Commission as those areas containing a minimum of 17 trees per acre with a diameter of at least four inches at breast height (4.5 feet above the ground).[12] The woodlands are classified as dry, dry-mesic, mesic, wet-mesic, wet hardwood, and conifer swamp forests; the last three are also considered wetlands. The Regional Planning Commission also maintains an inventory of woodlands within the Region which is updated every five years. In the drainage area tributary to Pewaukee Lake, shown on Map 29, approximately 1,032 acres of woodland were inventoried in 1995. These woodlands covered about 6 percent of the drainage area.

Specifically, woodlands in the Pewaukee Lake drainage basin, shown on Map 29, include southern dry hardwood forests, which are characterized by white oak (*Quercus alba*), shagbark hickory (*Carya ovata*), and black cherry (*Prunus serotina*); southern dry-mesic hardwood forests characterized by northern red oak (*Quercus borealis*) and white ash (*Fraxinus americana*); southern mesic hardwood forests dominated by sugar maple (*Acer saccharum*) and basswood (*Tilia americana*); wet-mesic hardwood forests dominated by green ash (*Fraxinus pennsylvania*), American elm (*Ulmus americana*), and silver maple (*Acer saccharinum*) and wet hardwood forests dominated by black willow (*Salix nigra*) and cottonwood (*Populus deltoides*).

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

Within the Pewaukee Lake drainage basin, woodlands are conspicuous along the western shore of the main lake basin. Additional wooded tracts are situated in the northern portion of the direct drainage area, with scattered smaller woodland areas in the southern portion of the drainage basin. Most of these wooded tracts contain dry to dry-mesic hardwoods. Woodlands adjacent to the northwestern lakeshore contain mesic hardwoods where sugar maples predominate.

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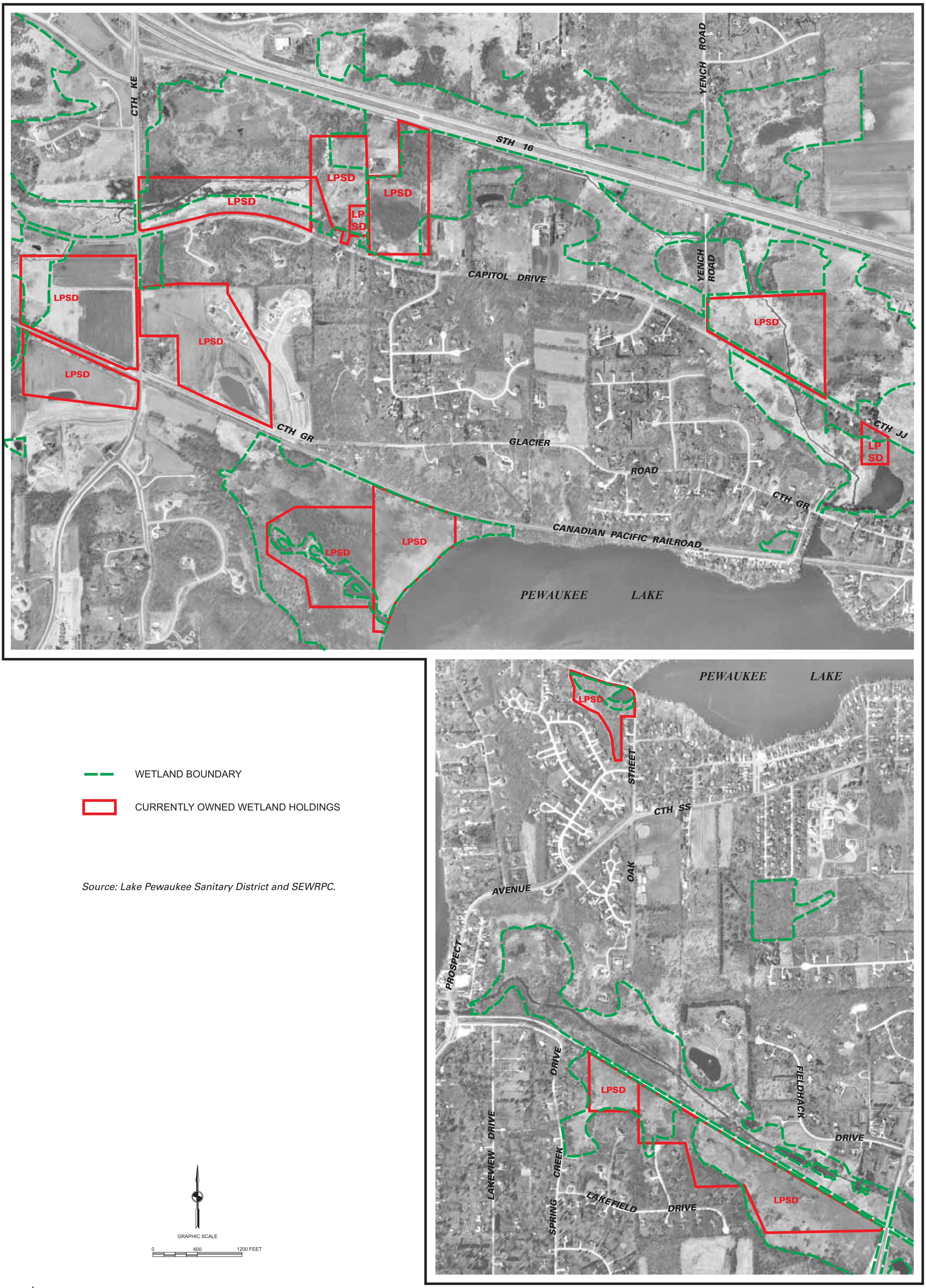
[12]*Bruce P. Rubin and Gerald H. Emmerich, Jr., "Refining the Delineation of Environmental Corridors in Southeastern Wisconsin,"* SEWRPC Technical Record*, Vol. 4, No. 2, March 1981*.

Map 30

WETLANDS PLACED INTO CONSERVANCY USAGE BY THE LAKE PEWAUKEE SANITARY DISTRICT: 2000

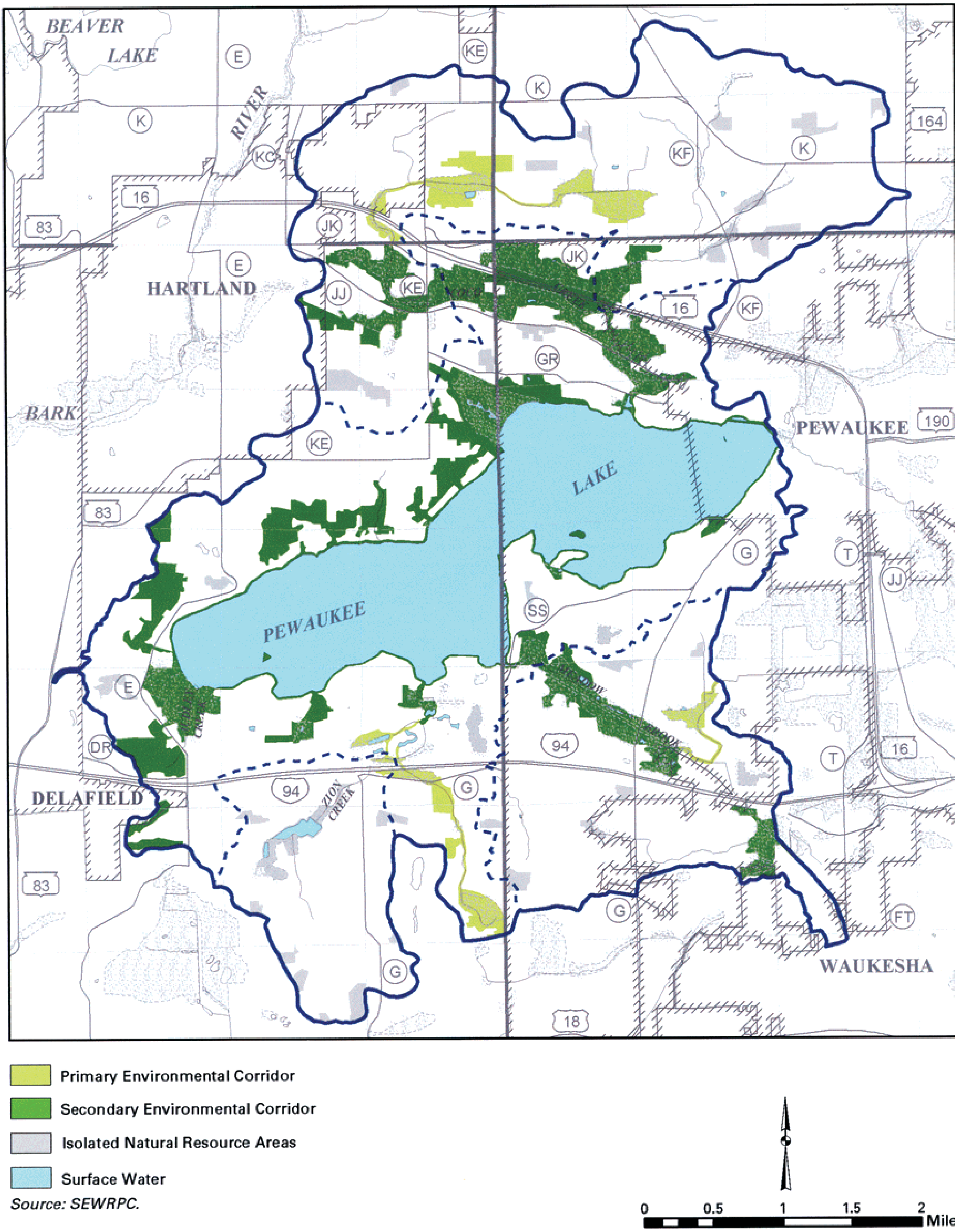


Source: Lake Pewaukee Sanitary District and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Map 31

ENVIRONMENTAL CORRIDORS AND NATURAL AREAS WITHIN THE DRAINAGE AREA TRIBUTARY TO PEWAUKEE LAKE: 1995



Source: SEWRPC.

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

ENVIRONMENTAL CORRIDORS

One of the most important tasks undertaken by the Commission as part of its regional planning effort was the identification and delineation of those areas of the Region having high concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, therefore, 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 the Commission. Primary environmental corridors include a wide variety of the abovementioned important resource and resource-related elements and are at least 400 acres in size, two miles in length, and 200 feet in width. The primary environmental corridors identified in the drainage area directly tributary to Pewaukee Lake are contiguous with environmental corridors and isolated natural areas lying outside the lake drainage area boundary, and, consequently, do not 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 any one element of the total environment may lead to a chain reaction of deterioration and destruction among the others. 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 and preserve the remaining environmental corridors within the drainage area directly tributary to Pewaukee Lake thus becomes apparent.

In the drainage area tributary to Pewaukee Lake, the riverbanks 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.[13] Within

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

the drainage area tributary to Pewaukee Lake, the county-owned Pewaukee Lake Access Fen, adjoining the southwestern shoreline of Pewaukee Lake, totaling 10 acres, is already in public ownership. The Pewaukee Lake Wetland, totaling 68 acres; the Pewaukee Lake Sedge Meadow, totaling 11 acres; and the Capitol Drive Sedge Meadow and Wet Prairie, totaling 91 acres, are recommended for acquisition by the Lake Pewaukee Sanitary District, and the Hartland Railroad Prairie, totaling four acres, is recommended for acquisition by the Village of Hartland.

Primary Environmental Corridors

The primary environmental corridors in Southeastern Wisconsin generally lie 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. During the initial planning period, the primary environmental corridors in the drainage area directly tributary to Pewaukee Lake in 1980 encompassed 2,347 acres, or 16 percent of the drainage area. These corridors are 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. Consequently, as of 1995, about 1,716 acres, or 11 percent, of the drainage area tributary to the Lake remained as primary environmental corridor, as shown on Map 31. The preservation of these corridors, thus, is one of the major ways in which the water quality of Pewaukee Lake can be maintained and perhaps improved.

Secondary Environmental Corridors

The secondary environmental corridors in the Pewaukee Lake direct drainage area are located generally along intermittent streams or serve as links between segments of primary environmental corridors. These 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. Secondary environmental corridors 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. Such corridors, while not as important as the primary environmental corridors, should be preserved in essentially open, natural uses as urban development proceeds within the direct drainage area, particularly when the opportunity is presented to incorporate the corridors into urban stormwater detention areas, associated drainageways, and neighborhood parks. Secondary environmental corridors encompassed 395 acres, or about 3.0 percent of the drainage area directly tributary to Pewaukee Lake, in 1980. As of 1995, about 370 acres, or 2 percent, of the drainage area tributary to the Lake remained identified as secondary environmental corridor, as shown on Map 31.

Isolated Natural Resource Areas

In addition to the environmental corridors, other, small concentrations of natural resource base elements exist within the drainage area directly tributary to Pewaukee Lake. These resource base elements are isolated from the environmental corridors by urban development or agricultural uses and, although separated from the environmental corridor network, have important natural values. Isolated natural resource areas may provide the only available wildlife habitat in an area, provide good locations for local parks and nature study areas, and lend an aesthetic character or natural diversity to an area. Important isolated natural resource features within Southeastern Wisconsin include a geographically well-distributed 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 areal extent within the drainage area directly tributary to Pewaukee Lake, as of 1980, totaled about 512 acres, or 4 percent of the direct drainage area. As of 1995, 405 acres, or 3 percent of the drainage area, remained identified as isolated natural resource features located within the drainage area, as shown on Map 31.

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 as 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 Pewaukee Lake, are discussed in this chapter.

RECREATIONAL USES AND FACILITIES

Pewaukee Lake is located within about a one-half hour drive from much of the metropolitan Milwaukee area. Although Pewaukee Lake is one of the largest lakes in southeastern Wisconsin, its location, many access sites, and degree of shoreline development contribute to a more intensive recreational usage than is found on many other lakes in the Region, and the Lake supports a full range of lake uses. These uses include angling—during both the summer and winter fishing seasons, recreational boating, swimming, and aesthetic viewing. Winter recreational uses of Pewaukee Lake also include cross-country skiing, ice boating, ice skating, and snowmobiling. The scope of these recreational uses engaged in on Pewaukee Lake is sufficiently broad to be consistent with the recommended use objectives of full recreational use and the support of a healthy warmwater sport fishery, as set forth in the adopted regional water quality management plan.

Angling

The Pewaukee Lake fishery has been supported by Wisconsin Department of Natural Resources (WDNR) stocking programs, and recently the Lake has become a popular "muskie lake" as a result of the muskellunge stocking program. As discussed in Chapter V, fisheries surveys indicate that the Lake also supports an excellent

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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.*

panfish stock, as well as “trophy-sized” largemouth bass, walleyed pike, and northern pike populations. Evidence of the good fishing is provided by the “towns” of ice fishing shelters that occur on the ice during the winter months, and by the relatively large numbers of fishing boats and shoreline anglers using the Lake during the summer.

Recreational Boating

Boat traffic on Pewaukee Lake is highly variable throughout the season, and from weekday to weekend. During August 1976, fishing boats constituted about 50 percent of the boat traffic on the Lake during weekends, accounting for 70 and 180 of the watercraft in use on two typical weekends. During these surveys, the majority of watercraft present was comprised of fishing boats and sailboats. At that time, powerboats and ski boats were still below critical levels, as defined by the recreational boating guidelines set forth in the adopted regional park and open space plan. During the 1976 surveys, high-speed watercraft were present at densities of between one fast boat per 166 acres (15 fast boats present on the Lake) and one fast boat per 62 acres (40 fast boats present on the Lake)—an area of 40 acres per boat being considered to be a minimum area for safe waterskiing and fast boating pursuant to the aforementioned Regional guidelines.

During 1995, boat counts by Commission staff during both week and weekend days in June and July resulted in a total of about 1,222 watercraft of all descriptions—fishing, pontoon, skiing, sailing, and rowing vessels and personal watercraft—being recorded, as shown in Tables 33 and 34.[2] Of these, between 89 and 104 were observed to be in operation during weekday mornings and afternoons, and between 240 and 264 were in operation during weekend mornings and afternoons, as shown in the tables. High-speed watercraft comprised the largest number of watercraft in operation on the Lake during both periods. During these periods, the densities of high-speed watercraft on the Lake ranged from about one boat per 38 acres to about one boat per 20 acres. Such densities exceed those considered appropriate for the conduct of safe high speed boating activities pursuant to the adopted Regional guidelines, and would be consistent with public perceptions that the Lake is heavily used, especially on weekends.

Additional boat surveys conducted by Commission staff during August 2000 indicated continuing recreational boating pressure on Pewaukee Lake. A total of 21 watercraft of various types—fishing, pleasure, skiing, and sailing vessels and personal watercraft—were in use on the Lake during the week day survey, and a total of 100 watercraft were in operation on the weekend day, as set forth in Tables 35 and 36. The density of high-speed watercraft on the weekend exceeded one boat per 25 acres. In addition, during the year 2000 surveys, more than 1,563 boats were observed to be moored on the Lake or stored on the lakeshore. Most of these watercraft were power boats, accounting for about 505 watercraft. Of the balance, about 287 were fishing boats, about 284 craft were pontoon boats, about 216 were sailboats, about 117 were personal watercraft (“jetskis”), about 77 were paddle boats, about 50 were canoes, about 13 were kayaks, and about 12 were sail boards (“windsurfers”), as set forth in Table 36.

Boating activities on the Lake are regulated by the state boating and water safety laws, and by a uniform local ordinance, adopted by the riparian municipalities, providing specific regulations for Pewaukee Lake. These ordinances are summarized in Appendix B.

Park and Open Space Sites

Pewaukee Lake provides an ideal setting for the provision of parks and open space sites and facilities. There is a publicly owned open space and lake access site on the western shore of Pewaukee Lake, which forms the eastern portion of the 416-acre Naga-Waukee County Park. This park site includes a public recreational boating access site (one on each Lake), a golf course, picnicking and camping areas, hiking and cross-country skiing trails, and a public swimming beach on Nagawicka Lake. In addition, the City of Pewaukee owns a public boating access site

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[2]*See SEWRPC Memorandum Report No. 56,* A Lakefront Recreational Use and Waterway Protection Plan for the Village of Pewaukee, Waukesha County, Wisconsin*, March 1996.*

Table 33

RECREATIONAL USE SURVEY ON PEWAUKEE LAKE: 1995

Date and Time	Weekend Participants							
	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
June 24, 1995								
Morning	55	44	22	15	2	60	42	240
Afternoon	13	83	14	23	4	99	28	264
Total for the day	68	127	36	38	6	159	70	504
Percent	13	25	7	8	1	32	14	100

Date and Time	Weekday Participants							
	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
July 3, 1995								
Morning	45	15	3	0	2	8	16	89
Afternoon	13	37	11	2	3	24	14	104
Total for the day	58	52	14	2	5	32	30	193
Percent	30	27	7	1	2	17	16	100

Source: SEWRPC.

Table 34

WATERCRAFT ON PEWAUKEE LAKE: JULY 1995

Type of Watercraft										
Power Boat	Fishing Boat	Pontoon Boat	Canoe	Paddle Boat	Sailboat	Kayak	Wind Surf Board	Personal Water Craft	Other	Total
472	230	212	25	56	178	- -	- -	49	- -	1,222

Source: SEWRPC.

located on the southern shore of the Lake. The City access site, however, does not have any parking facilities. Within the Village of Pewaukee, the Village Beach Park offers an approximately 0.8-mile-long beach and swimming area, and a fishing pier. The beach is heavily used throughout the summer and is generally considered to be overcrowded on weekends.[3]

According to the May 1976 survey conducted by the WDNR, 32 recreational access sites were present in the vicinity of Pewaukee Lake. Of these, 10 were considered by the WDNR to be in need of maintenance, and 22 sites were considered to be in good condition. Of these sites, three were considered to provide an adequate level

[3]Ibid.

Table 35

RECREATIONAL USE SURVEY ON PEWAUKEE LAKE: 2000

Date and Time	Weekend Participants							
	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
August 12, 2000								
9:45 a.m. to 10:45 a.m.	47	19	3	20	3	6	9	107
12:30 p.m. to 1:30 p.m.	20	70	4	10	8	110	20	242
Total for the day	67	89	7	30	11	116	29	349
Percent	19	25	2	9	3	33	9	100

Date and Time	Weekday Participants							
	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
August 15, 2000								
9:15 a.m. to 10:15 a.m.	15	3	0	3	1	1	0	23
1:00 p.m. to 2:00 p.m.	8	11	1	1	2	95	2	120
Total for the day	23	14	1	4	3	96	2	143
Percent	16	10	1	3	2	67	1	100

Source: SEWRPC.

Table 36

WATERCRAFT ON PEWAUKEE LAKE: AUGUST 2000

Type of Watercraft										
Power Boat	Fishing Boat	Pontoon Boat	Canoe	Paddle Boat	Sailboat	Kayak	Wind Surf Board	Personal Water Craft	Other	Total
505	287	284	50	77	216	13	12	117	2	1,563

Source: SEWRPC.

of public recreational boating access to Pewaukee Lake. At that time, a total of 330 parking spaces for car-trailer units were provided at the 32 existing access sites around the Lake.

Subsequent to that survey, changes to Chapter NR 1 of the *Wisconsin Administrative Code* established quantitative criteria for determining the adequacy of public recreation boating access, the maximum and minimum standards continuing to be based upon car-trailer units. As of 2002, pursuant to these standards, Pewaukee Lake continues to be assessed as having adequate public recreational boating access opportunities, primarily provided through the Naga-Waukee Park access site at the western extreme of the Lake.

Privately owned sites with boat access and mooring facilities include the Pewaukee Marina and Golden Anchor at the northwestern end of Pewaukee Lake, the Pewaukee Yacht Club and the Sports Dock Tavern at the south-eastern end of the western basin, Pier 347 on the eastern shore, and Smokey's Bait Shop also on the eastern shore.

These sites are shown on Map 32. Existing recreational facilities in the vicinity of Pewaukee Lake, including surrounding park areas situated off the lakeshore, are also shown on Map 32.

It is important to note that the provision of park and open space sites within the drainage area tributary to Pewaukee Lake should continue to be guided by the recommendations contained in the Waukesha County development plan.[4] The purpose of that plan, in part, is to guide the preservation, acquisition, and development of land for park, outdoor recreation, and related open space purposes and to protect and enhance the underlying and sustaining natural resource base of the City and Village. With respect to the Pewaukee Lake drainage area, the plan recommends the maintenance of existing park and open space sites in the area, and the continued development of the Lake Country Trail linking the Lake area with other regional trail systems. In addition, the plan recommends that the undeveloped lands in the primary environmental corridor drainage area tributary to Pewaukee Lake be retained and maintained as natural open space. These lands include the Pewaukee Lake Access Fen, the Pewaukee Lake Wetland, the Pewaukee Lake Sedge Meadow, and the Capitol Drive Sedge Meadow and Wet Prairie, as discussed in Chapter V.

The county-owned Pewaukee Lake Access Fen, adjoining the southwestern shoreline of Pewaukee Lake, is a 10-acre reserve comprising a good quality calcareous fen. The Fen has been identified in the regional natural area plan and critical species habitat plan as a natural area of countywide or regional significance (NA-2), containing regionally rare plant species, such as the lesser fringed gentian and Ohio goldenrod, and a good population of the State-designated threatened beaked spikerush. The privately owned, Pewaukee Lake Wetland, adjoining the northwestern shoreline of Pewaukee Lake, is a 68-acre wetland complex consisting of shallow marsh, sedge meadow and shrub-carr, while the Pewaukee Lake Sedge Meadow is a privately owned 11-acre area with a good quality sedge meadow and shallow marsh having large areas of lake sedge. These wetlands have been identified as natural areas of countywide or local significance (NA-3). The Capitol Drive Sedge Meadow and Wet Prairie is a 91-acre sedge meadow, wet-mesic prairie, and shallow marsh owned by the Lake Pewaukee Sanitary District, the City of Pewaukee, and private landowners. This wetland was identified as a natural area of countywide or local significance (NA-3).

Wisconsin Department of Natural Resources Recreational Rating
In general, Pewaukee Lake provides a variety of outdoor recreational opportunities. Based upon the outdoor recreation rating developed by the Wisconsin Department of Natural Resources, Pewaukee Lake received 59 of a possible 72 points, as shown in Table 37. This rating indicates that the Lake provides a range of recreational opportunities, including a unique "muskie" fishery, some good swimming beaches, boat launch sites, water quality conditions conducive to boating, and some marsh areas suitable for wildlife observation. Features that were considered to detract from the recreational rating included a minor rough fish problem, occasional algal blooms, and excessive macrophyte growths in portions of the Lake.

WATER USE OBJECTIVES

The regional water quality management plan recommended the adoption of full recreational and warmwater sport fisheries objectives for Pewaukee 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.

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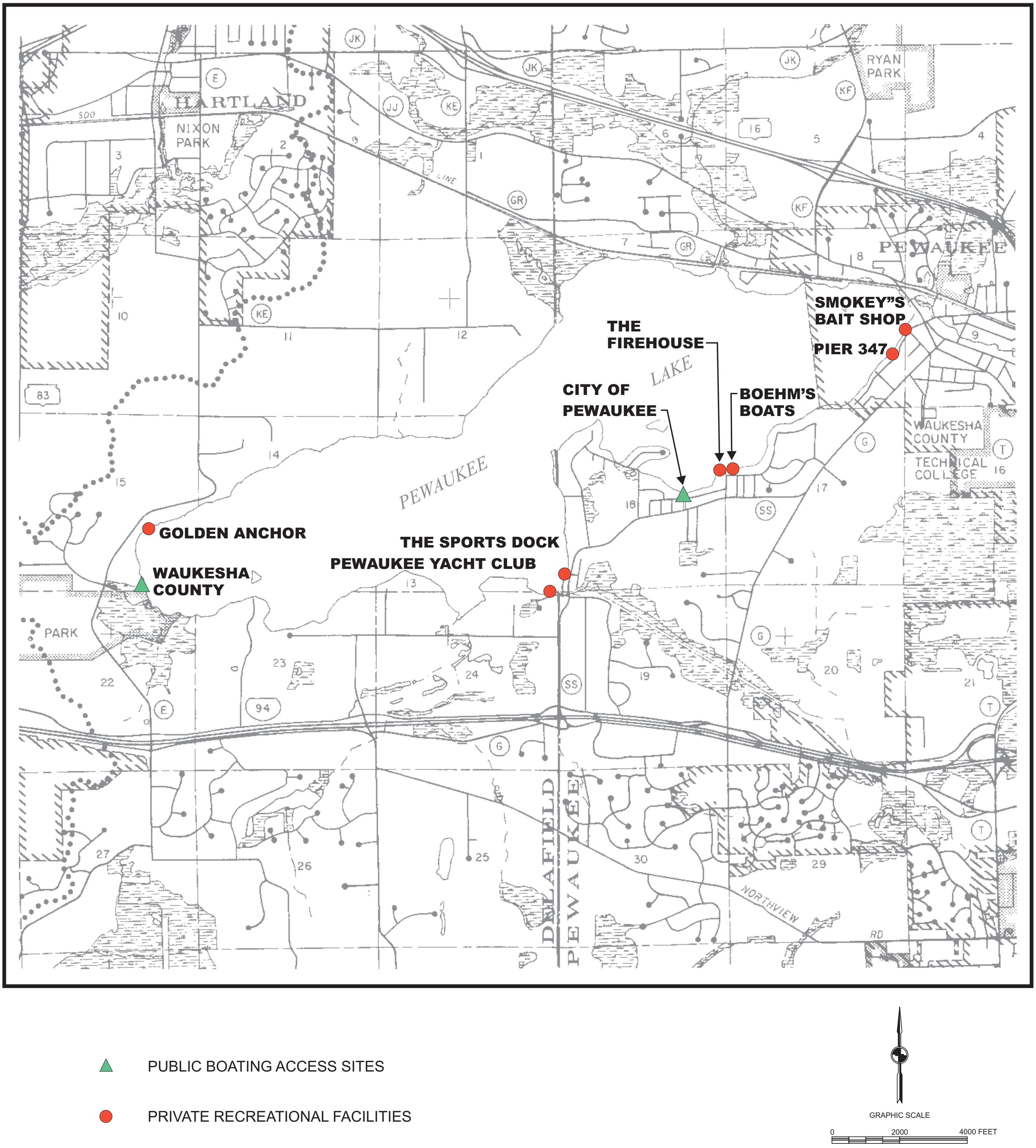
[4]*SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin*, August 1996; see also SEWRPC Community Assistance Planning Report No. 137,* A Park and Open Space Plan for Waukesha County*, December 1989.*

Map 32

PARKS AND BOAT ACCESS SITES ON PEWAUKEE LAKE: 2000



Source: Lake Pewaukee Sanitary District and SEWRPC.

Table 37

WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECREATIONAL RATING OF PEWAUKEE LAKE

Space: Total Area = 2,446 acres			Total Shore Length = 12.8 miles		
Quality (18 maximum points for each item)					
Fish:					
X 9	High production	__ 6	Medium production	__ 3	Low production
__ 9	No problems	X 6	Modest problems, such as infrequent winterkill, small rough fish problems	__ 3	Frequent and overbearing problems, such as winterkill, carp, excessive fertility
Swimming:					
X 6	Extensive sand or gravel substrate (75 percent or more)	__ 4	Moderate sand or gravel substrate (25 to 50 percent)	__ 2	Minor sand or gravel substrate (less than 25 percent)
__ 6	Clean water	X 4	Moderately clean water	__ 2	Turbid or darkly stained water
__ 6	No algal or weed problems	X 4	Moderate algal or weed problems	__ 2	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)	__ 2	Inadequate depths (less than 50 percent of basin more than five feet deep)
X 6	Adequate size for extended boating (more than 1,000 acres)	__ 4	Adequate size for some boating (200 to 1,000 acres)	__ 2	Limit of boating challenge and space (less than 200 acres)
__ 6	Good water quality	X 4	Some inhibiting factors, such as weedy bays, algal blooms, etc.	__ 2	Overwhelming inhibiting factors, such as weed beds throughout
Aesthetics:					
__ 6	Existence of 25 percent or more wild shore	X 4	Less than 25 percent wild shore	__ 2	No wild shore
X 6	Varied landscape	__ 4	Moderately varied	__ 2	Unvaried landscape
__ 6	Few nuisances, such as excessive algae, carp, etc.	X 4	Moderate nuisance conditions	__ 2	High nuisance condition
Total Quality Rating: 59 out of a possible 72					

Source: Wisconsin Department of Natural Resources and SEWRPC.

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

WATER QUALITY STANDARDS

The water quality standards 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 38. These standards are similar to those set forth in Chapters NR 102 and 104 of the *Wisconsin Administrative Code*, but were refined for planning purposes in terms of their application. Standards are recommended for temperature, pH, dissolved

Table 38

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.

oxygen, fecal coliform, and total phosphorus. These standards apply to the epilimnion of the lakes and to streams. The total phosphorus standard applies to spring turnover concentrations measured in the surface waters. Such contaminants as oil, debris, scum; or odor, taste, and color-producing substances; and toxins are not permitted in concentrations harmful to the aquatic life as set forth in Chapters NR 102 of the *Wisconsin Administrative Code*.

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

Chapter VII

ALTERNATIVE LAKE MANAGEMENT MEASURES

INTRODUCTION

Based upon review of the inventories and analyses set forth in Chapter II through VI, five issues were identified requiring consideration in the formulation of alternative and recommended lake management measures. These issues are related to: 1) nonpoint source pollution; 2) stormwater; 3) ecological valuable areas and aquatic plants; 4) water quality; and, 5) lake levels. The management measures considered herein are focused primarily on those measures which are applicable within the Lake Pewaukee Sanitary District, and to the City of Pewaukee, the Village of Pewaukee, and the Town of Delafield, with lesser emphasis given to those measures which are applicable to others with jurisdiction within the broader total drainage area tributary to Pewaukee Lake.

WATERSHED MANAGEMENT ALTERNATIVES

Nonpoint Source Pollution Abatement and Stormwater Management

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 watershed, 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 drainage area tributary to individual lakes and streams.

Land Use Management and Zoning

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 watershed. The type and location of future urban and rural land uses in the tributary drainage area to Pewaukee 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.

Development in the Shoreland Zone

Existing 1995 and planned buildout land use patterns and existing zoning regulations in the tributary area to Pewaukee Lake have been described in Chapter II. If the recommendations set forth in the adopted Waukesha County development plan and regional land use plan are followed, under buildout conditions, some additional urban residential development within the drainage area tributary to Pewaukee Lake would occur. Much of this residential development is likely to occur on agricultural lands. Infilling of existing platted lots and some backlot development, as well as the redevelopment and reconstruction of existing single-family homes and commercial structures on lakefront properties, also may be expected to occur. Recent surveillance indicates that this type of development is currently occurring. Accordingly, given the potential impact of lakeshore development on the lake resources, land use development or redevelopment proposals around the shoreline of Pewaukee Lake and within the drainage area directly tributary to the Lake should be evaluated for potential impacts on the Lake, as such proposals are advanced.

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.[1] The application of agrochemicals to such lands, in excess of the plant requirements, therefore, results in enhanced nutrient loading directly to the adjacent waterbodies. A reconnaissance by Wisconsin Department of Natural Resources (WDNR) and Commission staff conducted on Pewaukee Lake during August 2002 strongly suggested that such urban residential development riparian to the Lake may be contributing to observed aquatic plant growths adjacent to such developments—comparison of Maps 5 and 25 indicates this juxtaposition of new urban residential development and enhanced aquatic plant growth, including the growths of Eurasian water milfoil as shown on Map 26. To address these concerns, a number of communities are debating the enactment of fertilizer control ordinances in addition to the public informational programming discussed below; some communities, such as the Big Cedar Lake Protection and Rehabilitation District, also have purchased bulk lots of phosphorus-free lawn and garden fertilizers for resale to riparian landowners. Given the increasing importance of urban land uses within the riparian area of Pewaukee Lake, and within its drainage area, consideration of a comprehensive program to regulate urban agricultural practices appears to be warranted.

Development in the Tributary Drainage Area

The level of development envisioned in the Waukesha County development plan for the drainage basin tributary to Pewaukee 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 drainage area tributary to Pewaukee Lake is recommended. Changes in the zoning ordinances could 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 providing specific provisions and incentives to cluster residential development on smaller lots while preserving portions of the open space on each property or group of properties considered for development, utilizing the principles of conservation development.[2]

Stormwater Management on Development Site

With respect to stormwater management on development sites, as of 1999, the Cities of Delafield and Waukesha, and the Village of Hartland, had adopted stormwater management ordinances. These ordinances reflect current best practices insofar as the determination of stormwater flows, mitigation of flooding potential, and the control of contaminants from land use activities are concerned. The Village of Pewaukee and the Towns of Delafield, Lisbon, and Merton have adopted the Waukesha County stormwater management ordinance, while the City of Pewaukee has stormwater management standards built into other ordinances. Periodic review of these ordinances and their provisions for consistency with best management practices, and to ensure their currency with the state-of-the-art, should be undertaken on a regular basis to facilitate control of urban-sourced contaminants that would likely be delivered to the Lake.

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[1]*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.*

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

Protection of Environmentally Sensitive Lands
Environmentally sensitive lands within the drainage area tributary to Pewaukee Lake include wetlands, woodlands, and wildlife habitat areas. Nearly all of these areas within the Pewaukee Lake drainage area are included in the environmental corridors and isolated natural resource features delineated by the Regional Planning Commission. 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. These wetland areas are currently protected to a degree by current zoning and regulatory programs administered by the U.S. Army Corps of Engineers, WDNR, and County and municipal authorities under one or more of the Federal, State, County, and local regulations.

Some of the wetland, woodland, and wildlife habitat areas within the drainage area tributary to Pewaukee Lake, however, have been recommended for public acquisition in the adopted regional natural areas and critical species habitat management and protection plan. These lands include the Pewaukee Lake Access Fen, the Pewaukee Lake Wetland, the Pewaukee Lake Sedge Meadow, the Capitol Drive Sedge Meadow and Wet Prairie, and the Hartland Railroad Prairie.[3] Public acquisition of these lands, including acquisition by not-for-profit conservation organizations, as recommended in the adopted regional natural areas and critical species habitat protection and management plan is recommended.

The Lake Pewaukee Sanitary District currently is actively purchasing and acquiring wetland areas of significant importance in regards to the maintenance of flood and water pollution problems within the environmental corridors and stream systems in the drainage area tributary to Pewaukee Lake. Wetlands adjacent to lakes and streams help enhance water quality conditions, while preserving desirable open space characteristics for residents of the area to participate in a wide range of resource-oriented recreational activities, and to avoid the creation of new environmental and developmental problems as urbanization proceeds within the watershed.

Nonpoint Source Pollution Abatement
Watershed management measures may be used to minimize nonpoint source pollutant loadings from the watershed by locating development within a drainage basin in accordance with sound planning. 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; urban sources include contaminants transported by runoff from residential, commercial, industrial, transportation, and recreational land uses, and from construction activities. Alternative, watershed-based nonpoint source pollution control measures considered in this report are based upon the recommendations set forth in the regional water quality management plan,[4] in the Upper Fox River priority watershed plan,[5] and in the Waukesha County land and water resource management plan.[6]

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

[4]*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.*

[5]*Wisconsin Department of Natural Resources Publication No. WR-366-94*, A Nonpoint Sources Control Plan for the Upper Fox River Priority Watershed Project, *June 1994.*

[6]*Waukesha County*, Land and Water Resource Management Plan: 1999-2002, *January 1999.*

The regional water quality management plan recommends that the nonpoint source pollutant loadings from the areas tributary to Pewaukee Lake be reduced by up to 50 percent in urban areas and by up to 75 percent in rural areas, in addition to implementation of urban construction erosion controls, stream bank erosion controls, and onsite sewage disposal system management practices. The Upper Fox River Priority Watershed plan refined these recommendations, and proposed an overall reduction of phosphorus loading of about 38 percent. As described in Chapter IV, the most readily controllable loadings are associated primarily with runoff from urban lands within the direct drainage area tributary to the Lake and from urbanizing lands throughout the total drainage area tributary to the Lake that are linked to the Lake by way of streams and stormwater drainage systems. These loadings constituted about 20 percent of the total phosphorus and sediment loadings to Pewaukee Lake, and 100 percent of the heavy metals loadings, based upon 1995 land uses. Phosphorus loadings from the remainder of the tributary area, and from direct deposition onto the Lake surface, contributed the balance of the total loadings. The contributions of phosphorus, sediment and heavy metals from urban lands are expected to increase as agricultural lands are progressively converted to urban uses.

While some proportion of these contaminant loads may be attenuated as a consequence of the extensive wetland areas along the west branch tributary to Pewaukee Lake—also known as Coco Creek—and Zion Creek upstream of Pewaukee Lake, the ability of these wetlands to assimilate pollutants is wholly dependent upon the maintenance of their structure and function within 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 Pewaukee 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 croplands, woodlots, pastures, and grasslands in the drainage area tributary to Pewaukee 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 drainage area tributary to Pewaukee Lake.

Based upon the pollutant loading analysis set forth in Chapter IV, a total annual phosphorus load of about 6,500 pounds is estimated to be contributed to Pewaukee Lake. Of that mass, it is estimated that about 6,000 pounds per year, or 90 percent of the total loading, were contributed by runoff from rural land. In addition, it is estimated that about 1,300 tons of sediment, or about 74 percent of the total sediment load to Pewaukee Lake, were contributed annually from agricultural lands in the drainage area tributary to the Lake. As of 1995, such lands comprised about 5,800 acres, or about 37 percent of the drainage area tributary to Pewaukee Lake, which area is anticipated to diminish to about 2,200 acres, or less than 15 percent, of the tributary drainage area by the year 2020.

While agricultural land uses are anticipated to be a declining form of land usage within the drainage area tributary to Pewaukee Lake, the agricultural operations that remain within the drainage area will continue to contribute a significant proportion of the sediment load to the waterbody. Table 17 suggests that, based upon estimated contaminant loadings, agricultural land uses will continue to contribute about 40 percent of the total sediment load, or about 500 tons of sediment annually, to Pewaukee 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 or County Land Conservation Department, 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 1995, established urban land uses comprised about 5,300 acres, or about 34 percent, of the total drainage area tributary to Pewaukee Lake. The annual phosphorus loading from these urban lands was estimated to be about 560 pounds, or about 9 percent of the total load of phosphorus to the Lake. This is anticipated to increase to about 50 percent of the total load of phosphorus under buildout conditions. Those urban-sourced 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 Pewaukee Lake watershed for significant construction site erosion impacts if development continues in the tributary drainage 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-sourced pollutants from urban and urbanizing areas, and reduce urban nonpoint source pollution loads by up to about 50 percent.

As has been noted above, the Cities of Delafield and Waukesha, and the Village of Hartland, have adopted stringent stormwater management ordinances applicable to new development within the areas under their jurisdiction, since 1999. While these measures 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. As of 2001, the City of Delafield had adopted a detailed stormwater management plan that addresses these issues insofar as they relate to the urban development in the vicinity of the STH 83 and IH 94 intersection, and, as of 2002, the City had received

Chapter NR 191 Lake Protection Grant funds to prepare a similar plan for, among other areas, the urbanizing lands in the vicinity of the STH 83 and STH 16 intersection.[7]

Developing Area Nonpoint Source Controls

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

Construction sites, especially, may be expected to produce suspended solids and phosphorus loadings at rates several times higher than established urban land uses. Control of sediment loss from construction sites can be provided by measures set forth in the model ordinance developed by the Wisconsin Department of Natural Resources in cooperation with the Wisconsin League of Municipalities.[8] 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 drainage 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.

At the present time, Waukesha County has adopted construction site erosion control ordinances which are administered and enforced by the County, in both the shoreland and nonshoreland areas of the unincorporated areas of the drainage area tributary to Pewaukee 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. In the Cities of Delafield, Pewaukee and Waukesha, the Villages of Hartland and Pewaukee, and the Towns of Delafield, Lisbon and Merton, this function is performed by the respective Cities, Villages, and Towns. Because of the potential for development, some of it albeit unplanned, in the drainage area tributary to Pewaukee Lake, it is important that adequate construction erosion control programs, including enforcement, be in place.

Sewage System Management

Public Sanitary Sewerage System Management

Concentrations of urban development located along the shoreline of Pewaukee Lake have been included within a public sanitary sewer service area, as recommended in the adopted regional water quality management plan, as amended. However, lands lying outside this area, but identified as having a density of development equivalent to an urban concentration, would continue to be provided with sewage disposal through the use of onsite sewage disposal systems. Notwithstanding, the regional plan also recommends that sewerage needs in such areas be periodically reevaluated in light of changing conditions. Such an evaluation was completed during 1998, at which time the adopted sanitary sewer service area of the Lake Pewaukee Sanitary District was refined, with a further

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[7]*Development of detailed stormwater management plans for specific portions of the City of Delafield are being undertaken pursuant to recommendations set forth in SEWRPC Community Assistance Planning Report No. 262,* A Lake Management Plan for Nagawicka Lake, Waukesha County, Wisconsin*, March 2001.*

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

refinement being completed for the northwestern portion of the area during 2001 which clarified the boundaries between the Lake Pewaukee and Delafield-Hartland service areas.[9]

Onsite Sewage Disposal System Management

While the immediate lakeshore is sewered, portions of the drainage area tributary to Pewaukee Lake continues to be served by onsite sewage disposal systems. As reported in Chapter IV, total phosphorus loadings from onsite sewage disposal systems are estimated to contribute only a minor proportion of the total phosphorus load to the Lake, which proportion is anticipated to decline as public sanitary sewerage services are extended within the drainage area pursuant to the adopted regional water quality management plan[10] and sewer service area plan.[11] In addition to lake water quality considerations, sewage disposal options in the area have implications for groundwater quality and property values. Thus, onsite sewage disposal is an important consideration in the portions of the drainage area not within the planned public sanitary sewer service area. Two basic alternatives are available for abatement of pollution from onsite sewage disposal systems: continued reliance on, and management of, the onsite sewage disposal systems, and, alternatively, the expansion of the existing public sanitary sewer system.

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. 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. Waukesha County currently has such a program in place, pursuant to Chapter Comm 83 of the *Wisconsin Administrative Code* for onsite sewage disposal systems installed after 1983, and consideration is currently being given by the Wisconsin Legislature to extending this inspection program to all onsite sewage disposal systems.

IN-LAKE MANAGEMENT ALTERNATIVES

The reduction of external nutrient loadings to Pewaukee 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 continue to result in abundant macrophyte growth, that can result in restricted water use potentials, even after the implementation of watershed-based management measures. Given that Pewaukee Lake falls within this trophic range, the application of in-lake rehabilitation techniques should be considered.

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 some in-lake rehabilitation techniques require the issuance of permits from appropriate State and Federal agencies prior to implementation.

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[9]*SEWRPC,* Amendment to the Regional Water Quality Management Plan: Village of Hartland and Lake Pewaukee Sanitary District*, June 2001; SEWRPC,* Amendment to the Regional Water Quality Management Plan: Lake Pewaukee Sanitary District*, September 1998.*

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

[11]*SEWRPC,* Amendment to the Regional Water Quality Management Plan: Lake Pewaukee Sanitary District*, September 1998.*

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 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 fishery 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, 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 can also encourage the spread of rooted aquatic plants.

Nutrient inactivation is not recommended for Pewaukee Lake due to the generally soft sediments and shallow depth of management areas, the susceptibility to wind- and boat motor-induced mixing, and the overall pollutant loading which mediate against the effective use of nutrient inactivation.

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 watershed is generally preferable to attempting such control within a lake. Many of the techniques presented in the watershed 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 rerelease 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 Pewaukee Lake, especially given that internal loading from the lake sediments does not appear to be an important nutrient course to the water column. 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 entire 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 is 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 outlet control modifications, drawdown, and dredging.

Outlet Control Operations
The outflow from Pewaukee Lake is controlled by a dam located at the Pewaukee River outlet located on the eastern side of the Lake in the vicinity of Wisconsin Avenue in the Village of Pewaukee. The outlet structure has a variable discharge elevation that maintains an operating level governed by the dam operating permit issued by the Wisconsin Department of Natural Resources. Pursuant to this permit, lake elevations are to be maintained within the range of 852.20 to 852.80 feet National Geodetic Vertical Datum of 1929 (NGVD-29). The dam gates

at the Pewaukee Lake outlet are regulated so as to maintain a winter water level of 852.20 feet NGVD-29 and a summer water level of 852.80 feet NGVD-29. A minimum outflow of one-half inch is to be maintained at all times to meet minimum flow requirements set by the WDNR for the Pewaukee River. During periods of extreme high water, the dam gates are to be open fully and a “no-wake” restriction is placed on the Lake until the water level elevation of the Lake returns to 852.80 feet NGVD-29. Any changes in this operating regime are subject to WDNR Chapter 31, *Wisconsin Statutes*, permitting authority. No changes are currently recommended, although improved control over discharge rate alternations should be considered in the context of a Pewaukee River hydrologic and hydraulic planning and management program.

Drawdown

Drawdown refers to a 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 fisheries. With regard to aquatic plant management, periodic drawdowns 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 access to terrestrial insects, for example. Costs 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. 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, conducted pursuant to the dam operating permit, are designed to limit shoreland damage by ice and ice movements during the winter months.

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 reflooding, 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 sediments.

As noted above, the water level of Pewaukee Lake is controlled by a hydraulic control structure located on the eastern shore of the Lake. A limited drawdown could be obtained by opening the gate on the weir, while a total breaching of the dam would allow a drawdown of approximately six feet, exposing about 15 percent of the lake bottom. However, 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 recommended for Pewaukee Lake.

Water Level Stabilization
Riparian residents have reported significant seasonal changes in the water levels in Pewaukee Lake. 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 the 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 recommended, it is desirable from the point of view of aquatic habitat that water level fluctuations be maintained within these 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 watershed controls in reducing or minimizing the sediment sources. Federal and State permits are required for use of this option.

Dredging in Pewaukee Lake could be accomplished using several different types of equipment, including a hydraulic cutterhead dredge mounted on a floating barge in deeper water areas; a bulldozer and backhoe equipment in the shoreland area, especially if the Lake was 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 would 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 not require the removal of shoreland trees, resulting in less disturbance of the shoreline to provide access for trucks and equipment. Likewise, reduced water levels would allow conventional construction equipment access to the littoral portions of the waterbody. Nevertheless, given the potential recreational use impacts of a drawdown during both the summer and winter recreational seasons, use of these methods is not recommended.

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 Pewaukee Lake should be to increase water depth to maintain recreational boating access and increased public safety.

Notwithstanding, 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 Pewaukee 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 drainage area tributary to the lake. The sediment load reaching Pewaukee Lake comes from both urban and agricultural lands within the drainage area tributary to Pewaukee 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 watershed. Such practices should be implemented in the drainage 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 Wisconsin Department of Natural Resources 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 Pewaukee 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, extensive dredging of Pewaukee Lake is not considered a viable alternative at this time.

Aquatic Plant and Fisheries Management

Fisheries Management Measures

Pewaukee Lake provides a quality habitat for a healthy, warmwater fishery. Currently, adequate water quality, dissolved oxygen levels, sand and gravel shorelines, and diverse plant community exist for the maintenance of a sportfish population in the Lake. While winterkills have occurred in the past, winterkill is currently not a problem. The Lake supports a good largemouth bass and muskellunge fishery, along with a wide range of sportfish and panfish. In addition, the pugnose shiner, a State Threatened Species, and the lake chubsucker, a State Special Concern species, have been reported being caught in the Lake.

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 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. The environmentally valuable areas identified within the Lake and its watershed are the most important areas to be protected. In addition, limiting or restricting certain activities in sensitive areas of the Lake will prevent significant disturbance of fish nests and aquatic plant beds. The areas currently designated by the WDNR as sensitive areas within Pewaukee Lake, pursuant to authorities granted under Chapter NR 107 of the *Wisconsin Administrative Code*, are shown on Map 33. Within these areas, aquatic plant management measures are 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. Currently, about 99 percent of the shoreline of Pewaukee Lake is protected by some type of structural measure, as shown on Map 3. Four shoreline erosion control techniques were in use in 2000: vegetative buffer strips, rock 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.

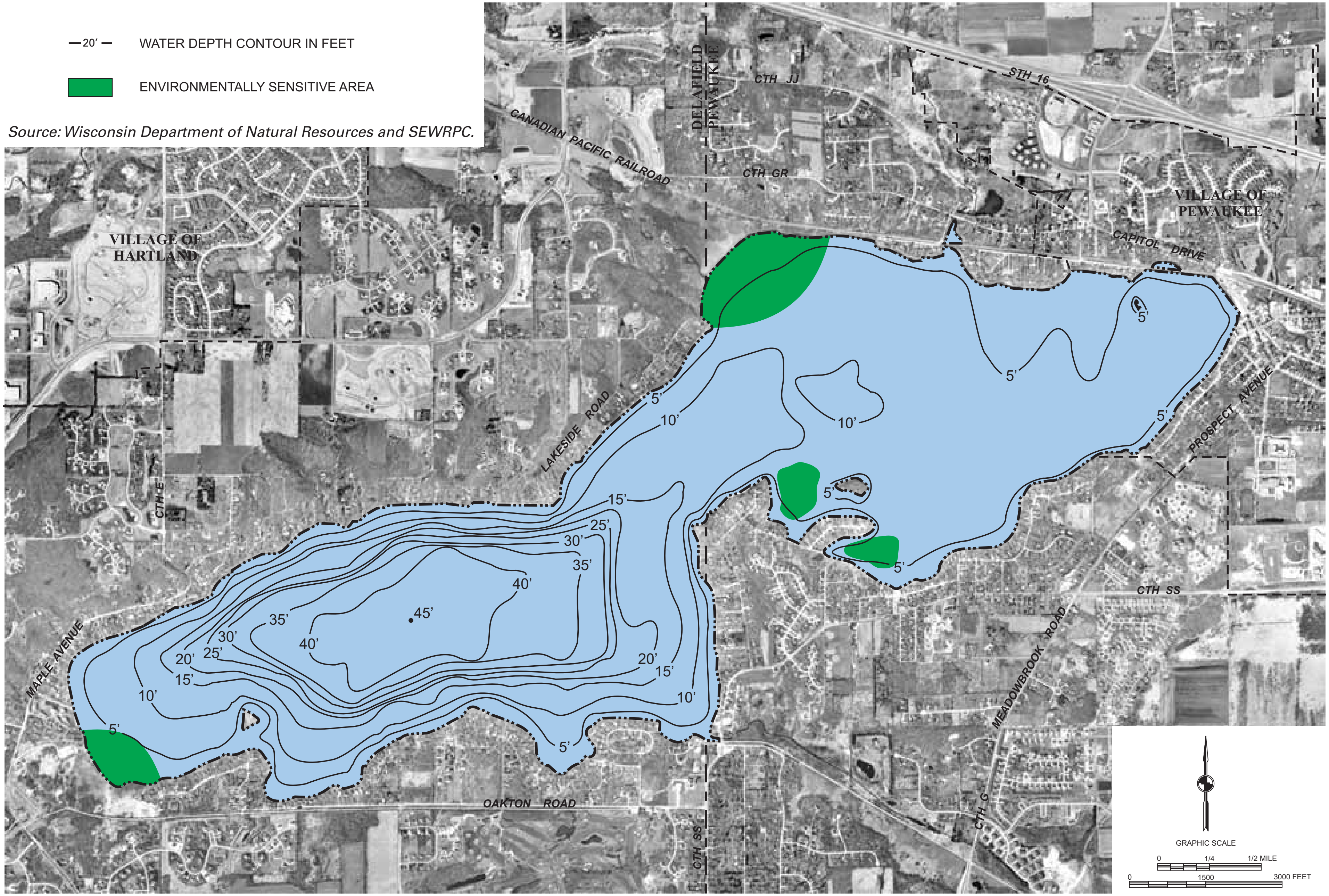
Desirable plant species that may be expected and encouraged to invade a buffer strip, or which could be planted, include arrowhead (*Sagittaria latifolia*), cattail (*Typha* spp.), common reed (*Phragmites communis*), water plantain (*Alisma plantago-aquatica*), bur-reed (*Sparganium eurycarpum*), and 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 Pewaukee 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.

The use of vegetated buffer strips and riprap, as shown in Figure 17, is recommended, especially in those areas of Pewaukee Lake 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

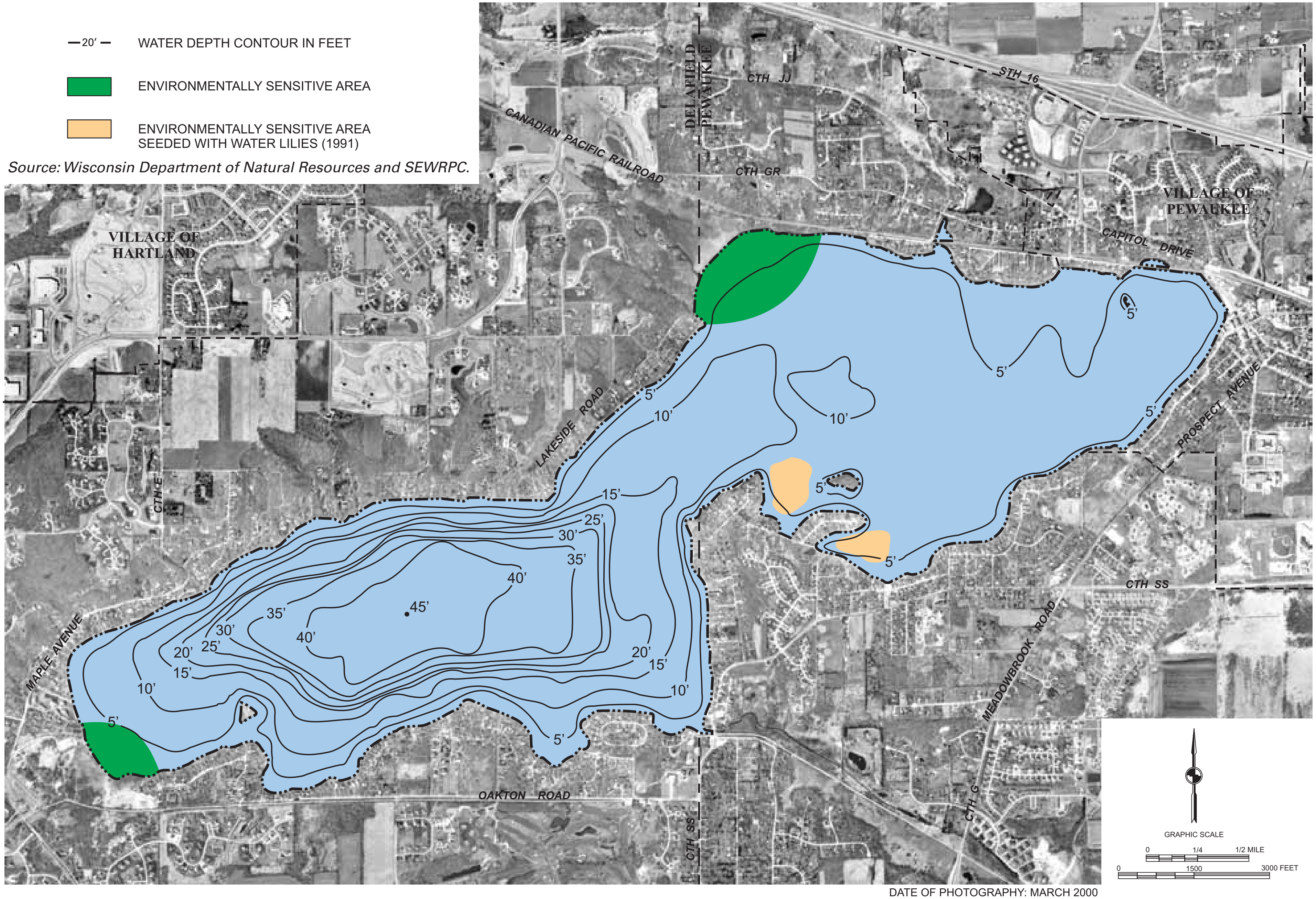
Map 33

WISCONSIN DEPARTMENT OF NATURAL RESOURCES-DELINEATED SENSITIVE AREAS IN PEWAUKEE LAKE: 1994



DATE OF PHOTOGRAPHY: MARCH 2000

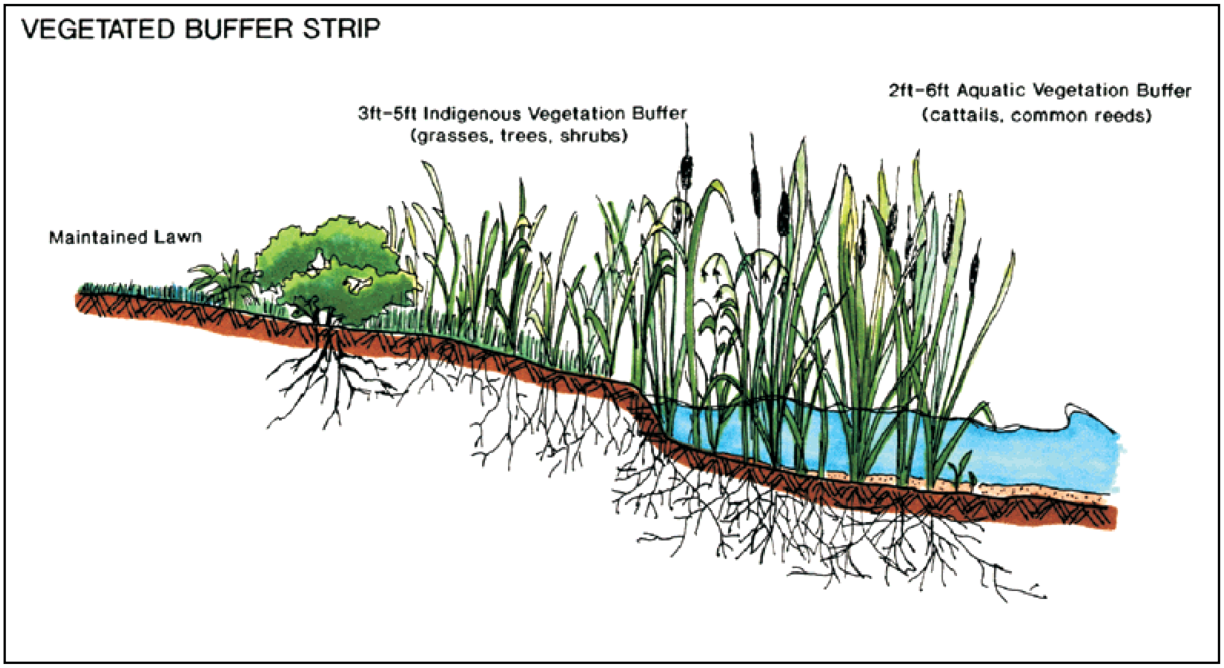
Map 33 (continued)

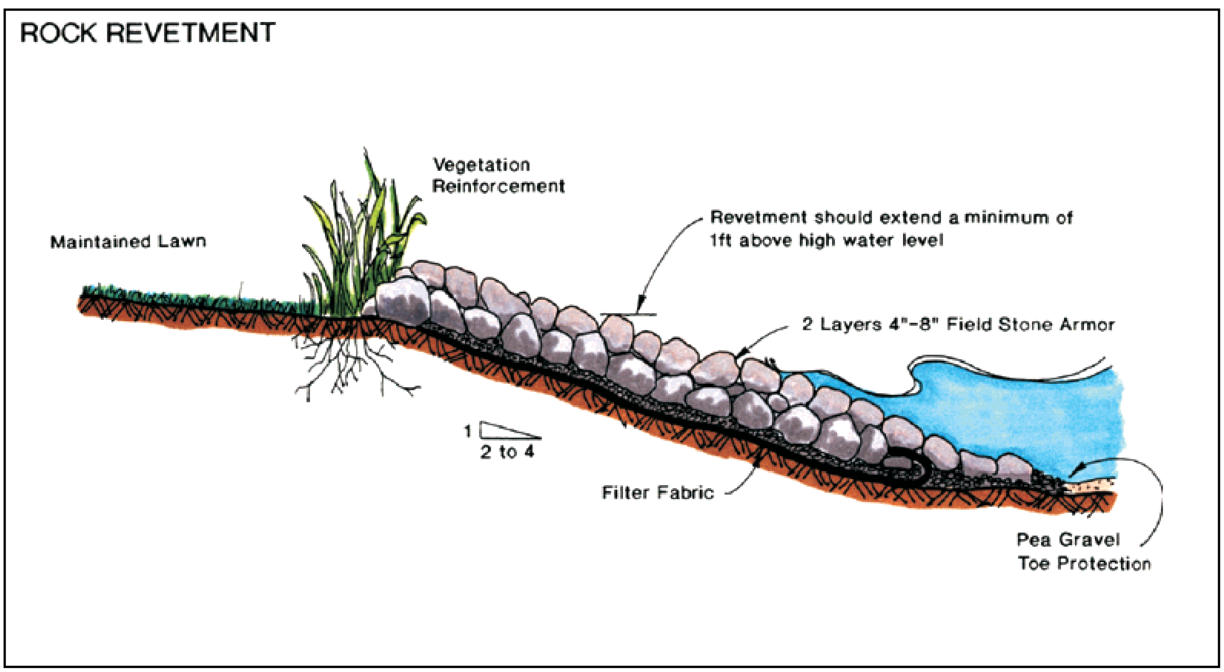


Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 17

PLAN 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.

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 proposed to be subject to the provisions of Chapter NR 328 of the *Wisconsin Administrative Code*, which Chapter, as of 2002, is currently in draft and under administrative review by the Wisconsin Natural Resources Board.

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 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 recommended for Pewaukee Lake.

As noted in Chapter V, Pewaukee Lake is currently managed for warmwater sportfish, and selective stocking is undertaken by the WDNR and private sport fish organizations. Continued fish stocking by the WDNR and the private organizations is recommended for Pewaukee 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 Wisconsin Department of Natural Resources 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 Pewaukee Lake are given in Table 28. 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 three groups: physical measures, which include lake bottom coverings and water level management; mechanical removal measures, which include harvesting and manual removal; and chemical measures, which include using aquatic herbicides and biological control measures, which in turn include the use of various organisms, including insects. Of these, chemical and biological measures are stringently regulated and require a State permit.

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 the Lake, but can be considered a specialized shoreland management zone at the water's edge.

Physical controls and mechanical harvesting may have side effects in the expansion of plant habitat and the spread of reproductive vegetative fragments.

Aquatic Herbicides
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.[12]

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 "weeds," such as Eurasian water milfoil, as both species share similar biological characteristics, being dicotyledons.

The advantages and disadvantages of chemical macrophyte control also apply to the chemical control of algae. Copper, the active ingredient in algicides, may accumulate in the bottom sediments, where excessive amounts are toxic to fish and benthic animals. Fortunately, copper is rapidly eliminated from human systems and few cases of copper sensitivity among humans are known.[13]

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

[13] *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.*

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*.

Although there is a demonstrated need to control aquatic plants in selected areas of Pewaukee 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 recommended.

Aquatic Plant Harvesting

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.[14]

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 erosion.

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.[15]

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

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[14]*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.*

[15]*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.*

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 Wisconsin Department of Natural Resources study found that four pounds of fish were removed per ton of plants harvested.[16]

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.[17] 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.

8. High capital and labor costs may be associated with harvesting programs. Macrophyte harvesting on Pewaukee Lake could be continued by the Village of Pewaukee and the Lake Pewaukee Sanitary District staff 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.

Various types of harvesters and harvesting practices are available to address the many issues encountered on Pewaukee Lake. The Village of Pewaukee currently operates an aquatic plant harvester, primarily in the easternmost portion near the outlet of the Lake, and the Lake Pewaukee Sanitary District operates along the nearshore areas of the western basin and the portion of the eastern basin not harvested by the Village.

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

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

A harvesting program 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.[18] 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 18, is suggested. The harvest of water lilies and emergent native plants, however, 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.[19] Stress can be brought on by watershed 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.[20]

Because of the demonstrated need for control of aquatic plants in Pewaukee Lake, harvesting is considered a viable continued management option. Mechanical harvesting of aquatic plants must be permitted by the State under Chapter NR 109 of the *Wisconsin Administrative Code*.

Manual Harvesting

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 advantage 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 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-feet 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-feet wide recreational corridor.

Biological Controls

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

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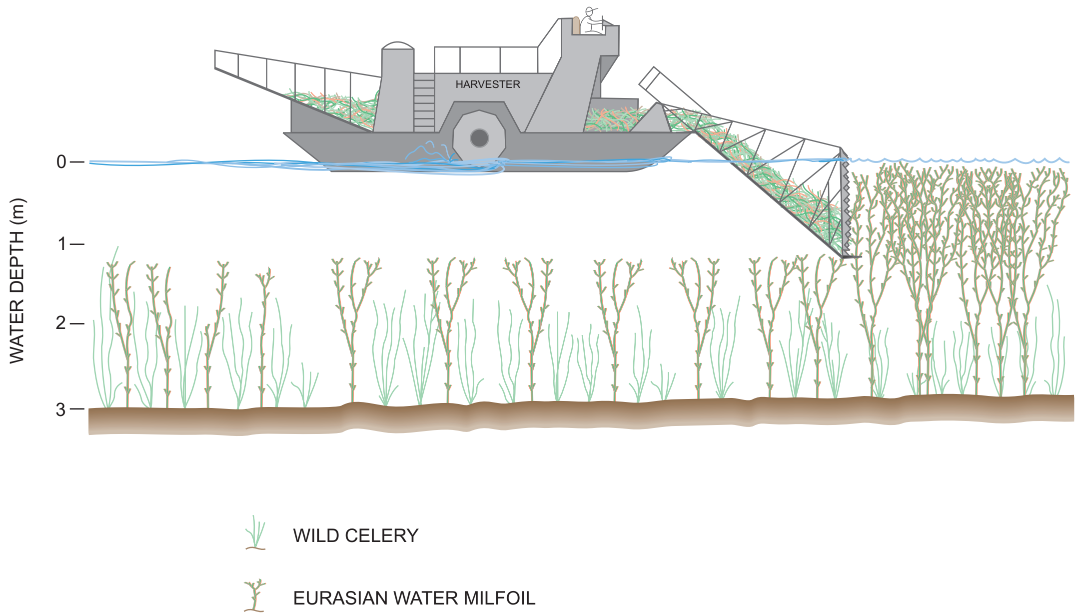
[18]*S. Nichols, Wisconsin Department of Natural Resources Technical Bulletin No. 77,* Mechanical and Habitat Manipulation for Aquatic Plant Management: A Review of Techniques*, 1974.*

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

[20]*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 18

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.

herbivorous insects.[21] 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.[22] 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.

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[21]*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.*

[22]*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.*

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.[23]

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 have been completed using *Eurhychiopsis lecontei* as a means of aquatic plant management control. These have resulted in variable levels of control, and, while priced competitively with aquatic herbicides, is not recommended as being practical for Pewaukee 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, 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.

Lake Bottom Covering

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 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 motorboating 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 Wisconsin Department of Natural Resources is required for use of sediment covers and light screens. Permits require inspection by the Department 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 recommended for Pewaukee Lake.

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[23]*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.*

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 recommended 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 environmental impacts. As shown in Table 18, 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 Pewaukee 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 Wisconsin Department of Natural Resources and the University of Wisconsin-Extension Service. The aquatic plant species lists provided in Chapter V, and the illustrations of common aquatic plants present in Pewaukee 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 a lake on an annual basis.

Of the submerged floating and free-floating aquatic plant species found in Pewaukee 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. While the Lake Pewaukee Sanitary District and Village of Pewaukee harvester crews conduct an extensive shoreline clean-up effort as part of the current aquatic plant management program, 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 and into new areas of the Lake.

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).[24] Providing the opportunity for the removal of plant fragments at the boat landing on Pewaukee 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 Wisconsin Department of Natural Resources and University of Wisconsin-Extension Service 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 approximately 200 feet of shore or 150 feet of pierheads. These areas typically coincide with water depths of less than five feet in depth. Demarcation of WDNR-delineated sensitive areas, Eurasian water milfoil control areas, and similar environmentally valuable or sensitive areas of the Lake is recommended. It is also recommended that the governmental bodies surrounding Pewaukee Lake continue to enforce recreational boating ordinance and winter lake use ordinance appended hereto as Appendix B.

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 the University of Wisconsin-Extension Service, the Wisconsin Department of Natural Resources, and the Waukesha County Department of Parks and Land Use. These latter 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. Other Waukesha County lake organizations, in cooperation with the Waukesha County Department of Parks and Land Use, have compiled and distributed information packets to landowners on water quality protection measures and residential "good housekeeping" practices. 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 Lake Pewaukee Sanitary District 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. The District also actively supports youth educational programming on the Lake and along the Pewaukee River corridor downstream of the Lake.

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. A number of these programs are currently being implemented at the middle school level, through the efforts of the science faculty at

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[24]*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.*

the Asa Clark Middle School, among others. Extension of these educational opportunities at the high school level is recommended. Programs and curricula such as Project WET, Adopt-A-Lake, and the Waukesha Water Walk program are available from and supported by the University of Wisconsin-Extension and Waukesha County, respectively. Through these programs, youth have an opportunity to experience "hands on" the aquatic environment and become better informed about current and future lake issues and concerns.

Finally, the participation of the Pewaukee Lake community in the Wisconsin Department of Natural Resources Self-Help Monitoring Program should be continued. Volunteer monitoring under the auspices of the WDNR "Self-Help Monitoring Program" involves citizens in taking Secchi-disc transparency readings in the Lake at regular intervals. The Lake Coordinator of the Wisconsin Department of Natural Resources-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, in the case of the City of Delafield, management and control of navigable waters is established pursuant to Section 62.11(5), *Wisconsin Statutes*, and, in the case of the Village of Pewaukee, pursuant to Section 61.34(1), *Wisconsin Statutes*, other public and private organizational alternatives for the management of lakes in the State of Wisconsin exist.[25] 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 Chapter 33, *Wisconsin Statutes*, utility districts created pursuant to the municipal statutes, and town sanitary districts created under Chapter 60, *Wisconsin Statutes*. The specific type (or types) of organization created is based upon the decision of the community.

In the case of Pewaukee Lake, general oversight of lake management activities currently is provided by the Lake Pewaukee Sanitary District with the advisory input from the City and Village of Pewaukee, and Town of Delafield. The Lake Pewaukee Sanitary District is a Chapter 60, *Wisconsin Statutes*, town sanitary district serving the Town of Delafield, and providing contract services to the City of Pewaukee. While no change in this organizational arrangement is anticipated, this section outlines those options that are available to the Pewaukee 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. Notwithstanding, a number of property owner associations exist around Pewaukee Lake. Membership 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. Currently, no lakewide association exists with a lake focus that serves the Pewaukee Lake community.

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

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

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. Although creation of a lake management district around Pewaukee Lake has been discussed on a number of occasions, it has generally been felt by the community that the Lake Pewaukee Sanitary District is an effective means of addressing lake management concerns. Sanitary districts with a lake focus are know as lake sanitary districts and perform many or all of the same functions as a lake protection and rehabilitation or management district.

Section 33.25, *Wisconsin Statutes*, provides for the formation of public inland lake protection and rehabilitation districts by petition. In the case of the Pewaukee Lake community, such a petition would be directed to Waukesha County, as the Lake falls within multiple municipalities. This petition would have to identify a name for the proposed district, define the boundaries of the district, and contain the signatures of 51 percent of the landowners or those of the owners of 51 percent of the land within the proposed district. In addition, the petition should set forth the necessity for the district, the basis upon which a district is being formed and the reason why a district is necessary, and the purpose that the district will serve, that the district will promote the public health, convenience, necessity, or public welfare and benefit the lands being included within the district.[26] In the case of Pewaukee Lake, an additional requirement applicable to the formation of a district, set forth in Section 33.24, *Wisconsin Statutes*, would be that approvals have to be obtained from the City and Village of Pewaukee for inclusion of their territory within the proposed district prior to the petition to form a lake management district being submitted to Waukesha County for consideration. Public inland lake protection and rehabilitation districts may also be formed by conversion of town sanitary districts, pursuant to Section 33.235, *Wisconsin Statutes*.

Creation of a public inland lake protection and rehabilitation district is not recommended at this time. Likewise, consideration of the creation of such a district or conversion of the town sanitary in future should be contingent upon need.

SUMMARY

This chapter has described options that could be employed in managing the types of problems recorded as occurring in Pewaukee 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 watershed inventory. Selected characteristics of these measures are summarized in Table 39.

An evaluation of the potential management measures for improving the Pewaukee 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, drawdown by water level control modifications, dredging, biological control of aquatic plants, lake bottom covering, and development of alternative institutions. The remaining measures are recommended to be considered further for incorporation in the recommended plan described in Chapter VIII.

[26]*Benefit has been defined in terms of the benefit to the district of having particular lands included within the district boundaries, rather than the benefit to the individual landowner. See University of Wisconsin-Extension,* Guide to Wisconsin's Lake Management Law, Tenth Edition*, 1996.*

Table 39

SELECTED CHARACTERISTICS OF ALTERNATIVE LAKE MANAGEMENT MEASURES FOR PEWAUKEE LAKE

Alternative Measure	Description	Estimated Costs: 2000		Considered Viable for Inclusion in Recommended Lake Management Plan
		Capital	Operation and Maintenance	
Land Use Management and Zoning	Implement regional land use and county development plans within watershed	- -	- -	Yes
	Maintain existing density management in lakeshore areas	- -	- -	Yes
	Develop and implement consistent stormwater management ordinances in all riparian communities	- -	- -	Yes
Protection of Environmentally Sensitive Lands	Implement regional natural areas and critical species habitat protection and management plan recommendations within watershed	- -	- -	Yes
Nonpoint Source Pollution Abatement	Implement regional water quality management plan, Upper Fox River priority watershed plan, and county land and water resource management plan recommendations within watershed	- -	- -	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 watershed	- -[a]	- -[a]	Yes
Urban Nonpoint Source Controls	Promote urban housekeeping practices, public educational programming, and grassed swales	- -[a]	- -[a]	Yes
	Implement additional urban nonpoint source controls, including street sweeping, catch basin cleaning, leaf litter and garden refuse collection, materials storage facility protection, and stormwater management measures in urban areas of the watershed	- -[a]	- -[a]	Yes
Developing Area Nonpoint Source Controls	Enforce construction site erosion control ordinances requiring soil stabilization, surface roughening, barriers, diversion swales, sediment traps and basins	$250 per acre	$25 per acre	Yes

Table 39 (continued)

Alternative Measure	Description	Estimated Costs: 2000		Considered Viable for Inclusion in Recommended Lake Management Plan
		Capital	Operation and Maintenance	
Public Sanitary Sewerage System Management	Conduct periodic review of sewer service area needs within sewered areas of the watershed	- -	- -	Yes
Onsite Sewage Disposal System Management	Implement onsite sewage disposal system management, including inspection and maintenance	- -	$100[b]	Yes
Water Quality Improvement Measures	Conduct alum treatment to achieve phosphorus inactivation in lake sediments	- -	$115,000	No
	Promote nutrient load reduction within the Lake basin through sediment management	- -	Variable	No
Hydraulic and Hydrologic Management	Modify outlet control operations	- -	- -	No[c]
	Drawdown	- -	- -	No
	Water level stabilization	- -	- -	No
	Dredging	- -	- -	No
Fisheries Management	Protect fish habitat	- -	- -	Yes
	Maintain shoreline and littoral zone fish habitat	- -	- -	Yes
	Continue stocking of selected game fish species and monitor rough fish populations	- -	- -	No
	Enforce size and catch limit regulations	- -	$1,200	Yes
Aquatic Plant Management	Use (limited) aquatic herbicides for control of nuisance plants such as Eurasian water milfoil and purple loosestrife	- -	Variable	Yes[d]
	Harvest aquatic plants to provide boating access lanes and fish lanes; remove Eurasian water milfoil canopy to promote growth of native plants	$100,000	$22,000	Yes[e]
	Manually harvest aquatic plants from around docks and piers	$100	- -	Yes
	Employ biological controls using inocula of Eurasian water milfoil weevils	- -	Variable	No
	Use sediment covers to shade out aquatic plant growth around piers and docks	- -	$40 to $220 per 700 square feet	No
	Conduct public informational and educational programming on aquatic plants and options for their management	- -	$100 to $300	Yes
Recreational Use Management	Enforce boating regulations to maximize public safety; improve signage	- -	$1,000[f]	Yes
	Develop time and/or space zoning schemes to limit surface use conflicts	- -	- -	No

Table 39 (continued)

Alternative Measure	Description	Estimated Costs: 2000 Capital	Estimated Costs: 2000 Operation and Maintenance	Considered Viable for Inclusion in Recommended Lake Management Plan
Public Informational and Educational Programming	Conduct public informational programming utilizing seminars and distribution of informational materials	- -	$1,200	Yes
	Support participation of schools in Project WET, Adopt-A-Lake, etc.	- -	- -	Yes
	Continue participation in Self-Help Monitoring Program	- -	$200	Yes
Institutional Development	Create a lake association for Pewaukee Lake	- -	- -	No[g]
	Create a public inland lake protection and rehabilitation district serving Pewaukee Lake	- -	- -	No

[a]*Cost of nonpoint source management practices to be determined by detailed farm plans and stormwater management plans.*

[b]*Onsite sanitary sewage disposal systems installed after 1983 are subject to regular inspection and maintenance requirements under Waukesha County Code; the cost shown represents an average pumping cost per property. (Note: the lakeshore areas of Pewaukee Lake are served by public sanitary sewers.)*

[c]*While no change to the current operational regime of the Pewaukee Lake dam is suggested, a review and evaluation of the operational regime is recommended to be conducted as part of a hydraulic and hydrologic study of the entire Pewaukee River system.*

[d]*In limited areas when necessary to control exotic, invasive species.*

[e]*Estimated capital cost is for new harvesting equipment to replace existing equipment, when needed.*

[f]*Cost for improved signage.*

[g]*Several property owner associations exist around Pewaukee Lake; these associations are expected to continue to operate and form valuable systems for delivery of informational programming to lake residents.*

Source: SEWRPC.

Chapter VIII

RECOMMENDED MANAGEMENT PLAN FOR PEWAUKEE LAKE

INTRODUCTION

This chapter presents a recommended management plan for Pewaukee Lake. The plan is based upon inventories and analyses of land use and land and water management practices, pollution sources in the drainage area tributary to Pewaukee 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. 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 40, 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 Pewaukee Lake is 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 drainage area tributary to the Lake, as set forth in the adopted Waukesha County development plan, 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 in the drainage area tributary to Pewaukee Lake, protection of environmentally sensitive lands, water quality improvement, hydraulic and hydrologic management, aquatic plant and fisheries 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,[1] the Upper Fox River priority watershed plan,[2] and the Waukesha County land and water resource management plan.[3]

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

[2]*Wisconsin Department of Natural Resources Publication PUBL-WR-366-94,* Nonpoint Source Control Plan for the Upper Fox River Priority Watershed Project*, June 1994.*

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

Table 40

RECOMMENDED MANAGEMENT PLAN ELEMENTS FOR PEWAUKEE LAKE

Plan Element	Subelement	Location	Management Measures	Management Responsibility
Land Use Control and Management	Land use development planning	Entire watershed	Observe guidelines set forth in the regional land use plan and Waukesha County development plan	Waukesha County, City of Pewaukee, City of Waukesha, Village of Hartland, Village of Pewaukee, Town of Delafield, Town of Lisbon, Town of Merton
	Density management	Lakeshore areas	Maintain historic lake front residential dwelling densities to extent practicable	City of Pewaukee, Village of Pewaukee, Town of Delafield
	Stormwater management plan development	IH 94, STH 83, and STH 16	Consider practices to reduce contaminant loads to Pewaukee Lake from urban development and highways	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield
	Protection of environmentally sensitive lands	Pewaukee Lake Access Fen, Pewaukee Lake Wetland, Pewaukee Lake Sedge Meadow, Capitol Drive Sedge Meadow and Wet Prairie, Hartland Railroad Prairie	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, City of Pewaukee, Village of Pewaukee, Town of Delafield, Lake Pewaukee Sanitary District
Nonpoint Source Pollution Control	Rural nonpoint source controls	Entire watershed	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 plan	USDA, WDATCP, Waukesha County
	Urban nonpoint source controls	Entire watershed	Promote sound urban housekeeping and yard care practices through informational programming	City of Pewaukee, Village of Pewaukee, Town of Delafield, Lake Pewaukee Sanitary District
		Entire watershed	Consider development of lawn care management and shoreland protection ordinances	City of Pewaukee, Village of Pewaukee, Town of Delafield
	Construction site erosion control and stormwater management ordinance	Entire watershed	Develop and enforce construction site erosion control and stormwater management ordinances; review ordinances for concurrency with proposed NR 152	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield
		New clustered developments in conservation subdivisions	Develop stormwater management systems where appropriate densities exist	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield

Table 40 (continued)

Plan Element	Subelement	Location	Management Measures	Management Responsibility
Nonpoint Source Pollution Control (continued)	Sewerage system management	Entire watershed	Periodically review current sewer service area facilities plan to continue to provide water-borne sewerage services to urban areas of the watershed	Lake Pewaukee Sanitary District, Waukesha County, City of Pewaukee, City of Waukesha, Village of Hartland, Village of Pewaukee, Town of Delafield, Town of Lisbon, Town of Merton
			Inspect and maintain onsite sewage disposal systems	Waukesha County, Lake Pewaukee Sanitary District, private landowners
Surface Water Quality Management	Water quality monitoring	Entire Lake	Continue participation in WDNR Self-help Monitoring Program; enroll in Expanded/TSI Self-help Monitoring Program	WDNR, Lake Pewaukee Sanitary District
			Consider participation in U.S. Geological Survey or University of Wisconsin-Stevens Point Environmental Task Force TSI monitoring program	Lake Pewaukee Sanitary District
Water Quantity and Lake Level Management	Dam operations and Lake level monitoring	Entire Lake	Maintain outlet structure and monitor water levels	WDNR, Village of Pewaukee
Fish Management	Fish survey and stocking program	Selected areas of Lake	Conduct fish survey to determine management and stocking needs; conduct periodic creel census	WDNR
	Habitat Protection and Lake Use Management	WDNR-delineated sensitive areas	Limit chemical treatments and harvesting pursuant to Chapter NR 107 requirements	WDNR, Lake Pewaukee Sanitary District
		WDNR-delineated sensitive areas	Manage aquatic plant harvesting program pursuant to Chapter NR 109 requirements	WDNR, Lake Pewaukee Sanitary District
	Shoreland Protection	Entire lake	Maintain existing shoreline structures and repair as necessary using vegetative means insofar as practicable; reconstruction may require WDNR Chapter 30 permits	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield, WDNR
	Minimize shoreland impacts on lake water quality and habitat	Lake shoreline	Restrict pollutant loading from stormwater discharges to the Lake through implementation of stormwater management practices	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield, WDNR
			Enforce adequate setbacks in shoreland areas	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield, 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, City of Pewaukee, Village of Pewaukee, Town of Delafield, WDNR

Table 40 (continued)

Plan Element	Subelement	Location	Management Measures	Management Responsibility
Fish Management (continued)	Minimize shoreland impacts on lake water quality and habitat (continued)	Lake shoreline (continued)	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	Private landowners, Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield, Lake Pewaukee Sanitary District, WDNR, UWEX
Aquatic Plant Management	Comprehensive plan refinement	Entire Lake	Update aquatic plant management plan every three to five years	WDNR, Village of Pewaukee, Lake Pewaukee Sanitary District
	Major and minor channel harvesting	Selected areas of Lake	Harvest aquatic plants as required to facilitate recreational boating access; restrict harvesting in spring and autumn to avoid disturbances in fish breeding areas and WDNR-delineated sensitive areas	Village of Pewaukee, Lake Pewaukee Sanitary District
	Chemical treatment	Selected areas of Lake and shoreland	Limited to control of nuisance aquatic plant growth where necessary; specifically target Eurasian water milfoil and curly-leaf pondweed around docks and piers and garlic mustard and purple loosestrife infestations	WDNR, Village of Pewaukee, Lake Pewaukee Sanitary District, private landowners
	Shoreline maintenance	Lakeshore areas	Collect floating plant fragments from shoreland areas to minimize rooting of Eurasian water milfoil and deposition of organic materials in Lake	Village of Pewaukee, Lake Pewaukee Sanitary District
Recreational Use Management	Boating Access	Public access sites	Maintain recreational boating access from the public access sites pursuant to Chapter NR 7 guidelines	Waukesha County, City of Pewaukee, WDNR
	Recreational boating and vehicular use	Entire Lake	Continue to enforce and periodically review, recreational boating (summer) and vehicular use (winter) ordinances	Waukesha County, City of Pewaukee, Village of Pewaukee, Town of Delafield, WDNR
Informational and Educational Program	Public informational and educational programming	Entire watershed	Continue public awareness and informational programming	Waukesha County, Village of Pewaukee, Lake Pewaukee Sanitary District, WDNR, UWEX
		Entire Lake	Encourage inclusion of lake studies in environmental curricula (e.g., Project WET, Adopt-A-Lake, Waukesha Water Walk)	Kettle Moraine School District, Pewaukee School District, UWEX, Waukesha County

Source: SEWRPC.

The recommended management measures for Pewaukee Lake are graphically summarized on Map 34, and are listed in Table 40. The recommended plan measures are more fully described in the following paragraphs. It should be noted that recreational use management and institutional development measures were also considered in developing this management plan, but were not included within the recommended management plan at this time. The recommended management agency responsibilities for watershed land management also are set forth in Table 40.

WATERSHED MANAGEMENT MEASURES

Land Use Control and Management

A fundamental element of a sound management plan and program for Pewaukee Lake is the promotion of a sound land use pattern within the drainage area tributary to the Lake. The type and location of rural and urban land uses in the drainage 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 drainage area tributary to Pewaukee 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), as refined through the Waukesha County development plan.[4] The recommended land use and county development plans envision that urban land use development within the drainage area tributary to Pewaukee 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 Regional Planning Commission-delineated environmental corridors described in Chapter V.

Development in the Shoreland Zone

A major land use issue which has the potential to affect Pewaukee 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 on the Lake, and will 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 drainage 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 Pewaukee Lake to the maximum extent practical is recommended.

It is further recommended that lakefront developments, as well as setback and landscaping provisions, be carefully reviewed by the City and Village of Pewaukee and Town of Delafield Plan Commissions and the Wisconsin Department of Natural Resources (WDNR). 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.

Development in the Tributary Drainage 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 drainage area. As previously noted, large-lot residential

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

Map 34

RECOMMENDED MANAGEMENT PLAN ELEMENTS FOR PEWAUKEE LAKE

—20'— WATER DEPTH CONTOUR IN FEET

AQUATIC PLANT MANAGEMENT

- H — WISCONSIN DEPARTMENT OF NATURAL RESOURCES-DELINEATED SENSITIVE AREAS
- G — GENERAL BOATING AND FISHING/ RECREATIONAL USE HARVESTING: MODERATE PRIORITY
- R — RIPARIAN ACCESS HARVESTING: HIGH PRIORITY
- H — HABITAT AREA HARVESTING: LOW PRIORITY
- O — OPEN WATER DEPTH GREATER THAN 25 FEET HARVESTING: NONE

LAND USE MANAGEMENT

- PROTECT ENVIRONMENTALLY VALUABLE AREAS
- MAINTAIN EXISTING SHORELINE STRUCTURES
- IMPLEMENT WAUKESHA COUNTY DEVELOPMENT PLAN AND REGIONAL LAND USE PLAN IN WASHINGTON COUNTY AND PROMOTE GOOD HOUSEKEEPING PRACTICES IN DRAINAGE AREA

MONITORING PROGRAM

- CONDUCT FISH SURVEY
- CONTINUE WATER QUALITY MONITORING
- REFINE AQUATIC PLANT SURVEY AT THREE-TO-FIVE-YEAR INTERVALS

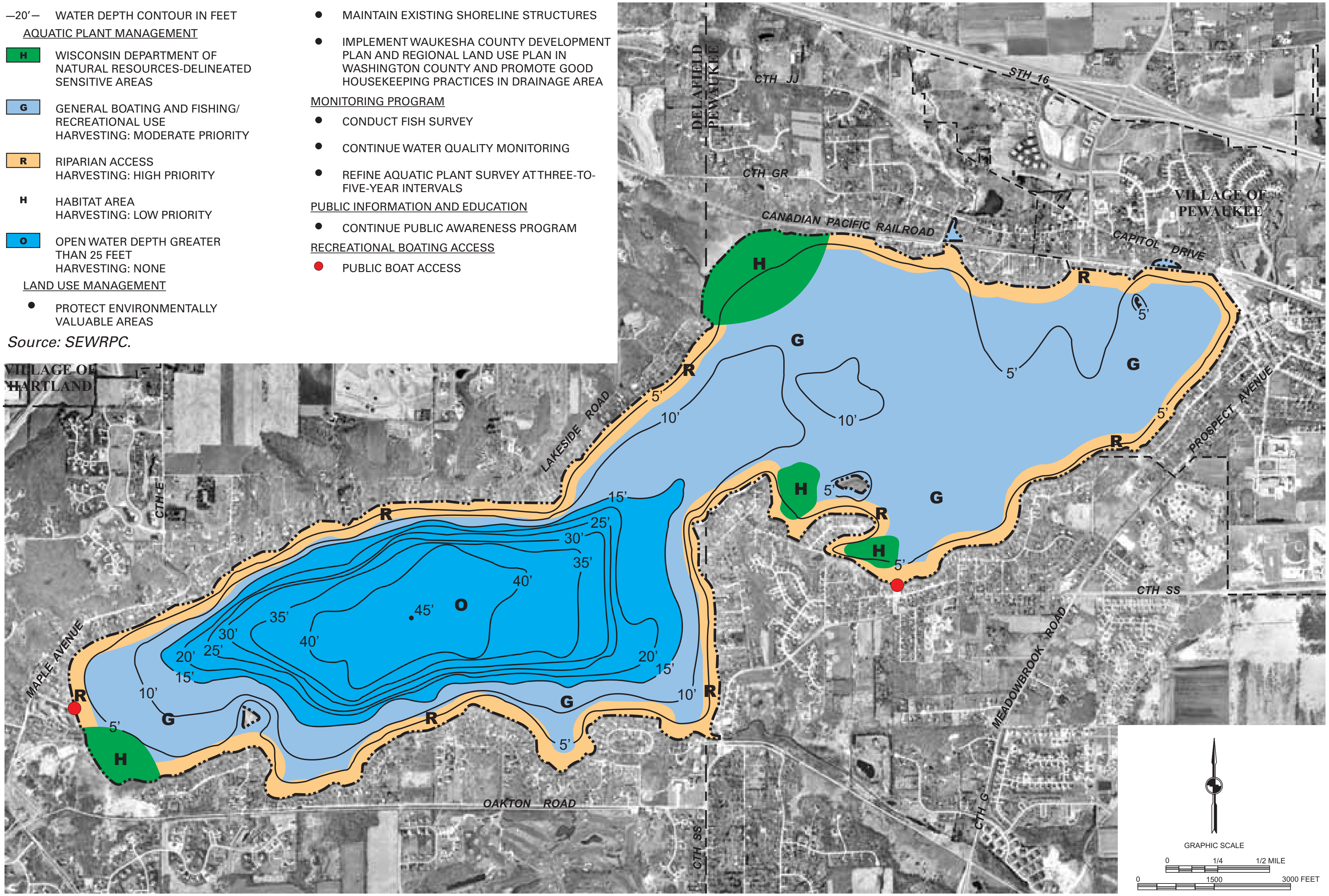
PUBLIC INFORMATION AND EDUCATION

- CONTINUE PUBLIC AWARENESS PROGRAM

RECREATIONAL BOATING ACCESS

- PUBLIC BOAT ACCESS

Source: SEWRPC.



DATE OF PHOTOGRAPHY: MARCH 2000

development is occurring in areas of the lake watershed in which such development was not envisioned in the adopted regional land use plan. If this trend continues, much of the open space areas remaining in the drainage 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 Lake. Under the full buildout condition envisioned under the Waukesha County development plan,[5] 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 drainage 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 Pewaukee 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.

Stormwater Management

It is recommended that the City of Pewaukee, the Village of Pewaukee, and the Town of Delafield 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 drainage 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 Pewaukee 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 drainage area tributary to Pewaukee Lake. The wetland areas within the drainage 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 Pewaukee Lake drainage 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.

Notwithstanding, 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 the Pewaukee Lake Wetland; the Pewaukee Lake Sedge Meadow; the Capitol Drive Sedge Meadow and Wet Prairie; and the Hartland Railroad Prairie.[6] Public acquisition of these lands is recommended. In this regard, implementation of the recom-

[5]Ibid.

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

mendations of the adopted park and open space plan for Waukesha County[7] would complement the protection and preservation of these environmentally sensitive lands.

Wetland Acquisition for Water Quality Protection
Significant areas of wetland exist within the drainage area tributary to Pewaukee Lake including those wetlands associated with major tributaries to Pewaukee Lake, which provide significant stormwater detention potential. The Lake Pewaukee Sanitary District has currently purchased and acquired approximately 245 acres of wetlands all within the drainage area tributary to Pewaukee Lake. The District has a wetland acquisition goal of approximately 350 acres. The acquisition of wetlands—to be preserved in essentially natural open space uses—located within environmental corridor lands and lands in the drainage area tributary to Pewaukee Lake is recommended.

Nonpoint Source Pollution Control
The recommended watershed land management measures are specifically aimed at reducing the water quality impacts on Pewaukee Lake of nonpoint sources of pollution within the tributary drainage 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 watershed 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 drainage area. The lakeshore areas tributary to Pewaukee Lake are largely served by a public sanitary sewerage system.

Nonpoint source control measures should be considered for the areas tributary to Pewaukee Lake, including the upstream tributary drainage area. The regional water quality management plan recommended a reduction of about 50 percent in urban, and of up to 75 percent in rural, nonpoint-sourced pollutants plus streambank erosion control, construction site erosion control, and onsite sewage disposal system management be achieved in the drainage area tributary to Pewaukee Lake. The Upper Fox River Priority Watershed plan subsequently refined these recommendations, and indicated an overall reduction of phosphorus loading of about 38 percent.

Nonpoint source pollution abatement controls in the drainage 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-sourced 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 City of Pewaukee, the Village of Pewaukee, the Town of Delafield, Waukesha County, and private landowners. Technical assistance can be provided by the U.S. Department of Agriculture Natural Resources Conservation Service; 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 City and Village of Pewaukee and the Town of Delafield, in coordination with the Wisconsin Department of Natural Resources, 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 U.S. Department of Agriculture Environmental Quality Incentive Program (EQIP), the Wisconsin Department of Natural Resources runoff management and lake protection programs, and various local land acquisition initiatives.

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

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 drainage area tributary to Pewaukee Lake include conservation tillage, integrated nutrient and pesticide management, and pasture 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 Pewaukee 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 become 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.[8]

Urban Nonpoint Source Pollution Controls

The development of urban nonpoint source pollution abatement measures for the Pewaukee Lake areas should be the primary responsibility of the City of Pewaukee, the Village of Pewaukee, and the Town of Delafield in Waukesha County. 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 Lake Pewaukee Sanitary District, in cooperation with the City, the Village and the Town, take the lead in sponsoring such programming for the Pewaukee Lake community through regular public informational meetings and mailings. The District should also ensure that relevant literature, available through the University of Wisconsin-Extension Service and the WDNR, is made available at these meetings and at the local Public Library and government offices. Such low-cost measures complement the City and Village of Pewaukee street sweeping program and litter collection activities.

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 Pewaukee Lake be prepared and distributed to property owners. This fact sheet could be distributed by the City and Village of Pewaukee, the Town of Delafield, and the Lake Pewaukee Sanitary District, with the assistance of the University of Wisconsin-Extension Service 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, the City and Village of Pewaukee, and the Town of Delafield 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 by the County 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. In the City of Pewaukee and the Village of Pewaukee, this function is performed by the municipal Building Inspection staff.

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[8] *Wisconsin Department of Natural Resources Publication PUBL-WR-366-94,* op. cit.

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 Pewaukee 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 drainage area to Pewaukee 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

Although the lakeshore areas tributary to Pewaukee Lake are served by public sanitary sewerage systems, portions of the direct and total drainage area to the Lake continue to be served by onsite sewage disposal systems. While such systems have been estimated to contribute less than one 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 City of Pewaukee and the Towns of Delafield, Merton, and Lisbon, 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 drainage area tributary to Pewaukee Lake served by public sanitary sewerage systems, it is recommended that the Lake Pewaukee Sanitary District, in cooperation with the City and Village of Pewaukee and the Town of Delafield, 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 District 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 Pewaukee Lake are summarized in Table 40 and are graphically summarized on Map 34. The major recommendations include water quality monitoring, hydrologic management, fisheries management and habitat protection, shoreland protection, aquatic plant management, recreational use management, and informational and educational programming.

Surface Water Quality Management

Continued water quality monitoring of Pewaukee Lake is recommended. Enrollment of one or more lake residents as WDNR Self-Help Monitoring Program volunteers is recommended. Such enrollment can be accomplished through the Southeast Region Office of the Wisconsin Department of Natural Resources. A firm commitment of time is required of the volunteers. In addition, participation in the trophic status index (TSI) Self-Help Monitoring Program, measuring nutrients, chlorophyll-*a*, and temperature, is recommended. Such monitoring should be conducted five times a year at a central station in the deepest portion of the lake basin. Monitoring programs are facilitated by the WDNR through the expanded Self-Help Monitoring Program and by the University of Wisconsin-Stevens Point Environmental Task Force Laboratory through their lake monitoring programs.

Water Quantity and Lake Level Management

As indicated in the lake and watershed inventory, outflow from Pewaukee Lake is controlled by a dam located on the eastern side of the Lake at West Wisconsin Avenue. The present actual operating regime of the dam is intended to maintain the lake level at an elevation which registers between 852.20 and 852.80 feet National geodetic Vertical Datum of 1929 (NGVD-29). The lake elevation is controlled by manual adjustment of the dam operating gate which adjustment is made periodically by a member of the Village of Pewaukee Public Works Department based upon the observed lake levels. Any change in this operating regime would require a petition from the Village of Pewaukee to the WDNR. Given the size and type of lake involved, it is considered reasonable to have an operating water level range of no less than 0.5 foot. Since such a range can be maintained with the existing operating system, no additional operational controls are deemed necessary. However, the existing gate operating system for the dam gate will need to be periodically maintained and repaired to keep it functional.

Concerns have been raised by residents regarding lake water levels being too low or too high. 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. Such concerns have been expressed not only by Lake residents but also by downstream landowners who are affected by waters discharged through the Lake Pewaukee impoundment. The variable level discharge associated with this dam potentially provides an opportunity to manage the lake levels so as to moderate flood flows through the system, and minimize concerns about the variable downstream flow to the Pewaukee River. Flows in the Pewaukee River are reported to be subject to dramatic changes that should be more gradual; during the summer months, flows in the River can experience a sudden, 18-inch drop leaving macrophytes exposed and fish stranded in small pools when the outflow structure is closed. Refinement of the dam operating protocol, therefore, is recommended.

In order to best develop a hydraulic and hydrologic operating regime that provides optimal benefit to both residents and lake users, as well as to the environment in the Lake and downstream in the Pewaukee River, the management program should be based upon a thorough understanding of the hydrology of the Pewaukee River system. The initial step in conducting such an analysis is to obtain records of stream flow and lake level on a regular and consistent basis. This is best accomplished by the installation of a stream and lake stage recording gauging station. It is recommended that consideration be given to the Lake Pewaukee Sanitary District contracting with the U.S. Geological Survey for the installation of such a station at the dam. The dam is currently equipped with a staff gauge, installed relative to a local datum—which means that the readings displayed on this gauge do not match actual elevation—that reportedly leaves observers confused and introduces room for error. As the staff gauge needs to be replaced, an opportunity exists to replace the gauge with an automatic continuous stage recording gauge.

Fisheries Management

Management of Species Composition

Three specific actions are recommended with respect to fisheries management: the conduct of a fishery survey and the formulation of refined stocking and size and bag limitations; the assessment of angling pressures; and, the analysis of potential contamination of fishes in the Lake.

The fishery survey should be conducted by the WDNR at the request of the Lake Pewaukee Sanitary District or other community-based organization and 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, undertaken between 1964 and 1982 and in 1998;

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, tiger muskellunge, muskellunge, and/or other game fish species, as appropriate, by the WDNR, in order to maintain a continuing, viable sport fishery.

The second recommended action relative to a fishery management program is an assessment of angling pressures on the Lake. This assessment should:

1. Provide data to determine the intensity of public use of the Pewaukee Lake fishery through creel surveys, citizen reporting activities, and evaluation of the fish survey data; and

2. Provide data to assess the impact of harvesting of fishes from the Lake, relative to the bag limits established for Pewaukee Lake.

Thirdly, given the fishing pressures on the Lake, it would be desirable to also conduct a one-time analysis of fish tissues for metal and toxic contamination at the time the fisheries survey was conducted.

These three actions are recommended to provide a sound basis for the District and the WDNR to consider developing a 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.

The cost of the recommended comprehensive fish survey is estimated to be $16,000.

Habitat Protection
The habitat protection measures recommended for Pewaukee Lake are, in part, provided by the recommended aquatic plant management program set forth below. The aquatic plant management plan is designed to provide for habitat protection by avoiding disturbances in fish breeding areas during spring and autumn; reducing the use of aquatic plant herbicides; and maintaining stands of native aquatic plants. In particular, this recommendation extends to, and includes, the WDNR NR 107 sensitive areas located along the western and northern shorelines of the Lake as shown on Map 33. In addition, it is recommended that environmentally sensitive lands, including wetlands along the western and northern lakeshore be preserved.

Shoreland Protection
Most of the Pewaukee 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.[9]

In addition to the foregoing measures, it is also recommended that the City of Pewaukee, the Town of Delafield, and the Village of Pewaukee continue 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 fishing as a recreational use of Pewaukee 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 Pewaukee 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. An aquatic macrophyte control plan consistent with Chapters NR 103, NR 107, and NR 109 of the *Wisconsin Administrative Code* is included as Appendix A of this report.

Alternative Methods for Aquatic Plant Control

Various aquatic plant management techniques—manual, mechanical, and chemical—are potentially applicable on Pewaukee Lake. A number of these methods have been employed with varying success on Pewaukee Lake in the past, although aquatic plant harvesting has been the major control measure utilized throughout the Lake in recent years.

Chemical Controls

Chemical controls, in the form of herbicides and algicides, have been used on Pewaukee Lake. However, an important goal of the Lake Pewaukee Sanitary District has been to manage the aquatic plant communities of the Lake without the use of chemicals. Currently, the use of herbicides on the Lake has been limited to individual applications around piers and docks.

As noted above, the aquatic herbicides diquat, endothall, and 2,4-D have been applied to Pewaukee Lake to control aquatic macrophyte growth, and the use of fluridone has been proposed. Diquat is a nonselective herbicide that will kill many aquatic plants, such as the pondweeds, bladderwort, and naiads that occur in Pewaukee Lake and 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, 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 the Lake, damaging or destroying nontarget plant species that provide needed habitat for fish and other aquatic life. Hence, this option is not feasible on the scale required to control the infestations of aquatic plants in Pewaukee Lake.

Chemical control may be a suitable technique for the control of relatively small-scale infestations of Eurasian water milfoil. Chemical applications in early spring have been found to be effective in controlling such

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[9]*Chapter NR 328 of the* Wisconsin Administrative Code *had been approved for public hearing by the Wisconsin Natural Resources Board at the time of writing. It is anticipated that the Code provisions contained therein would become law during late 2002 or early 2003.*

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.

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 considered a viable option on Pewaukee Lake to control nearshore plant growths, especially around piers and docks, and are encouraged by the Lake Pewaukee Sanitary District.

Mechanical Controls
Based on previous experience of the use of mechanical harvester technologies on Pewaukee Lake, mechanical harvesting of aquatic plants appears to be a practical and environmentally sensitive method of controlling plant growth and associated filamentous algae. The most significant impact of mechanical harvesting is the 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,[10] 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.

Creation of shared access lanes, allowing several residents to use the same lane, can result in increased use of these lanes and will help to keep them open for longer periods than would be the case if a less directed harvesting program was followed. Because of the demonstrated need for control of aquatic plants in Pewaukee Lake, and because the current lake uses continue to indicate a need for aquatic plant harvesting, harvesting is considered a viable management option that should be continued by the Lake Pewaukee Sanitary District and Village of Pewaukee.

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 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. Given that a significant number of lake homeowners are seasonal or elderly, it is not always feasible for the riparian owners to clean their shoreline when needed. To alleviate this problem, the Lake Pewaukee Sanitary District and Village of Pewaukee have incorporated a shoreline cleanup crew into their harvesting program. Currently, the shoreline cleanup crews remove nearly as much vegetation as do the harvester operators. While this operation continues to leave the control of rooted vegetation between the piers to the riparian owners, the continuation of the shoreline clean up program is considered to be a feasible part of the aquatic plant management plan for the Lake.

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[10]*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.*

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 drainage 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.

The Pewaukee Lake community has consistently supported informational and educational programming within their community. Efforts by the Lake Pewaukee Sanitary District staff, and staff of the Asa Clark Middle School, have not only encouraged environmentally sound behaviors within and downstream of the Lake, in the Pewaukee River, but 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 harvested and/or chemically treated, 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.

Modifications of the existing aquatic plant management program are recommended to enhance the use of Pewaukee Lake while maintaining the quality and diversity of the biological communities. The following recommendations are made:

1. Mechanical harvesting is recommended as the primary management method. 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. The harvesting should be carried out by the Lake Pewaukee Sanitary District and the Village of Pewaukee using its existing harvester and transport equipment.

2. 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.

3. 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 Pewaukee 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.

4. 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 the harvester 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 Pewaukee Lake and valuable macroscopic algae, such as *Chara* and *Nitella* are killed by this product.

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 Lake Pewaukee Sanitary District and Village of Pewaukee 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 ongoing collection of aquatic plant fragments and other debris by the Lake Pewaukee Sanitary District and Village of Pewaukee staff 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. Aquatic plant management limitations set forth within the WDNR Chapter NR 107 sensitive area determinations are incorporated herein by reference.

8. It is further recommended that the Lake Pewaukee Sanitary District and the Village of Pewaukee conduct a public informational program on the types of aquatic plants in Pewaukee 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 34. 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 Lake Pewaukee Sanitary District and the Village of Pewaukee. Implementation of this plan would entail a capital cost of about $210,500 for the District and about $92,500 for the Village, the majority of which would be required for the eventual replacement of equipment. Cost-share funding may be available for the acquisition of replacement equipment under the Chapter NR 7 Recreational Boating Facilities Grant Program administered by the Wisconsin Waterways Commission. Annual operation and maintenance costs of about $200,000 are estimated to be incurred by the District and the Village for the conduct of this program.

OTHER LAKE MANAGEMENT MEASURES

Recreational Use Management

Public Recreational Boating Access

With respect to boating ordinances applicable to Pewaukee 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 exotic invasive species within Pewaukee Lake, including zebra mussel and Eurasian water milfoil. Appropriate signage should be placed at the public 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 the Waukesha County and City of Pewaukee public recreational boating access sites. In addition, it is recommended that the City of Pewaukee and Waukesha County make disposal bins available at their public recreational boating access sites for disposal of plant materials and other refuse removed from watercraft using the public recreational boating access sites.[11]

Public Informational and Educational Programs

It is recommended that the Lake Pewaukee Sanitary District and the Village of Pewaukee assume the lead in the development of a public informational and educational program. Participation by the City of Pewaukee and Town of Delafield 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, 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 the University of Wisconsin-Extension Service. These cover topics such as beneficial lawn care practices and household chemical use. Such brochures should 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 Pewaukee Lake, it is recommended that the Lake Pewaukee Sanitary District and the local municipalities 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.[12]

The Lake Pewaukee Sanitary District and the municipalities are also encouraged to take an active role in encouraging the Kettle Moraine, Pewaukee, and Waukesha School Districts, and the Arrowhead Union High School, to adopt and utilize lake-related educational programs, such as Adopt-A-Lake and 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.

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[11]*The City of Pewaukee and Waukesha County Department of Parks and Land Use should continue to monitor experience with the use of high pressure washing stations for the control of zebra mussel currently being gained within the Laurentian Great Lakes Basin and consider adoption of those measures proven to be successful in limiting the spread of zebra mussel within the Region. The U.S.-Canadian International Joint Commission regularly provides informational materials on this and related subjects.*

[12]*Because the Lake Pewaukee Sanitary District is not a public inland lake protection and rehabilitation district, there is not statutory requirement that the District hold an annual meeting. However, the District could work with the local municipalities and other civic organizations to develop a regular series of informational programs that would benefit not only the Lake residents, but also the community at large.*

Institutional Development

In the case of Pewaukee Lake, general oversight of lake management activities currently is provided by the Lake Pewaukee Sanitary District with the advisory input from the City and Village of Pewaukee and the Town of Delafield. The Lake Pewaukee Sanitary District, as a Chapter 60, *Wisconsin Statutes*, town sanitary district, serves the Town of Delafield, and provides contract services to the City of Pewaukee. While no immediate change in this organizational arrangement is anticipated, consideration in the future maybe given to converting the sanitary district to a Chapter 33, *Wisconsin Statutes*, public inland lake protection and rehabilitation district which would allow more direct representation from within the Pewaukee Lake community with respect to lake management activities.

PLAN IMPLEMENTATION AND COSTS

The actions recommended in this plan largely represent an extension of ongoing actions being carried out by the Lake Pewaukee Sanitary District, the City of Pewaukee, the Village of Pewaukee, and the Town of Delafield, 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, such as monitoring, harvesting, and public awareness campaigns currently implemented by the Lake Pewaukee Sanitary District and Village of Pewaukee, are recommended to continue with refinements as proposed herein. Some aspects of these programs lend themselves to citizen involvement through participation in the Wisconsin Department of Natural Resources Self-Help Monitoring Program, and identification with environmentally sound owner-based land management activities. It is recommended that the Lake Pewaukee Sanitary District, 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 University of Wisconsin-Extension Service office, and SEWRPC.

A major cost element in the plan relates to the eventual replacement of harvesting equipment. Implementation of the recommended plan would entail a capital expenditure of about $212,500 for the District and $70,000 for the Village and an annual operation and maintenance expenditure of about $200,000 by the District and Village, including existing expenditures, over the next 10 years. The current, annual operation and maintenance budgets of the Sanitary District and Village for the harvesters is appropriate to cover this level of future investment. When it is necessary to replace the existing harvesting equipment, some of the capital costs could be offset with grants from the Wisconsin Waterways Commission under Chapters NR 7 Recreational Boating Facilities Grant Program, while additional cost share assistance may be available from the Wisconsin Waterways Commission for the conduct of Eurasian water milfoil control programs using chemical herbicides. Additional lake and watershed management measures may be cost-shared through the Chapter NR 191 Lake Protection Grant Program, Chapter NR 120 Nonpoint Pollution Abatement Program, or NR 153/NR 154 runoff management programs.

The suggested lead agency or agencies for initiating program-related activities, by plan element, are set forth in Table 40, and the estimated costs of these elements, linked to possible funding sources where such are available, are summarized in Table 41. In general, it is recommended that the Lake Pewaukee Sanitary District continue to provide a coordinating role for community-based lake management actions, in cooperation with the appropriate local government units.

Pewaukee Lake is a valuable natural resource in the Southeastern Wisconsin Region. Increases in population, urbanization, income, leisure time, and individual mobility forecast for the Region may be expected to result in additional pressure for development in the drainage area tributary to the Lake and for water-based recreation on the Lake. Adoption and administration of an effective lake management program for Pewaukee Lake, based upon the recommendations set forth herein, will provide the water quality protection needed to maintain conditions in Pewaukee Lake suitable for recreational use and for fish and other aquatic life.

Table 41

ESTIMATED COSTS OF RECOMMENDED LAKE MANAGEMENT MEASURES FOR PEWAUKEE LAKE

Plan Element	Subelement	Estimated Cost 2000-2020[a] Capital	Estimated Cost 2000-2020[a] Annual Operation and Maintenance	Potential Funding Sources[b]
Land Use Control and Management	Land use development planning	- -	- -	County, Cities, Villages, Towns
	Density management in the shoreland zone	- -	- -	Cities, Villages, Towns
	Stormwater management plan development	- -	- -	County, City, Villages
	Protection of environmentally sensitive lands	- -	- -	WDNR Lake Protection Grant and Stewardship Grant Programs, Waukesha County Land Conservancy, Lake Pewaukee Sanitary District
Nonpoint Source Pollution Control	Rural nonpoint source controls	- -[c]	- -[c]	County, USDA EQIP, WDNR/WDATCP Runoff Management Program
	Urban nonpoint source controls	- -[c]	- -[c]	County, WDNR/WDATCP Runoff Management Program
	Construction site erosion controls and stormwater management ordinances	- -[c]	$250-$500/acre[c]	County, municipalities, private firms, individuals
	Sewerage system management	- -[c]	$100-$200[c]	Lake Pewaukee Sanitary District, County, private firms, individuals
Surface Water Quality and Quantity Management	Water quality monitoring	- -	- -[d]	USGS, City, WDNR Self-Help and Ambient Lakes Monitoring Programs
Water Quantity and Lake Level Management	Water quantity monitoring	- -	- -[e]	Village of Pewaukee, USGS, WDNR
Fish Management	Fish survey	$16,000[d]	- -[d]	WDNR
	WDNR-delineated sensitive areas	- -	- -	Lake Pewaukee Sanitary District, Village of Pewaukee, WDNR
	Maintenance of structures	- -	- -	Private firms, individuals
	Minimize shoreland impacts on lake water quality and habitat	- -	- -	County, municipalities, private firms, individuals, WDNR
Aquatic Plant Management	Comprehensive plan refinement	- -	$1,500[f]	Lake Pewaukee Sanitary District, WDNR Lake Management Planning Grant Program
	Major/minor boating channel harvesting	$303,000[g]	$160,000	Lake Pewaukee Sanitary District, Village of Pewaukee, Wisconsin Waterways Commission
	Chemical treatment	- -	$1,000/acre[h]	Wisconsin Waterways Commission, individuals

Table 41 (continued)

Plan Element	Subelement	Estimated Cost 2000-2020[a] Capital	Estimated Cost 2000-2020[a] Annual Operation and Maintenance	Potential Funding Sources[b]
Recreational Use Management	Maintain recreational boating access; enforce existing boating and winter use ordinances	- -	- -	County, municipalities, WDNR
Informational and Educational Program	Public informational and educational programming	- -	$1,200	Lake Pewaukee Sanitary District, UWEX/ WDNR/WAL Lakes Partnership, school districts
Total	- -	$319,000	$161,200[i]	- -

[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, County is Waukesha County, City is the City of Pewaukee, Village is the Village of Pewaukee, Town is the Town of Delafield, 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]The WDNR Self-Help Monitoring Program and proposed creel survey involves no cost but does entail a time commitment from the volunteer; monitoring by the USGS can be cost-shared between the federal agency and local cooperators.

[e]Water quantity monitoring should be conducted in conjunction with a hydraulic and hydrologic analysis of the entire Pewaukee River system; USGS hydrological monitoring is proposed.

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

[g]Costs are based on the assumption that the existing harvester and ancillary equipment may eventually need replacement; cost-share assistance for harvester purchase may be available from the Wisconsin Waterways Commission Recreational Boating Facilities Grant Program. Planning costs assume that plan revisions will be completed at a cost of $6,000 every four years.

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

[i]Costs exclude the costs to the City of Pewaukee, Village of Pewaukee, and Town of Delafield related to land use planning and zoning, and exclude costs related to herbicide treatments.

Source: SEWRPC.

APPENDICES

Appendix A

AN AQUATIC PLANT MANAGEMENT PLAN FOR PEWAUKEE LAKE, WAUKESHA COUNTY, WISCONSIN

INTRODUCTION

This aquatic plant management plan is prepared by the Southeastern Wisconsin Regional Planning Commission staff as an integral part of the lake management plan for Pewaukee Lake.[1] It represents an important element of the ongoing commitment of the Lake Pewaukee Sanitary District and the City of Pewaukee, the Village of Pewaukee, and the Town of Delafield to sound environmental management with respect to the Lake. The plan is based upon field surveys conducted by Commission staff during the summer of 2000, and subsequent field reconnaissance surveys conducted during the 2001 and 2002 summer seasons, and follows the format adopted by the Wisconsin Department of Natural Resources (WDNR) for aquatic plant management plans pursuant to Chapters NR 103, NR 107, and NR 109 of the *Wisconsin Administrative Code*. Its scope is limited to those management measures which can be effective in the control of aquatic plant growth; those measures which can be readily undertaken by the Lake Sanitary District, the City of Pewaukee, Village of Pewaukee, and Town of Delafield in concert with the riparian residents; and those measures which will directly affect the recreational use of Pewaukee Lake. The aquatic plant management plan for Pewaukee Lake is comprised of eight elements:

1. A set of aquatic plant management objectives;
2. A brief description of the Lake and its watershed;
3. A statement of perceived use restrictions and need for aquatic plant management in Pewaukee Lake;
4. A review of past and present aquatic plant management measures utilized on Pewaukee Lake;
5. An evaluation of alternative means of aquatic plant management and a recommended plan for such management;
6. A description of the recommended plan;
7. A description of the equipment needs for the recommended plan; and
8. A recommended means of monitoring and evaluating the efficacy of the plan.

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[1]*SEWRPC Community Assistance Planning Report No. 58, 2nd Edition,* A Lake Management Plan for Pewaukee Lake, Waukesha County, Wisconsin*, December 2002.*

STATEMENT OF AQUATIC PLANT MANAGEMENT GOALS AND OBJECTIVES

The aquatic plant management program objectives for Pewaukee Lake were developed in consultation with the Lake Pewaukee Sanitary District and the Pewaukee Lake community. The primary goal of the aquatic plant management program is to provide a full range of recreational access opportunities for all lake users—focused on those areas of the Lake within which aquatic plants can become overly abundant—in a manner that preserves and maintains the underlying natural resource base of the Lake. Pursuant to the current aquatic plant management plan for Pewaukee Lake, prepared by the Lake Pewaukee Sanitary District staff,[2] this overarching goal is to be achieved through the accomplishment of a number of practical objectives, including:

1. Provision of boating access and access for sport anglers: by harvesting access channels and shoreline areas to approximately 250 feet in width and to provide cruising lanes for visually feeding gamefish to increase yields in these formerly inaccessible areas and to allow access for sport anglers in these areas.

2. Protection of the lake environment: by harvesting and, thereby, removing plant material from the Lake, nutrients and organic matter that otherwise would be added to the Lake bottom sediments through the decay process, spurring further aquatic plant growths and encouraging the growth of invasive plant species.

3. Enhancement of the native aquatic plant communities: by harvesting the canopy of invasive plant species such as Eurasian water milfoil to allow for deeper penetration of sunlight into the Lake to promote the competitive success of generally low-growing native aquatic plants and a greater diversity of aquatic plant species.

4. Maintenance of the ecological balance: by encouraging the competitive success and diversity of native plant communities, leading to a more balanced aquatic system better able to support the array of recreational uses to which the Lake is subjected.

5. Cooperation with Lake residents: by providing lakeshore residents with appropriate information on how to maintain their pier areas, manage their lawns and gardens, and utilize the natural resources of the Lake in a sustainable and environmentally friendly manner.

6. Collaboration with the residents of the drainage basin tributary to the Lake: by providing all residents of the drainage area tributary to Pewaukee Lake with appropriate information on how their actions affect the waterways tributary to the Lake, their local environment, and the natural resource base of the Lake and watershed.

7. Acquisition of wetlands and environmentally sensitive lands within the drainage basin tributary to the Lake to insure their permanent conservancy and the continuation of their ecosystem benefits.

This goal and its concomitant objectives remain unchanged.

PEWAUKEE LAKE AND ITS WATERSHED CHARACTERISTICS

Pewaukee Lake is located within the civil division limits of the City of Pewaukee, the Village of Pewaukee, and the Town of Delafield, all within Waukesha County. Surface water enters the Lake through several tributary streams: Audley Creek which enters Pewaukee Lake from the southwest, an unnamed tributary which enters the Lake from the south, Zion Creek which enters the Lake from the southeast, and Coco Creek which enters the Lake from the north. Water drains from Pewaukee Lake, over a low-head dam located within the Village of Pewaukee,

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[2] *Lake Pewaukee Sanitary District,* An Aquatic Plant Management Plan for Pewaukee Lake Pewaukee, Wisconsin*, January 1992.*

into the Pewaukee River, which flows in a southeasterly direction and ultimately discharges into the Fox River approximately 4.4 miles downstream of the Lake.

Pewaukee Lake is a through-flow natural drainage lake that was impounded by a low-head dam constructed in 1838. This impoundment increased the surface area of the Lake two-fold, to about 2,493 acres. The Lake is the largest lake in Waukesha County and the second largest lake in the Southeastern Wisconsin region. Pewaukee Lake is a drainage lake, or a lake having both a defined inflow and outflow, with two connected, yet distinct basins. The western basin, the original natural Lake, has a maximum depth of approximately 45 feet; while the eastern basin, originally a wetland, has a maximum depth of about 10 feet. The Lake level is presently controlled artificially by the dam located at the Lake outlet. There are three islands on the Lake: one in the western basin, and two in the eastern basin. A bathymetric map of the Lake is set forth as Map A-1.

The watershed area draining to Pewaukee Lake is approximately 23.15 square miles in areal extent. Portions of the watershed lie in the Cities of Pewaukee, Delafield, and Waukesha, the Villages of Hartland and Pewaukee, and the Towns of Delafield, Lisbon, and Merton.

Land Use and Shoreline Development

The importance of the Pewaukee Lake area as an attractive setting for residential development within a reasonable commuting distance of major commercial and industrial centers in Southeastern Wisconsin has increased steadily since the 1920s. In addition, many summer cottages have, over the years, been converted into year-round homes. By 1995, about 5,328 acres, or about 34 percent of the total drainage area tributary to Pewaukee Lake, were in urban land uses, with residential uses being the dominant urban land use. As of 1995, about 10,401 acres, or about 66 percent of the total drainage area tributary to Pewaukee Lake, were still in rural land uses. Of these uses, about 36 percent of the drainage area was in agricultural use. The shorelands of the Lake are generally considered to be fully developed, although some limited infilling, backlot development, and redevelopment of platted lots may be expected to occur. Nearly all of the shoreland around Pewaukee Lake has some form of shoreline protection. The islands within both Lake basins have some shoreline protection and are partially protected by shoreland vegetation. Map A-2 shows current shoreline conditions as of the year 2000.

Population

As of 1990, there were an estimated 14,500 persons residing within the total drainage area tributary to Pewaukee Lake. Population forecasts prepared by the Regional Planning Commission as a basis for the adopted regional land use plan[3] indicate that the population of the drainage area tributary to Pewaukee Lake may be expected to increase by about 41 percent over the 1990 level, to 20,400 persons, by the year 2010.

Aquatic Plants, Distribution and Management Areas

Several aquatic plant surveys have been conducted on Pewaukee Lake. The initial aquatic plant survey of Pewaukee Lake was conducted during August of 1976, with subsequent surveys having been conducted by the WDNR during the period from 1988 through 1997. Most recently, a survey of aquatic plant species in Pewaukee Lake was conducted by Commission staff during July and August of 2000. The eastern Lake basin contained areas with the most abundant flora due to its uniform shallow depth. All of the observed aquatic plants have been commonly observed within lakes in the Southeastern Wisconsin Region.

Aquatic Plants in Pewaukee Lake

A species list compiled by the Regional Planning Commission staff from data gathered during the year 2000 aquatic plant survey is set forth in Table A-1, along with notes on the ecological significance of each plant.

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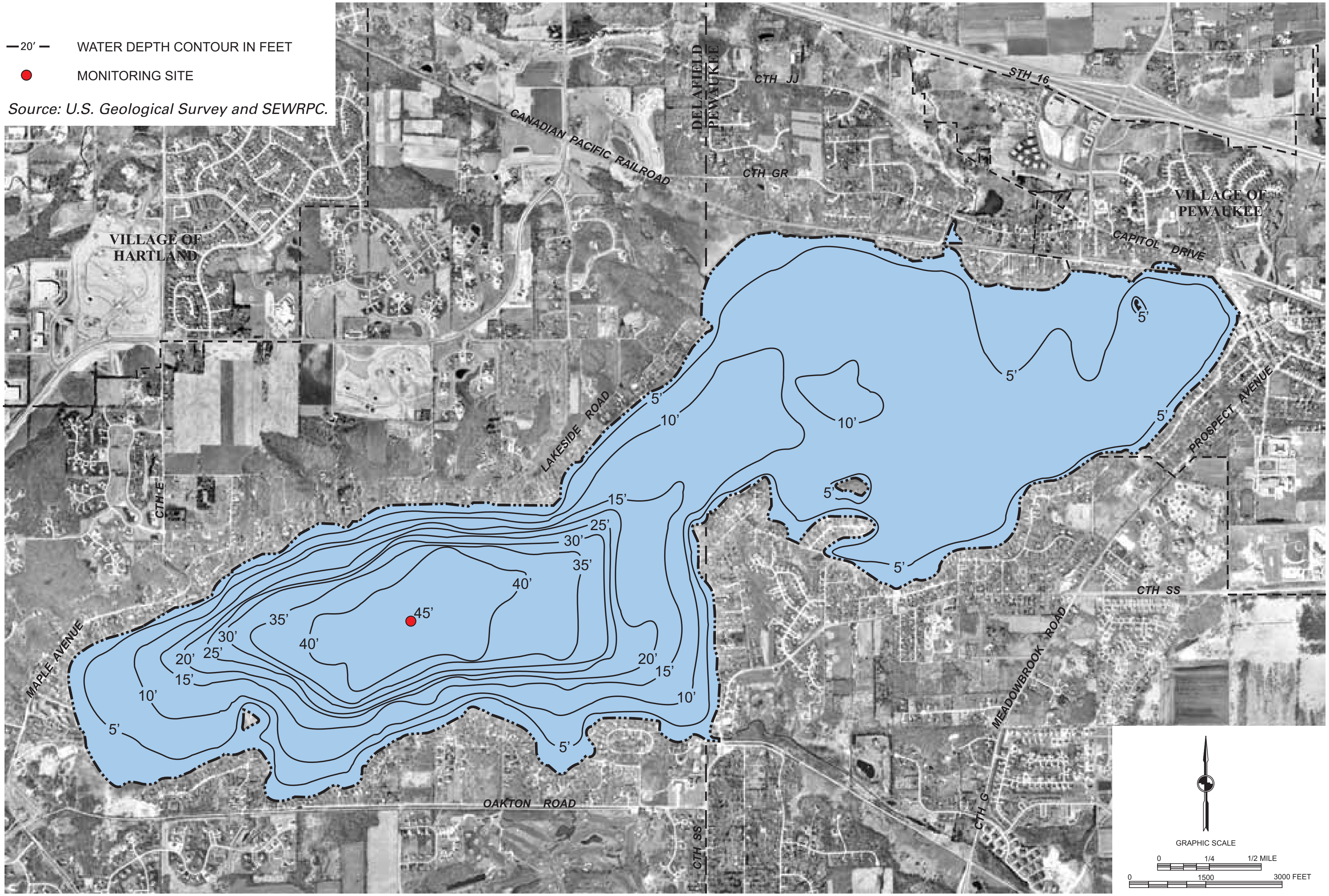
[3]*SEWRPC Planning Report No. 40,* A Regional Land Use Plan for Southeastern Wisconsin: 2010*, January 1992; SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin*, August 1996.*

Map A-1

BATHYMETRIC MAP OF PEWAUKEE LAKE



DATE OF PHOTOGRAPHY: MARCH 2000

Map A-2

SHORELINE PROTECTION STRUCTURES ON PEWAUKEE LAKE: 2000

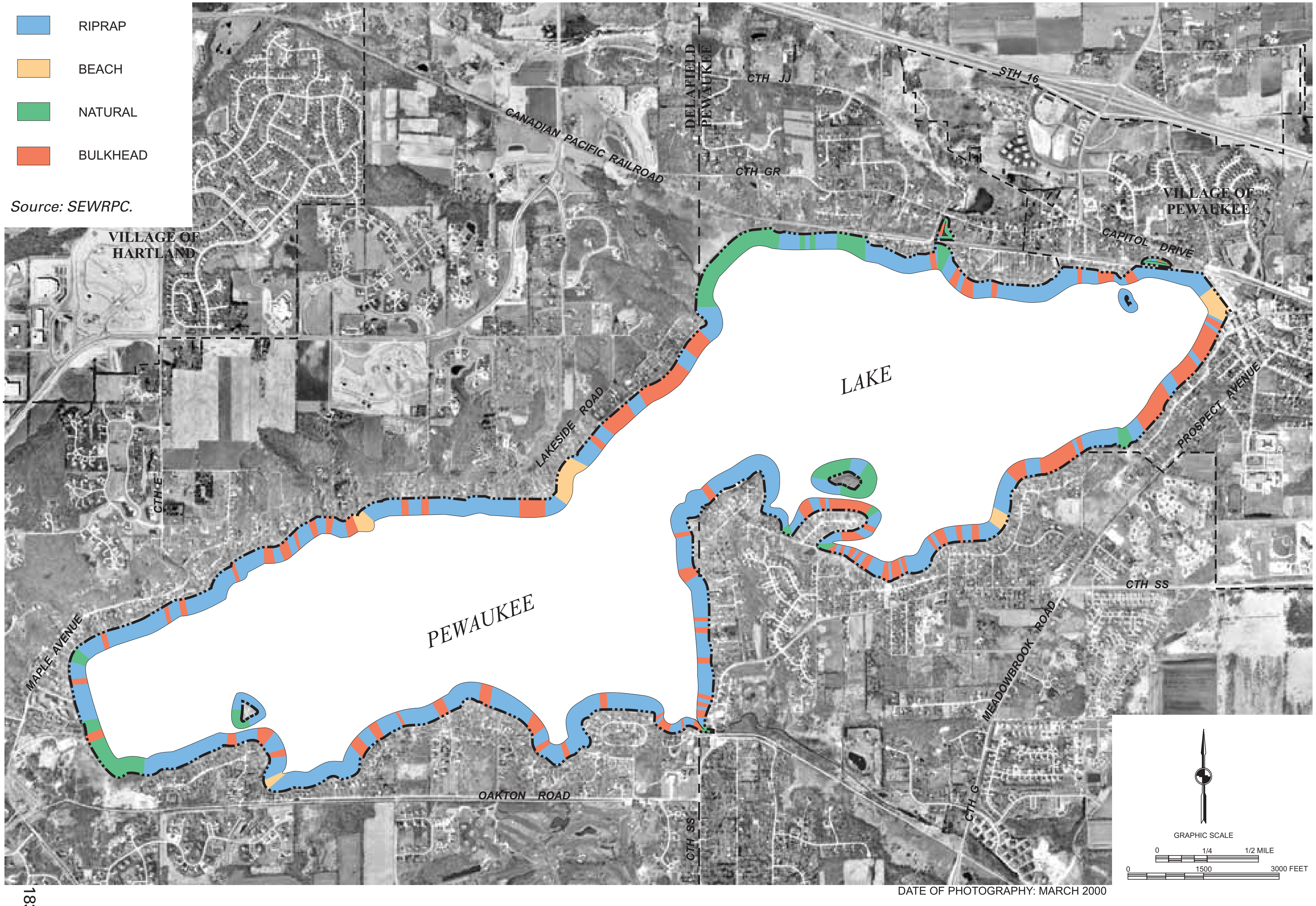


Table A-1

AQUATIC PLANT SPECIES PRESENT IN PEWAUKEE LAKE AND THEIR POSITIVE ECOLOGICAL SIGNIFICANCE: 2000

Aquatic Plant Species Present	Sites Found	Frequency of Occurrence (percent)[a]	Density at Sites Found[b]	Density in Whole Lake[b]	Ecological Significance[c]
Ceratophyllum demersum (coontail)	82	49.40	2.57	1.27	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris (muskgrass)	39	23.49	2.15	0.51	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)	22	13.25	1.86	0.25	Provides shelter and support for insects which are valuable as fish food
Lemna minor (lesser duckweed)	- -[d]	- -[d]	- -[d]	- -[d]	A nutritious food source for ducks and geese, also provides food for muskrat, beaver and fish, while rafts of duckweed provide shade and cover for insects, in addition extensive mats of duckweed can inhibit mosquito breeding
Lemna trisulca (forked duckweed)	- -[d]	- -[d]	- -[d]	- -[d]	Good food for ducks and geese, provides cover for fish and insects
Myriophyllum sp. (native water milfoil)	1	0.60	1.00	0.01	Provides valuable food and shelter for fish; fruits eaten by many wildfowl
Myriophyllum spicatum (Eurasian water milfoil)	137	82.53	3.27	2.70	None known
Najas spp. (bushy pondweeds)	72	43.37	2.61	1.13	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Nuphar sp. (yellow water lily)	- -[d]	- -[d]	- -[d]	- -[d]	Leaves, stems, and flowers are eaten by deer; roots eaten by beaver and porcupine; seeds eaten by wildfowl; leaves provide harbor to insects, in addition to shade and shelter for fish
Nymphaea odorata (white water lily)	- -[d]	- -[d]	- -[d]	- -[d]	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrat; roots eaten by beaver, deer, moose, and porcupine
Potamogeton amplifolius (large-leaf pondweed)[e]	8	4.82	1.50	0.07	Provides food, shelter and shade for some fish and food for some wildfowl. Provides shelter and support for insects, which are valuable as fish food
Potamogeton crispus (curly-leaf pondweed)	4	2.41	1.00	0.02	Provides food, shelter and shade for some fish and food for wildfowl
Potamogeton illinoensis (Illinois pondweed)[e]	1	0.60	3.00	0.02	Provides shade and shelter for fish; harbor for insects; seeds are eaten by wildfowl
Potamogeton natans (floating-leaf pondweed)	1	0.60	2.00	0.01	Provides food and shelter for fish and food for wildfowl

Table A-1 (continued)

Aquatic Plant Species Present	Sites Found	Frequency of Occurrence (percent)[a]	Density at Sites Found[b]	Density in Whole Lake[b]	Ecological Significance[c]
Potamogeton pectinatus (sago pondweed)[e]	34	20.48	1.56	0.32	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton praelongus (white-stem pondweed)[e]	5	3.01	1.20	0.04	Provides food and shelter for fish, waterfowl, and muskrats, beaver and deer; also good producer of food for trout and habitat for muskellunge
Potamogeton richardsonii (clasping-leaf pondweed)[e]	1	0.60	1.00	0.01	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-stemmed pondweed)	15	9.04	1.60	0.14	Provides some food for ducks
Utricularia sp. (bladderwort)	2	1.20	1.00	0.01	Provides good food and cover for fish
Vallisneria americana (water celery)[e]	43	25.90	2.51	0.65	Provides good shade and shelter, supports insects, and is valuable fish food
Zosterella dubia (water stargrass)	24	14.45	2.00	0.29	Provides food and shelter for fish, locally important food for waterfowl

NOTE: There were 166 points sampled during the July-August 2000 survey.

[a]*Maximum equals 100 percent.*

[b]*Maximum density equals 4.0.*

[c]*Information obtained from* A Manual of Aquatic Plants *by Norman C. Fassett,* Guide to Wisconsin Aquatic Plants*, Wisconsin Department of Natural Resources and* Through the Looking Glass…A Field Guide to Aquatic Plants*, Wisconsin Lakes Partnership.*

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

[e]*Considered a high-value aquatic plant species known to offer important values in specific aquatic ecosystems under Section NR 107.08 (4) of the* Wisconsin Administrative Code*.*

Source: SEWRPC.

Twenty species of aquatic plants were identified in Pewaukee Lake during this survey. The Commission staff found the greatest diversity of aquatic plants in Pewaukee Lake to be in the shallower, eastern basin of the Lake. The areas in which aquatic plant growth was found are shown in Map A-3, and representative illustrations of these aquatic plants can be found at the end of this appendix.

Plant growth occurred throughout most of the Lake where the water depth was less than 15 feet. Species that interfere with the recreational and aesthetic use of the Lake, such as *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Potamogeton crispus*, were all found to be present in the Lake. Eurasian water milfoil (*Myriophyllum spicatum)*, coontail (*Ceratophyllum demersum*), wild celery (*Vallisneria americana*), and muskgrass (*Chara* spp.) appeared to be the dominant species, while healthy populations of pondweeds (*Potamogeton* spp.) appeared to be scattered throughout the Lake. Pondweeds were most commonly found at depths of between five and 10 feet. Eurasian water milfoil was dominant throughout the Lake, but largely

Map A-3

AQUATIC PLANT COMMUNITY DISTRIBUTION IN PEWAUKEE LAKE: 2000

—20'— WATER DEPTH CONTOUR IN FEET

OPEN WATER

WATER LILIES

EURASIAN WATER MILFOIL

COONTAIL

COONTAIL, MUSKGRASS, WATER STAR GRASS, AND SAGO, FLAT-STEM, CURLY-LEAF, AND WHITE-STEM PONDWEEDS

COONTAIL, MUSKGRASS, WATER STAR GRASS, WATERWEED, AND SAGO, BUSHY, AND FLAT-STEM PONDWEEDS

COONTAIL, MUSKGRASS, WATER STAR GRASS, WILD CELERY, AND SAGO, BUSHY, FLAT-STEM, CURLY-LEAF, AND LARGE LEAF PONDWEEDS

COONTAIL, WATER STAR GRASS, WILD CELERY, WATERWEED, AND BUSHY, FLAT-STEM, CLASPING-LEAF PONDWEEDS

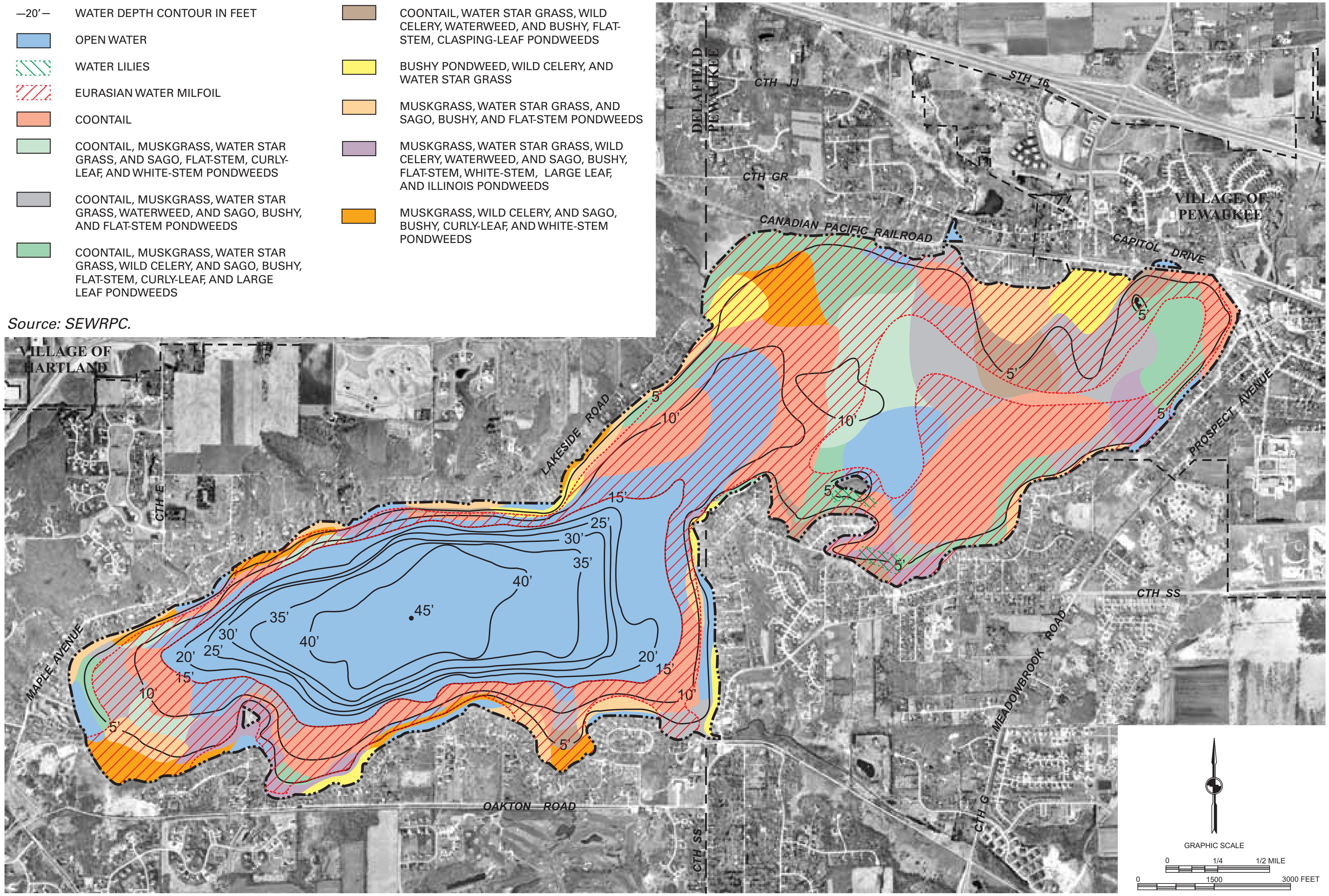
BUSHY PONDWEED, WILD CELERY, AND WATER STAR GRASS

MUSKGRASS, WATER STAR GRASS, AND SAGO, BUSHY, AND FLAT-STEM PONDWEEDS

MUSKGRASS, WATER STAR GRASS, WILD CELERY, WATERWEED, AND SAGO, BUSHY, FLAT-STEM, WHITE-STEM, LARGE LEAF, AND ILLINOIS PONDWEEDS

MUSKGRASS, WILD CELERY, AND SAGO, BUSHY, CURLY-LEAF, AND WHITE-STEM PONDWEEDS

Source: SEWRPC.



DATE OF PHOTOGRAPHY: MARCH 2000

confined to areas of the Lake with depths of between five and 15 feet—growths of this plant observed during the 2000 survey reached an areal extent that was not dissimilar to that reported from the Lake during 1988.

In general, Pewaukee Lake continues to support a healthy and diverse aquatic macrophyte community. Changes in the aquatic macrophyte species distribution and abundance in Pewaukee Lake, between 1988 and 2000, are summarized in Table A-2. The growths of Eurasian water milfoil (*Myriophyllum spicatum*) in the Lake during the year 2000 were among the heaviest growths of Eurasian water milfoil in recent years. These growths created nuisance conditions in much of the eastern basin of the Lake and in the western basin of the Lake where depths were less than about 12 feet. The resurgence of Eurasian water milfoil within the Lake during recent years may reflect the cyclical nature of the climatic regime within the Region, and the tolerance of the Eurasian water milfoil to colder water temperatures than those generally tolerated by native aquatic plant species.

Eurasian Water Milfoil

At the time of the year 2000 Commission survey, the dominant aquatic plant within the Lake was Eurasian water milfoil, *Myriophyllum spicatum*. Eurasian water milfoil is one of eight milfoil species found in Wisconsin and the only one that is known to be exotic or nonnative. Because of its nonnative nature, Eurasian water milfoil has few natural enemies and can exhibit "explosive" growth under suitable conditions, such as the presence of organic-rich sediments, or in areas where the lake bottom has been disturbed. It can displace native plant species and disrupt the ecosystem functioning of a lake as it lacks many of the positive ecological values of native aquatic plants. This particular species of milfoil has been known to become the dominant plant present in a lake with its ability to regenerate, to replace native vegetation, and to reduce the quality of fish and wildlife habitat.

Eurasian water milfoil is especially abundant in the eastern Lake basin of Pewaukee Lake where depths rarely exceed 10 feet, as well as within the littoral zone of the western basin at depths of between 5 and 15 feet. The abundant growths of Eurasian water milfoil are known to cause extreme problems for Pewaukee Lake due to its ability to grow to the lake surface, making certain recreational uses less enjoyable, if not dangerous, and impairing the aesthetic qualities of the waterbody. When Eurasian water milfoil is fragmented by boat propellers, or by other means, the fragments are able to sprout new roots and potentially colonize new sites. These fragments can also cling to boats, trailers, motors, propellers, and bait buckets, among other things, and stay alive for weeks, facilitating their transfer to other lakes.[4]

Environmentally Sensitive Areas

Two areas on Pewaukee Lake have been designated as environmentally sensitive areas by the Wisconsin Department of Natural Resources pursuant to Chapter NR 107 of the *Wisconsin Administrative Code*. Such a designation is made because of the importance of these areas to the maintenance of good water quality conditions and the biological integrity of the Lake. The areas are located within the embayment locally known as Taylor's Bay situated on the north central portion of the lakeshore and adjacent to the wetland complex south of the Waukesha County public access site along the western shore of the Lake. These areas are shown on Map A-4. Limited aquatic plant management actions are recommended for the Taylor's Bay area, and aquatic plant management measures are not recommended for the site adjacent to the wetland complex.

Fisheries, Wildlife and Waterfowl

Pewaukee Lake is well known for its sport fishing. The Wisconsin Department of Natural Resources Publication PUB-FH-800, *Wisconsin Lakes*, indicates that muskellunge, northern pike, largemouth bass, smallmouth bass and panfish are common, and walleyed pike are present in Pewaukee Lake. Because of the abundant muskellunge

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

Table A-2

SUBMERGENT PLANT SPECIES AND RELATIVE DENSITY IN PEWAUKEE LAKE: 1988-2000

Aquatic Plant Species	1988 Survey Density[a,b]	1991 Survey Density[a,b]	1994 Survey Density[a,b]	1997 Survey Density[a,b]	2000 Survey Density[b]
Ceratophyllum demersum (coontail)	2.75	2.97	2.22	2.40	2.57
Chara vulgaris (muskgrass)	1.77	1.03	1.50	1.13	2.15
Elodea canadensis (waterweed)	0.56	0.65	1.25	1.65	1.86
Myriophyllum sp. (native water milfoil)	- -	- -	1.20	1.91	1.00
Myriophyllum spicatum (Eurasian water milfoil)[c]	3.62	2.96	2.76	2.47	3.27
Najas flexilis (bushy pondweed)	2.07	1.47	1.79	0.63	2.61
Najas guadalupensis (southern naiad)	- -	- -	- -	1.72	- -
Potamogeton amplifolius (large-leaf pondweed)[d]	1.50	0.50	0.40	1.17	1.50
Potamogeton crispus (curly-leaf pondweed)[c]	1.82	1.58	0.88	- -	1.00
Potamogeton filiformis (thread-leaf pondweed)	- -	0.75	- -	- -	- -
Potamogeton illinoensis (Illinois pondweed)[d]	- -	- -	- -	- -	0.60
Potamogeton natans (floating-leaf pondweed)	- -	- -	- -	- -	0.60
Potamogeton pectinatus (sago pondweed)[d]	0.94	1.56	1.24	1.13	1.56
Potamogeton praelongus (white-stem pondweed)[d]	- -	- -	- -	- -	1.20
Potamogeton richardsonii (clasping-leaf pondweed)[d]	- -	0.42	0.25	- -	1.00
Potamogeton zosteriformis (flat-stemmed pondweed)	0.75	0.80	1.05	1.48	1.60
Potamogeton spp. (pondweed)	1.90	0.25	0.25	0.63	- -
Utricularia sp. (bladderwort)	0.25	- -	0.88	0.75	1.00
Vallisneria americana (water celery)[c]	0.77	0.79	1.16	1.50	2.51
Zosterella dubia (water stargrass)	0.75	0.75	0.63	0.67	2.00

NOTE: Species mean density for all sample points including sample points where a particular species did not occur in Pewaukee Lake: Abundant (density rating equals 4 to 5), Common (density rating equals 2 to 3), Scarce (density rating equals 1), and Absent (density rating equals 0).

[a]*Survey conducted by Wisconsin Department of Natural Resources as part of the Long-Term Trend Monitoring Program.*

[b]*Maximum density equals 5.0.*

[c]*Designated as invasive and nonnative aquatic plant species pursuant to section NR 109.07 of the* Wisconsin Administrative Code.

[d]*Considered a high-value aquatic plant species known to offer important values in specific aquatic ecosystems under Section NR 107.08 (4) of the* Wisconsin Administrative Code.

Source: Wisconsin Department of Natural Resources and SEWRPC.

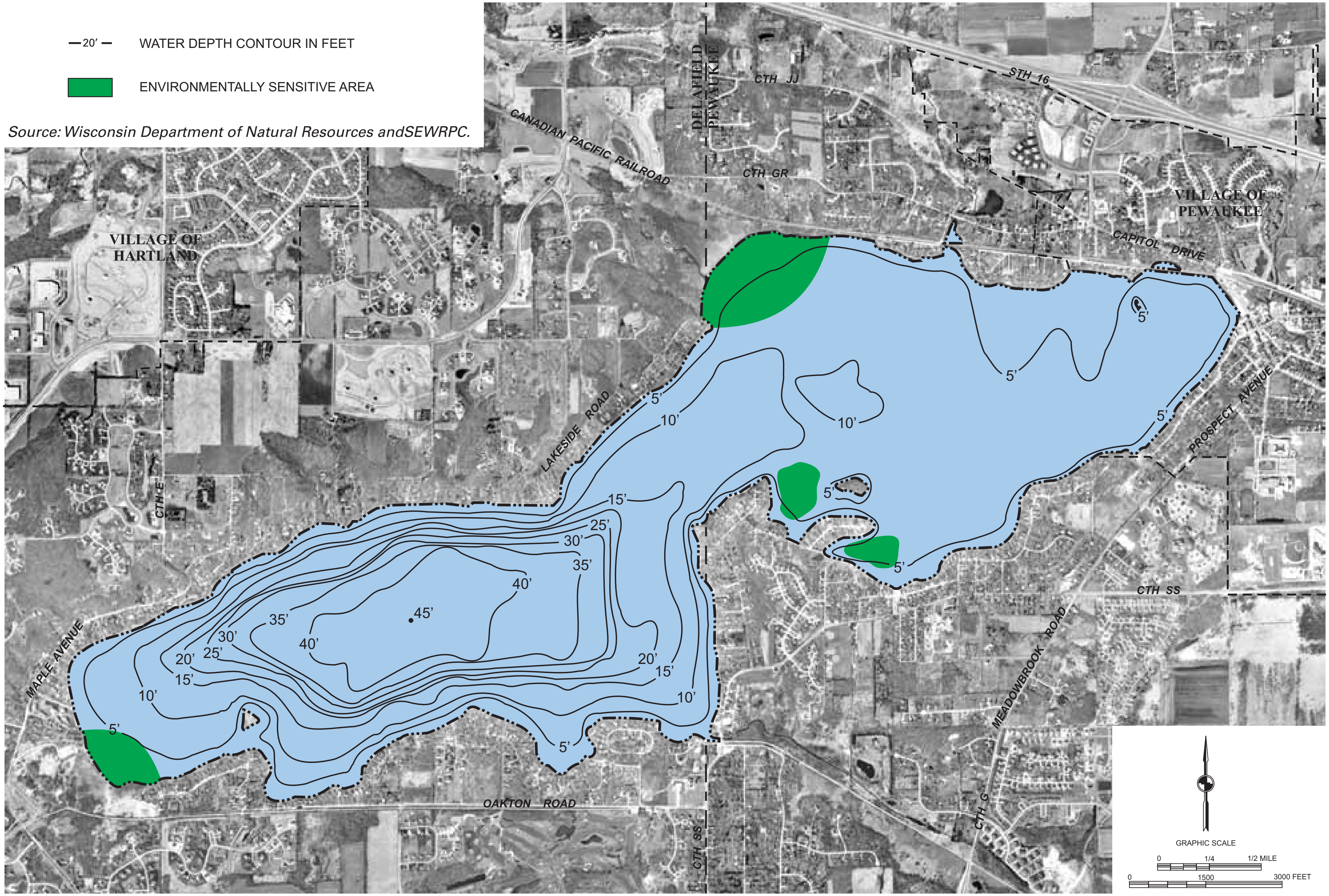
habitat present in the Lake, muskellunge fingerlings have been stocked annually since 1967. Walleyed pike are also stocked every other year.[5]

Given the urban nature of much of the shoreland of the Lake only smaller urban tolerant mammals are generally present. A somewhat more diverse animal community, and greater number of waterfowl, make use of the extensive outlying wetland and other habitat areas located throughout the tributary drainage area of Pewaukee

[5]*E. R. Schumacher, Wisconsin Department of Natural Resources Fish Management Report No. 131*, Creel Survey on Pewaukee and Nagawicka Lakes, Waukesha County, Summer 1982*, February 1987; Sue Beyler and Steve Gospodarek,* Pewaukee Lake 1998 Comprehensive Survey (WBIC 0772000)*, Wisconsin Department of Natural Resources, Internal Report File Ref: 3600, 2000.*

Map A-4

PEWAUKEE LAKE ENVIRONMENTALLY SENSITIVE AREAS: 1994



Lake. Muskrats and cottontail rabbits are probably the most abundant and widely distributed fur-bearing mammals in the immediate riparian areas. Larger mammals, such as the whitetail deer, are generally confined to the larger wooded areas and the open meadows found in the park and open space lands within the drainage area tributary to the Lake. The Pewaukee Lake drainage area supports a significant population of waterfowl including mallards and geese. During migration seasons, a greater variety of waterfowl may be present and in greater numbers.

Recreational Uses and Facilities

Pewaukee Lake is a multipurpose waterbody serving numerous forms of recreation, including both active and passive recreational uses. Boating, waterskiing, swimming, and fishing are popular activities during open water periods, and ice fishing and snowmobiling are common during closed water periods. The Lake is used year round as a visual amenity, with walking, bird watching, and picnicking being popular passive recreational uses of the waterbody and its surrounds.

Boating use of the Lake has been increasing, with maximum boating use of the Lake generally occurring between the hours of 10:00 a.m. and 2:00 p.m. The most recent boat survey, conducted by the Commission staff during the current planning program period, between these hours on a typical weekend day—August 12, 2000—indicated that about 113 watercraft of all descriptions were in use on the Lake. A weekday survey conducted on the Lake during this program—on August 15, 2000—indicated that about 20 watercraft of all descriptions were in use on the Lake.

There are two public boating access sites located on Pewaukee Lake, one at Naga-Waukee County Park, located east of STH 83 on the western shore of the Lake, and the other at a site owned by the City of Pewaukee and located on the southern shore of the Lake. The current public access sites are adequate to meet the criteria set forth in Section NR 1.91(11) of the *Wisconsin Administrative Code*.

In addition, as of 2000, there were six private recreational facilities offering boating access to the general public on Pewaukee Lake. There were also three other facilities that provided boat rentals without offering launching access to private boat owners. None of these private facilities meets the requirements for private providers that are included in the determinations of access availability under Section NR 1.91(7) of the *Wisconsin Administrative Code*.

In addition, the Village of Pewaukee Village Beach Park provides a major recreational venue not only for Village of Pewaukee residents but also for visitors to the Village.[6]

Local Ordinances

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. Local zoning regulations include general, or comprehensive, zoning regulations and special-purpose regulations governing floodland and shoreland areas. The Cities of Delafield, Pewaukee, and Waukesha; the Villages of Hartland and Pewaukee; and the Towns of Delafield, Lisbon, and Merton, in Waukesha County, within the drainage area tributary to Pewaukee Lake, all have adopted local zoning ordinances. The three towns within the drainage area tributary to Pewaukee Lake in Waukesha County have adopted their own zoning ordinances under village powers.

USE RESTRICTIONS IMPOSED BY AQUATIC PLANTS

Aquatic plant growth in Pewaukee Lake is perceived to have reached densities in portions of the Lake that interfere with recreational usage of the Lake, impeding boat traffic and making some areas of the Lake impassable without aquatic plant control. At numerous sample sites, plant growth recorded by the Commission staff exceeded

[6]*See SEWRPC Memorandum Report No. 56,* A Lakefront Recreational Use and Waterway Protection Plan for the Village of Pewaukee, Waukesha County, Wisconsin*, March 1996.*

a density rating of 3, indicating a moderate to abundant density. As noted above, Eurasian water milfoil is a major contributor to these higher densities. In particular, such excessive plant growth in the littoral zone makes access to the open water extremely difficult, and severely restrict shoreline angling and swimming. The abundance of aquatic plants in Pewaukee Lake also reportedly adversely affects riparian property values and the aesthetic advantage of residing on the Lake, and can have a significant impact in terms of the aesthetic enjoyment of visitors to the Lake. During the summer months, these beds of vegetation can become foul smelling and unsightly. The result is numerous public concerns and complaints particularly expressed throughout open water periods.

PAST AND PRESENT AQUATIC PLANT MANAGEMENT PRACTICES

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Thus, while previous interventions were likely, the first recorded efforts to manage the aquatic plants in Pewaukee Lake took place during 1950. Aquatic plant management activities in Pewaukee Lake can be categorized as chemical macrophyte and algal control, and macrophyte harvesting. As noted above, the growths of Eurasian water milfoil in the Lake during 2000 were among the heaviest growths of Eurasian water milfoil in recent years. Only during 1990 did the Lake Pewaukee Sanitary District's aquatic plant harvesting program exceed the amount of aquatic macrophytes harvested during 2000. This resurgence of Eurasian water milfoil within the Lake during recent years may reflect the cyclical nature of the climatic regime within the Region, and the tolerance of the Eurasian water milfoil to colder water temperatures than those generally tolerated by native aquatic plant species.

Chemical Controls

Perceived excessive macrophyte growths on Pewaukee Lake have historically resulted in application of a chemical control program. Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Chemical herbicides are known to have been applied to Pewaukee Lake from at least 1950 through 1989, as set forth in Table A-3.

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 Pewaukee Lake, and years of application during the period 1950 through 1967, are listed on Table A-3; the total amount of sodium arsenite applied over this 17-year period being about 334,232 pounds.

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

When it became apparent that arsenic was accumulating in the sediments of treated lakes, the use of sodium arsenite was discontinued in the State in 1969. The applications and accumulations of arsenic were found to present potential health hazards to both humans and aquatic life. Based upon 1978 data reported by the WDNR, the concentrations of arsenic within the lake sediments of Pewaukee Lake may exceed draft sediment quality criteria limits proposed by the Wisconsin Department of Natural Resources, and should be considered to pose a potential hazard—although water quality data reported by the WDNR for the period from 1964 through 1978 suggest that much of this arsenic residue may have been solubilized during periods of anoxia and flushed from the Lake through the outlet structure.

Table A-3

HISTORIC CHEMICAL CONTROLS ON PEWAUKEE LAKE: 1950–2000

Year	Total Acres Treated	Algae Control			Macrophyte Control				
		Copper Sulfate (pounds)	Blue Vitriol (pounds)	Cultrine or Cutrine-+	Sodium Arsenite (pounds)	2, 4-D (gallons)	Diquat (gallons)	Endothal (gallons)	Aquathol (gallons)
1950-1969	882.9	66,105	16,680	2,525.0 gallons	217,040	- -	- -	- -	- -
1960	375.8	- -	6,600	1,500.0 pounds	19,680	- -	- -	- -	- -
1961	364.4	- -	6,750	- -	21,600	- -	- -	- -	- -
1962	257.0	7,600	- -	322.6 pounds	5,124	53.0	- -	- -	- -
1963	361.0	6,215	- -	4,665.0 pounds	23,334	- -	- -	- -	- -
1964	413.0	5,450	- -	- -	21,792	- -	- -	- -	- -
1965	1,282.6	6,150	- -	- -	17,982	- -	- -	- -	- -
1966	240.4	2,464	- -	- -	2,280	- -	48.4	- -	52.4
1967	104.0	200	- -	- -	5,400	15.0	- -	- -	11.0
1968	404.8	1,250	- -	- -	- -	465.0	- -	- -	700.0
1969	127.0	200	- -	- -	- -	90.0	- -	- -	100.0
1970[a]	129.5	1,805	- -	- -	- -	15.0	- -	5	240.0
1971	56.6	240	- -	- -	- -	45.0	5.0	- -	- -
1972	59.3	140	- -	- -	- -	- -	10.0	- -	25.0
1973	168.4	- -	- -	- -	- -	578.0	- -	- -	135.0
1974	32.1	- -	- -	- -	- -	175.0	- -	- -	- -
1975	25.8	- -	- -	- -	- -	124.0	- -	- -	- -
1976	2.0	- -	- -	- -	- -	8.0 5.0 pounds	- -	- -	- -
1977	56.9	- -	- -	- -	- -	227.2	- -	- -	- -
1978	- -	- -	- -	- -	- -	- -	- -	- -	- -
1979	- -	- -	- -	- -	- -	- -	- -	- -	- -
1980	33.7	- -	- -	- -	- -	163.0	- -	- -	- -
1981	49.7	- -	- -	- -	- -	303.0	- -	- -	- -
1982	1.4	- -	- -	- -	- -	9.0	- -	- -	- -
1983	- -	- -	- -	- -	- -	- -	- -	- -	- -
1984	16.2	- -	- -	- -	- -	45.0	- -	- -	- -
1985	37.8	- -	- -	- -	- -	70.0	- -	- -	- -
1986	2.8	10	- -	5.0 gallons	- -	5.0	- -	- -	- -
1987	0.4	- -	- -	2.0 gallons[b]	- -	- -	- -	- -	- -
1988	0.5	- -	- -	- -	- -	10 pounds[b]	- -	- -	30.0 pounds[b]
1989	0.1	- -	- -	- -	- -	30 pounds[b]	- -	- -	- -
1990-2000	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total	- -	97,829	30,030	6,492.6 pounds, 2,532.0 gallons	334,232	2,390.2 gallons, 45.0 pounds	63.4	5	1,163.4 gallons, 30.0 pounds

[a]120 pounds of lime were applied in 1970.

[b]Private chemical treatments of aquatic plants.

Source: Wisconsin Department of Natural Resources and SEWRPC.

As shown in Table A-3, the aquatic herbicides diquat, endothall, and 2,4-D have also been applied to Pewaukee Lake to control aquatic macrophyte growth. Diquat and endothall (Aquathol) are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Endothall primarily kills pondweeds, but does not control such nuisance species as Eurasian water milfoil

(*Myriophyllum spicatum*). The herbicide 2,4-D is a systemic herbicide that is absorbed by the leaves and translocated to other parts of the plant; it is more selective than the other herbicides listed above and is generally used to control Eurasian water milfoil. However, it will also kill species such as water lilies (*Nymphaea* sp. and *Nuphar* sp.). The present restrictions on water use after application of these herbicides are given in Table A-4.

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to Pewaukee Lake. As shown in Table A-3, copper sulfate (Cutrine Plus) has been applied to Pewaukee Lake, on occasion. Like arsenic, copper, the active ingredient in many algicides including Cutrine Plus, may accumulate in the bottom sediments. Excessive levels of copper may be toxic to fish and benthic organisms, but, generally, have not been found to be harmful to humans.[7] Restrictions on water uses after application of Cutrine Plus are also given in Table A-4.

Macrophyte Harvesting
Excessive macrophyte growth on Pewaukee Lake has historically resulted in a control program that used both harvesting and chemicals. The existing macrophyte control program follows an aquatic management plan developed for the Lake in 1992.[8] The harvesting program emphasizes removal of nuisance plants necessary to facilitate recreational use, rather than 100 percent plant removal. Under this program, the City of Pewaukee contracts with the Lake Pewaukee Sanitary District to conduct the harvesting. In addition, the Village of Pewaukee also operates a complementary aquatic plant harvesting program on the Lake. The harvesting operations conducted by the Lake Pewaukee Sanitary District and the Village of Pewaukee are carried out using three Aquarius Systems harvesters, two being the H-620 model and one being an H-420 model, and three high-speed transport barges. One shore conveyer is used by the Sanitary District for off-loading.

Typically, harvesting prior to June 15 is limited to cutting access channels to facilitate navigation to piers and channels, as necessary. After mid-June, the harvesting operation is expanded within the areas of the Lake that experience nuisance plant conditions, within the slow-no-wake zone, up to approximately 200 feet from pierheads. During periods of exceptionally heavy aquatic plant growth, the aquatic plant harvesting operations may be expanded to two shifts, operating between 5:00 a.m. and 7:00 p.m. The volume of aquatic plant biomass harvested is shown graphically in Figure A-1, and the general location of the harvesting operations is shown on Map A-5. Permits are required pursuant to Chapter NR 109 of the *Wisconsin Administrative Code* to cut vegetation in lakes. The harvested plant material must be removed from the water.

ALTERNATIVE METHODS FOR AQUATIC PLANT CONTROL

Background
Various aquatic plant management techniques—manual, mechanical, physical, biological, and chemical—are potentially applicable on Pewaukee Lake. A number of these methods have been employed with varying success on Pewaukee Lake in the past, although aquatic plant harvesting has been the major control measure utilized throughout the Lake in recent years.

Physical Controls
Physical methods of aquatic plant control involve water level manipulation, placement of bottom barriers, and use of shoreline protection structures.

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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]*Lake Pewaukee Sanitary District,* An Aquatic Plant Management Plan for Pewaukee Lake, Pewaukee, Wisconsin, *January 1992*

Table A-4

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.

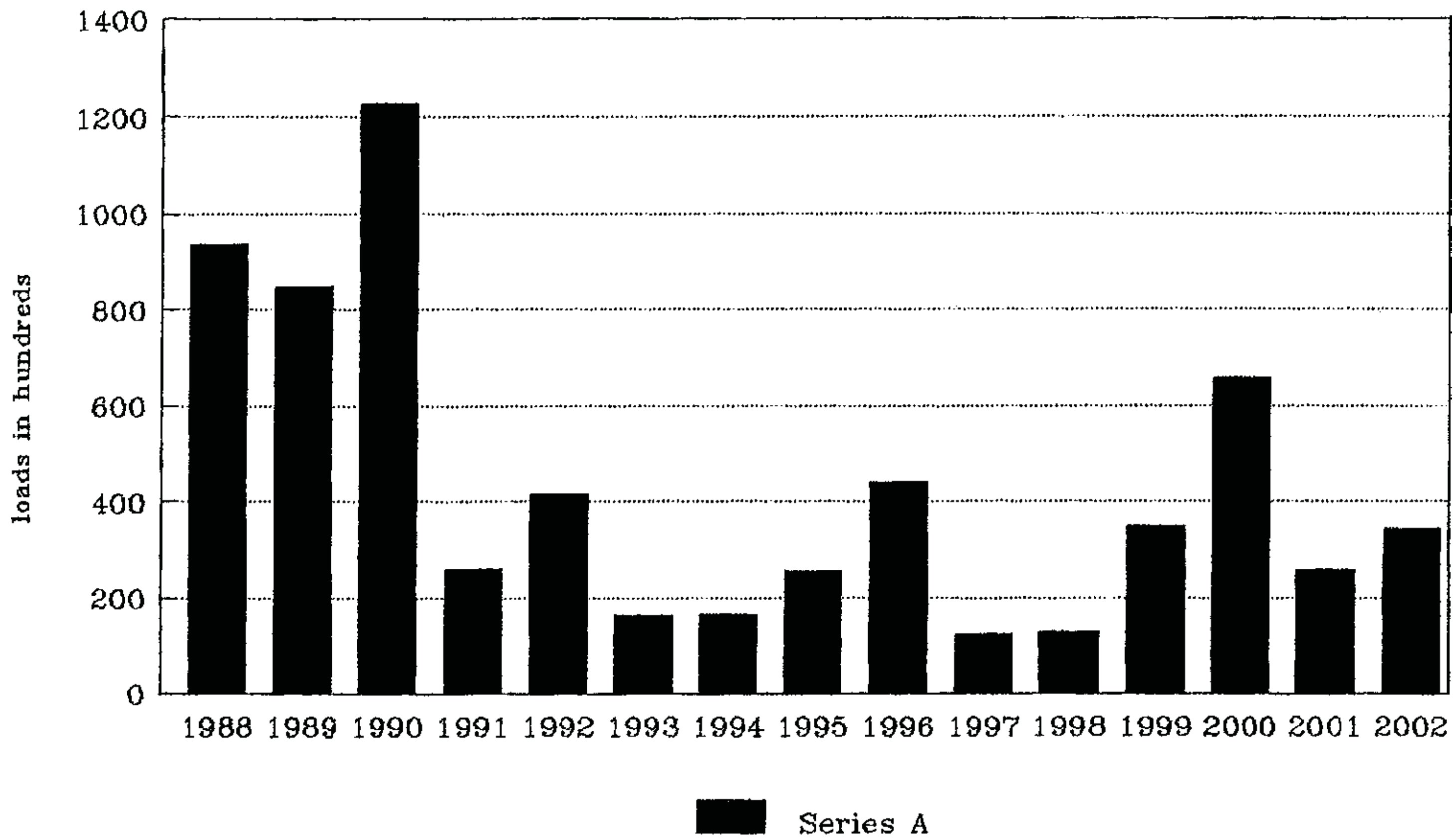
Water level manipulations generally focus on drawdowns that reduce the surface level of a waterbody in order to change or create specific types of habitat and thereby manage species composition within the waterbody. Drawdowns were not considered practical on Pewaukee Lake due to the heavy recreational demands placed on the Lake throughout the year. Drawdowns can also encourage algal blooms and the growths of some plant species. For these reasons, drawdowns are not a recommended technique for Pewaukee Lake at this time.

In certain situations, raising or frequently changing the lake level has also been considered as a water level manipulation measure for the control of certain nuisance species. Fluctuating water levels have limited practicality on Pewaukee Lake for reasons on the intensity of year round lake usage, while the ability to raise water levels for aquatic plant management purposes is limited by the topography of the Lake basin, which would create unacceptable risks of flooding of residential properties and infrastructure. Thus, for these reasons, raising or frequently changing water levels is not a recommended technique for Pewaukee Lake at this time.

Other physical controls, such as the placement of bottom barriers and use of shoreline protection structures such as vegetated buffer strips, may be more practicable for Pewaukee Lake. Extensive use of shoreline protection structures has occurred adjacent to the residential areas of Pewaukee Lake, primarily to control erosion of the shoreline. Depending upon the nature of the measures used, certain structures, such as vegetated buffer strips and enhanced littoral vegetation, can serve to filter out agro-chemicals that stimulate aquatic plant growth. While there is currently only limited opportunity for installing bottom barriers, increasing the extent of shoreline buffers around the Lake, especially within planned unit developments, provides an important and ready means of moderating the nutrient loads that stimulate the growth of aquatic plants.

Figure A-1

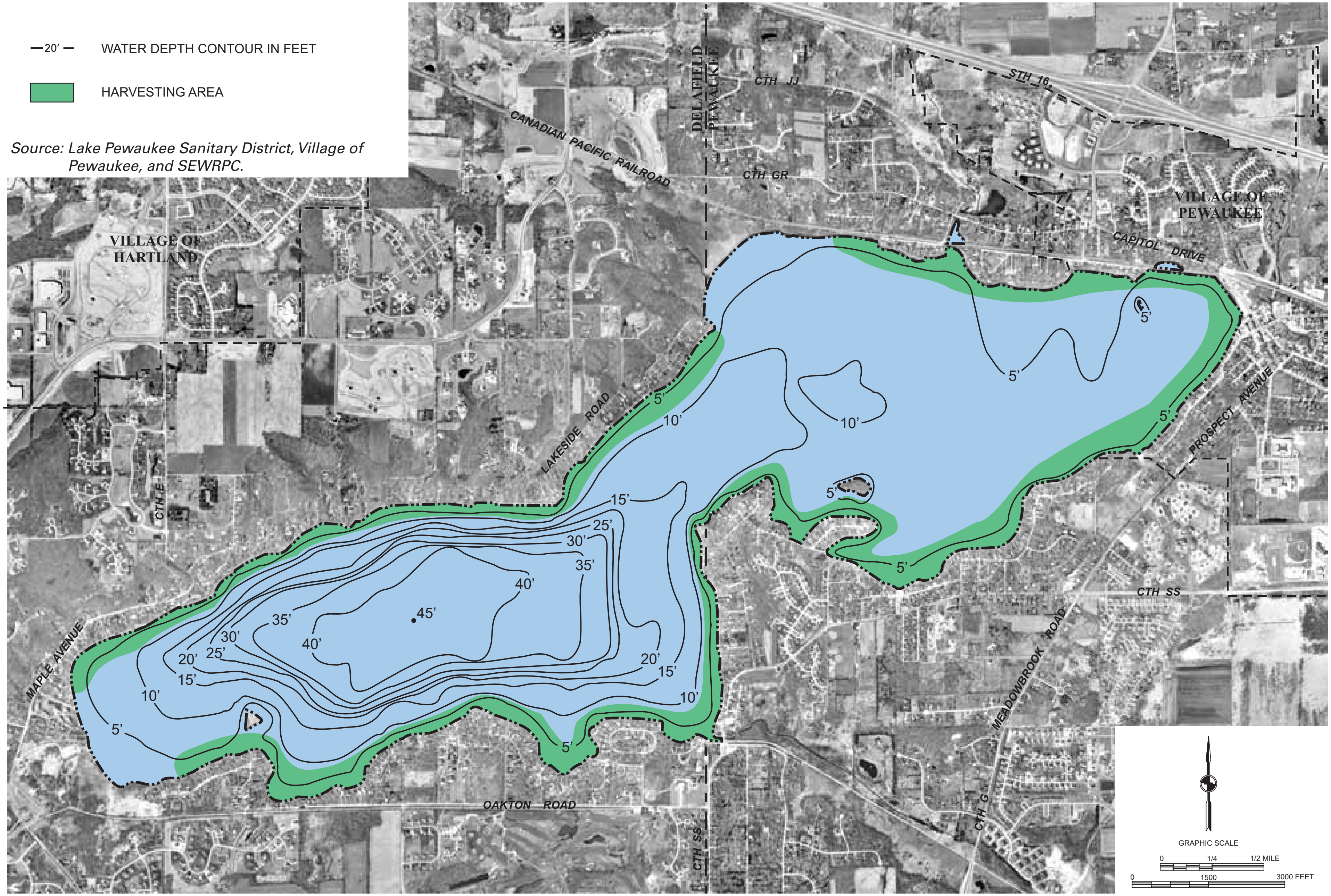
TYPICAL BIOMASS OF AQUATIC PLANTS HARVESTED FROM PEWAUKEE LAKE: 1988-2002



Source: Lake Pewaukee Sanitary District and SEWRPC.

Map A-5

AREAS OF PEWAUKEE LAKE ROUTINELY HARVESTED BY THE LAKE PEWAUKEE SANITARY DISTRICT



Source: Lake Pewaukee Sanitary District, Village of Pewaukee, and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Physical control options such as dredging and covering bottom sediments with sand and or plastic lining are techniques which may be used on a limited scale to eliminate macrophyte growth in localized areas, such as in swimming or boating access areas. While some limited dredging has been done on Pewaukee Lake in the vicinity of the Waukesha County public recreational boating access site on the southwestern shore of the Lake, extensive dredging to alleviate excessive macrophyte growth is not recommended due to the potential presence of arsenic residues in the Lake sediments from the extensive sodium arsenite applications conducted on the Lake during the 1950s and 1960s.

Chemical Controls
Chemical controls, in the form of herbicides and algicides, have been used on Pewaukee Lake. However, an important goal of the Lake Pewaukee Sanitary District has been to manage the aquatic plant communities of the Lake without the use of chemicals. Currently, the use of herbicides on the Lake has been limited to individual applications around piers and docks.

As noted above, the aquatic herbicides diquat, endothall, and 2,4-D have been applied to Pewaukee Lake to control aquatic macrophyte growth, and the use of fluridone has been proposed. Diquat is a nonselective herbicide that will kill many aquatic plants, such as the pondweeds, bladderwort, and naiads that occur in Pewaukee Lake and 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, 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 the Lake, damaging or destroying nontarget plant species that provide needed habitat for fish and other aquatic life. Hence, this option is not feasible on the scale required to control the infestations of aquatic plants in Pewaukee Lake.

Chemical control may be a suitable technique for the control of relatively small-scale infestations of Eurasian water milfoil. 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 Department of Natural Resources 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. A recommended checklist is provided as Figure A-2.

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 considered a viable option on Pewaukee Lake to control nearshore plant growths, especially around piers and docks, and are encouraged by the Lake Pewaukee Sanitary District.

Mechanical Controls
Based on previous experience of the use of mechanical harvester technologies on Pewaukee Lake, mechanical harvesting of aquatic plants appears to be a practical and environmentally sensitive method of controlling plant growth and associated filamentous algae. The most significant impact of mechanical harvesting is the removal of the organic plant biomass, decreasing nutrient inputs to the Lake. Potential negative impacts of mechanical

Figure A-2

DISTRICT CHECKLIST FOR HERBICIDE APPLICATION

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

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

Source: SEWRPC.

harvesting, as outlined by the U.S. Environmental Protection Agency,[9] 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.

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[9]*Environmental Protection Agency,* The Lake and Reservoir Restoration Guidance Manual*, 2nd Edition, August 1990, p. 146.*

Creation of shared access lanes, allowing several residents to use the same lane, can result in increased use of these lanes and will help to keep them open for longer periods than would be the case if a less directed harvesting program was followed. Because of the demonstrated need for control of aquatic plants in Pewaukee Lake, and because the current lake uses continue to indicate a need for aquatic plant harvesting, harvesting is considered a viable management option that should be continued by the Lake Pewaukee Sanitary District and Village of Pewaukee.

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 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. Given that a significant number of lake homeowners are seasonal or elderly, it is not always feasible for the riparian owners to clean their shoreline when needed. To alleviate this problem, the Lake Pewaukee Sanitary District and Village of Pewaukee have incorporated a shoreline cleanup crew into their harvesting program. Currently, the shoreline cleanup crew removes nearly as much vegetation as do the harvester operators. While this operation continues to leave the control of rooted vegetation between the piers to the riparian owners, the continuation of the shoreline clean up program is considered to be a feasible part of the aquatic plant management plan for the Lake.

Biological Controls

An alternative approach to controlling nuisance aquatic plant conditions is biological control. Recent WDNR studies have shown that *Eurhychiopsis lecontei*, an aquatic weevil species, has potential as a biological control agent for the control of Eurasian water milfoil. In 1989, the weevil was "discovered" during a study of the decline of Eurasian water milfoil growth in a Vermont pond. *Eurhychiopsis* subsequently proved to have significant impacts on Eurasian water milfoil both in the field and in the laboratory, and has been found to be far more widespread than previously thought. The adult weevil feeds on the milfoil plant, causing lesions which make the plant more susceptible to pathogens such as bacteria or fungi. During its feeding process, the weevil burrows into the stem of the plant, causing tissue damage to the plant such that its will lose buoyancy and collapse.[10] However, like all predator-prey relationships, the effectiveness of this organism as a Eurasian water milfoil control agent is limited by its numbers at any given time. While these numbers can be artificially enhanced by stocking, the use of these insects is highly labor-intensive and is subject to failure if the insects are exposed to the level of disturbances by boating traffic as might be expected in Pewaukee Lake. Thus, this type of control remains largely experimental in Wisconsin and, because of the sensitivity of the weevils to disturbance and heavy predation by native fishes, is not recommended for widespread application at this time.

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

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[10] *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.*

vigilance on the part of individual citizens and households within the drainage 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.

The Pewaukee Lake community has consistently supported informational and educational programming within their community. Efforts by the Lake Pewaukee Sanitary District staff, and staff of the Asa Clark Middle School, have not only encouraged environmentally sound behaviors within and downstream of the Lake, in the Pewaukee River, but have contributed to shoreland restoration efforts and lake monitoring as well. Thus, ongoing informational and educational programming is recommended.

RECOMMENDED AQUATIC PLANT MANAGEMENT PLAN

The recommended aquatic plant management plan consists of the integrated use of mechanical and manual harvesting designed to minimize the negative impacts on the ecologically valuable areas of the Lake, while providing a level of control needed to facilitate the desired recreational uses of the Lake. In addition, such harvesting is recommended to be supplemented by an ongoing informational and educational program.

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

1. The continued operation by the Lake Pewaukee Sanitary District and Village of Pewaukee of the existing harvesters and transport equipment.

2. Maintenance of the shared access channels, which should be harvested in such manner as 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.

3. Use of shallow harvesting to remove the surface canopy of nonnative plants such as Eurasian water milfoil, to provide a competitive advantage to the low-growing native plants in the Lake is recommended. By not disturbing these low-growing species, which generally grow within one to two feet of the lake bottom and in relatively low densities, and leaving the root stocks and stems of the cut plants in place, the resuspension of sediments in the Lake will be minimized. This type of harvesting should be focused, primarily, on boating channels around the perimeter of the main lake basins, and, secondarily, on other areas with extensive growths of Eurasian water milfoil.

4. Chemical herbicides, if found to be necessary, should be limited to controlling nuisance growths of exotic species in shallow water around docks and piers. Maintenance of shoreland areas around docks and piers remains the responsibility of individual property owners. It is recommended that chemical applications, if required, should be made by licensed applicators in early spring subject to State permitting requirements to maximize their effectiveness on nonnative plant species, minimize their impacts on native plant species, and act as a preventive measure to reduce the development of nuisance conditions. Only herbicides that are selective in their control, such as 2,4-D and fluridone, should be used. Algicides, such as Cutrine Plus, generally are not recommended as algal blooms are rare in the Lake, and valuable macroscopic algae, such as *Chara* and *Nitella*, may be killed by this product. During periods of intensive algal growth, as were observed during the year 2002, limited use of copper-based algicides, such as Cutrine Plus, could be considered in the vicinity of demarcated swimming areas, such as the Village Beach.

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 the mechanical harvester to maneuver between piers and boats and such maneuvering may entail liability for damage to boats and piers. As an alternative option it is recommended that the Lake Pewaukee Sanitary District and Village of Pewaukee obtain informational brochures regarding shoreline maintenance, such as information on hand-held specialty rakes made for this specific purpose, to be made available to these residents.

6. It is recommended that ecologically valuable areas be restricted from aquatic plant management activities, especially during fish spawning seasons in early summer and autumn.

7. The incorporation by the Lake Pewaukee Sanitary District and riparian communities of educational and informational programming within the aquatic plant management program for the Lake is recommended. Such programming can provide students and householders with information on the types of aquatic plants in Pewaukee Lake and 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. An organized aquatic plant identification day is one method of providing effective informational programming to lake residents. Other sources of information and technical assistance include the Department of Natural Resources Aquatic Plant Monitoring Program and the University of Wisconsin-Extension Service. The aquatic plant illustrations provided in this Appendix may assist individuals interested in identifying plants near their residences. Residents should be encouraged to observe and document changes in the abundance and types of aquatic plants in their part of the Lake on annual basis.

The recommended aquatic plant management plan for Pewaukee Lake is graphically summarized on Map A-6. As indicated on the map, it is proposed that aquatic plant management activities be restricted in certain ecologically valuable areas of the Lake. For this reason, aquatic plant management activities are recommended to be confined to zones related to access, boating, fishing, and habitat areas of the Lake. Aquatic plant management operations are recommended to be concentrated in the eastern basin of the Lake, and in the areas recommended for fishing and boating.

The ecologically valuable areas and identified Chapter NR 107 environmentally sensitive areas, should be restricted from harvesting. In addition, harvesting should not take place in shallow waters—generally three feet or less—to avoid disturbance of fish spawning areas and beds of native aquatic plants. Special care should be taken to avoid disturbing major spawning areas of bass in Pewaukee Lake during spring spawning season—May 1st to June 30th, annually.

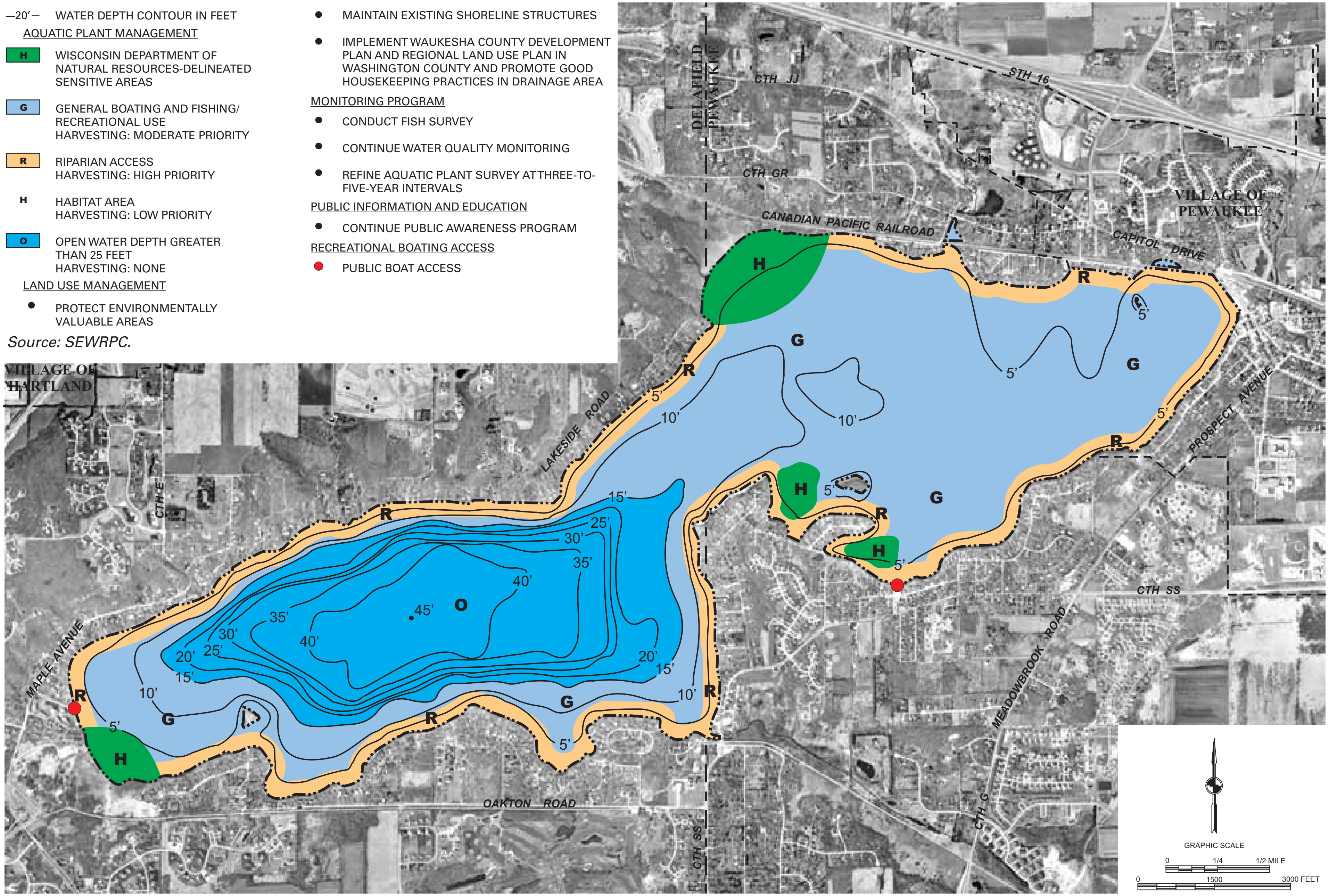
The primary objective of the management program is to accommodate recreational uses of the Lake, and to enhance the public perceptions of the Lake, without inflicting irreparable damage to the structure and functioning of the lake ecosystem. To accomplish this objective, specific control measures should be applied in each of the lake zones as summarized in Table A-5 and shown on Map A-6. The recommended sequence of the harvester operations on Pewaukee Lake is set forth in Figure A-3.

Depth of Harvesting and Treatment of Fragments

The H-620 aquatic plant harvester has a maximum cutting depth of 5.6 feet, while the H-420 aquatic plant harvester has a five-feet maximum cutting depth. While these depths exceeds the actual water depth of approximately 15 percent of the Lake, it is not the intention of the owners or operators of the equipment to denude the Lake of aquatic plants, given the intensive angling use of the waterbody; its morphology, in which portions may not be conducive to extensive motorized boat traffic; and the program goals. Sufficient plant materials will be retained in the Lake to minimize resuspension of lake bottom sediments and to maintain desirable plant communities, such as those dominated by the low-growing *Chara* spp. All plant cuttings and fragments will be collected *in situ*, to the extent practicable, by the harvesters. Those fragments accumulating along the shoreland areas will be collected by the Lake Pewaukee Sanitary District and Village of Pewaukee shoreland cleanup crews or by the riparian homeowners. Fragments collected by the homeowners can be used as garden mulch and compost.

Map A-6

RECOMMENDED AQUATIC PLANT MANAGEMENT PLAN FOR PEWAUKEE LAKE



Source: SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Table A-5

RECOMMENDED AQUATIC PLANT MANAGEMENT TREATMENTS FOR PEWAUKEE LAKE

Zone and Priority	Recommended Aquatic Plant Management Treatment
Zone G (general boating and fishing uses) Low-Priority Harvesting	Harvesting limited to maintaining 30-feet-wide navigational channels, up to 200 feet in width, along the perimeter of the Lake, and 30-foot-wide shared access lanes perpendicular to the shoreline extending towards the center of the Lake to allow boat access to the open water area of the Lake, as necessary Limited late season harvesting, late August to early September, may be necessary to maintain adequate open water areas in the central portion of the Lake Chemical use, if required, should be restricted to selective control of nuisance species near the public access Zone G is intended to accommodate fishing from a boat
Zone H (habitat) No Harvesting	It is recommended that selected areas of the Lake be preserved as high-quality habitat area This zone and adjacent lands should be managed for fish habitat No harvesting or in-lake chemical application should be permitted, except in special instances where selective herbicide application may be allowed for the control of nuisance species Debris and litter cleanup would be needed in some adjacent areas; the immediate shoreline should be preserved in natural, open use to the extent possible
Zone O (open water) No Harvesting	This zone should supplement those areas designate specifically for fishing and boating activities Includes areas greater than 15 feet in depth that require no harvesting.
Zone R (riparian access) High-Priority Harvesting	The entire area may not require intensive plant management Nuisance aquatic macrophyte growth within 200 feet of the shoreline should be harvested to provide maximum opportunities for boating, fishing, and limited swimming Areas between piers should not be harvested due to potential liability and maneuverability problems. Residents are encouraged to manually harvest aquatic plants in these areas Harvesting limited to maintaining 30-foot-wide navigational channels, up to 200 feet in width, along the perimeter of the Lake, and 30-foot-wide shared access lanes perpendicular to the shoreline extending towards the center of the Lake to allow boat access to the open water area of the Lake, as necessary Harvesting should be concentrated in areas of abundant macrophyte growth Patterns of harvesting will vary yearly dependant on macrophyte abundance Chemical use should be restricted to pier and dock areas and should not extend more than 100 feet from shore; subject to permit requirements
Approximate Total Area to Be Harvested	310 acres

Source: SEWRPC.

Buoyage

Temporary marker buoys may be used to direct harvesting operations in the lake basin by marking the areas to be cut. The size of the Lake may warrant the use of such buoys. Notwithstanding, the harvester operators will be provided with a laminated copy of the harvesting plan and made familiar with the plan and local landmarks to the degree necessary to carry out the plan without the use of buoyage. Harvesting operations will be regularly supervised by Sanitary District and Village staff.

Figure A-3

HARVESTING SEQUENCE FOR PEWAUKEE LAKE

A. HARVEST 30-FOOT WIDE CHANNELS TO OPEN WATER WITHIN THE ZONE EXTENDING UP TO 200 FEET FROM SHORE WITHIN **ZONE R**, AS SHOWN ON MAP A-6

B. HARVEST 30-FOOT WIDE CHANNELS TO OPEN WATER WITHIN **ZONE G** PERPENDICULAR TO THE SHORELINE, AS SHOWN ON MAP A-6

C. HARVEST, IF NECESSARY, NUISANCE GROWTHS OF EURASIAN WATER MILFOIL AND CURLY-LEAF PONDWEED WITHIN **ZONE O**, AS SHOWN ON MAP A-6

D. MAINTAIN HABITAT AREAS WITHIN **ZONE H** AS INDICATED BY THE WISCONSIN DEPART-MENT OF NATURAL RESOURCES AND SHOWN ON MAP A-6[a]

NOTE: Sequence A and B could be done concurrently in one area of the Lake as a time-saving measure.

[a]*No harvesting would be conducted in Zone H or within 200 feet of the islands.*

Source: SEWRPC.

Harvested Plant Material Disposal and Transfer Site(s)

Plant material will be removed from the harvesters on a transporter and conveyed to off-loading area, where it will be transferred to a dump truck using a conveyor and transported to disposal sites identified by the Pewaukee Lake Sanitary District and the Village of Pewaukee. Plant material will be collected and disposed of daily to avoid leaching of nutrients back into the impoundment and to minimize the visual degradation of the environment near the boat launch site. The operators will stringently monitor the off-loading site to ensure minimal disruption of boaters and of the people using the riparian areas of the Lake.

Precautions to Protect Wildlife and Ecologically Valuable Areas

As noted above, harvester operators will be provided with a laminated copy of the approved harvesting plan map and operational sequence chart, as set forth in Map A-6 and Figure A-3, showing the limits and priorities of harvesting operations. A copy of these items will be kept on the harvesters at all times. Operations will be prohibited in the Wisconsin Department of Natural Resources identified NR 107 sensitive areas. Harvesting operations in the areas identified as suitable for bass spawning will be restricted until the beginning of June to permit undisturbed spawning. Harvesting in all areas will be to a maximum depth of one foot above the lake bottom in order to provide adequate protection for the lake bottom, to minimize resuspension of the bottom sediments, and to allow low-growing native plants present within the system, such as *Chara* sp., to retain their competitive advantage over less-desirable invasive species, such as the Eurasian water milfoil.

Public Informational Programming
It is the policy of the Lake Pewaukee Sanitary District to maintain an active dialogue with the community. This dialogue is carried out through the medium of the public press and in public fora through various District Commissioner meetings, public meetings, and other scheduled hearings. Further, the Lake Pewaukee Sanitary District holds regular public informational meetings serving both community members and the schools within their jurisdiction. Staff are available during normal office hours to answer questions, respond to citizen concerns, and interact with the public as necessary.

Harvesting Schedule
The harvesting season should begin no earlier than mid May and will end no later than mid October of each year. Harvesting should average 40 hours per week over a five-day week, depending on weather conditions and plant growth, to minimize recreational conflicts. Further, harvesting should be confined to daylight hours to minimize public disturbances resulting from harvester and plant removal operations. As provided for above, the harvesting operations should also be modified to protect fish spawning areas and other ecologically valuable areas of the Lake as set forth on Map A-6.

EQUIPMENT NEEDS AND OPERATION

The Pewaukee Lake Sanitary District currently owns and operates two model H-620 harvesters, with three transporters and one shore conveyor, each with 10-year anticipated life spans. Replacement of two harvesters and one shore conveyors when necessary may be expected to cost about $212,500.

The Village of Pewaukee currently owns and operates one model H-420 or equivalent and one shore conveyor. Replacement of one harvester and one shore conveyor when necessary may be expected to cost about $70,000 and $22,500, respectively.

Harvester/Transporter:	Two Aquarius Systems Model H-620 or equivalent.[11]	
	One Aquarius Systems Model H-420 or equivalent.[12]	
Shore Conveyor:	Two Aquarius Systems Model S/C-34 or equivalent.[13]	
Costs:	Two Aquatic Plant Harvester with 12,000 pound capacity ($101,000 each)	$202,000
	One Aquatic Plant Harvester with 10,500 pound capacity	$ 70,000
	Two Shore conveyor ($22,500 each)	$ 45,000
	Total Costs	$317,000

Maintenance Schedule, Storage, and Related Costs
Routine maintenance will be performed on the respective harvesters by the Lake Pewaukee Sanitary District and Village of Pewaukee in accordance with the manufacturer's recommended maintenance schedule. Maintenance costs will be borne by the Lake Pewaukee Sanitary District and Village of Pewaukee. Winter storage of the harvesting equipment will be the responsibility of the Lake Pewaukee Sanitary District and Village of Pewaukee.

[11] *Purchase anticipated by the Lake Pewaukee Sanitary District.*

[12] *Purchase anticipated by the Village of Pewaukee.*

[13] *Purchase anticipated by the Lake Pewaukee Sanitary District and the Village of Pewaukee.*

Insurance Coverage
Insurance coverage on the respective harvesters will be incorporated into the policy held by the Lake Pewaukee Sanitary District and Village of Pewaukee on all capital equipment. Liability insurance for the operation of the harvesters will also be borne by the District and Village. The relevant certificates of insurance will be held by the Superintendent of the Lake Pewaukee Sanitary District and the Administrator of the Village of Pewaukee.

Operators, Training, and Supervision
The harvesters will be owned and operated by the Lake Pewaukee Sanitary District and Village of Pewaukee, respectively, who will be responsible for day-to-day operations of the equipment. The District and Village will provide operator training as required. Initial training will be provided by the manufacturer on delivery of the machinery.

Day-to-day supervision will be by the Lake Pewaukee Sanitary District and Village of Pewaukee staff.

MONITORING AND EVALUATION

Daily Record-Keeping Relating to the Harvesting Operation
Daily harvesting activities will be recorded by the operators of harvesting equipment in an operations log. An annual summary of the harvesting program will be submitted to the Lake Pewaukee Sanitary District Commission, or designated Committee of the Village of Pewaukee, and made available to the public at that time.

It is the intention of the Lake Pewaukee Sanitary District to undertake the lead in a periodic, formal review of the harvesting program as set forth in the Management Plan for Pewaukee Lake, a copy of which has been lodged with the WDNR's Southeast District Office.

Daily Record-Keeping Relating to the Harvesters
Daily maintenance and service records showing engine hours, fuel consumed and oil used, will be recorded in a harvester operations log.

ILLUSTRATIONS OF COMMON AQUATIC PLANTS FOUND IN PEWAUKEE LAKE

Bladderwort (Utricularia sp.)

Bushy Pondweed (Najas flexilis)

Clasping-Leaf Pondweed
(Potamogeton richardsonii)

Coontail (Ceratophyllum demersum)

Curly-Leaf Pondweed (<u>Potamogeton crispus</u>)

Eurasian Water Milfoil (Myriophyllum spicatum)

Flat-stem Pondweed (Potamogeton zosteriformis)

Floating-Leaf Pondweed (Potamogeton natans)

Illinois Pondweed (Potamogeton illinoensis)

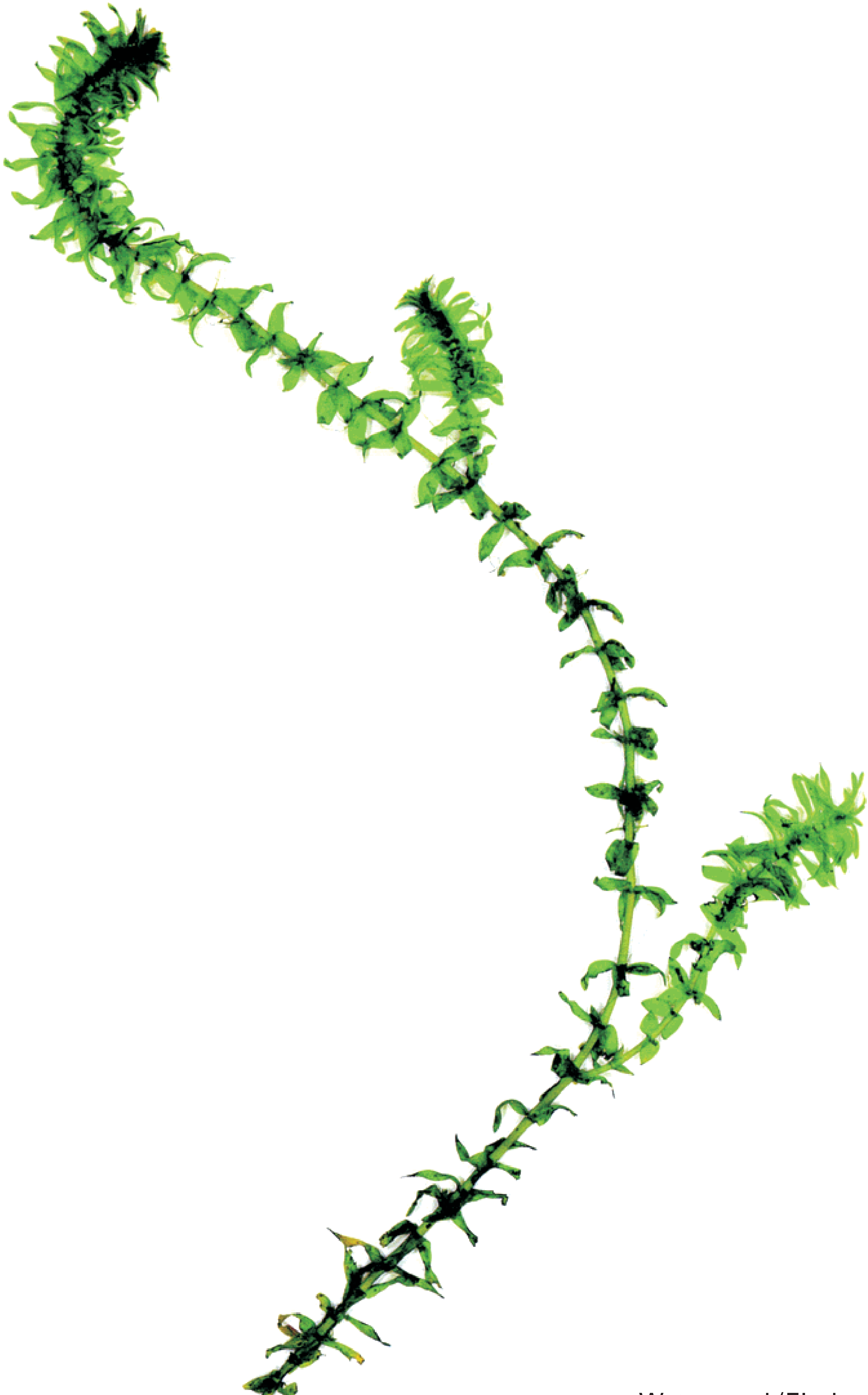
Large Leaf Pondweed (Potamogeton amplifolius)

Muskgrass (Chara vulgaris)

Native Water Milfoil (Myriophyllum sp.)

Sago Pondweed (Potamogeton pectinatus)

Water Stargrass (Zosterella dubia)



Waterweed (Elodea canadensis)

White-Stem Pondweed (Potamogeton praelongus)

Eel Grass / Wild Celery (<u>Valisneria americana</u>)

Appendix B

SUMMER AND WINTER REGULATIONS FOR PEWAUKEE LAKE

Pewaukee Lake - Summer Ordinance
CITY OF PEWAUKEE/VILLAGE OF PEWAUKEE
TOWN OF DELAFIELD

1. **INTENT**. The intent of this ordinance and revisions hereto is to provide safe and healthful conditions for the enjoyment of aquatic recreation consistent with public rights and interest and the capability of Pewaukee Lake as a water resource.

2. **APPLICABILITY AND ENFORCEMENT**. The provisions of this ordinance shall apply to the water of Pewaukee Lake within the jurisdiction of the Town of Delafield, Village of Pewaukee or City of Pewaukee. The provisions of this ordinance and Wisconsin statutes when applicable shall be enforced by the officers of the Water Safety Patrol Unit of the joint jurisdiction of the Town of Delafield, Village of Pewaukee and City of Pewaukee, under the direction of the City of Pewaukee Police Chief as the Chief of the Pewaukee Lake Water Safety Patrol, the Waukesha County Sheriff's Department and the Wisconsin Department of Natural Resources.

3. **STATE BOATING AND WATER SAFETY LAWS ADOPTED**. The statutory provisions describing and defining regulations with respect to water traffic, boats, boating and related water activities in Wisconsin Statutes 30.50 through 30.71 inclusive and as amended from time to time, exclusive of any provisions therein relating to the penalties to be imposed or the punishment for violation of said statutes, are hereby adopted and by reference made a part of this ordinance as if fully set forth herein. Any act required to be performed or prohibited by the provisions of any statute incorporated herein by reference is required or prohibited by this ordinance.

4. **DEFINITIONS**.

4.1 Designated Mooring area: An area of water established and marked as a mooring area by lawful authority or with authorization from such authority per W.S. 30.773

4.2 Navigation Lane: An area designated by authorized aids to navigation.

4.3 Personal Flotation Devices: Type I-life preserver (jacket type). Type II-buoyant vest (horse collar type). Type III-special purpose type (ski vests, fisherman's vest, or float coats) Type IV-buoyant cushions and ring buoys (throwable devices not designed to be worn), Type V-Coast Guard approved suits when worn

4.4 Public Access: Any access to the water by means of authorized public property.

4.5 Sensitive Environmental areas: Waters of Pewaukee Lake or flowing into Pewaukee Lake designated and posted as sensitive environmental areas by the three authorizing communities based upon recommendations of the Wisconsin Department of Natural Resources with use restrictions posted by the communities based upon recommendation of the DNR

4.6 Shore Zone: All surface water within two hundred (200) feet of any shore.

4.7 Slow-No-Wake: The slowest possible speed so as to maintain steerage.

4.8 Swimming Zone: An authorized area marked by regulatory markers to designate a swimming area.

5. **SPEED RESTRICTIONS**: Speed limit. Unless limited by 5.1- 5.3, no person shall operate a watercraft at a speed in excess of 50 mph.

5.1 Weekend Limits. No person shall operate a watercraft at a speed in excess of 40 mph from twelve o'clock noon to the published time of sunset on Saturdays, Sundays and the following holidays - Labor Day, Memorial Day, 4th of July and any intervening day celebrated as part of the holiday.

5.2 Special limits. No person shall at any time operate a watercraft or permit themself to be towed in excess of slow-no-wake within two hundred (200) feet of any shore, swimmer not in a designated swimming area, marked public swimming area, diving flag, canoe, rowboat, sailboat, non-operating motor watercraft, bridge, public access, designated anchorage or mooring area or sensitive environmental area.

5.3 General limits. No person shall operate a watercraft at a speed in excess of 10 mph between the published time of sunset and one hour after sunrise on all waters of Pewaukee Lake; provided that this provision shall not apply to watercraft participating in permitted races over a course laid out plainly marked and adequately patrolled.

6. **CAPACITY RESTRICTIONS.** No person shall operate or loan, rent or permit a watercraft to leave the place where it is customarily kept for operation on the waters with more passengers or cargo than a safe load.

7. **ADDITIONAL TRAFFIC RULES.** In addition to the boating rules adopted in section 3, the following rules shall apply to watercrafts using the waters of Pewaukee Lake:

7.1 Houseboat. Unless specifically permitted by the Water Safety Patrol, watercraft with sanitary facilities, living or camping facilities are prohibited.

7.2 Tie ups of watercraft. Unless specifically permitted by the Water Safety Patrol, prolonged anchoring, mooring, or drifting of nested watercrafts for more than 2 hours is hereby declared to be in conflict with the intent and purpose of the ordinance and is hereby prohibited.

8. **MOORINGS AND STATIONARY OBJECTS.**

8.1 Moored and anchored objects. No person shall erect or maintain any raft, ski jump, stationary platform, or any other obstacles to navigation more than two hundred (200) feet from the shore at any time unless a permit is obtained from the Chief of the Water Safety Patrol. All rafts and/or obstacles herein described shall be so constructed or anchored so that it has at least six (6) inches of free board above the water line, to the extent possible painted white, and has attached thereto not less than twelve (12) inches from each side of each corner or projection a red reflector not less than three (3) inches in diameter. All such objects shall be inscribed with the name and address of the owner and marked per W.S. 30.12 and 30.13.

8.2 Designated moorings. The shore zone is designated a mooring zone except in areas of heavy traffic where mooring may be prohibited by order of the Chief of the Water Safety Patrol. Unless permitted by the chief of the Water Safety Patrol, mooring for more than twenty-four (24) hours is prohibited other than by riparian owners or persons exercising riparian rights and as provided by the local community. Mooring of a watercraft other than an emergency craft is prohibited in swimming zones. Mooring for more than twenty-four (24) hours is prohibited elsewhere on the lake.

8.3 Public accesses. Mooring or anchoring of watercraft at public accesses other than at piers, as designated by the controlling governmental agency, is prohibited.

8.4 Mooring lights required. No person shall moor any unoccupied watercraft, raft, buoy, or other floating object more than two hundred (200) feet from the shoreline between sunset and sunrise unless a permit has been obtained from the Chief of the Water Safety Patrol and there is prominently displayed thereon a white light of sufficient size and brightness to be visible from any direction for a distance of two (2) miles on a dark night with a clear atmosphere. This provision shall not apply to the shore zone, objects moored in designated mooring areas or buoys marking race courses as provided herein.

8.5 Buoys marking race courses. Such buoys may be set without lighting provided that a permit has been obtained from the Chief of the Water Safety Patrol and that they are a bright color and are made of materials which will not damage a watercraft if struck.

8.6 Mooring buoys. All mooring buoys placed on the waters of the lake must comply with regulations of the Department of Natural Resources. Special permits shall be issued by the Chief of the Water Safety Patrol for temporary non-conforming buoys necessary during regattas and sporting events.

9. **SAFE OPERATION REQUIRED.**

9.1 No person shall operate, direct, or handle a watercraft in such a careless or negligent manner as to endanger the occupants of their or other watercraft.

9.2 No watercraft shall be operated in a repetitive circular, figure eight or other similar pattern in an area less than 300' in diameter and in a manner that creates a wake.

9.3 In addition to the provisions of W.S. 30.62, no person shall modify, tamper or alter any watercraft or the original equipment of any watercraft which increases the standard operating decibel level of said watercraft in violation of 30.62.

9.4 Unless specifically permitted by the Lake Patrol, no person shall operate, direct, or handle a motorized watercraft in a racing manner.

10. **SWIMMING REGULATIONS.**

10.1 No person shall swim from any unmanned watercraft unless such watercraft is anchored.

10.2 Distance from shore. No person shall swim more than two hundred (200) feet from the shore unless in a designated swimming zone or when accompanied by a competent person in a watercraft.

10.3 Hours limited. No person shall swim more than two hundred (200) feet from the shoreline between sunset and one hour after sunrise.

11. **WATER SKIING.**

11.1 Distance from shore, public accesses, and beaches. No person shall operate a watercraft for the purpose of towing a person on water skis, aquaplane, glider, kite, parachute, or similar device or permit themself to be towed for such purpose within two hundred (200) feet of the shoreline, outside limits of any swimming zone, other watercraft, any swimmer not in designated swimming area, diving flag, of any public access, of any designated anchorage or mooring area or of any buoyed/marked race course.

11.2 Personal flotation device. No person shall operate a watercraft for the purpose of towing a person on water skis, aquaplane, glider, kite parachute or similar device or permit them self to be towed for such purpose unless the person being towed is wearing a type I, II, III or V personal flotation device.

11.3 Length of Tow. The maximum length of any tow rope for towing a person water skiing, aquaplaning, gliding, kite flying, parachuting, or similar device shall be seventy-five (75) feet.

11.4 Exceptions. The limitations of this Section shall not apply to participants in ski meets or exhibitions authorized and conducted as provided in subsection 12.

12. **RACES, REGATTAS, SPORTING EVENTS AND EXHIBITIONS.**

12.1 Permit required. No person shall direct or participate in any watercraft 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 Chief of the Water Safety Patrol.

12.2 Permit. A permit issued under this section shall specify the course or any area of water to be used by participants in such events and the permittee shall be required to place markers, flags, or buoys approved by the Chief of the Water Safety Patrol designating the specific area or the general race course. Permits shall be issued only if in the opinion of the Chief the proposed use of the water can be carried out safely and without danger to or substantial obstruction of other watercrafts or persons using the lake. Permits shall be valid only for the hours and areas specified thereon.

12.3 Right-of-way participants. Watercraft and participants in any such permitted event shall have the right-of-way on the marked area and no other person shall obstruct such area during the race or event or interfere therewith.

13. **MARKER AND NAVIGATION AIDS, POSTING ORDINANCE.**

13.1 Duty of Chief. The Chief of the Water Safety Patrol unit is authorized and directed to place authorized markers, navigation aids and signs in such water areas as shall be appropriate to advise the public of the provisions of this Ordinance and to post and maintain a copy of this Ordinance at all public access points within the jurisdiction of the Village of Pewaukee, the Town of Delafield, the City of Pewaukee, and the County of Waukesha.

13.2 Standard markers. All markers placed by the chief of the Water Safety Patrol or any other person upon the waters of the lake shall comply with the regulations of the Department of Natural Resources.

13.3 Interference with markers prohibited. No person shall without authority remove, damage, or destroy or moor or attach any raft/watercraft to any buoy, beacon, or marker place in the waters of the lake by the authority of the United States, state, county, town, city, village, or by any private person pursuant to the provisions of this Ordinance.

14. **EMERGENCIES**. When the elevation of the lake is in excess of 853.4 above sea level as measured at the Village of Pewaukee dam, no person shall operate a water craft in excess of slow-no-wake in any area of the lake. During any other period of emergency as determined by the Chief, the Chief of the Water Safety Patrol is authorized to impose speed limit restrictions or other reasonable restrictions regarding the use of Pewaukee Lake. Any period of speed limit restrictions shall be no less than 24 hours in duration. Lake Patrol shall post restrictions at all public accesses.

15. **PENALTIES AND DEPOSITS.** Any officer of the Pewaukee Lake Water Safety Patrol has authority to issue citations and when warranted to arrest a person for violation of this Ordinance or applicable Wisconsin statutes and shall either permit such person to make a money deposit as provided in an approved bail/deposit schedule per Wisconsin statutes 30.80 or bring the person arrested before the Municipal Court for the City of Pewaukee or Waukesha County Circuit Court as the case may be without unnecessary delay. Deposits may be made by mail or delivery to locations designated by the Chief of the Water Safety Patrol.

15.1 Permits referred to in this ordinance shall be issued by the Pewaukee Lake Water Safety Patrol. There shall be no permit fee for single activities. There shall be one $20.00 permit fee for recurrent and like activities including supporting activities, conducted throughout the boating season by a person or entity.

The above ordinance amendments shall take effect immediately upon passage and posting or publication as provided by law.

Passed and adopted May, 2001.

CAUTION - CHECK ICE CONDITIONS BEFORE GOING UPON FROZEN LAKE SURFACE.

WINTER REGULATIONS FOR PEWAUKEE LAKE

(1) INTENT. It is the intent of these regulations to provide the basic guidelines and parameters for the safe and healthful use of and conduct of activities on Pewaukee Lake during periods when the lake is frozen or partially frozen subject to the grant of authority under Section 30.81 of Wisconsin Statutes.

(2) COMPLIANCE WITH STATE LAWS. Except as otherwise specifically provided in this Section, the current and future statutory provisions of Section 23.33, 86.192, 161.47, and Chapters 125, 350, 938 through 948 of the Wisconsin Statutes, described and defining regulations generally with respect to vehicles and traffic conduct, snowmobiles; signage and all terrain vehicles; exclusive of any provisions therein relating to penalties to be imposed and exclusive of any regulations for which the statutory penalty is a term of imprisonment, are adopted and by reference made a part of this code as if fully set forth herein. Any act, required to be performed or prohibited by any current or future statute incorporated herein by reference is required or prohibited by this 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 statewide regulation.

(3) DEFINITION OF SELECTED WORDS AND TERMS

a. ATV - All-Terrain Vehicle means any engine driven device as defined as Section 340.01(2g), Wisconsin Statutes, and any other multi-axle, two, three and four wheeled vehicles, or combination wheel and track (runner) vehicles, not otherwise defined herein, powered by a small motor(s) or fan and designed to be operated on snow, ice, grass, dirt, gravel, sand and wetland whether required to be licensed by State Law.
b. SNOWMOBILE - means any engine driven vehicle as defined in Section 340.01(58a), Wisconsin Statutes.
c. AUTOMOBILE - means any motor vehicle as defined by 340.01(4), Wisconsin Statutes, and including mini-vans.
d. MOTOR TRUCK - means any motor vehicle as defined by 340.01(34) and including pickup trucks, regular size vans and combination automobile/trucks.
e. RV'S - means any Recreational Vehicles as defined by 340.01(29), (6m), (33m) designed or constructed to operate either under their own power or towed, and designed to be used for temporary habitation
f. MOTORCYCLE - means any motorized vehicles as defined by 3340.01(32) and including motorized bicycles and scooters.
g. ICEBOAT - A sailboat-like structure with runners or wheels intended to be wind powered on a solid surface.
h. VEHICLES - Includes all the above vehicles plus any other vehicle powered by motor or wind.

i. ICE SHANTIES - Those structures parked or erected on the ice for use as warming buildings and ice fishing shelters, and not including RV's, trucks and automobiles.

j. ACTIVITIES AND EVENTS shall include, but not be limited to, sporting events, fisheries, iceboat races, exhibitions, and vehicle races.

(4) **DESIGNATION OF PEWAUKEE LAKE ZONES.** There shall, hence-forth be designated two zones on Pewaukee Lake; namely, a SHORE ZONE and LAKE ZONE, defined as follows:

a. SHORE ZONE - All area of the lake between the lake shore and a point 500 feet distance from the lake shore.

b. LAKE ZONE - All area of the lake more than 500 feet from each and all shores of Pewaukee Lake.

(5) **REGULATION WITHIN THE SHORE ZONE**

a. MAXIMUM SPEED LIMIT within the SHORE ZONE shall be 10 MPH for all vehicles.

b. ACTIVITIES AND EVENTS within the SHORE ZONE are limited to those requiring no motor or wind powered vehicle.

c. PARKING All vehicles, except iceboats, are prohibited from parking within the SHORE ZONE between 1:30 AM and dawn. Iceboats shall be securely tethered at a dock or at the shore and outside of traveled lanes.

(6) **REGULATION WITHIN THE LAKE ZONE**

a. MAXIMUM SPEED LIMIT within the LAKE ZONE shall be as follows:

1. Iceboats - No iceboat shall be operated at a speed greater than is reasonable and prudent under the conditions and having regard for the actual and potential hazards then existing.
2. Snowmobiles - 50 MPH in daylight and 25 MPH at night.
3. ATV's - 35 MPH in daylight and 25 MPH at night.
4. All other vehicles including but not limited to automobiles, motor trucks, RV's and motorcycles other than iceboats, snowmobiles, or ATV's - 20 MPH.
5. No vehicle may be operated anywhere on Pewaukee Lake over the speed of 10 MPH within 200 feet of an ice shanty, parked vehicle or person.

b. ACTIVITIES AND EVENTS within the LAKE ZONE featuring motorized vehicles of any type are prohibited.

c. PARKING of all vehicles is prohibited within the LAKE ZONE between the hours of 1:30 AM and dawn. In addition, no vehicle may be parked unattended within the LAKE ZONE.

(7) **GENERAL REGULATIONS OF VEHICLE OPERATION IN BOTH SHORE AND LAKE ZONES**

a. No vehicle may be operated anywhere on Pewaukee Lake between the hours of 1:30 AM and dawn.

b. All vehicles shall avoid and may not operate on cleared skating areas and in areas where authorized events are being held.

c. No person shall use or operate any vehicle in any manner so as to endanger persons on the ice.
d. No person while operating a vehicle shall push, pull, or tow any person on skates or skis.
e. No person while operating a vehicle shall push, pull, or tow any device whether occupied or unoccupied unless such device is attached by a rigid tow bar to the frame of the towing vehicle. Such devices shall include but not be limited to sleds, toboggans, and inner tubes.
f. No person shall operate any motorized vehicle in an erratic, free wheeling manner, all maneuvers including but not limited to "wheelies", "donuts", "skating" the vehicle, "spinning out" and wheel spinning are specifically prohibited on Pewaukee Lake.
g. Excluding municipal and emergency personnel, no person shall operate any propeller or fan driven surface vehicle on Pewaukee Lake.
h. No person shall operate any internal combustion powered vehicle which is not properly equipped with a muffler, and shall, generally, operate in a manner so as not to create excessive noise.
i. No person shall operate any motorized vehicle during the period beginning one half-hour after sunset and ending at dawn unless equipped with and using adequate, operating head light(s) and tail light(s).
j. No person shall throw, place or permit to remain on or below the surface of Pewaukee Lake any glass, earth, stones, grass, brush, leaves, petroleum product, garbage, excrement, refuse, waste, filth or other litter.
k. Ice shanties
   1) No ice shanty may be placed or left on the ice after March 5 or before December 1 unless a shorter period is ordered by the Chief of the Lake Patrol. Any ice shanty placed or left in violation of this regulation shall be impounded and the owner fined as stipulated herein.
   2) Ice shanties shall at all times display a red light reflective material of at least nine (9) square inches in size on all sides approximately 3-1/2 feet from the bottom of the shanty and visible from 100 feet away.
   3) Ice shanties or shelters left on the lake overnight shall display the name, address and phone number of the owner on or near the door or entryway on the exterior of the shanty.
   4) Ice shanties shall be constructed of materials which will not be destroyed or quickly deteriorated by wind and rain.
l. Ice cutting
   1) Holes cut, augured, or chiseled in the ice for purposes of fishing shall be no larger than 12 inches in the largest dimension.
   2) Holes cut, augured or chiseled in the ice for purposes of diving, may be larger than 12 inches in the largest dimension but such holes must be clearly marked with light-reflective markers and when not in use the ice replaced in the hole and markers placed until the hole freezes solid and is not a hazard.

(8) <u>WINTER LAKE PATROL DESIGNATED</u>

a. <u>There is hereby designated</u> a Pewaukee Winter Lake Patrol which shall be administered, operated, equipped and manned as set forth in inter-municipal agreements between or among those units of government having local lake jurisdiction.

b. Winter Lake Patrol officers shall be authorized police officers and shall have the duty to patrol the lake to ensure safe conduct and operations on the lake, to assist in emergencies, to enforce these regulations, and to be visible and helpful to persons using the lake.

c. It shall be unlawful to fail or refuse to comply with any lawful order, signal, or direction of a Lake Patrol Officer, and no operator of a vehicle, after having received a visual or audible signal from an officer, or marked Police vehicle shall flee or attempt to elude any officer by wilful or wanton disregard of such signal so as to interfere with or endanger the operation of the Police vehicle, or the Officer, or other vehicles or pedestrians, nor shall such operator increase the speed of the vehicle or extinguish the lights of the vehicle in an attempt to elude or flee apprehension.

d. The cost of maintaining and operating the Winter Lake Patrol shall be borne by the units of government abutting that part of the lake being patrolled with the total costs and responsibilities being apportioned between or among the participants as set forth in an inter-municipal agreement(s) separate from these regulations.

(9) SPECIAL EVENTS, RISKS AND LIABILITIES

a. No specific sporting event, fisheree, iceboat race, or exhibition shall be conducted on Pewaukee Lake unless permission for such activity or event has been provided, in writing, by the Chief of the Lake Patrol.

b. If at any time the Chief of the Lake Patrol observes that the lake is unsafe for vehicle operation or other activity, he may officially declare the lake unsafe and order it closed to traffic and/or activity.

c. All traffic and activity on Pewaukee Lake shall be at the risk of the operator of the vehicle or pedestrian as set forth in Section 30.81(3) of Wisconsin Statutes and nothing in this ordinance shall be construed as shifting or placing such risk or liability to other parties, or units or agencies of government.

SEVERABILITY.

The several sections of this ordinance are declared to be severable. If any section or portion thereof shall be declared by a decision of a court of competent jurisdiction to be invalid, unlawful, or unenforceable, such decision shall apply only to the specific section or portion thereof directly specified in the decision and not affect the validity of all other provisions, sections, or portions thereof of the ordinance which shall remain in full force and effect. Any other ordinances whose terms are in conflict with the provisions of this ordinance are hereby repealed as to those terms that conflict.

TOWN BOARD, TOWN OF PEWAUKEE
TOWN BOARD, TOWN OF DELAFIELD
VILLAGE BOARD, VILLAGE OF PEWAUKEE

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 chapter.[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
	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 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.

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 conversation 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.

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.