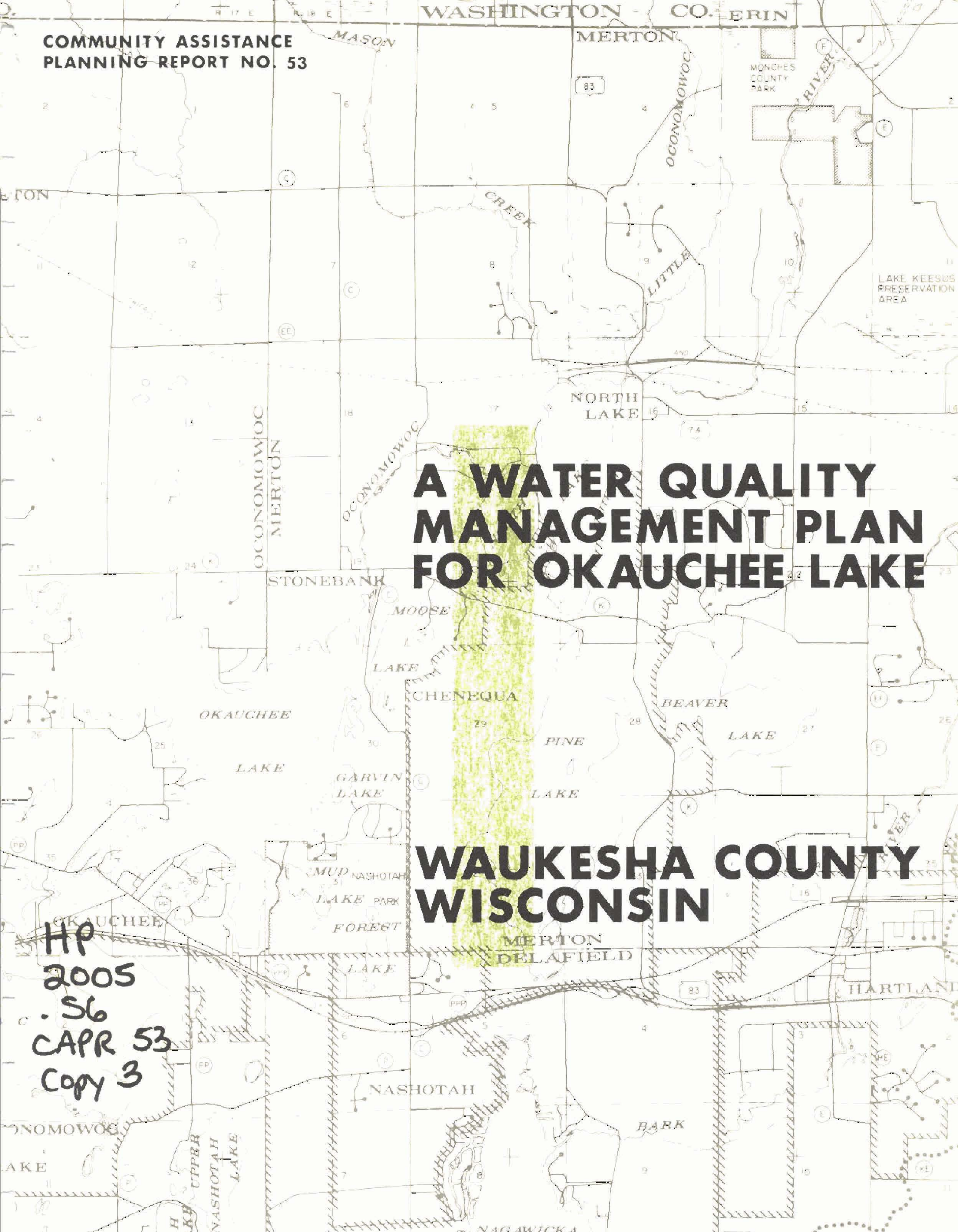
COMMUNITY ASSISTANCE
PLANNING REPORT NO. 53

A WATER QUALITY MANAGEMENT PLAN FOR OKAUCHEE LAKE

WAUKESHA COUNTY WISCONSIN



SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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COMMUNITY ASSISTANCE PLANNING REPORT
NUMBER 53

A WATER QUALITY MANAGEMENT PLAN FOR OKAUCHEE LAKE

WAUKESHA COUNTY, WISCONSIN

Also Reporting on Lower Okauchee and Upper Oconomowoc Lakes

Prepared by the

Southeastern Wisconsin Regional Planning Commission
P. O. Box 769
Old Courthouse
Waukesha, Wisconsin 53187

In Cooperation with the
Wisconsin Department of Natural Resources
Madison, Wisconsin 53707

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August 1981

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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August 25, 1981

TO: All Units and Agencies of Government and Citizen Groups
Involved in Water Quality Management for Okauchee Lake

In 1976 the Southeastern Wisconsin Regional Planning Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources to study the water quality conditions of Okauchee Lake, identify existing and potential problems related thereto, and propose measures which could be applied to resolve those problems and to protect and enhance the water quality of the lake. The findings and recommendations of that study are presented in this report.

The report describes the physical properties of Okauchee Lake, the quality of its waters, and the conditions affecting that quality, including existing land use and the present utilization of the lake. All sources of pollution of the lake are identified and, to the extent possible, quantified; and alternative, as well as recommended, means for the abatement of these sources of pollution and for the protection and enhancement of the water quality of the lake are described.

During the preparation of this report, members of the Commission staff met with local elected officials and concerned citizens to discuss the preliminary findings and recommendations of the study and to receive the comments and suggestions of the local elected officials concerned, lakeshore property owners, and interested citizens. Four such meetings were held--on June 3, August 22, and October 29, 1980, and on January 20, 1981. The findings and recommendations of this report reflect the pertinent comments and suggestions made at those meetings.

The water quality management plan presented herein constitutes a refinement of the areawide water quality management plan adopted by the Regional Planning Commission in July 1979. Accordingly, upon adoption by the local units and agencies of government concerned with water quality management for Okauchee Lake and subsequent adoption by the Regional Planning Commission, the plan presented in this report will become an element of the adopted areawide water quality management plan.

The plan presented in this report is believed to provide a sound guide to the making of development decisions concerning the wise management of Okauchee Lake as an aesthetic and recreational asset of immeasurable value. Accordingly, careful consideration and adoption of the plan presented herein by all of the concerned water quality management agencies is respectfully urged. In its continuing role in the coordination of water quality management planning and plan implementation within southeastern Wisconsin, the Regional Planning Commission stands ready to assist the various units and agencies of government concerned in carrying out the recommendations contained in this report.

Respectfully submitted,

Kurt W. Bauer
Executive Director

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Chapter I

INTRODUCTION

Thirteen major inland lakes in southeastern Wisconsin were studied under a special program conducted by the Southeastern Wisconsin Regional Planning Commission in cooperation with the Wisconsin Department of Natural Resources, local lake protection and rehabilitation districts, and other lake organizations. Eight of the 13 lakes--Eagle Lake, Friess Lake, Lac La Belle, North Lake, Oconomowoc Lake, Pewaukee Lake, Pike Lake, and Wandawega Lake--were studied by the Regional Planning Commission in cooperation with the Wisconsin Department of Natural Resources, Bureau of Research, and four of the lakes--Ashippun Lake, George Lake, Okauchee Lake, and Paddock Lake--were studied by the Regional Planning Commission in cooperation with the Wisconsin Department of Natural Resources, Office of Inland Lake Renewal, and the local lake protection and rehabilitation districts concerned. One of the 13 lakes--Geneva Lake--was studied by the Regional Planning Commission in cooperation with the Geneva Lake Watershed Environmental Agency. The objectives of these studies were to acquire definitive information concerning lake water quality and related land use and land management practices in the lake drainage area; to identify the factors affecting lake water quality, particularly the amount, kind, and temporal distribution of pollutants contributed by the various sources; and to develop recommendations for the abatement of pollution in order to maintain or improve water quality conditions.

On May 20, 1976, the Southeastern Wisconsin Regional Planning Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources to study Okauchee Lake. The cooperative study included the design and conduct of a water quality sampling program to determine existing lake water quality conditions, and inventories and analyses of pertinent tributary drainage area characteristics affecting water quality conditions, including land use and management practices, existing water uses and sources of pollution. The detailed lake water quality sampling program was conducted from December 1976 through November 1977. Some inventory data collected as recently as 1980, however, are incorporated into this report. Because of their close proximity and hydraulic relationships, this report addresses Lower Okauchee Lake and Upper Oconomowoc Lake, as well as Okauchee Lake proper. This report summarizes the results of the sampling program and other related inventories and provides an evaluation and interpretation of the data collected and collated. From these analyses, feasible alternative actions for the maintenance and enhancement of lake water quality are proposed and evaluated, and water quality management measures are recommended.

Okauchee Lake is a 1,198 acre[1] lake located within U. S. Public Land Survey Township 8 North, Range 17 East, Town of Oconomowoc, and Township 8 North, Range 18 East, Town of Merton, in Waukesha County. Lower Okauchee[2] and Upper

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[1]*In SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, (1969), the area of Okauchee Lake was reported to be 1,187 acres, as measured from 1956 aerial photographs. Based on 1975 aerial photographs, the area of Okauchee Lake was estimated to be 1,198 acres. The difference in area of 0.9 percent is well within the accuracy limitations of the techniques used to measure the lake area.*

[2]*Lower Okauchee Lake is also referred to as Little Okauchee Lake by some residents.*

Oconomowoc Lakes are 47 acres and 36 acres in size, respectively, and both are located entirely within Township 8 North, Range 17 East, Town of Oconomowoc. All three lakes are fed by, and drain to, the Oconomowoc River. Properly managed, the 3,366.4 acre drainage area directly tributary to these lakes can contribute to the maintenance of the lakes as important assets to the residents of the County and the Region of which the County is an integral part.

This report discusses the physical, chemical, and biological characteristics of the lakes together with pertinent related characteristics of the tributary drainage area, as well as the feasibility of various water quality management alternatives which may enhance water quality conditions in the lakes. The primary management objectives for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes include: 1) providing water quality suitable for the maintenance of fish and other aquatic life, 2) reducing the severity of existing nuisance problems due to excessive macrophyte growths which constrain or preclude intended water uses, and 3) improving opportunities for water-based recreational activities.

The local units of government, as represented on the Okauchee Lake Management District, were asked to review a preliminary draft of this report, and comments based upon that review are incorporated into this report. Accordingly, the lake water quality management plan herein presented should constitute a practical guide for the management of the water quality of Okauchee Lake, Lower Okauchee Lake, and Upper Oconomowoc Lake, and for the management of the land surfaces which drain directly to these lake bodies.

Chapter II

PHYSICAL DESCRIPTION

LAKE BASIN AND SHORE CHARACTERISTICS

Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes are fed by and drain to the Oconomowoc River. The lakes lie within glacial outwash deposits and are bordered by a terminal moraine. Basic hydrographic and morphometric data for the three lakes are presented in Table 1. The morphometry of the Okauchee, Lower Okauchee, and Upper Oconomowoc Lake basins is illustrated in Map 1. Figure 1 presents an aerial photograph of the lakes and surrounding shorelines.

About 7 percent of Okauchee Lake has a water depth less than 5 feet, 41 percent has a water depth between 5 and 10 feet, 22 percent has a water depth between 10 and 40 feet, and 30 percent of the lake has a water depth of more than 40 feet. The mean depth of Okauchee Lake is 24.9 feet and the maximum depth is 115 feet. Okauchee Lake is 2.2 miles long and 1.4 miles wide at its widest point. The major axis of the lake lies in a northeasterly-southwesterly direction. Okauchee Lake has a volume of approximately 29,788 acre-feet and a surface area of about 1,198 acres. The shoreline of the lake has a length of 15.2 miles, and the shoreline development factor is 3.1. Thus, the Okauchee Lake shoreline is about three times as long as that of a circular lake of the same area.

About 18 percent of Lower Okauchee Lake has a water depth less than 5 feet, 61 percent has a water depth between 5 and 10 feet, and 21 percent has a depth of more than 10 feet. The mean depth of Lower Okauchee Lake is 7.6 feet and the maximum depth is 14 feet. Lower Okauchee Lake is 0.4 mile long and 0.2 mile wide at its widest point. The major axis of the lake lies in a northeasterly-southwesterly direction. Lower Okauchee Lake has a volume of approximately 357 acre-feet and a surface area of about 47 acres. The shoreline of Lower Okauchee Lake has a length of 1.5 miles, and the shoreline development factor is 1.5.

About 31 percent of Upper Oconomowoc Lake has a water depth less than 5 feet, 38 percent has a water depth between 5 and 10 feet, and 31 percent has a depth of more than 10 feet. The mean depth of Upper Oconomowoc Lake is 7.4 feet and the maximum depth is 14 feet. Upper Oconomowoc Lake is 0.4 mile long and 0.2 mile wide at its widest point. The major axis of the lake also lies in a northeasterly-southwesterly direction. Upper Oconomowoc Lake has a volume of approximately 267 acre-feet and a surface area of about 36 acres. The shoreline of Upper Oconomowoc Lake has a length of 1.8 miles, and the shoreline development factor is 2.1.

Okauchee Lake is a natural lake basin and was originally created by the melting of at least two ice blocks entrapped in glacial deposits. The lake level was naturally controlled until about 1838, when a dam was constructed at the lake outlet, raising the lake level 9 feet. As a result, there are now numerous submerged stumps in the shallow areas and several islands in the lake. The dam was used to power a sawmill operation until about 1870, a flour mill operation until about 1878, and a feed mill operation until 1911. In 1911 a new dam was built about 2,000 feet downstream from the old dam--which was partially removed to assure navigability--forming what is now called Lower Okauchee Lake. The dam replacement was constructed of reinforced concrete and was initially used to generate electricity. The lake levels were controlled at this site until 1961 when, because of the need for repairs to the existing dam, yet another new dam was constructed about 1,800 feet downstream from the then existing dam--which

Table 1

HYDROGRAPHY AND MORPHOMETRY OF OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1975

Parameter	Okauchee	Lower Okauchee	Upper Oconomowoc
Size			
Area of Lake (acres)	1,198	47	36
Area of Total Drainage Area (square miles)	70.19[c]	--[d]	--[d]
Area of Directly Tributary Drainage Area (square miles)	5.26[c]	--[d]	--[d]
Lake Volume (acre-feet)	29,788	357	267
Residence Time[a].............	9.9 months	6.2 days	4.4 days
Shape			
Length of Lake (miles)	2.2	0.4	0.4
Length of Shoreline (miles)	15.2[e]	1.5	1.8
Width of Lake (miles).........	1.4	0.2	0.2
Shoreline Development Factor[b].....................	3.1	1.5	2.1
Depth			
Mean (feet)	24.9	7.6	7.4
Maximum (feet)	115.0[f]	14.0	14.0

[a]*The "residence time" is estimated as the time period required for the full volume of the lake to be replaced by inflowing waters, during a year of normal precipitation.*

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

[c]*Includes direct drainage areas to Lower Okauchee and Upper Oconomowoc Lakes.*

[d]*Included in Okauchee Lake value.*

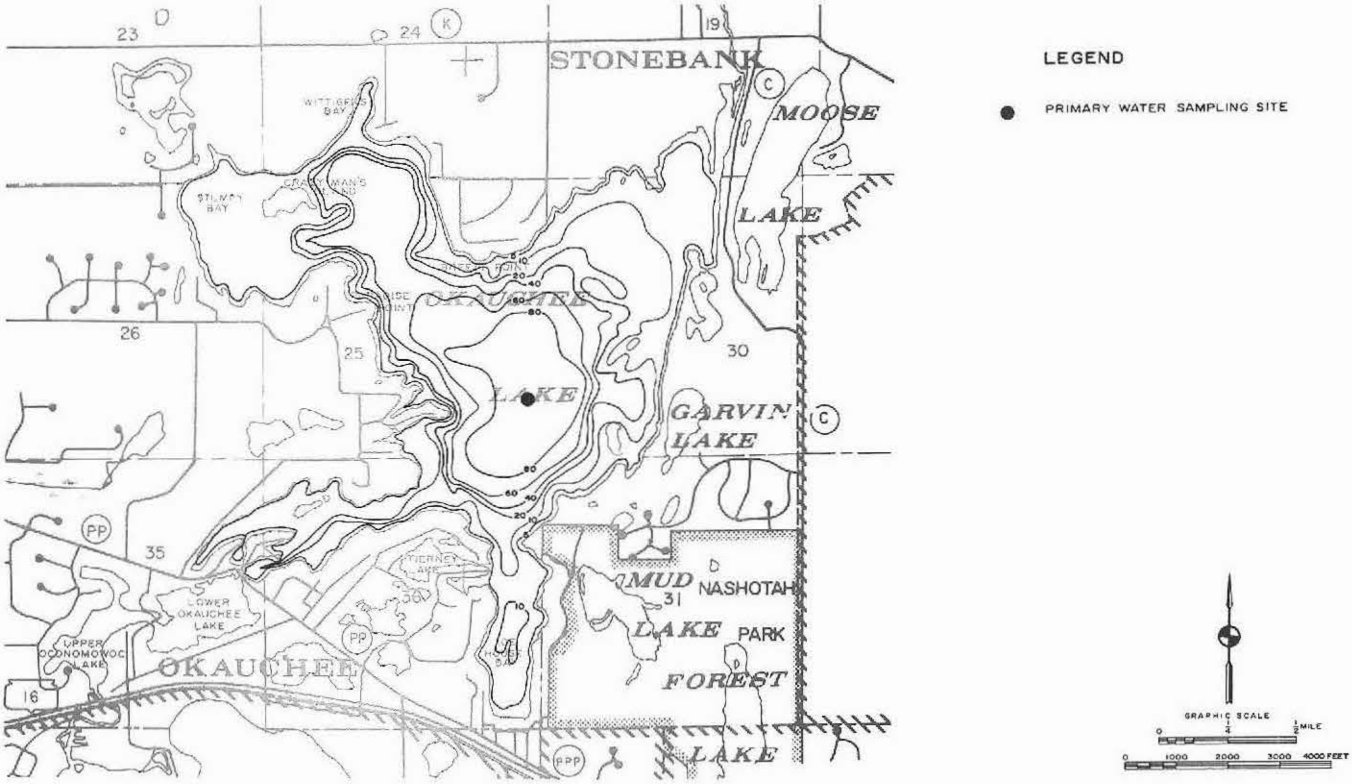
[e]*Based on measurement of the lake shoreline from a 1" = 500' scale lake survey map.*

[f]*Based on information provided by members of the Okauchee Lake Management District.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 1

HYDROGRAPHIC AND MORPHOMETRIC MAP OF, AND WATER QUALITY SAMPLING SITE FOR, OKAUCHEE LAKE



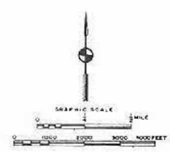
Source: SEWRPC.

was partially removed by the Lake Shore Development Corporation--thereby creating Upper Oconomowoc Lake. Thus, as of 1980, the lake levels were controlled by a reinforced concrete dam with a 46 foot wide spillway and two lift-gates permitting the lake to be maintained at normal elevations varying from 872.60 to 873.71 feet National Geodetic Vertical Datum (NGVD). The top of the weir controlling the water level is at an elevation of 873.71 feet NGVD, and the top of the dam sill is at an elevation of 877.80 feet NGVD. The Town of Oconomowoc is responsible for the continued operation and maintenance of the existing dam. Both Lower Okauchee and Upper Oconomowoc Lakes were formed over what were once primarily marshlands.

Lake bottom sediment types are shown on Maps 2, 3, and 4. Okauchee Lake has a great variety of bottom sediment types, with a combination of muck and marl, and marl alone, constituting 27.4 and 24.9 percent, respectively, of the total mapped bottom area of Okauchee Lake. Substantial areas of muck alone, and a combination of muck, marl, and detritus also exist in Okauchee Lake. Sand, gravel, and rock bottom types are scattered along the shoreline, most particularly along the northwest shoreline of the lake proper, and along the western shoreline of Ice House Bay located on the south end of the lake. Lower Okauchee Lake has the most homogeneous bottom sediment type of the three lakes with 97 percent being muck. Upper Ocono-

Figure 1

AERIAL PHOTOGRAPH OF OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES AND SURROUNDING SHORELINE



Source: SEWRPC.

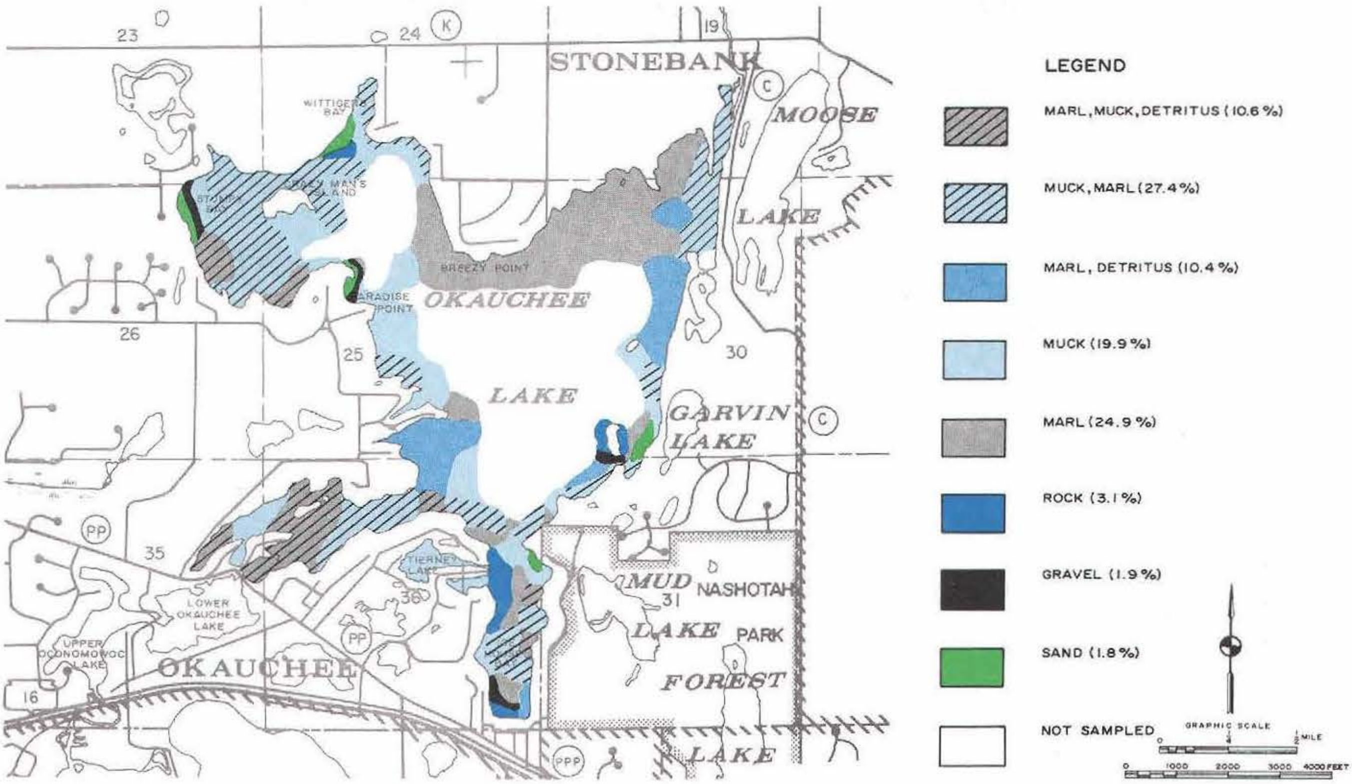
mowoc Lake, perhaps because of its relatively recent date of formation, exhibits an unusual mix and diversity of bottom sediment types, with considerable areas of muck, clay, and gravel.

Watershed Characteristics

The drainage area directly tributary to Okauchee, Lower Okauchee and Upper Oconomowoc Lakes--that is, that land area which drains directly into the lakes--totals 3,366.4 acres, or 5.26 square miles, in extent and is shown on Map 5. The total drainage area to the lake, including the area drained by the Oconomowoc River is 44,921.6 acres, or 70.19 square miles. The lakes have a combined relatively low watershed-to-

Map 2

BOTTOM SEDIMENT TYPES IN OKAUCHEE LAKE



Source: Environmental Resource Assessments and SEWRPC.

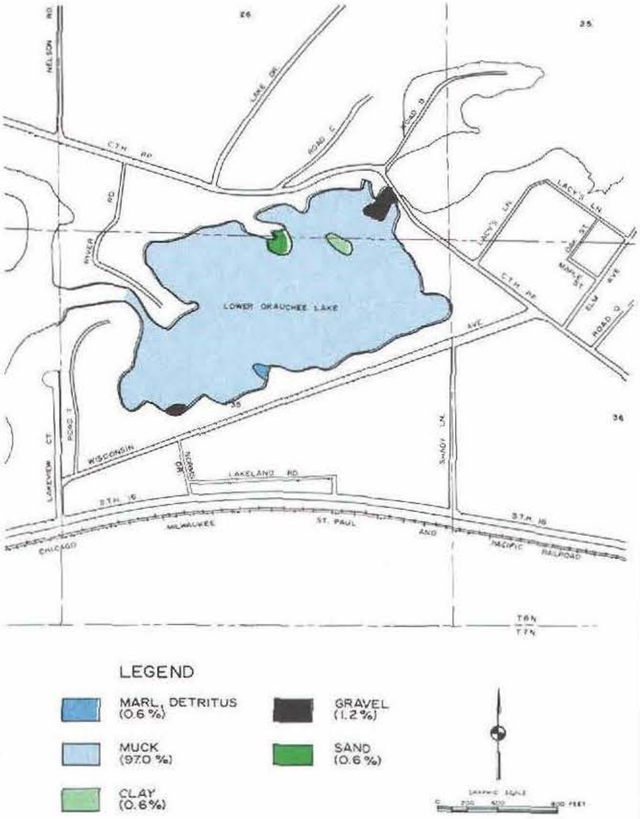
lake area ratio of 2.6 if only the directly tributary area is considered. A much higher watershed-to-lake area ratio of 35 is computed when the total drainage area of the upstream Oconomowoc River system is included. The Oconomowoc River is the only perennial inlet to the lakes. The discharge from Upper Oconomowoc Lake enters Oconomowoc Lake about one mile downstream from the Upper Oconomowoc Lake outlet. The Oconomowoc River, which supports resident fish populations, joins the Rock River about 18 miles downstream from Upper Oconomowoc Lake, at a point of confluence located in Jefferson County.

Climate and Hydrology

Long-term average monthly air temperature and precipitation values for the Okauchee Lake area are set forth in Table 2. These averages were taken from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Oconomowoc. The records of this station may be considered typical of the lake area. Table 2 also sets forth runoff values derived from U. S. Geological Survey (USGS) flow records for the Rock River at Afton, in Jefferson County, Wisconsin. The mean annual temperature based upon 24 years of record is 46.6°F. The mean annual precipitation also based upon 24 years of record is 29.60 inches. More than half the yearly precipitation normally occurs 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, less

Map 3

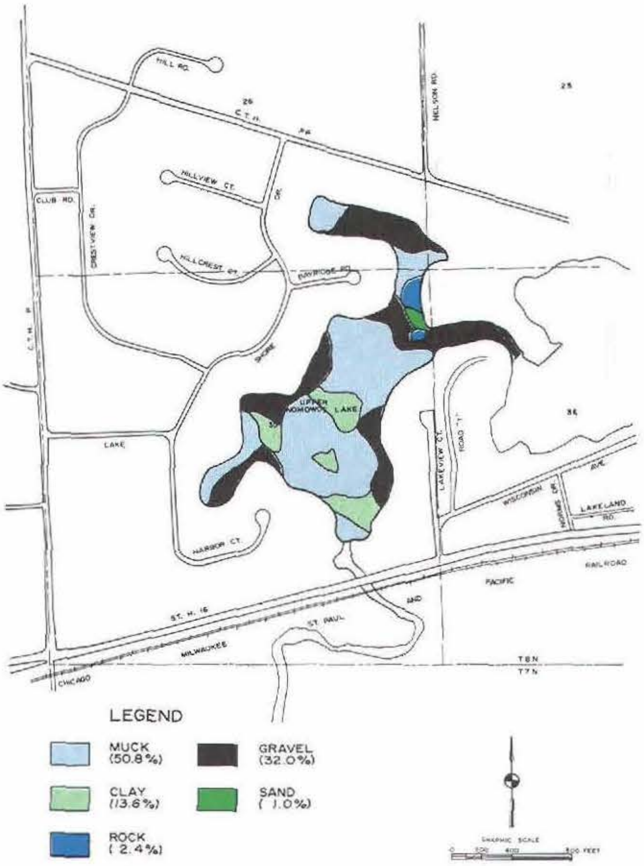
BOTTOM SEDIMENT TYPES IN LOWER OKAUCHEE LAKE



Source: Environmental Resource Assessments and SEWRPC.

Map 4

BOTTOM SEDIMENT TYPES IN UPPER OCONOMOWOC LAKE



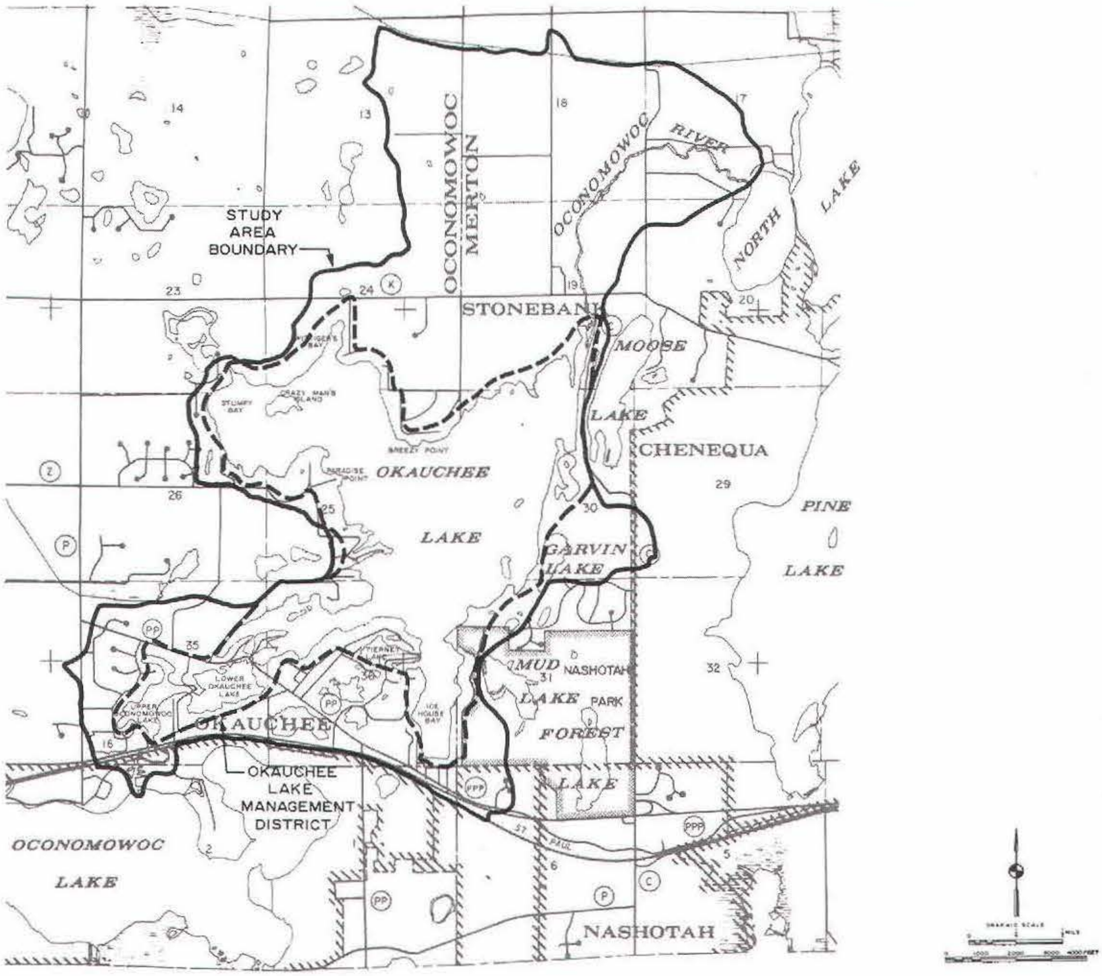
Source: Environmental Resource Assessments and SEWRPC.

than 15 percent of the summer precipitation is converted to surface runoff, but intense summer storms may occasionally produce high rates and amounts of runoff. Approximately 30 percent of the annual precipitation normally occurs during the winter or early spring when the ground is frozen, resulting in high rates and amounts of surface runoff during those seasons. Impervious areas, such as street surfaces, parking lots, and rooftops, increase the amount of surface runoff and decrease soil infiltration.

The 12-month period over which the Okauchee Lake water quality sampling study was carried out--December 1976 through November 1977--was a period of average temperatures and slightly higher-than-average amounts of precipitation in southeastern Wisconsin, as indicated in Table 2. Temperatures were generally below normal during the early winter of 1976, above normal in the spring of 1977, and about normal for the remainder of the study period. Preciptation at Oconomowoc was about 6.82 inches above normal, with the greatest increased

Map 5

DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES



Source: SEWRPC.

amounts occurring in July and August 1977. However, a severe drought occurred in southeastern Wisconsin in the period immediately preceding, and including the first several months of, the study period. The extreme drought conditions lasted from approximately May 1976 through April 1977, and five of the first six months of the study period--from December 1976 through May 1977--experienced below normal amounts of precipitation. Groundwater levels were substantially reduced by this drought, and these reduced groundwater levels were, in turn, reflected in the below normal flow levels in the Rock River. At Afton, the flow of the Rock River during the study period was only 55 percent of normal. Therefore, while precipitation amounts were higher than normal during the study period, the hydrologic regime of the lakes may not have fully recovered from the effects of the preceding drought period.

The water level of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes is primarily determined by the level of the dam located at the Upper Oconomowoc Lake outlet. The dam has a normal operating

Table 2

LONG TERM AND 1976-1977 STUDY YEAR CLIMATOLOGICAL AND RUNOFF DATA FOR THE OKAUCHEE LAKE AREA

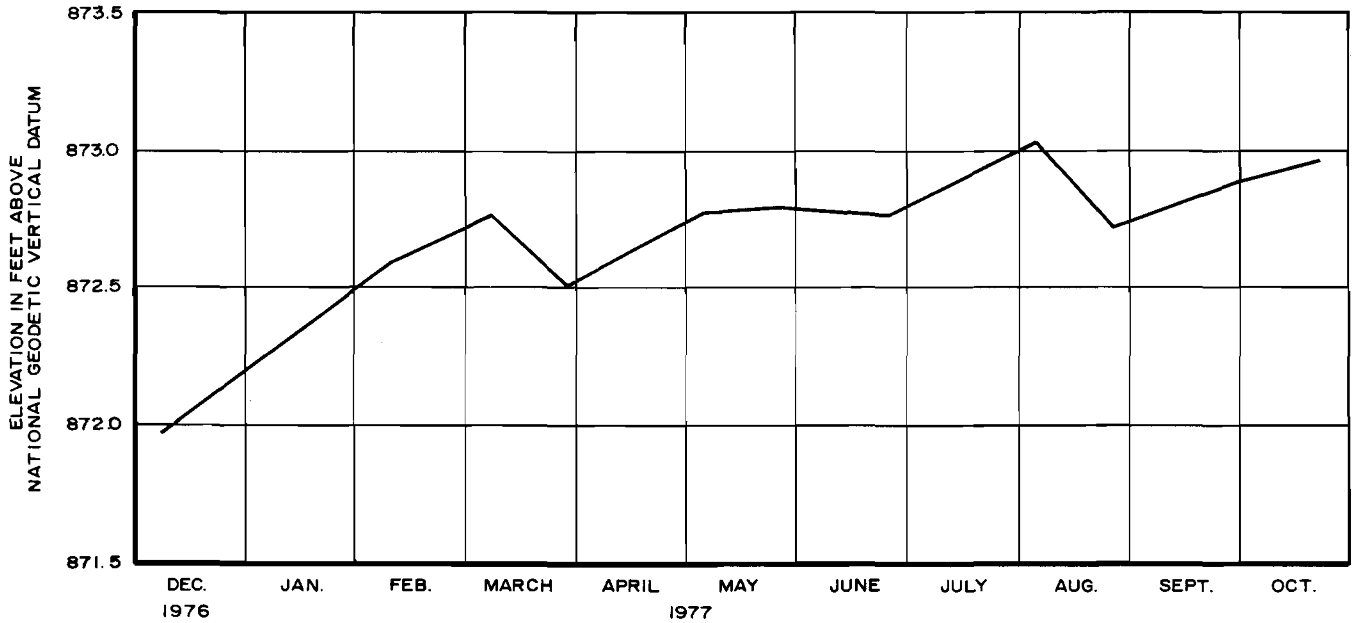
	Long Term Average Monthly Values												
Climatological Data	December	January	February	March	April	May	June	July	August	September	October	November	Annual
Mean monthly air temperature - °F (Oconomowoc) (1954-1977)..........	23.5	16.9	22.0	32.2	46.9	58.1	67.3	72.1	70.3	61.8	51.2	36.8	46.6
Mean monthly precipitation - inches (Oconomowoc) (1954-1977)..........	1.34	0.95	0.81	1.70	2.79	3.03	3.77	3.89	3.67	3.54	2.33	1.78	29.60
Mean runoff-inches (Rock River at Afton) (1914-1978).........	0.46	0.42	0.46	1.14	1.36	0.85	0.56	0.45	0.34	0.37	0.41	0.45	7.27

	Study Period Average Monthly Values												
	1976	1977											
Climatological Data	December	January	February	March	April	May	June	July	August	September	October	November	Annual
Mean monthly air temperature - °F (Oconomowoc).........	12.7	2.4	19.3	39.5	51.7	65.6	65.1	74.4	66.6	61.8	48.7	36.7	45.4
Departure from normal monthly mean air temperature - °F (Oconomowoc).........	-10.8	-14.5	-2.7	7.3	4.8	7.5	-2.2	2.3	-3.7	0.0	-2.5	-0.1	-1.2
Precipitation-inches (Oconomowoc).........	0.29	0.63	0.49	3.48	2.61	1.08	4.13	7.55	6.74	4.77	2.09	2.56	36.42
Departure from normal precipitation-inches (Oconomowoc).........	-1.05	-0.32	-0.32	1.78	-0.18	-1.95	0.36	3.66	3.07	1.23	-0.24	0.78	6.82
Runoff-inches (Rock River at Afton)...............	0.17	0.17	0.15	0.42	0.65	0.22	0.17	0.22	0.43	0.33	0.54	0.53	4.0
Departure from normal runoff-inches (Rock River at Afton)...............	-0.29	-0.25	-0.31	-0.72	-0.71	-0.63	-0.39	-0.23	0.09	-0.04	0.13	0.08	-3.27

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

Figure 2

LAKE LEVEL FLUCTUATIONS IN OKAUCHEE LAKE: DECEMBER 1976-OCTOBER 1977



Source: Environmental Resource Assessments, Wisconsin Department of Natural Resources, and SEWRPC.

level, as established by Wisconsin Department of Natural Resources, at elevations of 872.60 to 873.71 feet NGVD. As shown in Figure 2, the level of Okauchee Lake rose from a low elevation of 871.99 feet NGVD in early December 1976, at the height of the severe drought, to a high elevation of 873.03 feet in early August 1977, and then dropped slightly to elevations ranging from 872.70 to 872.97 feet from late August through late October 1977.

Water budgets for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes were computed from estimated precipitation, Oconomowoc River inflow and outflow, direct tributary surface runoff, groundwater inflow and outflow, evaporation, and lake level data, and are set forth in Table 3. For Okauchee Lake during the year of the study, it is estimated that approximately 35,914 acre-feet of water entered the lake. Of this total, about 24,330 acre-feet of water, or 68 percent, were contributed by inflow from the Oconomowoc River; about 6,516 acre-feet, or 18 percent, were contributed from groundwater inflow; about 3,620 acre-feet, or 10 percent, were contributed by direct precipitation on the lake surface; and about 1,448 acre-feet, or 4 percent, was contributed by surface runoff from the direct tributary drainage area. Of the total water output from Okauchee Lake of about 35,914 acre-feet, about 20,995 acre-feet, or 59 percent, were discharged via the Oconomowoc River; about 10,860 acre-feet, or 30 percent, left as groundwater outflow; about 2,896 acre-feet, or 8 percent, evaporated from the surface of the lake; and about 1,163 acre-feet, or 3 percent, were represented by increased storage in the lake basin with a resulting higher lake level. Because of the relatvely small size of Lower Okauchee and Upper Oconomowoc Lakes, the Oconomowoc River accounts for over 97 percent of both the water inputs to, and water outputs from, these two lakes.

Table 3

HYDROLOGIC BUDGETS FOR OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: DECEMBER 1976-NOVEMBER 1977

Input	Okauchee Lake		Lower Okauchee Lake		Upper Oconomowoc Lake	
	Volume (acre feet)	Percent of Total	Volume (acre feet)	Percent of Total	Volume (acre feet)	Percent of Total
Oconomowoc River.......	24,330	68.0	20,995	99.0	20,666	98.8
Groundwater............	6,516	18.0	--[a]	--[a]	--[a]	--[a]
Direct Precipitation...	3,620	10.0	142	0.7	115	0.6
Overland Runoff (from Direct Drainage Area)..................	1,448	4.0	47	0.3	131	0.6
Total	35,914	100.0	21,184	100.0	20,912	100.0
Output						
Oconomowoc River.......	20,995	59.0	20,598	97.2	20,440	97.7
Groundwater............	10,860	30.0	426	2.0	344	1.6
Evaporation............	2,896	8.0	114	0.5	91	0.5
Lake Storage...........	1,163	3.0	46	0.3	37	0.2
Total	35,914	100.0	21,184	100.0	20,912	100.0

[a]Assumed to be negligible, based on study field data and resulting water budget.

Source: SEWRPC.

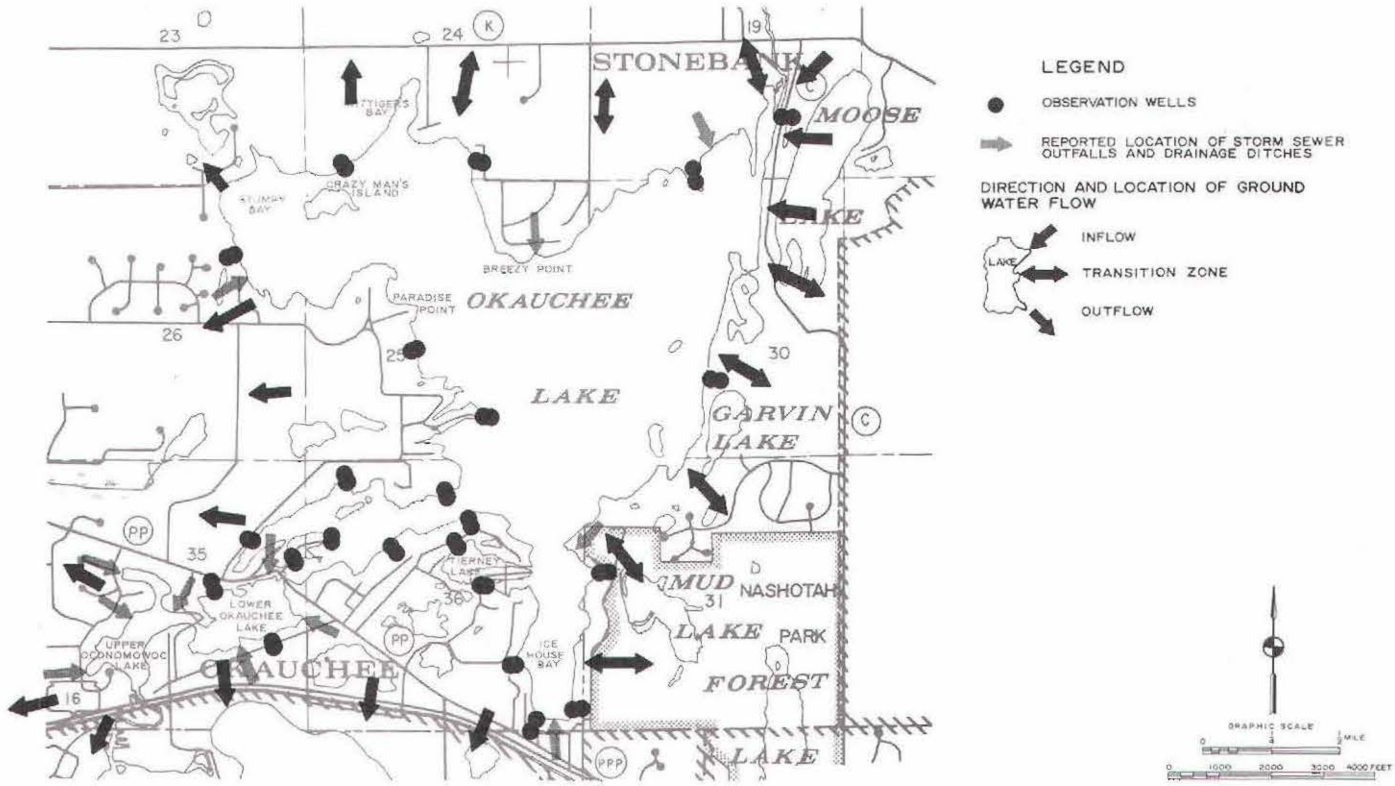
Twenty-three pairs of groundwater sampling wells, as shown on Map 6, were used to measure the direction and flow of groundwater around the lakes. In 42 of the 46 wells, the groundwater quality was measured. Groundwater inflow to Okauchee Lake was found to occur only along the northeast shore of the lake near the Oconomowoc River inlet. Much of the northern and eastern shores of Okauchee Lake were found to serve as transition zones, with groundwater sometimes flowing into, and sometimes out of, the lake. The remaining Okauchee Lake shoreline and Lower Okauchee and Upper Oconomowoc Lakes appeared to serve as groundwater recharge areas. It should be noted that low groundwater levels during the study period may have had an undetermined affect on measured flows at the test wells.

Map 6 also shows the location of known storm sewer outlets and drainage ditches which discharge into the lakes. There were 5, 3, and 4 known discrete locations of surface drainage discharge to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, respectively. The water discharged from these outlets was included in the estimated direct tributary surface water volumes as presented above.

The hydraulic residence time is important in determining the expected response time of the lake to increased or reduced nutrient and other pollutant loadings. The hydraulic residence time for Okauchee Lake during the study period of December 1976 through November 1977, which was, as already noted, a year of slightly above average precipi-

Map 6

LOCATION OF GROUNDWATER SAMPLING WELLS AND SURFACE DRAINAGE OUTLETS AND THE DIRECTION OF GROUNDWATER FLOW AROUND OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1976-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

tation, was approximately 10 months. Because of their relatively small volumes, the hydraulic residence times of both Lower Okauchee and Upper Oconomowoc Lakes ranged from four to six days.

SOIL TYPE AND CONDITIONS

Composition, slope, use, and management are among the more important factors determining the effect of soils on lake water quality. Major specific soil types were inventoried in the drainage area directly tributary to the lakes and analyzed in terms of the associated hydrologic characteristics. An assessment was made of soil erodibility and soil suitability for use of onsite septic tank sewage disposal systems. These assessments were then used to identify areas of incompatible land use and management.

Soil composition and slope are important factors affecting the rate, amount and quality of storm water runoff. The shape and stability of aggregates of soil particles--expressed as soil structure--influence the permeability, infiltration rate, and erodibility of soils. Slope is important in determining storm water runoff rates, and hence, susceptibility to erosion.

Soils within the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes can be categorized into the four main hydrologic

Table 4

GENERAL HYDROLOGIC SOIL TYPES IN
THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE,
LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

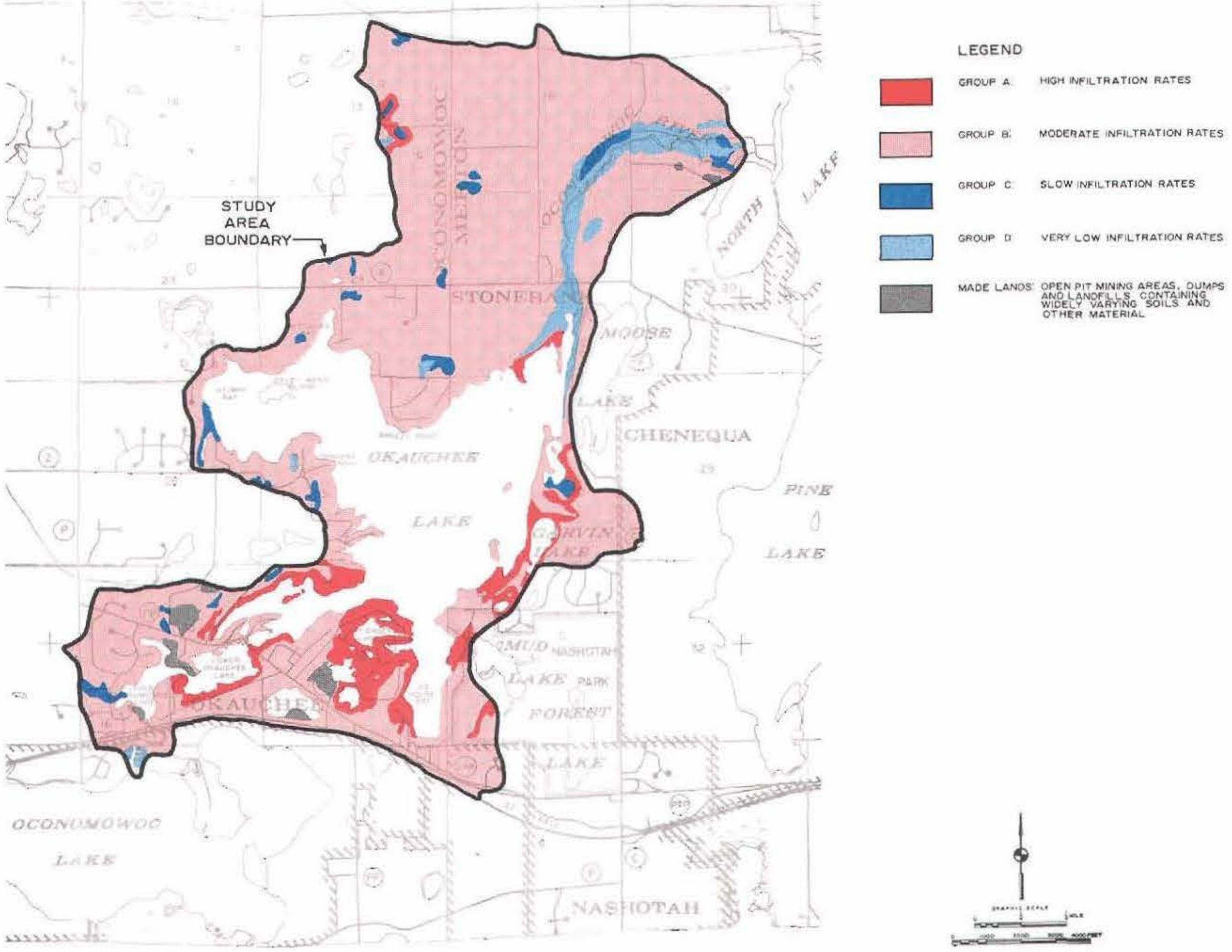
Group	Soil Characteristics	Extent (acres)	Percent of Total
A	High infiltration rates Well drained and excessively drained sandy or gravelly soils High rate of water transmission and low runoff potential	279.4	8.3
B	Moderate infiltration rates Moderately well drained Moderately coarse textures Moderate rate of water transmission	2,793.8	83.0
C	Slow infiltration rate Moderately fine or fine-textured layers that impede downard movement of water Slow rate of water transmission	84.1	2.5
D	Very low infiltration rates Clay soils with high shrink-swell potential; soils with a high permanent water table; soils with a clay pan or clay layer at or near the surface; shallow soils over nearly impervious substrate Very slow rate of water transmission	161.8	4.8
Made Land	Open pit mining areas, man-made fill areas, dumps and landfills containing widely varying soils and other materials	47.3	1.4
Total		3,366.4	100.00

Source: SEWRPC.

groups and "made" land, as indicated in Table 4. The relative proportion of the total area of the direct drainage area covered by each of the hydrologic soil groups is: Group A, well drained soils, 8.3 percent; Group B, moderately drained soils, 83.0 percent; Group C, poorly drained soils, 2.5 percent; Group D, very poorly drained soils, 4.8 percent; and "made land", 1.4 percent. The extent of these soils and their location within the drainage area are shown on Map 7. The major specific soil types present within the direct tributary drainage area are: Fox silt loam, Theresa silt loam, Casco loam, Casco-Rodman complex, Hochheim loam, St. Charles silt loam, Brookston silt loam, and marsh soils.

Map 7

HYDROLOGIC SOIL GROUPS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES



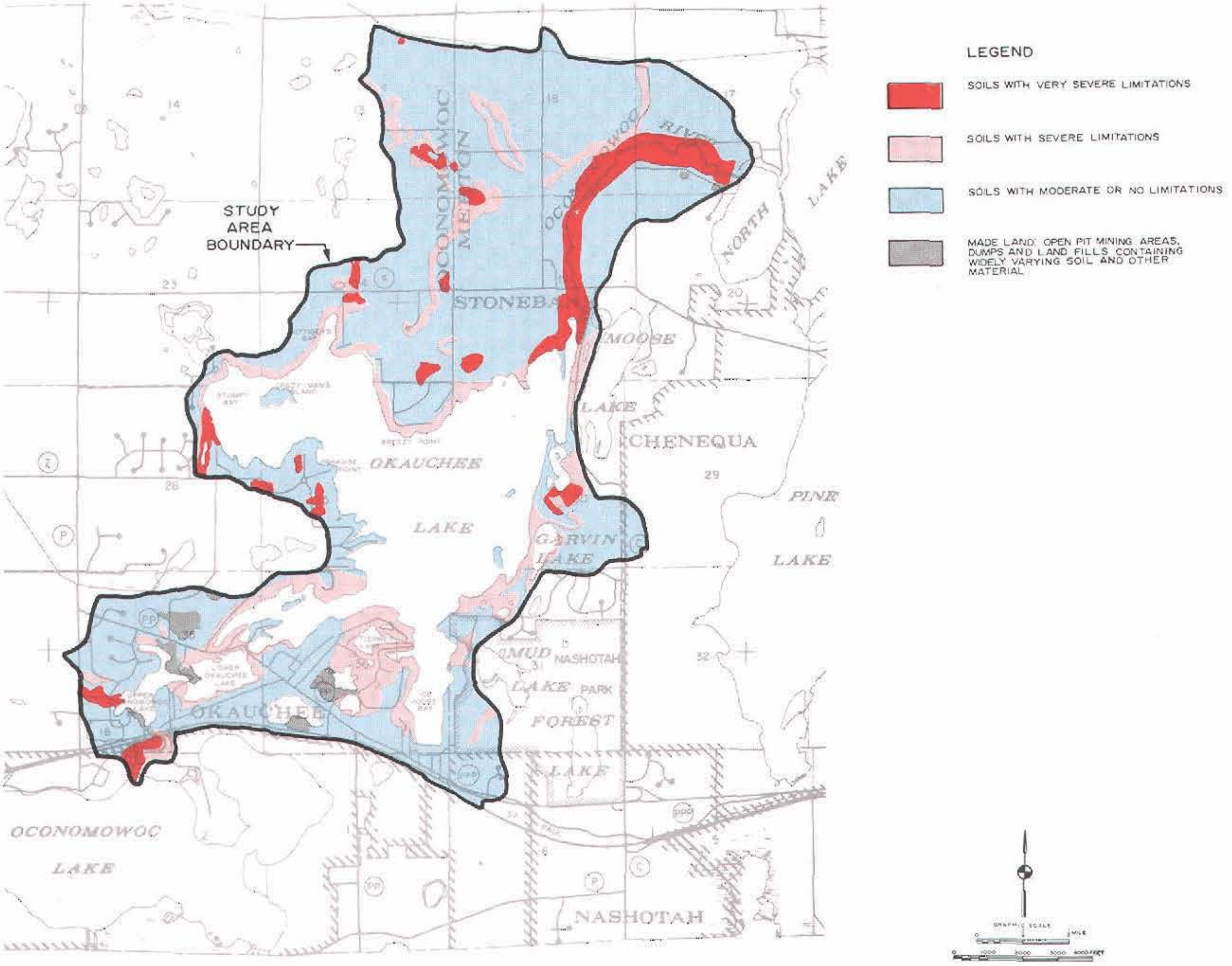
Source: SEWRPC.

Soils within the direct tributary area were examined for their suitability for septic tank system use. The suitability of soils for such systems is indicated on Map 8 according to three major groupings: suitable, severely limited, and very severely limited for septic systems on lots of one acre or less in area. These soil categories cover 79, 15, and 6 percent of the total drainage area respectively. In the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, as of 1975, 508 of the estimated 1,335 septic systems, or 38 percent, were located on soils having severe or very severe limitations for the use of such systems.

Land uses within the tributary drainage area are generally compatible with the soil types. Except for the sewage disposal uses noted above, residential development within the lake watershed is compatible with the soil characteristics. Another consideration for water-

Map 8

SUITABILITY OF SOILS FOR CONVENTIONAL PRVATELY OWNED ONSITE SEWAGE DISPOSAL SYSTEMS ON LOTS ONE ACRE OR LESS IN SIZE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

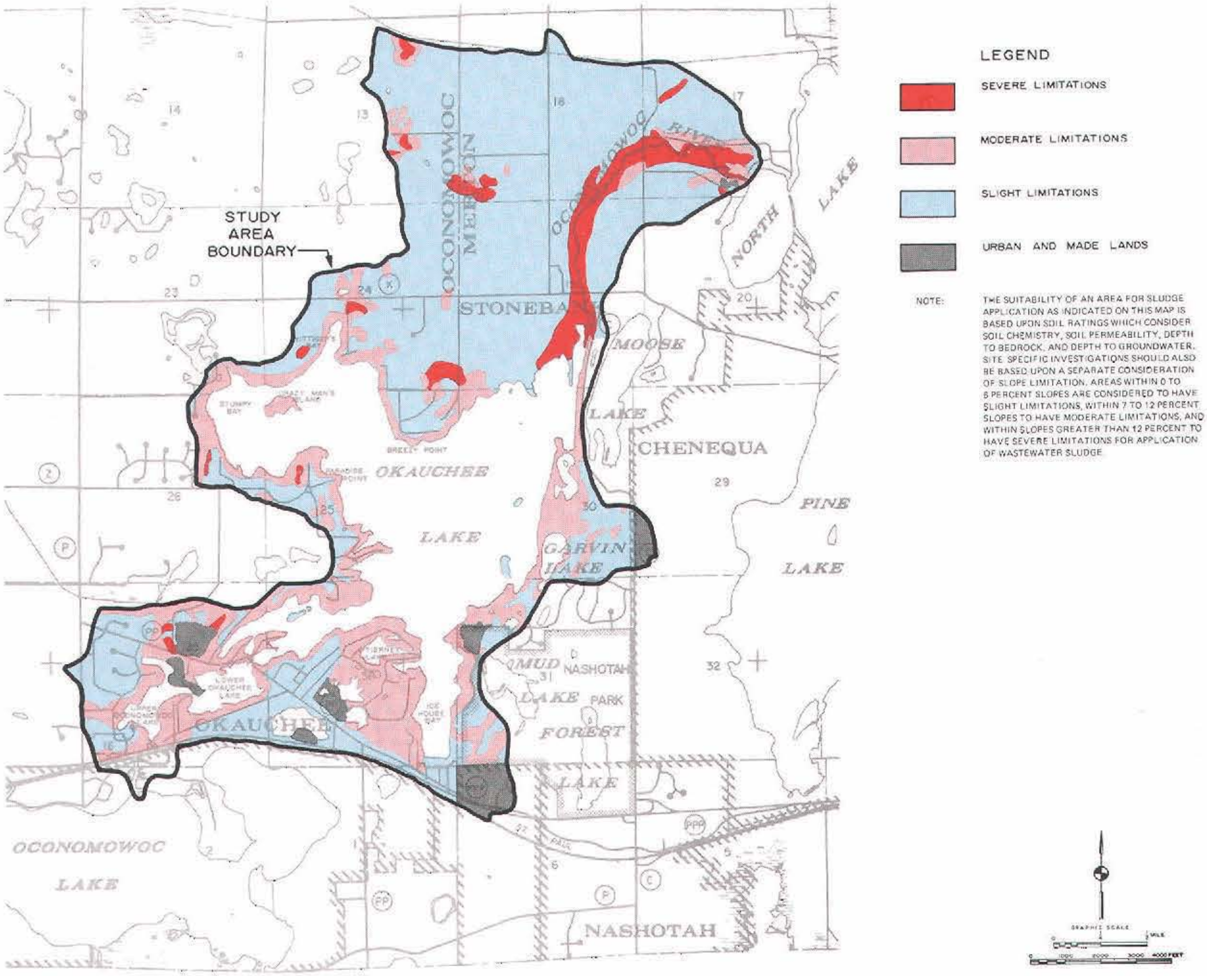


Source: SEWRPC.

shed management is the suitability of the soils for land application of residual wastewater treatment sludges. The Commission inventory of wastewater sludge management practices within the Region indicated that, in 1976, sludge was not applied in the drainage area directly tributary to the lakes. About 69.0 percent of the total area of the direct drainage area to Okauchee Lake is covered by soils rated as having only slight limitations for wastewater sludge application, as shown on Map 9. The remaining areas are covered by soils which have limitations for sludge application; and any such application in these areas could potentially be detrimental to lake water quality.

Map 9

SUITABILITY OF SOILS FOR WASTEWATER SLUDGE APPLICATION IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES



Source: SEWRPC.

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Chapter III

HISTORICAL, EXISTING, AND FORECAST LAND USE AND POPULATION LEVELS

INTRODUCTION

Water pollution problems, and ultimate solutions to those problems, are a function of the human activities within the drainage area of a water body and of the ability of the underlying natural resource base to sustain those activities. This is especially true in an area directly tributary to a lake, because lakes are more susceptible than streams to water quality degradation, and such degradation is more likely to interfere with desired water uses.

Superimposed on the irregular direct tributary drainage area boundary of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes is a generally rectilinear pattern of local civil division boundaries, as shown on Map 10. The drainage area directly tributary to the lakes includes portions of the City of Delafield, the Villages of Chenequa and Oconomowoc Lake, and of the Towns of Merton, Oconomowoc, and Summit, all in Waukesha County. None of these civil divisions lies entirely within the direct tributary drainage area. The area and proportion of the direct drainage area lying within the jurisdiction of each civil division, as of 1975, are set forth in Table 5. Geographic boundaries of the civil divisions are an important factor which must be considered in any water quality management planning effort for a lake, since these local units of government provide the basic structure of the decision-making framework within which intergovernmental environmental problems must be addressed. In addition to these general purpose units of government about 706 acres, or 21 percent of the direct tributary drainage area, lies within the boundaries of the Okauchee Lake Management District, a special purpose unit of government with responsibilities for lake management.

POPULATION

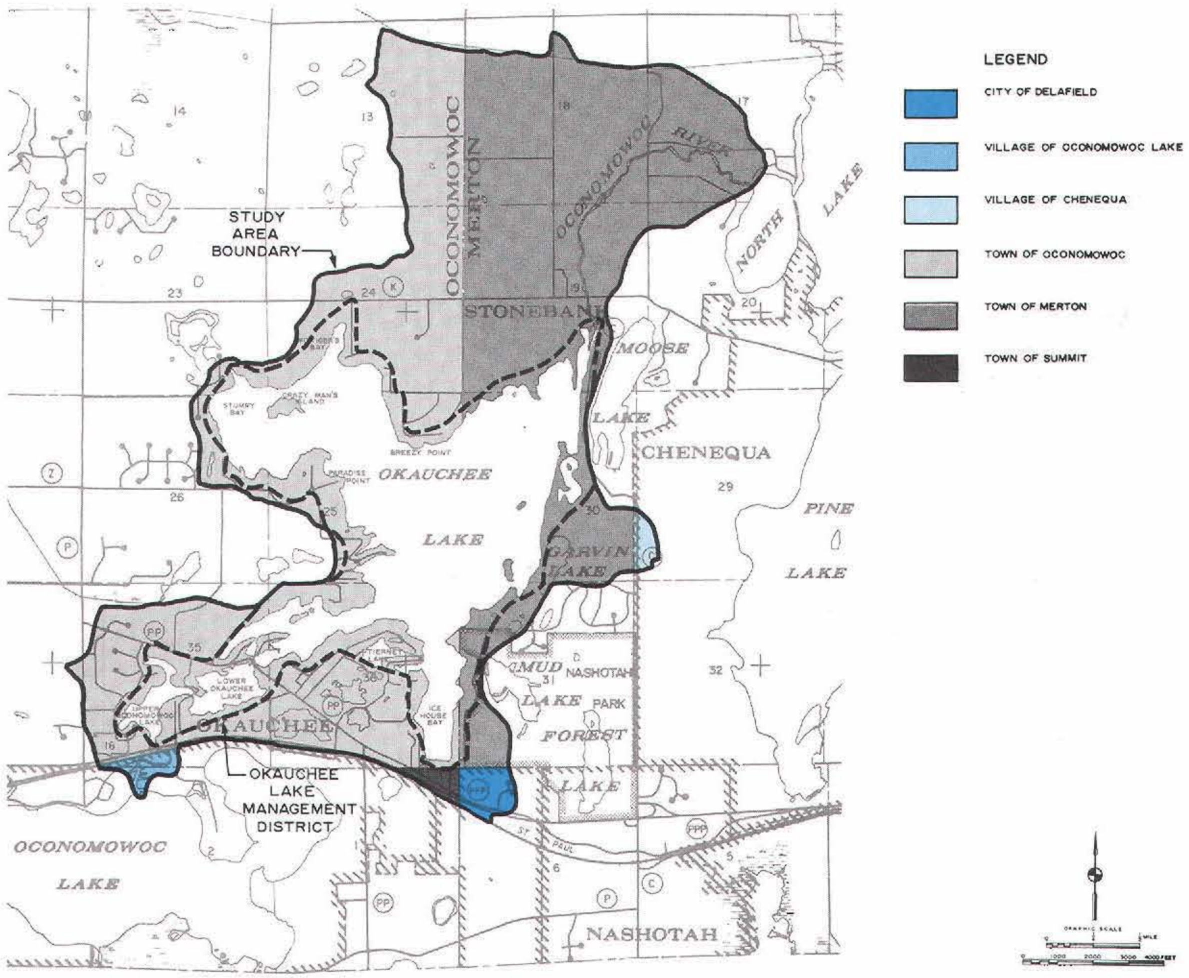
As indicated in Table 6, the resident population of the drainage area tributary to Okauchee Lake has increased rapidly since 1950. The 1975 resident population of the drainage area, estimated at about 4,160 persons, was double the estimated 1950 population. Population forecasts prepared by the Regional Planning Commission, on the basis of a normative regional land use plan, indicate, as shown in Table 6, that the population of the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes should increase to a level of about 6,000 persons by the year 2000. A comparison of historical, existing, and forecast population levels for the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, Waukesha County, and the Southeastern Wisconsin Region, is set forth in Figure 3. Since 1950, population in the direct drainage area of the lakes has increased at a lower rate than in Waukesha County, but at a higher rate than in the Southeastern Wisconsin Region. Forecast population growth to the year 2000 in the direct drainage area of the lakes is expected to continue this pattern. This population growth may be expected to place a steadily increasing stress on the natural resource base of the lakes' drainage area, and both water resource demands and use conflicts may be expected to increase.

LAND USE

The type, intensity, and spatial distribution of land uses are important determinants of the resource demands in the lake drainage area. The existing land use pattern can best be understood within the context of its historical development.

Map 10

CIVIL DIVISION AND LAKE MANAGEMENT DISTRICT BOUNDARIES IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1975



Source: SEWRPC.

The movement of European settlers into the Southeastern Wisconsin Region began about 1830. Completion of the U. S. Public Land Survey in southeastern Wisconsin in 1836 and subsequent sale of public lands brought a rapid influx of settlers into the area. Map 11 shows the original plat of the U.S. Public Land Survey for the Okauchee Lake area. Land division in the Okauchee Lake area began in the 1830's. Map 12 and Table 7 indicate the historic urban growth pattern since 1850 in the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes.[1] The largest increases in urban development occurred in the periods 1920 to 1940 and from 1963 to 1970.

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[1]Urban development is defined, for the purposes of this report, as an area containing a closely spaced network of land access streets and attendant facing urban land uses such as residential, commercial, industrial, governmental, and institutional uses.

Table 5

AREAL EXTENT OF CIVIL DIVISIONS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: JANUARY 1, 1976

Civil Division	Civil Division Area Within Direct Drainage Area (square miles)	Percent of Direct Drainage Area Within Civil Division	Percent of Civil Division Within Direct Drainage Area
Waukesha County			
City			
Delafield	0.09	1.24	0.86
Villages			
Chenequa	0.05	0.69	1.08
Oconomowoc Lake	0.09	1.24	2.88
Towns			
Merton	3.09	42.56	10.74
Oconomowoc	3.90	53.72	11.62
Summit	0.04	0.55	0.13
County Subtotal	7.26	100.00	1.25
Total	7.26[a]	100.00	--

[a]*Includes the 2.0 square miles of surface water area of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes.*

Source: SEWRPC.

Table 6

HISTORIC AND FORECAST RESIDENT POPULATION OF THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1950-2000

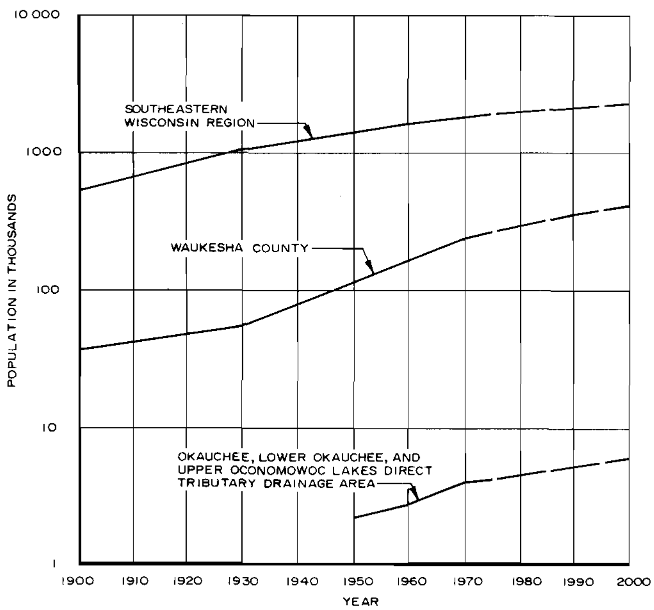
Year	Population
1950	2,080
1960	2,640
1970	3,920
1975	4,160
2000	6,000

Source: SEWRPC.

The existing land use pattern in the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, as of 1975, is shown on Map 13 and the existing land uses are quantified in Table 8. As indicated in Table 8, about 37.2 percent of the total direct drainage area was in urban land use, with the dominant urban land use being residential, encompassing 72.1 percent of the urban land area. Most of the medium-density residential development is located south of the Okauchee Lake outlet and east of Lower Okauchee Lake. Most of the residential development along the immediate shoreline of the lake occurs at low densities.

Figure 3

COMPARISON OF HISTORICAL, EXISTING, AND FORECAST POPULATION TRENDS FOR THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES, WAUKESHA COUNTY, AND THE SOUTHEASTERN WISCONSIN REGION



Source: SEWRPC.

Table 7

EXTENT OF HISTORIC URBAN GROWTH IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1850-1975

Year	Extent of Urban Development[a] (acres)
1850	--
1880	13
1900	13
1920	158
1940	621
1950	639
1963	649
1970	847
1975	946

[a]*Urban development is defined, for the purpose of this report, as an area containing a closely spaced network of land access streets and attendant facing urban land uses such as residential, commercial, industrial, governmental, and institutional uses.*

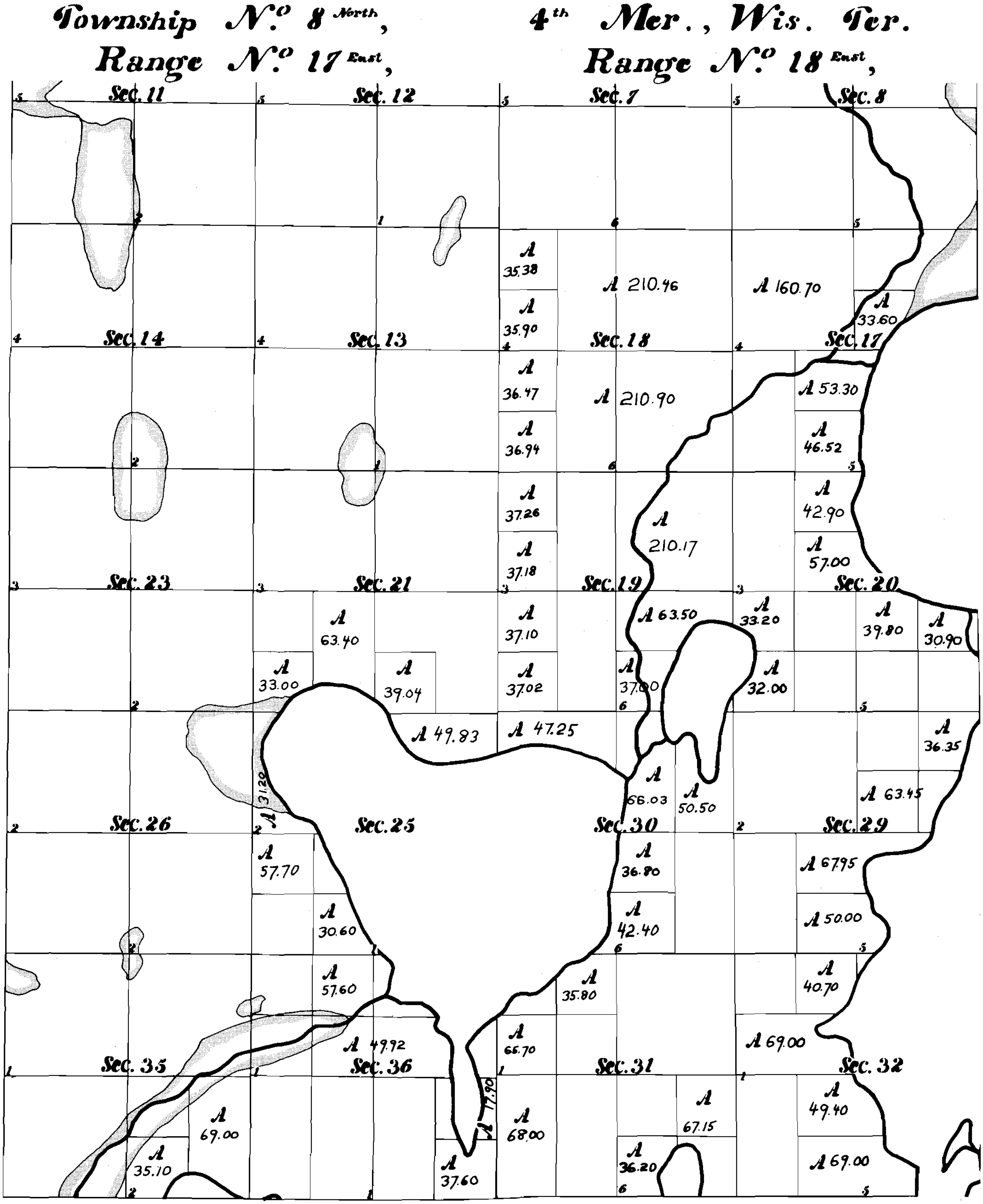
Source: SEWRPC.

Slightly less than half--47.4 percent--of the lake drainage area was in agricultural use, such uses being primarily located north of Okauchee Lake; open land and woodland areas comprised 8.7 percent of the drainage area. Wetlands and water areas--other than the three lakes themselves--accounted for 6.7 percent of the total direct tributary area.

If present trends continue, accommodation of the approximately 1,840 new residents expected to reside in the direct drainage area between 1975 and 2000 will require further conversion of land from rural to urban use. The year 2000 land use plan adopted by the Regional Planning Commission, as set forth in summary form on Map 14 and quantified in Table 8, recommends that most new residential development in the direct drainage area of the lakes occur at low densities. Compared to existing land uses, a 19 percent increase in urban land uses, and a 20 percent increase in residential land uses are recommended to occur by year 2000. The agricultural land located north of Okauchee Lake is designated prime agricultural land, and is recommended to remain in agricultural

Map 11

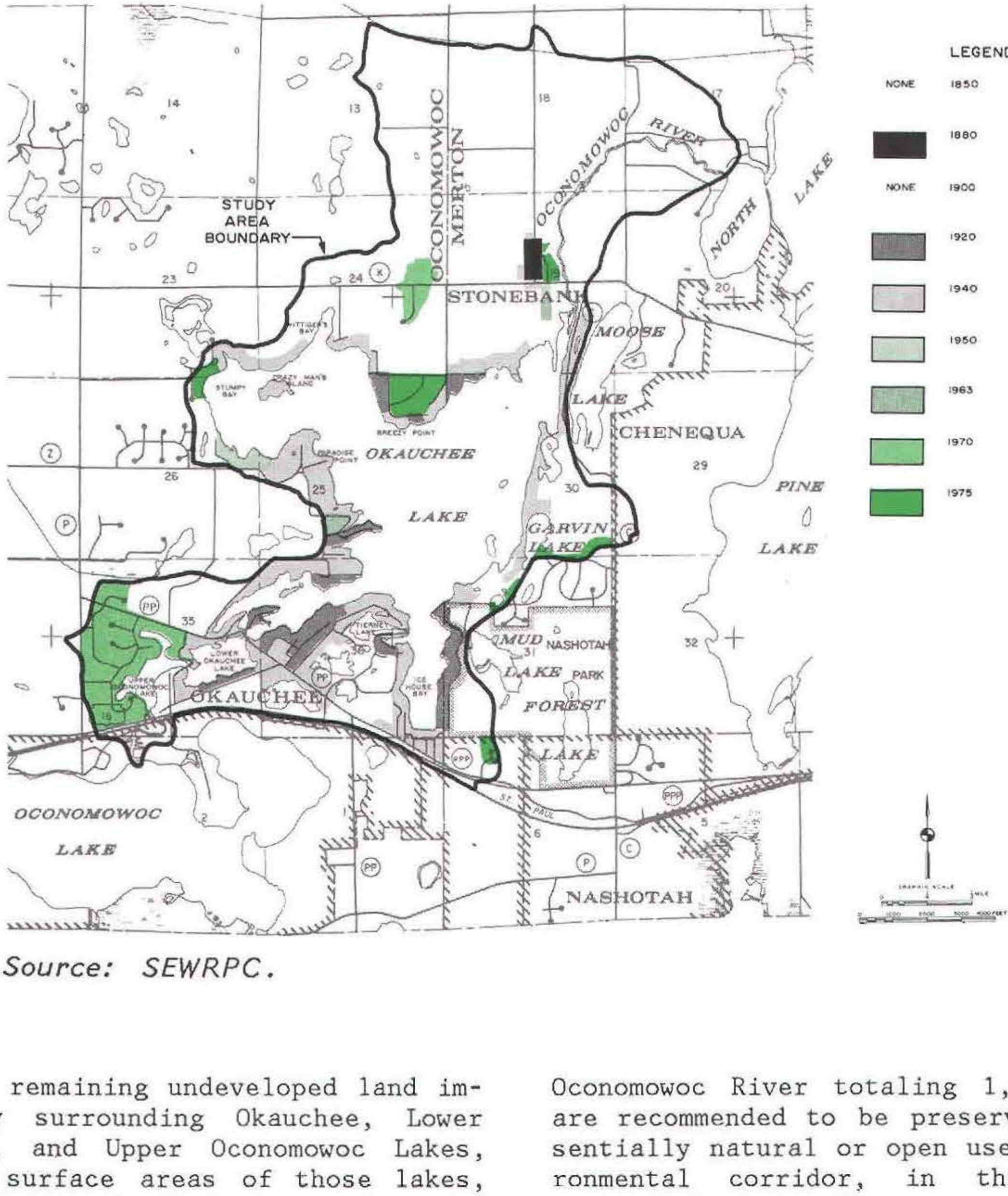
ORIGINAL UNITED STATES PUBLIC LAND SURVEY MAP FOR THE DRAINAGE AREA DIRECTLY TRIBUTARY TO THE OKAUCHEE LAKE AREA: 1836



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

Map 12

HISTORIC URBAN GROWTH IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1850-1975

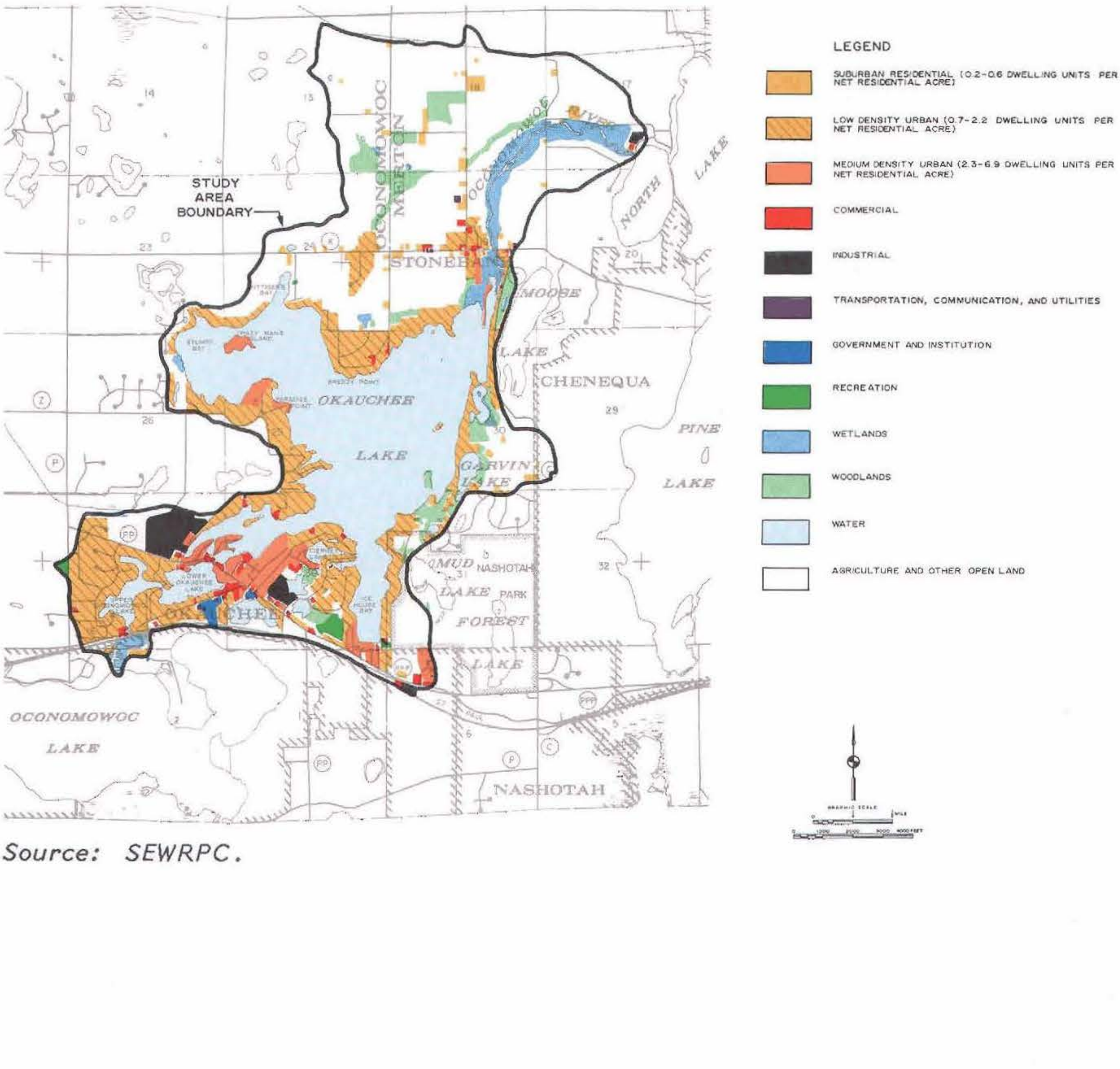


Source: SEWRPC.

use. The remaining undeveloped land immediately surrounding Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, and the surface areas of those lakes, along with certain lands lying along the Oconomowoc River totaling 1,964 acres, are recommended to be preserved in essentially natural or open uses as environmental corridor, in the adopted regional land use plan.

Map 13

EXISTING LAND USE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1975



Source: SEWRPC.

Table 8

EXISTING 1975 AND PLANNED 2000 LAND USE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

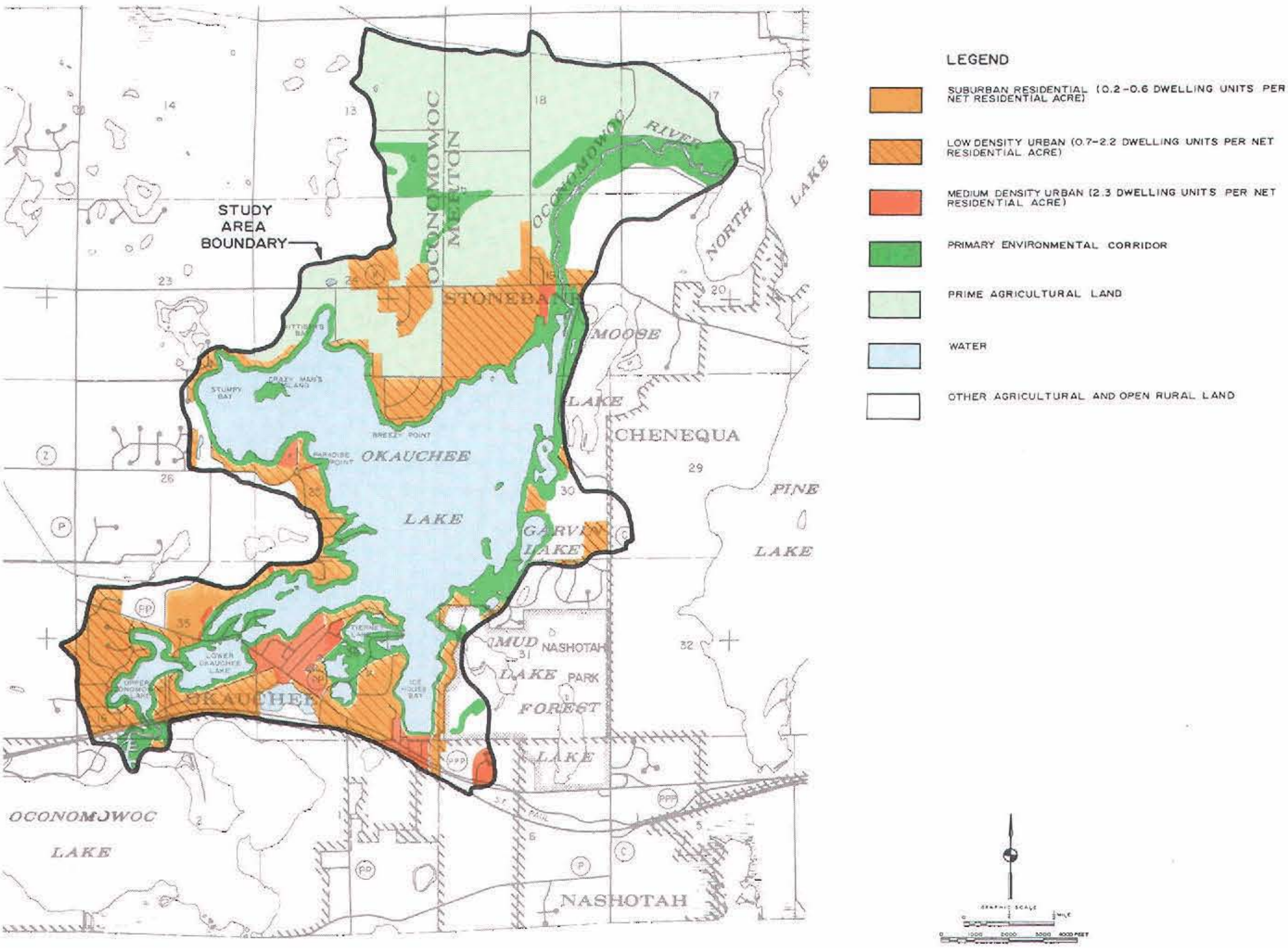
Land Use Categories	Existing 1975			Planned 2000		
	Acres	Percent of Major Category	Percent of Study Area	Acres	Percent of Major Category	Percent of Study Area
Urban						
Residential						
Medium-Density....................	126.00	10.1	3.7	126.00	8.5	3.7
Low-Density.......................	707.13	56.6	21.1	890.52	59.9	26.5
Suburban Density..................	68.00	5.4	2.0	68.00	4.6	2.0
Residential Subtotal	901.13	72.1	26.8	1,084.52	73.0	32.2
Commercial........................	41.64	3.3	1.2	41.88	2.8	1.3
Industrial........................	8.85	0.7	0.3	8.85	0.6	0.3
Govermental and Institutional.....	14.99	1.2	0.4	16.73	1.1	0.5
Transportation, Communication, and Utilities....................	264.05	21.2	7.9	313.50	21.1	9.3
Recreational......................	19.24	1.5	0.6	20.85	1.4	0.6
Urban Land Use Total	1,249.90	100.0	37.2	1,486.33	100.0	44.2
Rural						
Agriculture.......................	1,595.39	75.4	47.4	1,393.02	74.1	41.4
Water[a]...........................	94.48	4.5	2.8	94.48	5.0	2.8
Wetlands..........................	132.16	6.2	3.9	132.16	7.0	3.9
Woodlands.........................	182.87	8.6	5.4	182.87	9.8	5.4
Other Open Lands..................	111.55	5.3	3.3	77.49	4.1	2.3
Rural Land Use Total	2,116.45	100.0	62.8	1,880.02	100.0	55.8
Direct Drainage Area Total	3,366.35	--	100.0	3,366.35	--	100.0

[a]Excludes the surface areas of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes.

Source: SEWRPC.

Map 14

GENERALIZED PLANNED LAND USE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 2000



Source: SEWRPC.

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Chapter IV

WATER QUALITY

HISTORICAL DATA

Okauchee Lake is an important water resource in southeastern Wisconsin which has historically received considerable attention by limnological researchers. Limnological studies of Okauchee Lake date back to the early 1900's when E.A. Birge and C. Juday,[1] widely recognized lake researchers, collected basic information on the lake. As shown in Table 9, water chemistry data for Okauchee Lake were collected in 1926, 1943, 1944, 1959, and in 1960. While a review of these historical data indicate considerable variation in water quality conditions, much of this variation in the earlier years of sampling must be attributed to the different types of analytical methods which were used. A comparison of the historical data set forth in Table 9 to more recent data set forth in Table 11 (see page 35) indicates that--except for the dissolved oxygen analyses--the data base is not sufficient to permit documentation of any long-term trends in the water quality of Okauchee Lake. Historically measured dissolved oxygen profiles of Okauchee Lake are discussed below.

RECENT PHYSICAL AND CHEMICAL CHARACTERISTICS

The water quality of Okauchee Lake has been monitored periodically from 1973 through 1978. Limited water quality data are also available for Lower Okauchee and Upper Oconomowoc Lakes. The resulting data were used in the management plan preparation to determine the condition of the lake and to characterize its suitability for recreational use and the support of fish and other aquatic life. The primary station for most sampling activities was located at the deepest portion of Okauchee lake, as shown on Map 1. Typical monthly temperature and dissolved oxygen profiles taken at this station are shown in Figure 4. Water temperatures in Okauchee Lake ranged from a minimum of 32°F (0°C) during the winter to a maximum of 83°F (27°C) during the summer.

Complete mixing of deep lakes such as Okauchee Lake is restricted by thermal stratification during the summer, and by ice cover during the winter. Thermal stratification is a result of differential heating of the lake water and water temperature density relationships. Water is unique among liquids in that it reaches its maximum density--weight per unit volume--at about 39°F. As summer begins, the lake absorbs the sun's energy at the surface. Wind action and to some extent, internal heat transfer transmit some of this energy to the underlying waters. As the upper layer of water is heated by the sun's energy, however, a physical barrier begins to form between the warmer surface water and the lower, heavier, colder water as shown in Figure 4, graphs E, I, and M for the month of July. This "barrier" is marked by a sharp temperature gradient known as the metalimnion or thermocline, which separates the warmer, lighter, upper layer of water--called the epilimnion--from the cooler, heavier, lower layer--called the hypolimnion. Although this barrier is easily crossed by fish, it essentially prohibits the exchange of water between the two layers, a condition which has a great impact on both chemical and biological conditions and activities in Okauchee Lake. The development of the thermocline begins in

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

Table 9

HISTORICAL WATER QUALITY CONDITIONS OF OKAUCHEE LAKE: 1926-1960

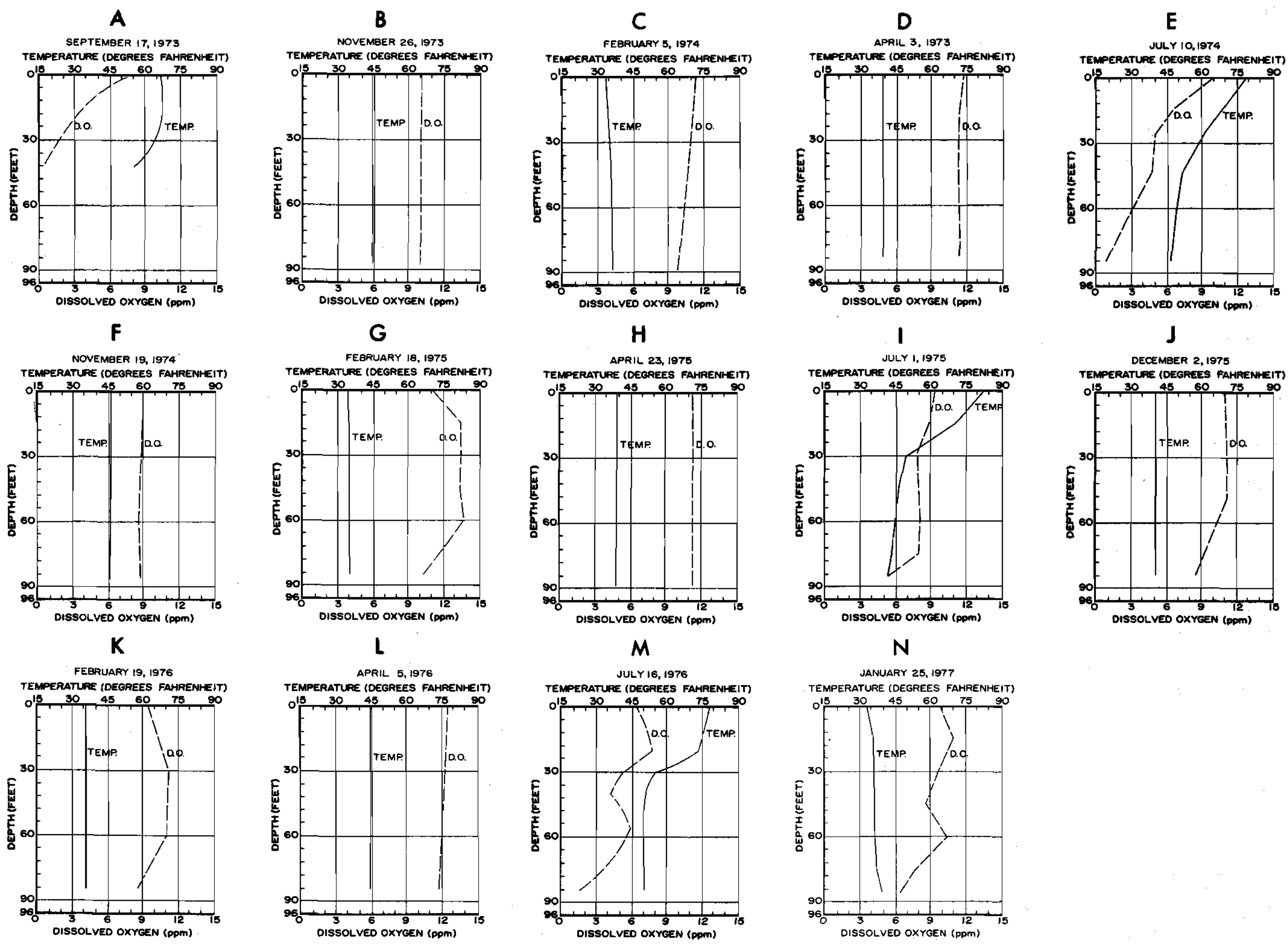
Water Quality Parameter (miligrams per liter)	Sample Date										
	November 1926	July 1943	November 1943	April 1944	July 1944	July 1959	November 1959	April 1960	July 1960	Range	Mean
Nitrate and Nitrite Nitrogen.....	--	0.08	0.22	0.14	0.09	0.08	0.07[a]	0.34	0.08	0.07[a]-0.34	0.14
Ammonia Nitrogen......	0.07	--	--	--	--	--	--	--	--	0.07	0.07
Organic Nitrogen......	--	0.38	0.32	0.39	0.53	0.69	0.79	0.55	0.24	0.24-0.79	0.40
Phosphate Phosphorus..	0.003	0.003	0.003	0.003	0.003	0.095	0.020	0.010	0.059	0.003-0.095	0.022
Total Phosphorus......	0.160	0.042	0.026	0.020	0.033	0.127	0.026	0.052	0.124	0.020-0.160	0.068

[a]Nitrate Nitrogen only.

Source: Wisconsin Department of Natural Resources.

Figure 4

TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR OKAUCHEE LAKE: 1973-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

early summer and reaches its maximum in late summer. This stratification period lasts until the fall, when air temperatures cool the surface water and wind action results in the disappearance of the thermocline.

As the surface water cools, it becomes heavier, sinking and displacing the warmer water below. The colder water sinks and mixes under wind action to erode the thermocline until the entire column of water is of uniform temperature as shown in Figure 4, graph F. This action, which follows summer stratification, is known as the fall turnover. When the water temperature drops below 39°F, it again becomes lighter and "floats" near the surface. Eventually the water near the surface is cooled to 32°F at which temperature ice begins to form and covers the surface of the lake, isolating it from the atomosphere for up to four months. In Okauchee Lake, ice cover typically exists from December to early April. Winter stratification occurs as the colder, lighter water and ice remain close to the surface, again separated from the relatively warmer, heavier water near the bottom of the lake. Spring brings a reversal of the process. As the ice thaws and the upper layer of water warms, it becomes more dense and begins to approach the temperature of the warmer, lower water until the entire water column reaches the same temperature. Mixing, induced by the wind, continues until the water temperature reaches 39°F, as shown for April in Figure 4, graph D. This lake season, which follows winter stratification, is referred to as the spring turnover. Beyond this point, the water warms at the surface and again becomes lighter and floats above the colder water. Wind and resulting waves carry, to a limited extent, some of the energy of the warmer, lighter water to lower depths. Thus begins the formation of the thermocline and another summer thermal stratification.

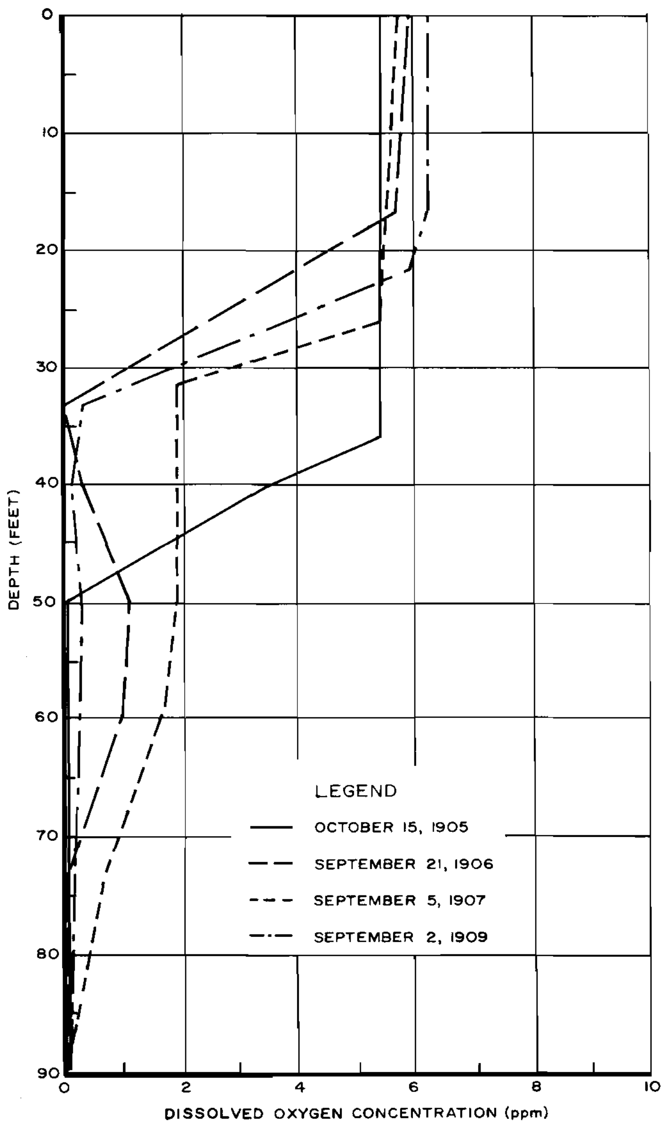
Dissolved oxygen levels are one of the most critical factors affecting a lake ecosystem. In shallow, fertile lakes, and small bays of large lakes, winter brings the threat of dissolved oxygen depletion and fish mortality under ice cover. If the ice cover is thick and snow cover is deep, light penetration is sometimes insufficient to maintain oxygen-production from the plants in the lake. When plant life dies, it, along with organic bottom muck, consumes dissolved oxygen in the process of decaying, resulting in oxygen depletion which kills fish if the supply of dissolved oxygen is not sufficient to meet the total demand. This condition, commonly referred to as winterkill, has generally not been a problem in the open waters of Okauchee Lake. Dissolved oxygen levels at most depths were found to be more than adequate for the support of fish throughout the winter, as shown in Figure 4, graphs C, G, K, and N, for the months of January and February.

Dissolved oxygen profiles during summer stratification on Okauchee Lake show total oxygen depletion in the hypolimnion. Beginning in early summer, as the thermocline develops, the lower, colder body of water (hypolimnion) becomes isolated from the upper, warmer layer (epilimnion), cutting off the surface supply of dissolved oxygen to the hypolimnion; while in the epilimnion, wind turbulence or atmospheric equilibrium, wave action, and plant photosynthesis maintain an adequate supply of dissolved oxygen. Gradually, if there is not enough dissolved oxygen to meet the total oxygen demand from decaying material, the dissolved oxygen concentration may be reduced to zero. This oxygen depletion was observed in Okauchee Lake as shown in Figure 4, graphs A, E, and M for the months of September and July, and is common of many lakes in southeastern Wisconsin. In September 1973, the dissolved oxygen level at a depth of 42 feet dropped to 0.3 parts per million (ppm). This depleted oxygen level will cause many species of fish to move upward in the water column, where higher dissolved oxygen concentrations exist.

Dissolved oxygen profiles of Okauchee Lake were also measured during the late

Figure 5

HISTORICAL LATE SUMMER DISSOLVED OXYGEN PROFILES FOR OKAUCHEE LAKE: 1905-1909



Source: E.A. Birge and C. Juday, 1911 and SEWRPC.

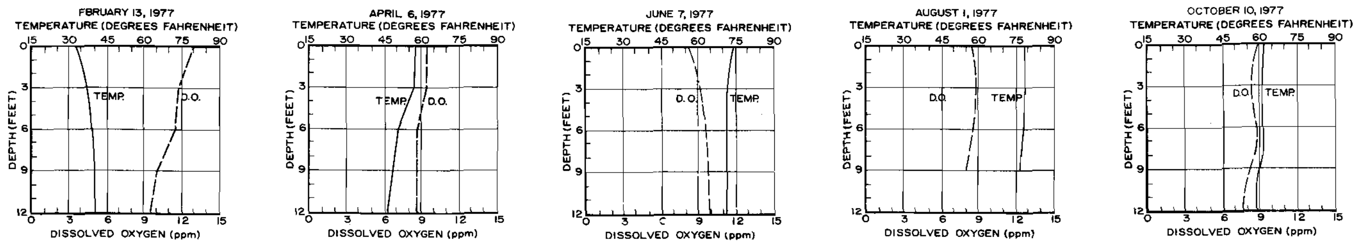
summers of 1905 to 1909. These profiles, as shown in Figure 5, indicate that depletion of oxygen in the hypolimnion during summer was also common in the early 1900's. In 1909, a serious cisco kill (a cold water fish species) occurred during the summer, probably caused by high temperatures and low dissolved oxygen levels in the hypolimnion. There appears to have been little change in the dissolved oxygen levels and characteristics of Okauchee Lake over the 70-year period of record.

Temperature and dissolved oxygen profiles for Lower Okauchee and Upper Oconomowoc Lakes were also measured during the study period of December 1976 through October 1977. The profiles for these lakes, as shown in Figures 6 and 7, indicate that a distinct thermal stratification during summer does not occur in either lake and that dissolved oxygen levels in both lakes are high at all depths throughout the year, because 1) initially their entire water supply consisted of the highly oxygenated surface waters of Okauchee Lake; 2) the average hydraulic retention time of these lakes ranged from only 4.4 to 6.2 days; and 3) these relatively shallow lakes are mixed by wind action from top to bottom routinely throughout the summer. Dissolved oxygen levels in these two lakes were generally adequate to support most forms of aquatic life throughout the winter.

The range of depths within which photosynthetic activity occurs depends, to a large extent, on the transparency of the water. A Secchi Disc was used to measure water clarity. This is a black and white, 8-inch disc which is lowered to a depth where it is just no longer visible from the surface. Water clarity in lakes is typically highly variable. Secchi Disc depth measurements for the period of 1973 through 1977 for Okauchee Lake and for April through October 1977 for Lower Okauchee and Upper Oconomowoc Lakes are shown in Figure 8. In Okauchee Lake, the Secchi Disc readings ranged from a low of 4.8 feet in July 1974 to a high of 22.6 feet in February 1976, with an average of 9.5 feet. Because Lower Okauchee and Upper Oconomowoc Lakes are shallower and therefore subject to greater mixing and generally have more easily disturbed muck bottom sediments than Okauchee Lake has, the Secchi Disc measurements for these lakes are considerably less than those for Okauchee

Figure 6

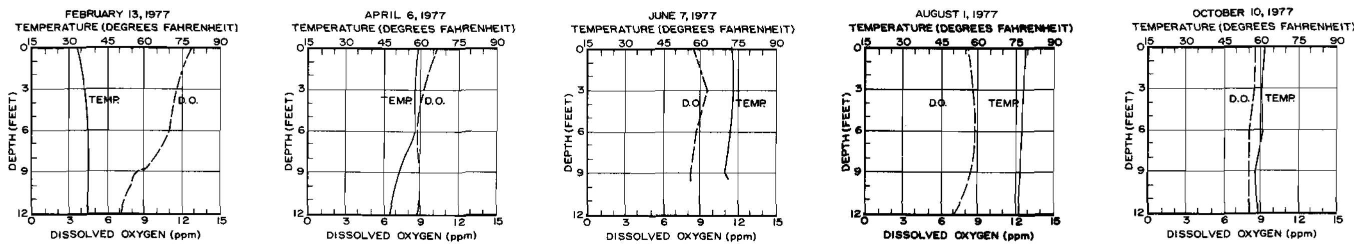
TEMPERATURE AND DISSOLVED OXYGEN PROFILES
FOR LOWER OKAUCHEE LAKE: 1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 7

TEMPERATURE AND DISSOLVED OXYGEN PROFILES
FOR UPPER OCONOMOWOC LAKE: 1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

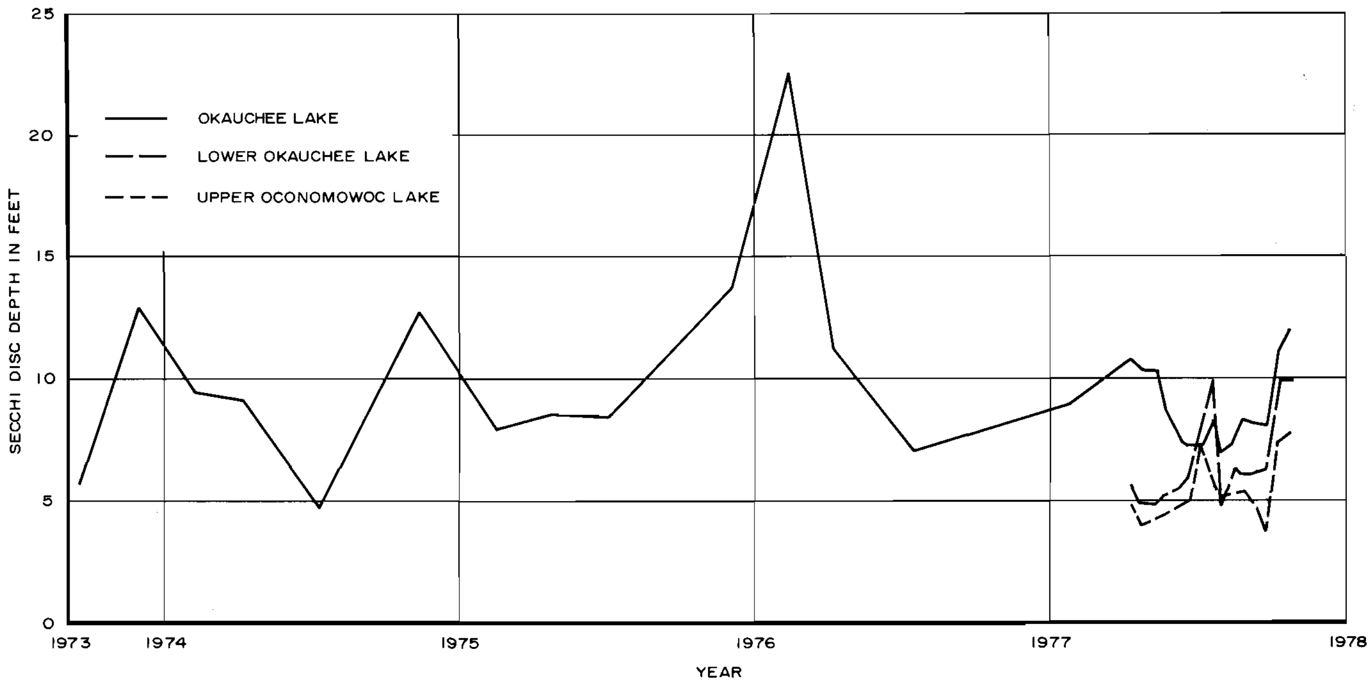
Lake. In Lower Okauchee Lake, the Secchi Disc readings ranged from a low of 4.8 feet in late April and early May 1977 to a high of 10.0 feet in mid-July and October 1977, with an average of 6.6 feet. In Upper Oconomowoc Lake, the Secchi Disc readings ranged from a low of 4.0 feet in late April and late September 1977, to a high of 8.0 feet in late October 1977, with an average of 5.3 feet.

Chlorophyll-a is the major photosynthetic pigment in algae. The amount of chlorophyll-a present is an indicator of the biomass of live algae in the water. The level of chlorophyll-a concentration is useful in determining the trophic status of lakes and hence their suitability for certain water uses. As shown in Table 10, Chlorophyll-a was measured seven times in Okauchee Lake; six times in 1972 and once in 1976. The chlorophyll-a values in Okauchee Lake ranged from a low of 3.4 micrograms per liter (μg/l) in November 1976, to a high of 14.9 μg/l in June 1972.

Water samples collected from Okauchee Lake between 1973 and 1978 were tested for pH (acidity), specific conductance (a measure of the amount of dissolved solids), magnesium, sodium, potassium, iron, calcium, manganese, sulfate, alkalinity, turbidity, chloride, and different forms of the plant nutrients nitrogen and phosphorus. Ranges and mean values found for these water quality indicators are set forth in Table 11.

Figure 8

MEASURED SECCHI DISC DEPTHS IN OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1973-1977



Source: Wisconsin Department of Natural Resources.

Table 10

MEASURED CHLOROPHYLL-a CONCENTRATIONS IN OKAUCHEE LAKE: 1972 and 1976

Date	Source	Concentration (micrograms per liter)
June 21, 1972	1[a]	12.7
	2[a]	14.9
August 19, 1972.........	1[a]	4.0
	2[a]	4.1
November 11, 1972	1[a]	7.7
	2[a]	6.7
November 9, 1976	1[b]	3.4

[a]*Report on Okauchee Lake, Waukesha County, Wisconsin, EPA Region V, Working Paper No. 64, June 1975.*

[b]*Wisconsin Department of Natural Resources, Lake Survey Form, November 1976.*

Source: Wisconsin Department of Natural Resources and the U.S. Environmental Protection Agency.

Table 11

WATER QUALITY CONDITIONS OF OKAUCHEE LAKE: 1973-1978

Water Quality Parameter[a]	September 17, 1973	November 26, 1973	November 6, 1973[b]	February 5, 1974	April 3, 1974	April 5, 1974[b]	July 10, 1974	November 19, 1974	February 18, 1975	April 23, 1975	July 1, 1975
Nitrite and Nitrate Nitrogen...........	0.15	0.23	0.53	0.53	0.56	1.05	0.53	0.31	0.40	0.60	0.45
Ammonia Nitrogen.....	0.22	0.14	0.27	<0.01	0.08	0.03	0.15	0.17	0.06	0.03	<0.03
Organic Nitrogen.....	0.53	0.46	0.53	0.18	1.02	0.68	0.86	0.87	0.50	0.57	0.40
Total Nitrogen.......	0.89	0.82	1.33	0.70	1.65	1.76	1.54	1.34	0.95	1.20	0.83
Phosphate Phosphorus.	0.030	0.040	0.020	0.060	0.030	0.005	0.040	0.070	0.020	0.040	0.010
Total Phosphorus.....	0.06	0.06	0.03	0.06	0.05	0.01	0.06	0.07	0.04	0.05	0.02
Calcium.............	--	48.5	53.0	41.1	86.3	--	46.7	95.5	49.3	47.0	41.0
Magnesium...........	41.6	30.3	31.0	26.0	41.3	--	22.7	44.0	38.0	33.5	44.0
Sodium..............	11.6	6.3	7.6	7.7	9.0	12.0	6.7	8.5	3.7	6.0	6.7
Potassium...........	2.1	2.0	2.1	0.8	1.9	3.8	1.3	0.95	1.7	3.4	5.0
Iron................	--	--	--	--	--	--	--	--	--	--	--
Manganese...........	--	--	--	--	--	--	--	--	--	--	--
Specific Conductance (micromhos/cm)......	445	479	494	487	493	500	468	497	518	482	448
Sulfate.............	33.0	35.0	34.0	39.3	37.0	44.0	37.7	36.5	40.7	41.0	36.7
Chloride............	12.7	12.7	14.0	12.7	13.0	12.0	15.3	12.5	14.0	12.0	13.7
pH (standard units)..	8.0	8.2	8.1	8.1	8.1	8.1	8.4	8.3	8.2	8.3	8.3
Alkalinity..........	200.3	218.0	254.0	218.7	221.3	212.0	210.7	215.0	221.8	212.5	203.3
Turbidity (Formazin Units)....	2.2	1.2	1.7	1.5	0.7	3.2	1.3	1.4	1.4	2.2	1.6

Water Quality Parameter[a]	December 2, 1975	February 19, 1976	April 5, 1976	July 16, 1976	November 9, 1976	January 25, 1977	April 15, 1977[b]	August 1, 1977[b]	November 2, 1977[b]	April 14, 1978[b]	Range	Mean
Nitrite and Nitrate Nitrogen...........	0.27	0.72	0.51	0.16	0.23	0.16	0.20	0.17	0.11	0.35	0.11-1,05	0.39
Ammonia Nitrogen.....	0.11	<0.03	0.09	0.10	0.08	0.15	0.17	0.01	0.05	<0.03	0.01-0.27	0.10
Organic Nitrogen.....	0.64	0.42	0.44	0.91	1.35	0.86	0.53	0.23	1.25	0.50	0.18-1.35	0.65
Total Nitrogen.......	1.01	1.13	1.04	1.17	1.64	1.17	0.90	0.40	1.41	0.88	0.40-1.76	1.13
Phosphate Phosphorus.	0.010	--	0.010	0.020	0.030	0.030	--	0.010	0.008	0.007	0.005-0.070	0.026
Total Phosphorus.....	0.03	--	0.03	0.03	0.04	0.10	0.01	0.02	0.04	0.02	0.01-0.10	0.04
Calcium.............	41.5	45.3	56.0	44.3	47.5	40.7	48.0	--	48.0	50.0	40.7-95.5	49.5
Magnesium...........	40.0	33.7	33.5	34.3	42.5	39.7	35.0	--	41.0	37.0	22.7-44.0	36.3
Sodium..............	5.0	9.0	10.0	4.7	6.0	6.0	5.0	--	5.0	31.0	3.7-31.0	8.4
Potassium...........	1.2	5.1	1.8	2.4	1.4	1.2	1.9	--	2.4	2.0	0.95-5.1	2.2
Iron................	0.09	<0.09	0.10	0.11	0.50	0.34	--	--	--	0.80	<0.09-0.80	0.29
Manganese...........	<0.03	0.03	<0.03	0.09	0.16	0.15	--	--	--	<0.30	<0.30-<0.30	0.11
Specific Conductance (micromhos/cm)......	448	480	481	478	461	479	519	365	433	418	365-519	470
Sulfate.............	35.5	35.3	28.0	13.7	--	--	--	--	--	--	13.7-44.0	35.1
Chloride............	11.5	23.7	12.0	11.3	13.5	16.0	15.0	24.0	16.0	19.0	11.3-24.0	14.6
pH (standard units)..	8.2	8.2	8.2	8.1	7.9	8.2	7.7	7.8	8.3	8.0	7.7-8.4	--
Alkalinity..........	208.0	204.0	210.0	200.0	200.0	229.3	206.0	204.0	192.0	208.0	192.0-254.0	211.7
Turbidity (Formazin Units)....	0.95	1.9	1.4	1.3	2.4	7.4	1.0	--	1.3	1.3	0.95-7.4	2.4

[a]All values reported in miligrams per liter unless otherwise specified.

[b]Values for these dates are from samples taken at the water surface. All other values are the average from samples taken at two or more depths.

Source: Wisconsin Department of Natural Resources.

Chloride concentrations ranged from 11.3 to 24.0 milligrams per liter (mg/l), with an average of 14.6 mg/l, which is typical of lakes in southeastern Wisconsin. Chloride concentrations are known to be increasing in southeastern Wisconsin lakes. Sources of chlorides include road deicing salt, treated and untreated sewage, animal wastes, water softeners, and natural leaching of rock minerals.

Conductivity ranged from 365 to 519 micromhos per centimeter (micromhos/cm), with an average of 470 micromhos/cm; pH fluctuated between 7.7 and 8.4 standard units. The metals data collected are typical of the hard water lakes in the area. Turbidity, another measure of poor water clarity, is low to moderate throughout the year. Total alkalinity was about average for lakes in Waukesha County.

The nutrients nitrogen and phosphorus, which are necessary for the growth of aquatic plants, including algae, have a significant effect on the suitability of lakes for recreational activities. In lakes where supplies of nutrients are limited, plant growth is limited and the lakes are typically clear and classified as oligotrophic. Where abundant supplies of nutrients are available, aquatic plant growth is usually prolific, resulting in nuisance algae blooms and/or excessive macrophyte growth. Lakes experiencing these conditions are unattractive for certain recreational uses.

Phosphorus concentrations in Okauchee Lake were found to exceed slightly the levels believed necessary to support periodic nuisance algae blooms. The recommended water quality standard for recreational use and warmwater fish and aquatic life set forth in the Regional Planning Commission's adopted regional water quality management plan indicates that algae blooms are likely to occur in lakes where the total phosphorus concentration exceeds 0.02 mg/l during the spring turnover. This is the level considered in the regional plan as needed to limit algae and aquatic plant growth to levels consistent with the recreational and warmwater fishery and aquatic life water use objectives. In Okauchee Lake during the period of 1973 through 1978, the mean concentration of total phosphorus was 0.03 mg/l during the spring turnover and 0.04 mg/l on an annual basis.

The ratio of total nitrogen to total phosphorus (N:P) in lake water indicates which nutrient is the factor most likely limiting aquatic plant growth in a lake.[2] 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, in Okauchee Lake the N:P ratio was always equal to or greater than 14:1, except in February 1974 and January 1977, when the ratio was 11.7:1, and in November 1973, when the ratio was 13.7:1. This indicates that summer aquatic plant growth in Okauchee Lake is limited by phosphorus.

Sediment contributions, although not measured, also have an important effect on the condition of a lake. As a lake bottom is covered by material washed into the lake or by the remains of aquatic plants, valuable benthic habitats may be destroyed, substrate suitability to accommodate rooted macrophytes may be increased, fish spawning areas may be destroyed, and aesthetic nuisances may develop. In addition, sediment particles may act as a transport mechanism for other substances, such as phosphorus, nitrogen, organic substances, pesticides, and heavy metals, from the watershed and atmosphere.

EXISTING AND PROBABLE FUTURE POLLUTION SOURCES AND LOADINGS

Phosphorus has been identified as the factor generally limiting aquatic plant

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

Table 12

NITROGEN-PHOSPHORUS RATIO FOR OKAUCHEE LAKE: 1973-1978

Sample Date	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Nitrogen to Phosphorus Ratio
September 17, 1973.....	0.89	0.06	14.8
November 26, 1973	0.82	0.06	13.7
November 1973	1.33	0.03	44.3
February 5, 1974.......	0.70	0.06	11.7
April 3, 1974...........	1.65	0.05	33.0
April 1974..............	1.76	0.01	176.0
July 10, 1974...........	1.54	0.06	25.7
November 19, 1974	1.34	0.07	19.1
February 18, 1975......	0.95	0.04	23.8
April 23, 1975..........	1.20	0.05	24.0
July 1, 1975............	0.83	0.02	41.5
December 2, 1975.......	1.01	0.03	33.7
April 5, 1976...........	1.04	0.03	34.7
July 16, 1976...........	1.17	0.03	39.0
November 9, 1976	1.64	0.04	41.0
January 25, 1977	1.17	0.10	11.7
April 1977..............	0.90	0.01	90.0
July 1977...............	0.40	0.02	20.0
November 1977	1.41	0.04	35.3
April 1978..............	0.88	0.02	44.0

Source: Wisconsin Department of Natural Resources and SEWRPC.

growth in Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes and excessive levels of phosphorus in the lake are likely to result in conditions which interfere with the desired use of the lake. Existing 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's water quality simulation model.

Table 13 sets forth the estimated phosphorus loads to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes under 1971 and anticipated year 2000 conditions, if no nonpoint source controls are implemented in the lake watershed. Direct tributary phosphorus loads in the lake watershed may be expected to decrease slightly because of the planned provision of sanitary sewers to the drainage area. The estimated annual direct tributary total phosphorus load to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes is 4,267 pounds and 3,573 pounds under existing and anticipated year 2000 conditions, respectively. The major direct tributary sources of phosphorus in the lake drainage area under existing conditions are livestock operations, septic tank systems, and direct atmospheric contributions to the water surface. Septic tank systems are not expected to be a major source of phosphorus under anticipated year 2000 conditions following the provision of sanitary sewer service to the lake drainage area. In addition to the direct tributary phosphorus load, about 2,900 pounds of phosphorus, representing about 40 percent of the total phosphorus

Table 13

ESTIMATED TOTAL PHOSPHORUS LOADS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1975 AND 2000

Source	Existing 1975			Anticipated 2000[a]		
	Extent (acres)	Total Loading (pounds per year)	Percent Distribution	Extent (acres)	Total Loading (pounds per year)	Percent Distribution
Residential Land........	892.0	119	2.8	1,075.4	140	3.9
Commercial Land........	41.6	26	0.6	41.9	26	0.7
Industrial Land.........	8.8	6	0.1	8.8	6	0.2
Government and Institutional Land	15.0	9	0.2	16.7	11	0.3
Transportation, Communication and Utilities Land..........	264.0	166	3.9	313.0	197	5.5
Construction Activities..............	9.1	409	9.6	9.1	409	11.4
Recreational Lands	19.2	3	0.1	20.8	3	0.1
Septic Tank System	508 Systems[b]	737	17.3	5 Systems[b]	8	0.2
Urban Subtotal	--	1,475	34.6	--	800	22.3
Agricultural Land	1,595.4	130	3.0	1,393.0	114	3.2
Direct Atmospheric Contributions..........	1,377.5	689	16.1	1,377.5	689	19.3
Woodlands	182.9	22	0.5	182.9	22	0.6
Wetlands	132.2	--	--	132.2	--	--
Open Land	111.5	11	0.2	77.5	8	0.2
Livestock...............	588 Animal Units[c]	1,940	45.6	588 Animal Units[c]	1,940	54.4
Rural Subtotal	--	2,792	65.4	--	2,773	77.7
Total	--	4,267[d]	100.0	--	3,573[d]	100.0

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

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

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

[d] *Does not include the 1975 estimated phosphorus load of 2,900 pounds per year or the year 2000 anticipated phosphorus load of 1,500 pounds per year contributed by the upstream drainage from the Oconomowoc River.*

Source: SEWRPC.

load to the lakes, is contributed under existing conditions by the upstream drainage from the Oconomowoc River. Under anticipated year 2000 conditions, and following the implementation of recommended point and nonpoint water pollution control measures in the upstream drainage areas, the phosphorus load from the Oconomowoc River is expected to decrease to about 1,500 pounds per year, representing about 30 percent of the total phosphorus load to the lakes. Within the annual load estimates of construction erosion as a source of sediment and phosphorus to Okauchee Lake is included the highway construction associated with State Trunk Highway (STH) 16. During the preparation of this report, there was discussion involving the Okauchee Lake Management District, the Wisconsin Department of Transportation, and the Wisconsin Department of Natural Resources concerning the storm water runoff and related sediment and nutrient problems in Ice House Bay at the point of discharge of a storm sewer lying in Jaeckle's Boulevard and draining portions of STH 16 and surrounding areas. This topic is addressed in Appendix B, "Analysis of Stormwater Management Alternatives for STH-16 Drainage Area at Ice House Bay, Okauchee Lake."

Trophic Condition Rating

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 aquatic life communities is often correlated to the degree of nutrient enrichment which has occurred. There are three terms usually used to describe the trophic status of a lake: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes. These lakes characteristically support relatively few aquatic plants and often do not contain 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 may support productive fisheries. 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 plant growths and/or experience frequent algae blooms. If the lakes are shallow, fish winterkills may be common. While portions of these lakes are not ideal for swimming and boating, many eutrophic lakes support very productive fisheries.

The trophic status of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes was evaluated by the application of three commonly used methods: the Lake Condition Index, the Dillon and Rigler Model, and the Trophic State Index.

Uttormark and Wall developed a method for lake classification based on four indicators of eutrophication: dissolved oxygen levels; water clarity (transparency); occurrence of fish winterkills; and recreational use impairment due to algae blooms and/or macrophyte growth. A measure--referred to as a Lake Condition Index--was devised in which points are assigned for undesirable symptoms of water pollution.[3] Thus, if a lake exhibits no undesirable symptoms of eutrophication, it receives no points and has a Lake Condition Index of zero.

[3] *P. D. Uttormark and J.P. Wall, Lake Classification--A Trophic Characterization of Wisconsin Lakes, Environmental Protection Agency Report No. EPA-660/3-75-033, 1975.*

Conversely, a lake with all the undesirable characteristics in the most severe degree has a Lake Condition Index of 23. Under the Uttormark-Wall classification system, Okauchee, Lower Okauchee, and Upper Oconomowoc Lake all received a Lake Condition Index of 5--as set forth in Table 14--which is indicative of mesotrophic lakes. This value for the three lakes is higher--that is, more eutrophic--than only 3 of the 22 rated lakes in Waukesha County, and higher than only 7 of the 65 rated lakes in the seven-county Southeastern Wisconsin Region, as shown in Table 15. Therefore, based on the Lake Condition Index, Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes are less eutrophic than most lakes in Waukesha County and in southeastern Wisconsin.

Dillon and Rigler developed a model for predicting the total phosphorus concentration of a lake during the spring turnover based on the physical characteristics of the lake, hydrologic data, and phosphorus loading data.[4] The predicted phosphorus concentrations can also be correlated to average summer chlorophyll-a and Secchi Disc (water transparency) levels. Using phosphorus

[4] *D. J. Dillon and F. H. Rigler, "A Simple Method for Predicting the Capacity of a Lake for Development Based on Lake Trophic Status," Journal of the Fisheries Research Board of Canada, Volume 32 (1975), pp. 1519-1531.*

Table 14

LAKE CONDITION INDEX CALCULATION FOR OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

Lake Conditions	Lake Condition Index Penalty Points[a]		
	Okauchee	Lower Okauchee	Upper Oconomowoc
Dissolved Oxygen Conditions	2	0	0
Water Transparency	1	2	2
History of Fish Winterkills[b]	0	0	0
Extent and Severity of Macrophytes and Algae	2	3	3
Total	5	5	5

[a] *Lake Condition Index Trophic Classification:*
0-1 very oligotrophic
2-4 oligotrophic
5-9 mesotrophic
10-12 eutrophic
13-23 very eutrophic

[b] *For the purposes of this analysis, early spring die-offs of fish are not considered winterkills.*

Source: SEWRPC.

Table 15

LAKE CONDITION INDEX OF SELECTED MAJOR LAKES IN SOUTHEASTERN WISCONSIN: 1975

Watershed	Major Lake Name	County	Lake Condition Index[a]	Category
Des Plaines..	Benet and Shangrila	Kenosha	13	very eutrophic
Des Plaines..	Paddock	Kenosha	9	mesotrophic
Fox	Beulah	Walworth	7	mesotrophic
Fox	Big Muskego	Waukesha	12	eutrophic
Fox	Bohners	Racine	6	mesotrophic
Fox	Booth	Walworth	6	mesotrophic
Fox	Browns	Racine	8	mesotrophic
Fox	Buena	Racine	6	mesotrophic
Fox	Camp	Kenosha	14	very eutrophic
Fox	Center	Kenosha	6	mesotrophic
Fox	Como	Walworth	13	very eutrophic
Fox	Denoon	Waukesha	8	mesotrophic
Fox	Eagle	Racine	20	very eutrophic
Fox	Eagle Spring	Waukesha	5	mesotrophic
Fox	Echo	Racine	6	mesotrophic
Fox	Elizabeth	Kenosha	6	mesotrophic
Fox	Geneva	Walworth	5	mesotrophic
Fox	Green	Walworth	9	mesotrophic
Fox	Little Muskego	Waukesha	12	eutrophic
Fox	Long	Racine	17	very eutrophic
Fox	Lower Phantom	Waukesha	9	mesotrophic
Fox	Marie	Kenosha	8	mesotrophic
Fox	Middle	Walworth	7	mesotrophic
Fox	Mill	Walworth	8	mesotrophic
Fox	North	Walworth	13	very eutrophic
Fox	Pell	Walworth	12	eutrophic
Fox	Pewaukee	Waukesha	13	very eutrophic
Fox	Pleasant	Walworth	4	oligotrophic
Fox	Potters	Walworth	12	eutrophic
Fox	Powers	Kenosha	8	mesotrophic
Fox	Silver	Kenosha	8	mesotrophic
Fox	Spring	Waukesha	4	oligotrophic
Fox	Tichigan	Racine	21	very eutrophic
Fox	Upper Phantom	Waukesha	6	mesotrophic
Fox	Wandawega	Walworth	13	very eutrophic
Fox	Waubeesee	Racine	7	mesotrophic
Fox	Wind	Racine	7	mesotrophic
Milwaukee ...	Big Cedar	Washington	5	mesotrophic
Milwaukee ...	Little Cedar	Washington	5	mesotrophic
Milwaukee ...	Mud	Ozaukee	10	eutrophic
Milwaukee ...	Silver	Washington	3	oligotrophic

Table 15 (continued)

Watershed	Major Lake Name	County	Lake Condition Index[a]	Category
Rock	Beaver	Waukesha	7	mesotrophic
Rock	Comus	Walworth	15	very eutrophic
Rock	Delavan	Walworth	14	very eutrophic
Rock	Druid	Washington	6	mesotrophic
Rock	Five	Washington	12	eutrophic
Rock	Friess	Washington	3	oligotrophic
Rock	Golden	Waukesha	8	mesotrophic
Rock	Keesus	Waukesha	8	mesotrophic
Rock	Lac La Belle	Waukesha	10	eutrophic
Rock	Loraine	Walworth	12	eutrophic
Rock	Lower Nemahbin	Waukesha	5	mesotrophic
Rock	Middle Genesee	Waukesha	3	oligotrophic
Rock	Nagawicka	Waukesha	13	very eutrophic
Rock	North	Waukesha	5	mesotrophic
Rock	Oconomowoc	Waukesha	8	mesotrophic
Rock	Okauchee	Waukesha	5	mesotrophic
Rock[b]	Lower Okauchee	Waukesha	5	mesotrophic
Rock[b]	Upper Oconomowoc	Waukesha	5	mesotrophic
Rock	Pike	Washington	3	oligotrophic
Rock	Pine	Waukesha	7	mesotrophic
Rock	Silver	Waukesha	5	mesotrophic
Rock	Tripp	Walworth	6	mesotrophic
Rock	Turtle	Walworth	5	mesotrophic
Rock	Upper Nashotah	Waukesha	4	oligotrophic
Rock	Upper Nemahbin	Waukesha	7	mesotrophic
Rock	Whitewater	Walworth	7	mesotrophic

[a] *Lake Condition Index Trophic Classification*

0-1 very oligotrophic
2-4 oligotrophic
5-9 mesotrophic
10-12 eutrophic
13-23 very eutrophic

[b] *Major lakes are defined as having a surface area of at least 50 acres. Lower Okauchee and Upper Oconomowoc Lakes have surface areas of 47 acres and 36 acres, respectively.*

Source: SEWRPC.

loads estimated by the Commission's water quality simulation model, the Dillon and Rigler model was applied to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes under existing conditions. The model analysis resulted in a predicted total phosphorus concentration of 0.03 mg/l for Okauchee Lake, and 0.05 mg/l for both Lower Okauchee and Upper Oconomowoc Lakes. These predicted values are above the recommended SEWRPC phosphorus standard of 0.02 mg/l established for lakes to support recreational use and warmwater fish and aquatic life, as discussed in Chapter 7. For Okauchee Lake, an average summer chlorophyll-a concentration of 10.0 micrograms per liter (µg/l) and an average summer Secchi Disc depth of 6.8 feet are also predicted. These data indicate that Okauchee Lake would be classified as a mesotrophic-eutrophic lake. The predicted average summer chlorophyll-a concentrations and Secchi Disc depth for Lower Okauchee and Upper Oconomowoc Lakes are 18.3 µg/l and 4.3 feet, and 21.1 µg/l and 3.8 feet, respectively. Based on these data, Lower Okauchee and Upper Oconomowoc Lakes would be classified as eutrophic. Table 16 compares the predicted phosphorus concentration, chlorophyll-a concentration, and Secchi Disc depth to measured data for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. The table indicates that the predicted values compare reasonably well with measured values.

A third measure of trophic condition can be achieved by the application of the Trophic State Index (TSI). The Trophic State Index may be computed using total phosphorus, Secchi Disc, and chlorophyll-a measurements to assign a trophic status rating to a lake.

The equations for calculating these three TSI values are:

$$\text{TSI}_{\text{Total Phosphorus}} = 10\left(6 - \left[\frac{\text{Natural log of }\left(\frac{40.5}{\text{Total Phosphorus in } \mu g/l}\right)}{\text{Natural log of 2}}\right]\right)$$

$$\text{TSI}_{\text{Secchi Disc}} = 10\left(6 - \left[\frac{\text{Natural log of Secchi Disc in Meters}}{\text{Natural log of 2}}\right]\right)$$

$$\text{TSI}_{\text{Chlorophyll-a}} = 10\left(6 - \left[\frac{2.04-0.68 \text{ Natural log of Chlorophyll-a in } \mu g/l}{\text{Natural log of 2}}\right]\right)$$

Table 16

COMPARISON OF PREDICTED AND MEASURED TOTAL PHOSPHORUS, CHLOROPHYLL-a, AND SECCHI DISC LEVELS IN OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

	Okauchee Lake			Lower Okauchee Lake			Upper Oconomowoc Lake		
		Measured[d]			Measured[d]			Measured[d]	
Water Quality Parameter	Predicted[c]	Range	Mean	Predicted[c]	Range	Mean	Predicted[c]	Range	Mean
Total Phosphorus[a] Concentration (mg/l)...	0.03	0.01-0.05	0.03	0.05	--	--	0.05	--	--
Chlorophyll-a[b] Concentration (µg/l)...	10.0	4.0-14.9	8.9	18.3	--	--	21.1	--	--
Secchi Disc Depths[b] (feet)................	6.8	4.7-8.5	7.3	4.3	5.0-7.7	6.7	3.8	4.7-7.1	5.5

[a]Concentration during the spring turnover.

[b]Average summer value.

[c]Based on the Dillon and Rigler (1974) Model.

[d]Based on measured data from 1973 through 1978.

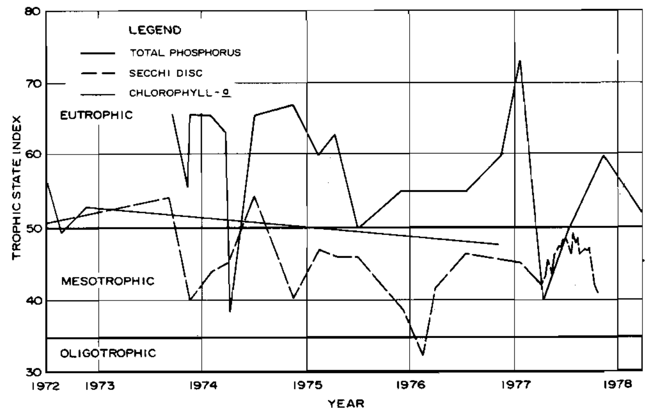
Source: Wisconsin Department of Natural Resorces and SEWRPC.

TSI ratings of less than 35 are indicative of oligotrophic lakes; ratings of 35 to 50 signify mesotrophic lakes; and ratings higher than 50 are indicative of eutrophic lakes.[5]

Figure 9 sets forth the TSI calculations for the period of June 1972 through April 1978 for Okauchee Lake. The Secchi Disc values shown on Figure 9 indicate that Okauchee Lake is a mesotrophic lake, whereas the total phosphorus values indicate that Okauchee Lake is generally a eutrophic lake. The values do not indicate any long-term trends in water quality conditions. The trophic state index values based on phosphorus concentrations were generally higher than the trophic state index calculations based on Secchi Disc levels or chlorophyll-a levels. This may be due to arsenic interference in the phosphorus test procedures. About 181,580 pounds of sodium arsenite were applied during the period 1950 through 1966 for aquatic weed control, as discussed in the aquatic plant management section of this report. Much of the applied arsenic was deposited in the bottom sediments, and this arsenic may be released from the sediments to the water column during anaerobic conditions. Therefore, some arsenic may still have been in the water during the sampling period represented in Figure 9. Since arsenic appears in the test as colorimetrically equivalent to phosphorus, the normal measurement technique for phosphorus measures arsenic as well. Because of this interference, the phosphorus levels presented with Figure 9 may be elevated due to the presence of arsenic. Studies in Big

Figure 9

TROPHIC STATE INDEX CALCULATIONS FOR OKAUCHEE LAKE: 1972-1978



Source: SEWRPC.

Cedar Lake, Washington County, have indicated that in the 1960's and early 1970's, arsenic interference resulted in apparent "phosphorus" levels which were at least twice as high as actual levels.[6] The extremely high apparent "phosphorus" levels of 0.12 mg/l shown for Okauchee Lake in Table 9 for the summers of 1959 and 1960, years when sodium arsenite was applied, probably reflect this arsenic interference. Accordingly, some degree of elevated phosphorus concentrations may reasonably be assumed for all of the sample period.

Based on the above classifications and analyses, it may be concluded that the characteristics of Okauchee Lake are indicative of a mesotrophic lake.

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[5] *R. E. Carlson. "A Trophic State Index for Lakes," Limnology and Oceanography, Volume 22, No. 2 (1977), pp. 361-369.*

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

Chapter V

NATURAL RESOURCE BASE AND RECREATIONAL ACTIVITIES

AQUATIC PLANTS

Macrophytes

Aquatic macrophytes play an important role in the ecology of southeastern Wisconsin lakes. Depending on 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 because they provide habitat for other forms of aquatic life and may remove nutrients from the water that otherwise may contribute to excessive algae growth. However, aquatic plants may become a nuisance when they reach such heavy densities that they interfere with swimming and boating activities. Many factors, including lake configuration, depth, water clarity, nutrient availability, bottom substrate, wave action, and type and size of fish population present, determine the distribution and abundance of aquatic macrophytes in a lake.

To document the types, distribution, and relative abundance of aquatic macrophytes in Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, surveys were conducted during the first week of June 1977 and during the last week of August 1977. The vegetation was identified and the frequency of occurrence and the relative abundance of each species was noted at 136 sampling locations within Okauchee Lake, 59 locations within Lower Okauchee Lake, and 67 locations within Upper Oconomowoc Lake. Map 15 shows the location of surveyed aquatic macrophytes. The macrophyte species, frequency of occurrence, and relative abundance are listed in Table 17. Illustrations of representative macrophyte species identified in the three lakes are set forth in Appendix A.

In general, the macrophyte growth in Okauchee Lake was found to be moderate to high. The maximum water depth at which macrophyte growth occurred was about 15 feet. Macrophytes grow on about 45 percent of the lake bottom and macrophytes extend to the surface of the water over about 20 percent of the surface area of the lake. The dominant macrophytes were stonewort (Chara sp.), coontail (Ceratophyllum demersum), water milfoil (Myriophyllum exalbescens), water milfoil, (Myriophyllum spicatum), and sago pondweed (Potamogeton pectinatus).

In Lower Okauchee and Upper Oconomowoc Lakes macrophytes grow at all depths and cover 75 to 80 percent of the lake bottoms. Dominant macrophytes in both Lower Okauchee and Upper Oconomowoc Lakes are water milfoils, coontail, stonewort, and sago pondweed. In all three lakes, the abundance of macrophytes greatly decreased from June to August. Much of this decrease may be attributed to macrophyte harvesting and aquatic plant control chemicals applied during the summer by the Lake Management District.

Heavy growths of coontail and the dominance of water milfoils, which were noted to be present in Okauchee Lake, are often indicative of fertile lakes. Other macrophytes identified in the lakes which may produce nuisance conditions include pondweeds (Potamogeton spp.), bushy pondweed (Najas spp.), and wild celery or eel grass (Vallisneria americana).

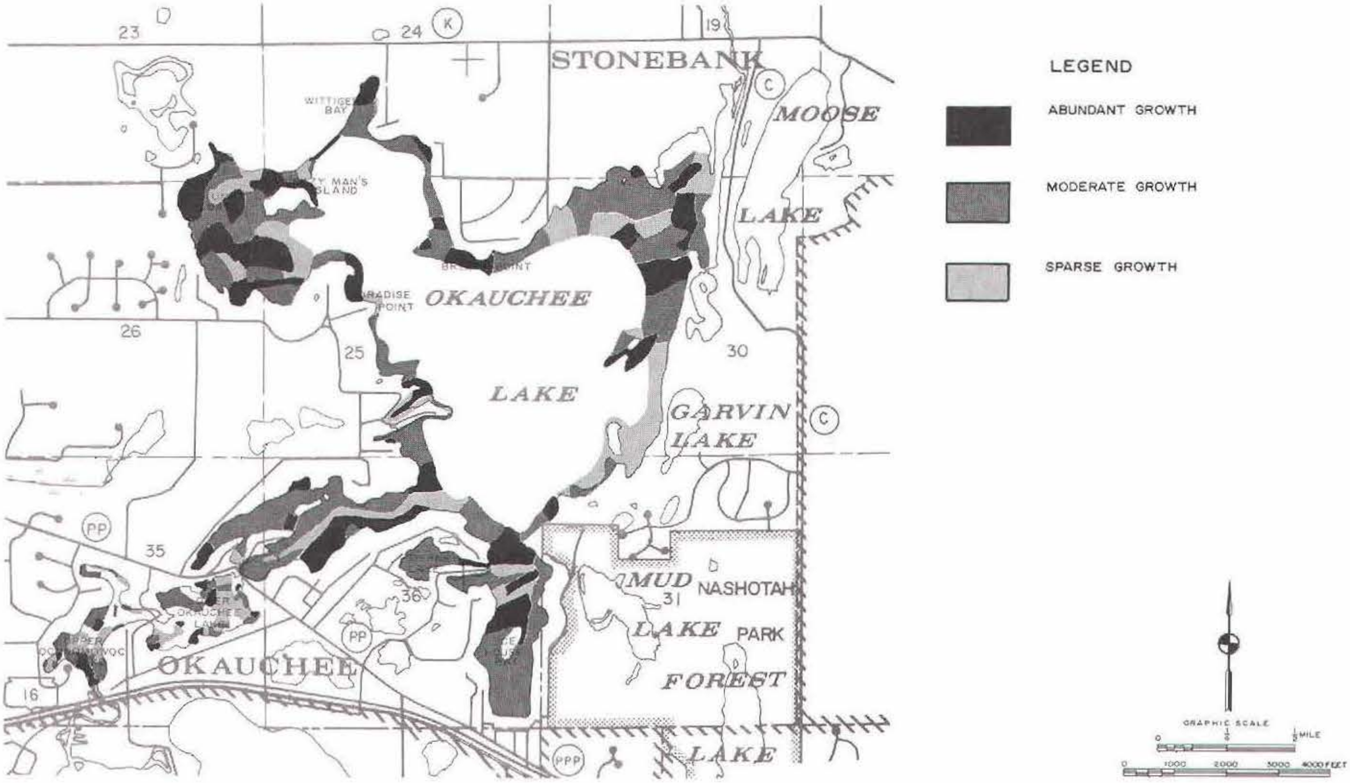
Many species of macrophytes also provide benefits for the lakes. Stonewort, wild celery or eel grass, bushy pondweeds, and pondweeds provide food, shelter, and habitat for wildlife. Coontail, stonewort, bushy pondweeds, and pondweeds, bladderworts, and wild celery or eel grass provide valuable food and shelter for fish and other aquatic life.

Algae

Algae are small, generally microscopic plants that are found in all lakes and streams. They occur in a wide variety of

Map 15

LOCATION OF AQUATIC MACROPHYTES IN OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

forms, in single cells or colonies, and can be either attached or free floating. Algae are primary producers that form the base of the aquatic food chain. Through photosynthesis, they convert energy and nutrients to the compounds necessary to support life in the aquatic system. Oxygen, which is vital to higher forms of life in a lake or stream, is also produced in the photosynthetic process.

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 (blooms) of blue-green algae can occur when excessive nutrient supplies are available, optimum sunlight and temperature conditions exist, and there is a lack of competition from or predation by other species.

Algae blooms may reach nuisance proportions in fertile--or eutrophic--lakes,

Table 17

SUMMARY OF MACROPHYTE SURVEYS OF OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: JUNE AND AUGUST 1977

Scientific Name	Common Name	Okauchee Lake				Lower Okauchee Lake				Upper Oconomowoc Lake			
		Percent Frequency of Occurrence[a]		Relative Abundance[b]		Percent Frequency of Occurrence[a]		Relative Abundance[b]		Percent Frequency of Occurrence[a]		Relative Abundance[b]	
		June	August	June	August	June	August	June	August	June	August	June	August
Anacharis canadensis	Waterweed	0.7	0.7	Very sparse	Very sparse	--	--	--	--	4.5	0.0	Sparse	Absent
Ceratophyllum demersum	Coontail	43.4	25.7	Common	Common	69.5	49.1	Common	Common	28.9	17.9	Common	Abundant
Chara species	Stonewort or mockgrass	69.9	58.0	Abundant	Common	55.9	11.9	Abundant	Common	32.8	29.9	Abundant	Common
Eleocharis acicularis	Spike rush	--	--	--	--	--	--	--	--	0.0	1.5	Absent	Sparse
Heteranthera dubia	Water star grass	0.0	1.5	Absent	Sparse	--	--	--	--	4.5	6.0	Very sparse	Sparse
Megalodonta Beckii	Water marigold	2.2	0.0	Very sparse	Absent	--	--	--	--	--	--	--	--
Myriophyllum exalbescens	Water milfoil	58.8	44.1	Common	Common	76.3	32.2	Common	Sparse	73.1	67.5	Abundant	Common
Myriophyllum spicatum	Water milfoil	37.5	0.7	Common	Common	--	--	--	--	--	--	--	--
Myriophyllum verticillatum	Water milfoil	26.5	0.0	Sparse	Absent	--	--	--	--	--	--	--	--
Najas flexilis	Bushy pondweed	5.2	8.8	Common	Common	25.4	18.6	Sparse	Sparse	7.5	6.0	Sparse	Sparse
Najas marina	Bushy pondweed	18.4	24.3	Common	Abundant	1.7	3.4	Very sparse	Sparse	--	--	--	--
Nuphar variegatum	Yellow water lily	0.7	0.0	Very sparse	Absent	--	--	--	--	--	--	--	--
Nymphaea tuberosa	White water lily	1.5	0.7	Sparse	Very sparse	--	--	--	--	--	--	--	--
Polygonum natans	Water smartweed	0.0	0.7	Absent	Very sparse	--	--	--	--	--	--	--	--
Potamogeton amplifolius	Large-leaf pondweed	1.5	3.7	Abundant	Sparse	1.7	0.0	Common	Absent	0.0	1.5	Absent	Abundant
Potamogeton berchtoldii	Small pondweed	8.8	0.0	Sparse	Absent	--	--	--	--	--	--	--	--
Potamogeton crispus	Cruly-leaf pondweed	14.0	2.2	Common	Sparse	15.2	0.0	Sparse	Absent	13.4	0.0	Sparse	Absent
Potamogeton gramineus	Variable pondweed	2.2	2.9	Common	Sparse	1.7	0.0	Very sparse	Absent	--	--	--	--
Potamogeton illinoensis	Illinois pondweed	2.9	0.0	Sparse	Absent	1.7	0.0	Common	Absent	--	--	--	--
Potamogeton pectinatus	Sago pondweed	42.7	27.9	Common	Common	44.1	45.8	Common	Sparse	7.5	7.5	Common	Sparse
Potamogeton praelongus	Whitestem pondweed	--	--	--	--	3.4	0.0	Sparse	Absent	--	--	--	--
Potamogeton zosteriformes	Flat stemmed pondweed	0.0	0.7	Absent	Very sparse	--	--	--	--	--	--	--	--
Ranunculus longirostris	Stiff water crawfoot	--	--	--	--	--	--	--	--	1.5	0.0	Very sparse	Absent
Utricularia species	Bladder wort	3.7	5.2	Sparse	Sparse	1.7	0.0	Very sparse	Absent	1.5	0.0	Very sparse	Absent
Vallisneria americana	Wild celery or Eel grass	34.6	36.8	Common	Abundant	8.5	13.6	Common	Abundant	--	--	--	--

[a]The percent of frequency of occurrence refers to the percent of the 138 sampling sites in which the plant species was noted.

[b]The relative abundance refers to the density of that species where it is found.

Source: Environmental Resources Assessments.

resulting in the accumulation of surface scum or slime. In some cases, heavy concentrations of wind-blown algae accumulate on shorelines, where they die and decompose, causing noxious odors and unsightly conditions. The decaying process of algae consumes oxygen, sometimes depleting available supplies and resulting in fish kills. Also, certain species of decomposing blue-green algae may release toxic materials into the water.

In Okauchee Lake, analyses of the type and abundance of algae present indicated relatively low concentrations of algae in June and July. However, nuisance growths of algae occur in bays and along shorelines. The algae populations were greatest from late April to early May, due to a spring bloom of the yellow-green algae Dinobryon. The presence of blue-green algae, such as Anabaena, Microcystis, Aphanothece, and Chroococcus, indicates a potential for algae "bloom" conditions. Chroococcus and Aphanothece were the dominant algae from August to early September. Illustrations of representative algae species identified in Okauchee Lake are set forth in Appendix A.

AQUATIC ANIMALS

Zooplankton

Zooplankton are microscopic floating animals which inhabit the same environments as phytoplankton, or microscopic plants. An important link in the aquatic food chain, zooplankton feed mostly on algae and, in turn, are a good food source for fish. The seasonal succession of zooplankton species within Okauchee Lake during the study year was dominated by a spring pulse of Daphnia and Cyclops species, rotifers, and ostracods. Population cycles during summer are variable, being affected by changes in the food supply and predation by fish and other zooplankton. The density of zooplankton individuals remained low during the summer and into early autumn of 1977, when the study was concluded. Illustrations of representative algae species identified in Okauchee Lake are set forth in Appendix A.

Fish

Okauchee Lake supports a relatively large and diverse fish community. Wisconsin Department of Natural Resources (DNR) survey reports indicated that from 1946 through 1975, 30 different fish species have been captured in the lake, as shown on Table 18. The pugnose shiner (Notropis anogenus), sampled in 1975, is currently listed by the DNR as a threatened species. The data do not indicate any major long-term changes in the fishery resource of Okauchee Lake. Variations in the species sampled are likely the result of different sampling techniques and levels of effort. Illustrations of representative fish species identified in Okauchee Lake are set forth in Appendix A.

Fish kills have been reported on seven different occasions in Okauchee Lake. A partial winter kill occurred in a few shallow localized bays in the winter of 1976-1977. Fish kills also occured during the summers of 1966, 1974, and 1976. These kills, which all occurred in June, also occurred in shallow bays and were probably caused by spawning stress as well as dissolved oxygen depletion. Kills of cisco were reported in the late summers of 1909, 1955, and 1966. Cisco require cool water temperatures to exist and death may occur when the cooler, deeper water beneath the thermocline becomes depleted of dissolved oxygen. In general, the fish kills in Okauchee Lake have been infrequent and limited in extent and severity. The fish populations have not been seriously affected by the occasional kills.

The Oconomowoc River between North Lake and Okauchee Lake is reportedly heavily used by northern pike and walleye for spawning. The gravel and rubble riffle areas and shallow pools within the Oconomowoc River are suitable for reproduction by these species. The shallow marsh areas bordering the Oconomowoc River are also used by northern pike for spawning. The Oconomowoc River is considered vital to the continued natural reproductive success of northern pike and walleye in Okauchee Lake.

Historically, numerous types of fish were reported by the DNR to have been stocked in Okauchee Lake. The fish stocking record for the period of 1933-1978 is shown in Table 19. Prior to 1957, at least eight species were stocked in the lake--bluegill, largemouth bass, walleye, bullhead, perch, northern pike, smallmouth bass and crappie. All life stages were stocked, including eggs, fry, fingerlings and adults. Between 1933 and 1957 fish were stocked every year except four. Stocking was discontinued in 1957 because of the lack of an adequate public access site. Upon the provision of adequate public access to the lake in 1978, about 27,000 walleye fingerlings were introduced into the lake that year.

WILDLIFE RESOURCES

Wildlife habitat areas were initially inventoried by the Regional Planning Commission in 1963 and this initial inventory was updated in 1970 for the Commission by the Wisconsin Department of Natural Resources, Bureau of Research. The wildlife habitat areas were classified by the Commission as deer, pheasant, waterfowl, muskrat-mink, songbird, or mixed habitat. These designations were applied to help characterize a particular habitat area as meeting the particular requirements of the indicated species. This classification does not imply that the named species is the most important or dominant species in that particular habitat. For example, an area designated as a deer habitat may also provide squirrel and songbird habitat.

Table 18

SPECIES OF FISH CAPTURED IN OKAUCHEE LAKE: 1946-1975

Common Name[a]	Scientific Name	Date of Survey[b]				
		1946	1950	1960	1969	1975
Banded killifish	Fundulus diaphanus	--	--	--	--	X
Black crappie	Pomoxis nigromaculatus	X	X	X	X	X
Blackchin shiner	Notropis heterodon	--	--	--	--	X
Blackstriped topminnow	Fundulus notatus	--	--	--	--	X
Bluegill	Lepomis macrochirus	X	X	X	X	X
Bluntnose minnow	Pimephales notatus	X	--	--	--	--
Bullhead[c]	Ictalurus species	X	X	X	X	X
Carp	Cyprinus carpio	X	X	--	--	X
Central quillback carpsucker	Carpiodes cyprinus	--	--	--	--	X
Dogfish	Amia calva	X	X	--	--	X
Garfish	Lepisosteus osseus	--	X	--	--	--
Golden shiner	Notemigonus crysoleucas	--	--	--	--	X
Grass pickerel	Esox americanus vermiculatus	--	--	--	--	X
Green sunfish	Lepomis cyanellus	X	--	--	X	X
Hornyhead chub	Nocomis biguttatus	X	--	--	--	--
Iowa darter	Etheostoma exile	--	--	--	--	X
Lake chubsucker	Erimyzon sucetta	X	--	--	--	X
Largemouth bass	Micropterus salmoides	X	X	X	X	X
Logperch	Percina caprodes	X	--	--	--	X
Northern blacknose shiner	Notropis heterolepis	X	--	--	--	X
Northern pike	Esox lucius	X	X	X	X	X
Pugnose shiner[d]	Notropis anogenus	--	--	--	--	X
Pumkinseed	Lepomis gibbosus	--	--	X	--	X
Rainbow darter	Etheostoma caeruleum	X	--	--	--	--
Rock bass	Ambloplites rupestris	X	X	X	X	X
Smallmouth bass	Micropterus dolomieui	--	--	--	--	X
Walleye	Stizostedion vitreum vitreum	X	X	X	X	X
White sucker	Catostomus commersoni	--	X	--	--	X
Yellow perch	Perca flavescens	X	--	--	--	--

[a]Two additional species were noted by the Lake District Commissioners to have been observed in the lake. These were the White bass (Morone chrysops) and Lake cisco (Coregonus artedi).

[b]The intensity of sampling effort was not the same for all of the surveys.

[c]Yellow, brown, and black bullheads were captured.

[d]Listed by the Wisconsin Department of Natural Resources as a threatened species which appears likely within the foreseeable future to become endangered in the state.

Source: Wisconsin Department of Natural Resources.

Table 19

FISH STOCKED IN OKAUCHEE LAKE: 1933-1978

	Bass[a]		Bass, Perch, and Bluegill (combined)		Black Bass		Bluegill		Bullhead		Crappie		Crappie and Bluegill (combined)	
Year	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]
1933	--	--	--	--	154	Unknown	--	--	--	--	--	--	--	--
1934	--	--	--	--	784	Fingerling	--	--	--	--	--	--	--	--
1935	800	Unknown	2,000	Unknown	5,750	Fingerling	7,500	Fingerling	--	--	--	--	3,500	Unknown
1936	680	Unknown	--	--	2,000	Unknown	1,316	Unknown	116	Unknown	800	Unknown	--	--
1937	--	--	--	--	--	--	11,000	Adult	--	--	2,000	Adult	--	--
1938	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1939	--	--	--	--	--	--	--	--	300	Adult	--	--	--	--
									600	Fingerling				
									4,000	Yearling				
1940	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1941	--	--	--	--	--	--	2,000	Fingerling	--	--	--	--	--	--
1942	--	--	--	--	--	--	10,000	Fingerling	--	--	--	--	--	--
1943	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1944	--	--	--	--	--	--	4,000	Fingerling	--	--	--	--	--	--
1945	--	--	--	--	--	--	--	--	5,000	Adult	--	--	--	--
1946	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1947	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1948	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1949	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1950	No Stocking													
1951	No Stocking													
1952	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1953	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1954	No Stocking													
1955	No Stocking													
1956	--	--	--	--	--	--	550	Adult	--	--	--	--	--	--
1957	No Stocking													
to														
1977	No Stocking													
1978	--	--	--	--	--	--	--	--	--	--	--	--	--	--

	Largemouth Bass		Northern Pike		Perch		Pickerel[b]		Smallmouth Bass		Sunfish		Walleye	
Year	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]	Number	Size[c]
1933	--	--	--	--	--	--	--	--	--	--	--	--	948,150	Unknown
1934	--	--	--	--	--	--	--	--	--	--	--	--	112,860	Fry
1935	--	--	--	--	700,000	Fry	1,500	Fingerling	--	--	--	--	4,614,920	Fry
1936	--	--	--	--	926	Unknown	500	Unknown	--	--	--	--	2,400,600	Fry
1937	13,750	Fingerling	1,500	Fingerling	11,000	Adult	--	--	80	Adult	--	--	6,140,000	Fry
					28,000	Fingerling								
					12,250,000	Fry								
1938	9,000	Fingerling	5,000	Fingerling	--	--	--	--	--	--	--	--	4,312,000	Fry
1939	9,700	Fingerling	143,865	Fry	2,000	Adult	--	--	--	--	900	Adult	3,524,800	Fry
					6,000	Fingerling					2,500	Fingerling		
					11,827,000	Eggs								
1940	10,200	Fingerling	--	--	11,827,200	Eggs	--	--	--	--	--	--	3,524,800	Fry
1941	16,000	Fingerling	--	--	11,612,160	Eggs	--	--	--	--	--	--	5,500,000	Fry
1942	8,000	Fingerling	--	--	1,720,320	Eggs	--	--	--	--	--	--	2,500,000	Fry
1943	6,000	Fingerling	--	--	--	--	--	--	--	--	--	--	3,000,000	Fry
1944	5,000	Fingerling	--	--	--	--	--	--	--	--	--	--	1,000,000	Fry
1945	4,000	Fingerling	--	--	--	--	--	--	--	--	--	--	2,000	Fingerling
													1,200,000	Fry
1946	4,000	Fingerling	--	--	--	--	--	--	--	--	--	--	2,100,000	Fry
1947	4,000	Fingerling	--	--	--	--	--	--	--	--	--	--	--	--
1948	4,000	Fingerling	--	--	--	--	--	--	--	--	--	--	--	--
1949	10,625	Fingerling	--	--	--	--	--	--	--	--	--	--	--	--
1950														
1951														
1952	6,250	Fingerling	--	--	--	--	--	--	--	--	--	--	31,000	Fingerling
1953	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1954														
1955														
1956	181	Adult	--	--	--	--	--	--	--	--	--	--	7,900	Fingerling
1957														
to														
1977														
1978	--	--	--	--	--	--	--	--	--	--	--	--	27,000	Fingerling

[a] It is not known whether these stocked bass were smallmouth or largemouth bass.

[b] These fish are possibly northern pike rather than pickerel.

[c] 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.

The five major criteria used to determine the value of these wildlife habitat areas are listed as follows:

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

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

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

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

5. Disturbance. Minimum levels of disturbance from human activities are necessary.

On the basis of these five criteria, the wildlife habitats in the Okauchee Lake watershed were rated as high, medium, or low quality. The quality ratings used are defined below:

1. High-value 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 the other criteria listed above.

2. Medium-value wildlife habitat areas generally lack one of the five aforementioned criteria for a wildlife habitat area.

3. Low-value wildlife habitat areas are remnant in nature in that they generally lack two or more of the five aforementioned criteria for a wildlife habitat area, but may nevertheless be important if they are located in proximity to other medium- and/or high-value habitat areas, if they provide corridors linking higher value wildlife habitat areas, or if they provide the only available range in an area.

As shown on Map 16, the drainage area directly tributary to Okauchee Lake contains a limited amount of wildlife habitat, most of which is located in the northern portions of the drainage area. Within the drainage area directly tributary to Okauchee Lake, woodlands cover approximately 183 acres, and wetlands and open water areas exclusive of the lake surface constitute approximately 227 acres. The woodlands located in the north central portion of the watershed provide high- and medium-value squirrel habitat. The wetland complex adjacent to the Oconomowoc River inlet provides high- and medium-value muskrat-mink habitat and high-value waterfowl and pheasant habitat. Finally, several small, isolated open water areas north, west, and southeast of the lake provide limited low- and medium-value waterfowl habitat. The waterfowl areas located in Township 8 North, Range 17 East, Section 13, are ranked as high-value habitat.

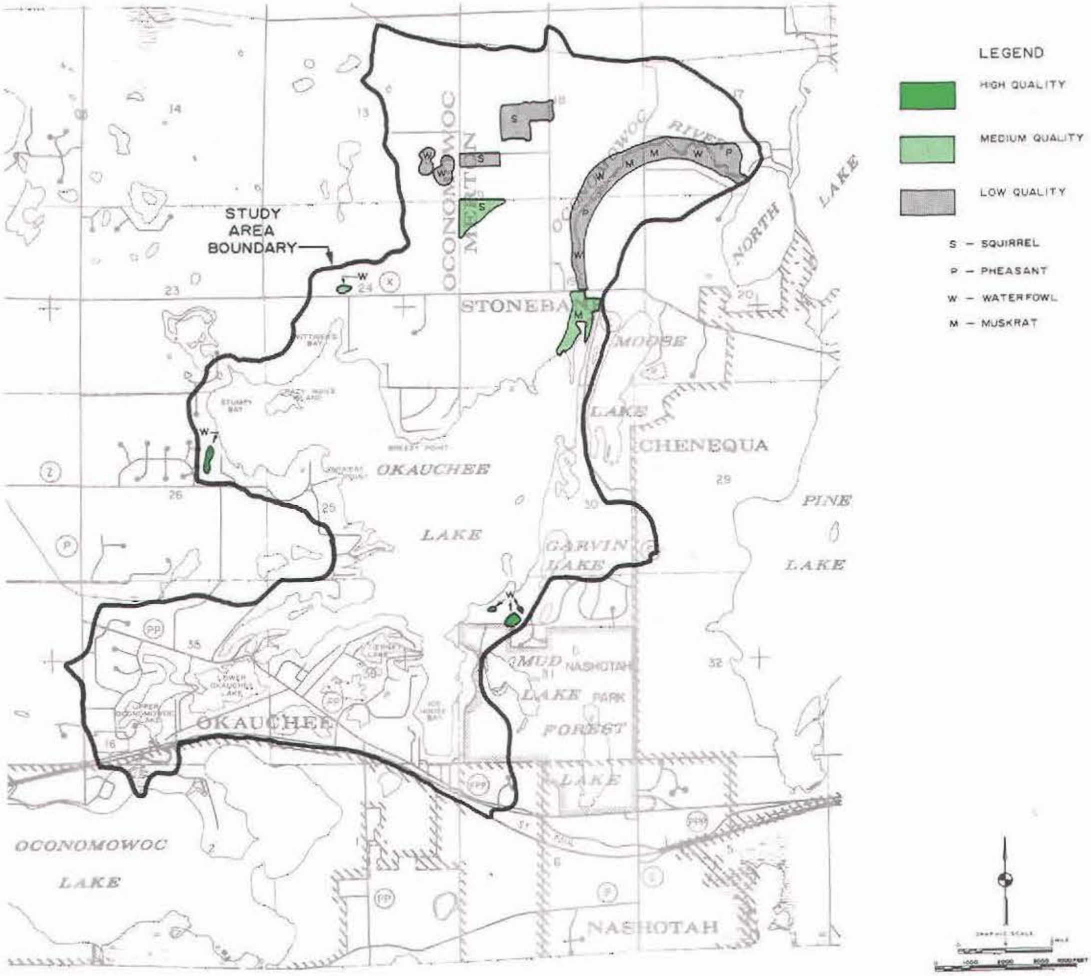
WOODLANDS

Woodlands in southeastern Wisconsin are defined as those areas which contain 17 or more trees per acre which have at least a four-inch diameter at breast height.[1] In addition, the native wood-

[1] *The diameter at breast height (dbh) is measured at 4.5 feet above the ground.*

Map 16

WILDLIFE HABITAT IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1980



Source: SEWRPC.

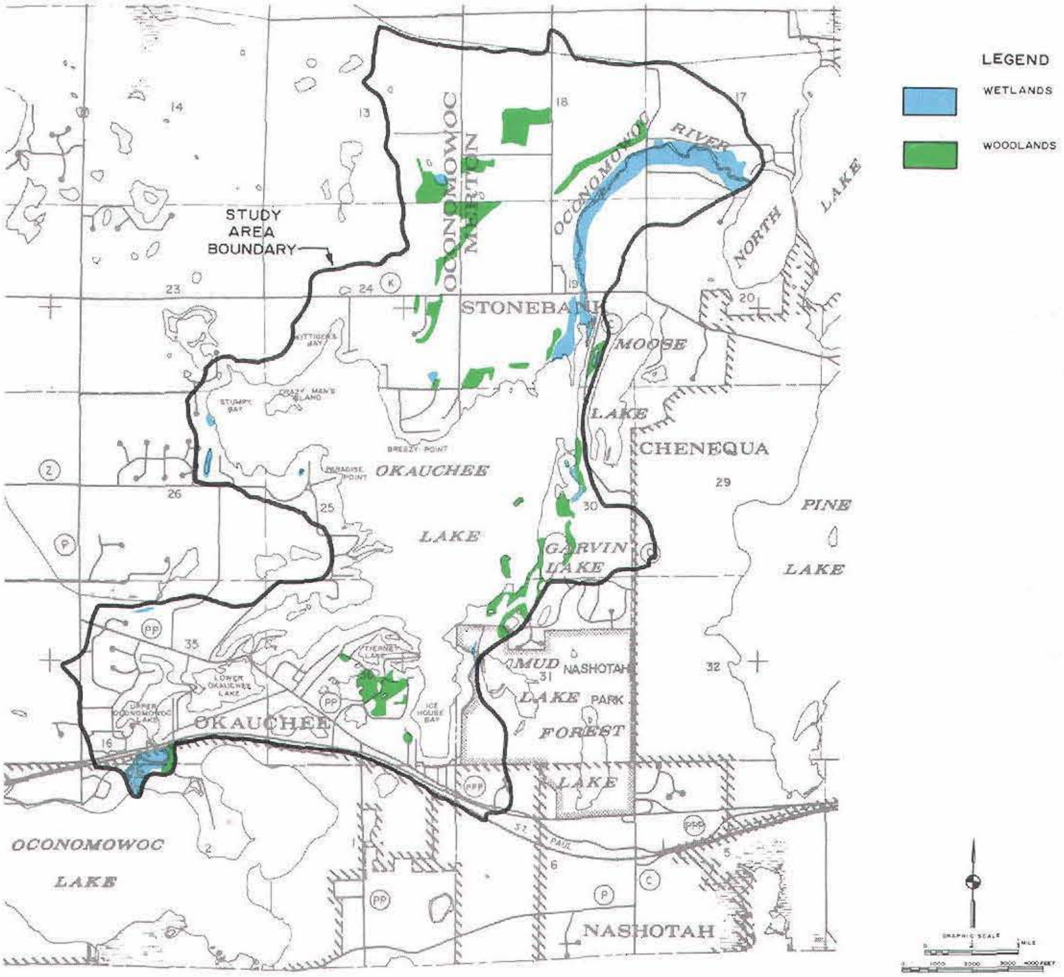
lands are classified as dry, dry-mesic, mesic, wet-mesic, and wet hardwood forests and conifer swamp forests. The latter three woodland classifications are also considered wetlands and, for the purposes of this report, are discussed in the section on wetlands. The drainage area directly tributary to Okauchee Lake contains five of the native woodland classifications.

Specifically, the woodlands in the Okauchee Lake drainage area, shown on Map 17, include southern dry hardwood forests, which are characterized by white oak (Quercus alba), shagbark hickory (Carya ovata), black cherry (Prunus serotina), and red cedar (Juniperus virginiana); southern dry-mesic hardwood forests characterized by northern red oak (Quercus borealis), white ash (Fraxinus americana), and basswood (Tilia americana); and southern mesic hardwood forests dominated by sugar maple (Acer saccharum).

Within the Okauchee Lake drainage area, woodlands are found as scattered woodlots along the southeast, southwest, and north shore of the lake, with some

Map 17

WETLANDS AND WOODLANDS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1980



Source: SEWRPC.

relatively large, contiguous tracts in the northern portion of the watershed. Most of these wooded tracts contain southern dry to dry-mesic hardwoods. However, a single stand of southern mesic hardwoods, dominated by large mature sugar maple trees, is located in the southwest one-quarter of Section 18 in the Town of Merton.

WETLANDS

Wetlands in southeastern Wisconsin are classified as deep marsh, shallow marsh, bog, fen, low prairie, southern sedge meadow, fresh (wet) meadow, shrub carr, southern wet and wet-mesic hardwood forest, and conifer swamp. The major wetland communities located in the drainage area directly tributary to Okauchee Lake, shown on Map 17, include deep and shallow marsh, sedge meadow, fresh (wet) meadow, and shrub carr. Table 20 characterizes the wetland plant species typically found in the drainage basin.

Lowland forests in the Okauchee Lake drainage basin include southern wet to southern wet-mesic hardwood forests which are characterized by the prevalence of black willow (Salix nigra), cottonwood (Populus deltoides), green

Table 20

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

Typhaceae	
Typha latifolia	Broadleaf cat-tail
Typha angustifolia	Narrowleaf cat-tail
Sparganiaceae	
Sparganium eurycarpum	Bur-reed
Gramineae	
Glyceria striata	Fowl manna grass
Phragmites communis	Reed grass
Calamogrostis canadensis	Canada bluejoint grass
Spartina pectinata	Prairie cord grass
Phalaris arundinacea[a]	Reed canary grass
Cyperaceae	
Scirpus validus	Softstem bulrush
Scirpus acutus	Hardstem bulrush
Scirpus atrovirens	Green bulrush
Carex stricta	Tussock sedge
Carex lacustris	Lake sedge
Carex spp	Sedges
Iridaceae	
Iris versicolor	Blue flag
Salicaceae	
Salix nigra	Black willow
Salix interior	Sandbar willow
Salix discolor	Pussy willow
Ulmaceae	
Ulmus americana	American elm
Polygonaceae	
Rumex orbiculatus	Water dock
Polygonum natans	Smartweed
Aceraceae	
Acer negundo	Boxelder
Rhamnaceae	
Rhamnus cathartica[a]	Common buckthorn
Lythraceae	
Decodon verticillatus	Water willow
Lythrum salicaria[a]	Purple loosestrife
Umbelliferae	
Angelica atropurpurea	Angelica
Oxypolis rigidior	Cowbane
Cornaceae	
Cornus amomum	Silky dogwood
Cornus stolonifera	Red osier dogwood
Oleaceae	
Fraxinus pennsylvanica	Green ash
Asclepiadaceae	
Asclepias incarnata	Marsh milkweed
Verbenaceae	
Verbena hastata	Blue vervain
Labiatae	
Pycnanthemum virginianum	Mountain-mint
Lycopus uniflorus	Northern bugle weed
Lycopus americanus	Common water horehound
Mentha arvensis	Wild mint
Caprifoliaceae	
Sambucus canadensis	Elderberry
Cucurbitaceae	
Echinocystis lobata	Wild cucumber
Compositae	
Bidens coronata	Bur marigold
Ambrosia trifida	Giant ragweed
Solidago gigantea	Giant goldenrod
Aster Novae-angliae	New England aster
Aster puniceus	Redstem aster
Aster luciduous	Swamp aster
Eupatorium maculatum	Joe-pye weed
Eupatorium perfoliatum	Boneset

NOTE: This table is presented in taxonomic order.

[a]Alien or nonnative plant species.

Source: SEWRPC.

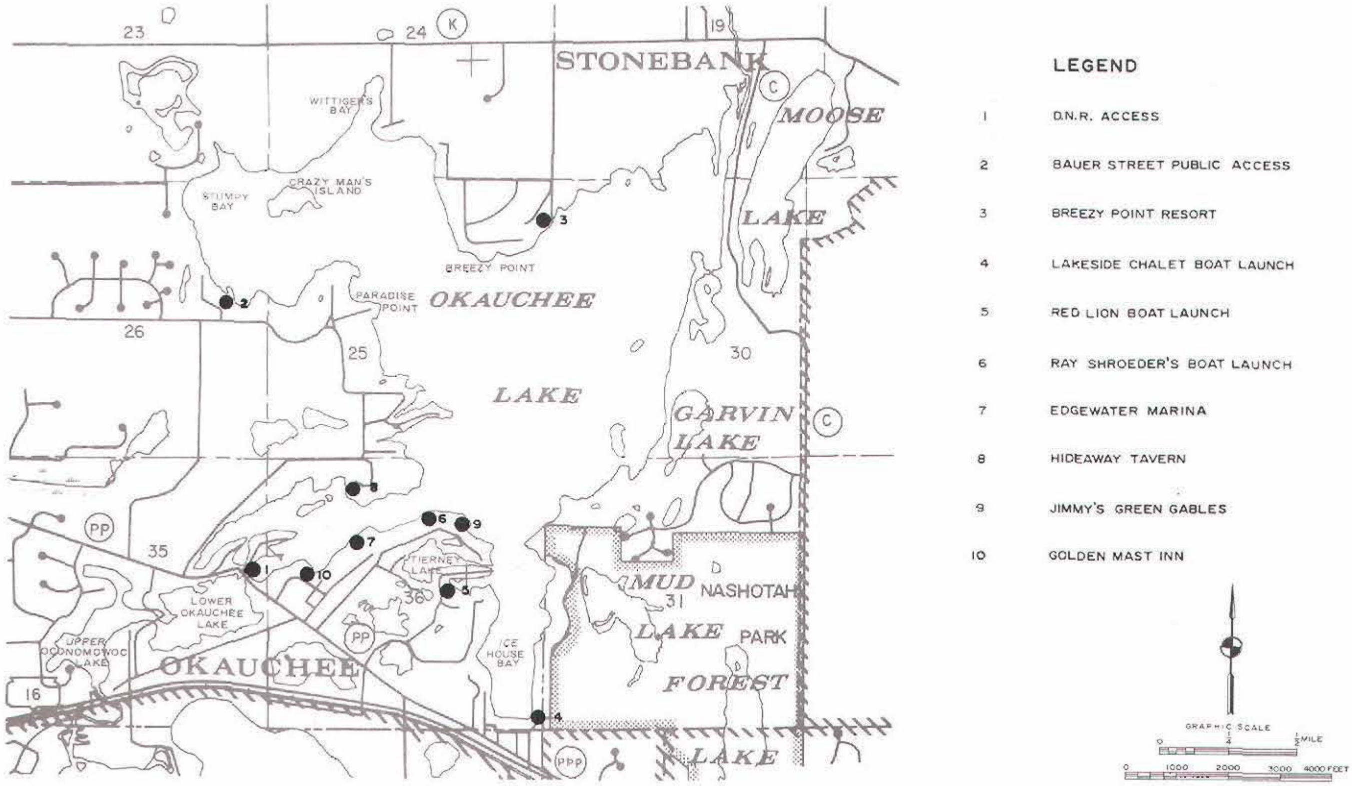
ash (Fraxinus pennsylvanica), silver maple (Acer saccharinum), and American elm (Ulmus americana).

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 bluejoint grass (Calamagrostis canadensis). Sedge meadows that are drained or disturbed to some extent typically succeed to shrub carrs. Shrub carrs, in addition to the sedges and grasses found in the sedge meadows, contain an abundance of shrubs such as willows (Salix spp.) and red osier dogwood (Cornus stolonifera). In extermely disturbed shrub carrs, the willows, red osier dogwoods, and sedges are replaced by such exotic plants as honeysuckle (Lonicera sp.), buckthorn (Rhamnus sp.), and the very aggressive reed canary grass (Phalaris arundinacea). The highest quality sedge meadows in the basin are located in the wetland complex adjacent to the Oconomowoc River and along the southwest lakeshore in Section 35, Township 8 North, Range 17 East.

Fresh (wet) meadows are essentially lowland grass meadows which are dominated by Canada bluejoint grass and forbes such as marsh (Aster simplex), red-stem (Aster puniceus), and New England (Aster Novae-angliae) asters; and giant goldenrod (Solidago gigantea). Several disturbed fresh (wet) meadows are located throughout the Okauchee Lake drainage basin and are largely associated with southern sedge meadows, shallow marshes, and shrub carrs. Many of the fresh (wet) meadows have been subject to alterations such as plowing, grazing, and water-level changes and are subsequently dominated by the European strain of reed canary grass, rather than Canada bluejoint grass.

Map 18

LOCATION OF LAKE ACCESS SITES ON OKAUCHEE LAKE: 1980



Source: Wisconsin Department of Natural Resources.

Several small, shallow, and deep marshes are scattered throughout the western portion of the direct tributary drainage area and along the Oconomowoc River. These areas are dominated by broad leaf and narrow leaf cat-tail (Typha spp.) and their hybrids, bur-reed (Sparganium eurycarpum), lake sedge (Carex lacustris), bulrush (Scirpus sp.), common reed (Phragmites communis), and water willow (Decodon verticillatus).

RECREATIONAL USE

Okauchee Lake has a large surface area generally free of shallow areas, excessive algae growths, and underwater hazards and therefore provides opportunities for a variety of water-based outdoor recreation activities, including boating, fishing, swimming, and nature study. Underwater hazards do exist in the area known as "Stumpy Bay." Boating, fishing, and swimming are popular summer outdoor recreation activities on Okauchee Lake. As already noted, Okauchee Lake provides a high quality habitat for northern pike, largemouth bass, walleye, panfish, and other fish species. An ongoing fish management program is being conducted by the Wisconsin Department of Natural Resources (DNR). An aerial survey of boating activity on Okauchee Lake on a weekend during August 1974, indicated that sailing was the most popular boating activity, followed by fishing, motorboating, and waterskiing. Lower Okauchee and Upper Oconomowoc Lakes, primarily because of their relatively smaller size and shallower water depths, provide less opportunity for recreational use.

Two publicly owned boat access sites--one owned and operated by the DNR and the other by the Town of Oconomowoc--are depicted on Map 18 and described in Table 21. Eight additional privately owned and operated boat access sites are set forth on Map 18 and in Table 21, and

Table 21

BOAT ACCESS SITES ON OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1980

Location	Owner	Name	Site Number
Township 8 North, Range 17 East, Section:			
35	Wisconsin Department of Natural Resources ..	DNR Access	1
26	Town of Oconomowoc ...	Bauer Street Public Access	2
25	Private.................	Breeze Point Resort	3
36	Private.................	Lakeside Chalet Boat Launching	4
36	Private.................	Red Lion Boat Launching	5
36	Private.................	Ray Schroeder's Boat Launching	6
36	Private.................	Edgewater Marina	7
36	Private.................	Hideaway Tavern Boat Launching	8
36	Private.................	Jimmy's Green Gables	9
36	Private.................	Golden Mast Inn	10

Source: Wisconsin Department of Natural Resources and Okauchee Lake Management District.

provide opportunities for the general public to participate in water-based outdoor recreation activities on Okauchee Lake. These sites consist of a boat launch area which permits the launching and beaching of boats, and includes an area for the parking of automobiles and trailers. The Wisconsin Department of Natural Resources, under guidelines established in the Wisconsin Administrative Code, Chapters NR 1.90 and NR 1.92, and the Regional Planning Commission, under the adopted regional park and open space plan, recommend that at least one public access site open to the general public be provided on all major inland lakes. On Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes this recommendation is met by the DNR owned and operated boat access site, located between Lower Okauchee and Upper Oconomowoc Lakes, which provides 19 parking spaces for cars and/or car/trailer combinations. With the private commercial access, walk-in access, rights-of-way and the DNR access site, Okauchee Lake has adequate public access at this time.

In general, Okauchee Lake provides opportunities for a variety of outdoor recreation activities in a high-quality setting. In the study year, only a few problems, such as excessive macrophyte growth, were considered to limit the resource value of the lake for water-based outdoor recreation. An outdoor recreational rating technique was developed to summarize the outdoor recreational value of inland lakes. As shown in Table 22, Okauchee Lake scored 53 out of a possible 72 rating points, placing it among those lakes in southeastern Wisconsin providing diverse, high quality outdoor recreation opportunities. In order to assure that Okauchee Lake will continue to provide such recreation opportunities, the resource values of the lake must be protected and preserved. Compared to Okauchee Lake, Lower Okauchee and Upper Oconomowoc Lakes have more limitations for recreational use. As set forth in Tables 23 and 24, both lakes received a recreational rating of 44 out of a possible 72 points, or somewhat less than the Okauchee Lake rating.

Table 22

RECREATIONAL RATING OF OKAUCHEE LAKE: 1980

Boating:		
X 6 Adequate depths (>75% of basin>5')	___ 4 Adequate depths (50-75% of basin >5' deep)	___ 2 Adequate depths (<50% of basin)
X 6 Adequate size for extended boating (>1,000 acres)	___ 4 Adequate size for some boating (200-1,000 acres)	___ 2 Limit of boating challenge and space (<200 acres)
___ 6 Good water quality	X 4 Some inhibiting factors such as weedy bays, algae blooms, etc.	___ 2 Overwhelming inhibiting factors such as weed beds throughout
Subtotal: 16		
Fishing:		
___ 9 High production	X 6 Medium production	___ 3 Low production
X 9 No problems	___ 6 Modest problems such as infrequent winterkill, small rough fish problems	___ 3 Frequent and overbearing problems such as winterkill, carp, excessive fertility
Subtotal: 15		
Swimming:		
___ 6 Sand or gravel (75% or more)	___ 4 Sand or gravel (25-75%)	X 2 Sand or gravel (<25%)
___ 6 Clean water	X 4 Moderately clean	___ 2 Turbid or darkly stained
___ 6 No algae or weed	X 4 Moderate algae or weed problems	___ 2 Frequent algae or weed problems
Subtotal: 10		
Aesthetics:		
___ 6 Existence of 25% or more wild shore	X 4 Less than 25% wild shore	___ 2 No wild shore
___ 6 Varied landscape	X 4 Moderately varied landscape	___ 2 Unvaried landscape
___ 6 Few nuisances such as excessive algae, carp, dumps, etc.	X 4 Moderate nuisance conditions	___ 2 High nuisance conditions
Subtotal: 12		
Total Quality Rating: 53 out of a possible 72		

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 23

RECREATIONAL RATING OF LOWER OKAUCHEE LAKE: 1980

Boating:		
X 6 Adequate depths (>75% of basin>5')	___ 4 Adequate depths (50-75% of basin >5' deep)	___ 2 Adequate depths (<50% of basin)
___ 6 Adequate size for extended boating (>1,000 acres)	___ 4 Adequate size for some boating (200-1,000 acres)	X 2 Limit of boating challenge and space (<200 acres)
___ 6 Good water quality	X 4 Some inhibiting factors such as weedy bays, algae blooms, etc.	___ 2 Overwhelming inhibiting factors such as weed beds throughout
Subtotal: 12		
Fishing:		
___ 9 High production	X 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
Subtotal: 12		
Swimming:		
___ 6 Sand or gravel (75% or more)	___ 4 Sand or gravel (25-75%)	X 2 Sand or gravel (<25%)
___ 6 Clean water	X 4 Moderately clean	___ 2 Turbid or darkly stained
___ 6 No algae or weed	X 4 Moderate algae or weed problems	___ 2 Frequent algae or weed problems
Subtotal: 10		
Aesthetics:		
___ 6 Existence of 25% or more wild shore	___ 4 Less than 25% wild shore	X 2 No wild shore
___ 6 Varied landscape	X 4 Moderately varied landscape	___ 2 Unvaried landscape
___ 6 Few nuisances such as excessive algae, carp, dumps, etc.	X 4 Moderate nuisance conditions	___ 2 High nuisance conditions
Subtotal: 10		
Total Quality Rating: 44 out of a possible 72		

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 24

RECREATIONAL RATING OF UPPER OCONOMOWOC LAKE: 1980

Boating:		
X 6 Adequate depths (>75% of basin >5')	___ 4 Adequate depths (50-75% of basin >5' deep)	___ 2 Adequate depths (<50% of basin)
___ 6 Adequate size for extended boating (>1,000 acres)	___ 4 Adequate size for some boating (200-1,000 acres)	X 2 Limit of boating challenge and space (<200 acres)
___ 6 Good water quality	X 4 Some inhibiting factors such as weedy bays, algae blooms, etc.	___ 2 Overwhelming inhibiting factors such as weed beds throughout
Subtotal: 12		
Fishing:		
___ 9 High production	X 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
Subtotal: 12		
Swimming:		
___ 6 Sand or gravel (75% or more)	___ 4 Sand or gravel (25-75%)	X 2 Sand or gravel (<25%)
___ 6 Clean water	X 4 Moderately clean	___ 2 Turbid or darkly stained
___ 6 No algae or weed	X 4 Moderate algae or weed problems	___ 2 Frequent algae or weed problems
Subtotal: 10		
Aesthetics:		
___ 6 Existence of 25% or more wild shore	___ 4 Less than 25% wild shore	X 2 No wild shore
___ 6 Varied landscape	X 4 Moderately varied landscape	___ 2 Unvaried landscape
___ 6 Few nuisances such as excessive algae, carp, dumps, etc.	X 4 Moderate nuisance conditions	___ 2 High nuisance conditions
Subtotal: 10		
Total Quality Rating: 44 out of a possible 72		

Source: Wisconsin Department of Natural Resources and SEWRPC.

Chapter VI

EXISTING WATER QUALITY MANAGEMENT ACTIONS AND INSTITUTIONAL STRUCTURES AFFECTING WATER QUALITY

WATER QUALITY MANAGEMENT ACTIONS

Sewage Disposal

The sanitary and household wastewaters from all 4,160 persons estimated to reside in the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes as of 1975, were treated and disposed of through the use of onsite systems. An onsite sewage treatment and disposal system may be a conventional septic tank system, a mound system, or a holding tank. As of 1975, 1,335 septic tank systems were estimated to be in operation in the tributary drainage area to the lakes. No holding tanks or mound systems were reported as of that year.

A septic tank system consists of two components: a septic tank proper used to provide partial treatment of the raw sewage--by skimming, settling and anaerobic decomposition--and the soil absorption field for final treatment and disposal of liquid discharged from the septic tank. Both components are installed below the ground surface. The septic tank is a water-tight tank intended to separate floating and settleable solids from the liquid fraction of domestic sewage and to discharge the liquid, together with its burden of dissolved substances, into the biologically active zone of the soil mantle through a subsurface percolation system. The discharge system may be a tile field, a seepage bed or an earth-covered sand filter. Liquid passing through the active soil zone percolates downward until it strikes an impervious layer of soil or the groundwater. Thus, the purpose of the percolation system is to dispose of sewage effluents by utilizing the same natural processes which lead to the accumulation of groundwater.

Providing that a septic tank system is located, installed, used, and maintained properly, and that there is an adequate depth--four to five feet--of moderately permeable, unsaturated soil below the drainage field, the system should operate with few problems for periods of up to 20 years. However, as previously noted, not all residential development within the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes is located in areas covered by soils suitable for septic tank use.

Failure of a septic tank system occurs when the soil surrounding the seepage area will no longer accept or properly stabilize the septic tank effluent, when the groundwater rises to levels which will no longer allow for uptake of liquid effluent by the soils, or when age or lack of proper maintenance cause the system to malfunction. Hence, septic system failure may result from improper location, poor installation in soils with severe limitations for system use, improper design or installation of the system, or inadequate maintenance. In many older, improper installations, the septic tank effluent may not receive the benefit of soil filtration, but rather is discharged directly from the septic tank through a drain tile to surface waters.

A precise identification of septic tank problems requires a complete sanitary survey. A sanitary survey was conducted in the lake watershed by the Waukesha County Board of Health in 1977 and 1978. In the survey, 826 septic tank systems were inspected. Of these, 22 systems, or 3 percent, were identified as having an obvious discharge of sewage to either the surface or to the groundwater. In addition, 40 systems, or 5 percent, were identified as discharging improperly treated sewage to either the lake surface or the groundwater and as not being in compliance with provisions of the then existing state plumbing codes. The survey could not assure identification of wet weather effluent ponding problems. Because of the difficulty in identifying malfunctioning septic tank systems by sewage discharges, which are not easily observed, and because of the intermittent use of systems by seasonal residents, surveys of this type may underestimate the total extent of failing septic tank systems.

As of 1980, no portions of the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes were served by sanitary sewers.

Existing Zoning Regulations

A 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. The drainage area directly tributary to Okauchee Lake includes portions of six civil divisions, including the City of Delafield, the Villages of Chenequa and Oconomowoc Lake, and the Towns of Merton, Oconomowoc, and Summit, all in Waukesha County. Consequently, six zoning ordinances are administered within the Okauchee Lake direct drainage area. The zoning ordinance currently in effect within the City of Delafield was initially approved and adopted by the City in April 1964 and was most recently amended in September 1978. The zoning ordinances for the Villages of Chenequa and Oconomowoc Lake were initially approved and adopted in June 1929 and March 1960, respectively; and were most recently amended in August 1971 and April 1962, respectively. The zoning ordinance for the Town of Merton was initially approved and adopted in November, 1949 and was most recently amended in May of 1974. The zoning ordinance for the Town of Summit was initially approved and adopted in November 1952 and was most recently amended in August 1977. The zoning ordinance currently in effect within the Town of Oconomowoc is administered jointly by the Town and Waukesha County. The ordinance was initially approved in February 1959, was ratified by the Town in April 1959, and was most recently amended in September 1979.

A summary of the zoning districts currently available for use in the six civil divisions is presented in Table 25. The areas of land placed in each of the districts are shown on Map 19 and are quantified in Table 25.

In addition to the six comprehensive zoning ordinances administered within the Okauchee Lake direct drainage area, the Waukesha County Board of Supervisors adopted a Shoreland and Floodland Protection Zoning Ordinance in 1970. This ordinance, prepared pursuant to the requirements of the Wisconsin Water Resources Act of 1965, imposes special land use regulations on all lands located within 1,000 feet of the shoreline of any navigable lake, pond, or flowage, and within 300 feet of the shoreline of any navigable river or stream or to the landward side of the floodplain, whichever is greater. The area zoned for shoreland and floodland protection within the Okauchee Lake direct drainage area was identified and the zoning ordinance adopted in 1970. The area is shown on Map 20.

The availability of 95 percent of the total area of the watershed for essentially urban and suburban land use development under the existing zoning ordinances enourages the diffusion of urban-type development throughout the watershed in a manner that conflicts with the recommendations contained in the adopted regional land use and water quality management plans. In order to prevent undesirable urban development in the Okauchee Lake direct drainage area, it will be necessary for the zoning administrators within the six civil divisions concerned to critically review the individual zoning ordinances and accompanying zoning district maps for the Okauchee Lake direct drainage area and amend the ordinances and district maps so as to preserve and enhance the existing natural resource base of the Okauchee Lake direct drainage area.

Table 25

SUMMARY OF EXISTING COMPREHENSIVE ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

Zoning District	Permitted Uses		Conditional/Special Uses	Area Regulations Lot Size		Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
	Principal	Accessory		Minimum Area	Minimum Width		
TOWN OF OCONOMOWOC ZONING ORDINANCE							
C-1 Conservancy District	Open space uses	--	Outdoor recreation facilities, quarrying, refuse disposal sites, fish hatcheries	No minimum	No minimum	16	0.5
A-E Exclusive Agricultural District	Open space uses, agricultural uses	--	Outdoor recreation facilities, quarrying, refuse disposal sites, fish hatcheries	No minimum	No minimum	--	--
A-1 Agricultural District	Single-family residence, agricultural uses	Garages, barns, home occupations	Airports, gift shops, kennels, churches, cemeteries, fish hatcheries, special agricultural uses, laboratories, mobile home parks, motels and hotels, outdoor theater, planned unit development, outdoor recreation facilities, public buildings, quarrying, refuse disposal sites, restaurants and taverns	3 acres	200 feet	147	5.0
A-1a Agricultural District	Single-family residence, agricultural uses	Garages, barns, home occupations	Airports, churches, cemeteries, fish hatcheries, special agricultural uses, laboratories, mobile home parks, motels and hotels, outdoor theaters, planned unit development, outdoor recreation facilities, public buildings, quarrying, refuse disposal sites	1 acre	150 feet	--	--
A-2 Rural Home District	Single-family residence, agricultural uses	Garages, barns, home occupations	Gift shops, churches, cemeteries, fish hatcheries, laboratories, planned unit development, outdoor recreation facilities, public buildings, refuse disposal sites, restaurants and taverns	3 acres	200 feet	--	--
A-3 Suburban Estate District	Single-family residence, agricultural uses	Garages, barns, home occupations	Gift shops, churches, cemeteries, fish hatcheries, planned unit development, outdoor recreation facilities, public buildings, refuse disposal sites, restaurants and taverns	2 acres	175 feet	--	--
R-1 Residential District	Single-family residence use	--	Gift shops, churches, centeries, fish hatcheries, motels and hotels, planned unit development, outdoor recreational facilities, public buildings, restaurants and taverns	1 acre	150 feet	323	9.6
R-1a Residential District	Single-family residence use	--	Gift shops, churches, cemeteries, fish hatcheries, motels and hotels, planned unit development, outdoor recreational facilities, public buildings, restaurants and taverns	1 acre	150 feet	--	--
R-2 Residential District	Single-family residence use	--	Gift shops, churches, cemeteries, fish hatcheries, motels and hotels, planned unit development, outdoor recreational facilities, public buildings, restaurants and taverns	30,000 square feet	120 feet	420	12.5
R-3 Residential District	Single-family residence use	--	Gift shops, churches, cemeteries, fish hatcheries, motels and hotels, multiple-family dwellings, planned unit development, outdoor recreational facilities, public buildings, restaurants and taverns	20,000 square feet	120 feet	622	18.4
P-1 Public District	Recreational, governmental, institutional uses	--	Churches, cemeteries, fish hatcheries, laboratories, motels and hotels, planned unit development, outdoor recreational facilities, public buildings, quarrying, refuse disposal sites	No minimum	No minimum	33	1.0
B-1 Restricted District	Single-family, multiple-family, limited retail and service uses	--	Churches, cemeteries, fish hatcheries, mobile home parks, planned unit development, outdoor recreational facilities, public buildings, refuse disposal sites, restaurants, and	20,000 square feet	120 feet	--	--

Table 25 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations Lot Size: Minimum Area	Area Regulations Lot Size: Minimum Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
			TOWN OF OCONOMOWOC ZONING ORDINANCE (continued)				
B-2 Local Business District	Retail and service, single-family, multiple-family uses	--	Service stations, kennels, churches, cemeteries, fish hatcheries, drive-in foods, mobile home parks, motels and hotels, multiple-family dwellings, outdoor theater, planned unit development, recreational facilities, public buildings, quarrying, refuse disposal sites	20,000 square feet	120 feet	21	0.6
B-3 General Business District	Commercial uses	Single-family residence	Service stations, kennels, churches, cemeteries, fish hatcheries, drive-in foods, mobile home parks, motels and hotels, multiple-family dwellings, outdoor theater, planned unit development, outdoor recreational facilities, public buildings, quarrying, refuse disposal sites	20,000 square feet	120 feet	8	0.2
Q-1 Quarrying District	Quarrying, open space, agricultural, single-family residence uses	--	Churches, cemeteries, fish hatcheries, mobile home parks, motels and hotels, planned unit development, outdoor recreational facilities, public buildings, quarrying, refuse disposal sites	3 acres	200 feet	--	--
M-1 Limited Industrial District	Commercial, limited industrial (low impact on surrounding residential uses)	Single-family residence	Service stations, kennels, cemeteries, fish hatcheries, drive-in foods, special agricultural uses, laboratories, mobile home parks, motels and hotels, outdoor theaters, planned unit development, outdoor recreational facilities, public buildings, quarrying, refuse disposal sites	1 acre	150 feet	--	--
M-2 General Industrial District	Quarrying, industrial, commercial uses	Single-family residence	Service stations, kennels, cemeteries, fish hatcheries, drive-in foods, special agricultural uses, laboratories, mobile home parks, motels and hotels, outdoor theaters, planned unit development, outdoor recreational facilities, public buildings, quarrying, refuse disposal sites	1 acre	150 feet	--	--
Subtotal	--	--	--	--	--	1,590	47.2
			TOWN OF MERTON ZONING ORDINACE				
C-1 Conservancy District	Grazing, harvesting of wild crops, hunting and fishing, sustained yield forestry, dams and hydroelectric power stations, telephone and telegraph and power transmission line uses	--	None	No minimum	No minimum	175	5.2
A-1 Agricultural District	Any use permitted in the C-1 Conservancy District, one-family dwellings, public parks and recreation areas, farming, roadside stands, horticulture, home occupations, professional office uses	Private garages, private boathouses, guesthouses, kennels, occupations, and professional offices	Airports, landing fields, antique shops, studios, automobile service stations, animal hospitals, cemeteries, churches, commercial fish and bait ponds, drive-in establishments, laboratories for testing and experimental purposes	3 Acres	200 feet	885	26.3

Table 25 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations Lot Size: Minimum Area	Area Regulations Lot Size: Minimum Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
TOWN OF MERTON ZONING ORDINANCE (continued)							
A-2 Rural Home District	All uses permitted in the A-1 Agricultural District, one-family dwellings, keeping of poultry	--	Animal hospitals, kennels, cemeteries, churches, commercial fish and bait ponds, residential planning unit development, public and semi-public uses, private clubs	3 Acres	200 feet	--	--
A-3 Suburban Estate District	Any use permitted in the A-2 Rural Home District	--	Same as A-2 Rural Home District	2 Acres	175 feet	--	--
R-1 Residential District	Any use permitted in the A-2 Rural Home District	--	Same as A-2 Rural Home District	1 Acre	150 feet	340	10.1
R-2 Residential District	Any use permitted in the R-1 Residential District	--	Same as A-2 Rural Home District	30,000 square feet	120 feet	--	--
R-3 Residential District	Any use permitted in the R-2 Residential District, two-family dwellings	--	Same as A-2 Rural Home District	20,000 square feet	120 feet	85	2.5
P-1 Public District	None	--	Private clubs, public and semi-public uses	No minimum	No minimum	82	2.4
B-1 Restricted Business District	Small retail shops, boarding houses, offices	--	Same as A-2 Rural Home District	20,000 square feet	120 feet	--	--
B-2 Local Business District	Any use permitted in the B-1 Restricted Business District	--	Same as A-2 Rural Home District	20,000 square feet	120 feet	30	0.9
B-3 General Business District	Wholesalers, distributors, theaters, dance halls, dry cleaning, auto sales, etc.	--	Antique shops, studios, auto service stations, animal hospitals, cemeteries, churches, commercial fish or bait ponds, drive-in establishments, feed lots, laboratories, private clubs, public and semi-public uses, disposal sites	20,000 square feet	120 feet	5	0.2
Q-1 Quarrying District	Any use permitted in A-1 Agricultural District and residential uses accessory to permitted uses, quarrying	Manufacture of concrete, building blocks, production of ready-mixed concrete	Animal hospitals, cemeteries, commercial fish or bait shops, public and semi-public uses, disposal sites	1 Acre	150 feet	--	--
M-1 Limited Business District	Any use permitted in B-3 General Business or A-1 Agricultural District, light industry	--	Same as B-3 General Business	1 Acre	150 feet	--	--
M-2 General Industrial District	Any use permitted in M-1 Limited Industrial District, quarrying	--	Same as B-3 General Business District	1 Acre	150 feet	--	--
Subtotal	--	--	--	--	--	1,602	47.6
CITY OF DELAFIELD ZONING ORDINANCE							
C-1 Conservancy District	Harvesting of wild crops, sustained yield forestry, hydro-electric power stations, utility conduits and lines, nonresidential buildings in conjunction with raising of animals, public parks and buildings uses	--	Developments which are compatible and harmonious with the natural features of the conservancy district area	No minimum	No minimum	--	--

Table 25 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations Lot Size: Minimum Area	Area Regulations Lot Size: Minimum Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
CITY OF DELAFIELD ZONING ORDINANCE (continued)							
A-1 Agricultural District	One-family dwellings in conjunction with farm operation, accessory uses and buildings, nurseries, greenhouses, hatcheries, roadside stands uses	Private garages, carports, utility buildings, model homes, temporary roadside stands, home occupations, professional offices	Legal nonconforming uses, commercial kennels, cemeteries, noncommercial clubs and outdoor recreation areas, riding academies, public and semi-public governmental buildings, solar energy collection devices, quarrying and mineral extraction	3 Acres	200 feet	--	--
A-1E Exclusive Agricultural District	One-family dwellings in conjunction with farm operation, ordinary farm uses, accessory uses and buildings, nurseries, greenhouses, horticulture, roadside stands	Same uses as permitted in A-1 Agricultural District	Same as in A-1 District	3 acres	200 feet	--	--
RE-3 Three-Acre Rural Estate District	Single-family dwellings, essential services, keeping of horses for noncommercial purposes	Same as uses permitted in A-1 Agricultural District	Legal nonconforming uses; commercial kennels; cemeteries; noncommercial clubs and outdoor recreation areas; riding academies; public, semi-public and governmental buildings; temporary model home and sales office; solar energy collection devices; planned developments; quarrying and mineral collection	3 Acres	200 feet	--	--
RE-2 Two-Acre Rural Estate District	Single-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	2 Acres	200 feet	--	--
RE-1 One-Acre Rural Estate District	Single-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	1 Acre	140 feet	--	--
RL-1 Residential Lake District	Single-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	40,000 square feet	100 feet	--	--
RL-1A Residential Lake District	Single-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	20,000 square feet	80 feet	--	--
R-1 Single-Family Residence District	Single-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	30,000 square feet	120 feet	--	--
R-2 Single and Two-Family Residence District	Single- and two-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	30,000 square feet	120 feet	--	--
R-3 Single- and Two-Family Residence District	Single- and two-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	20,000 square feet	100 feet	--	--
R-4 Single and Two-Family Residence District	Single- and two-family dwellings, essential services	Same uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	7,900 square feet	66 feet	7	0.2
R-5 Planned Development District	Single- and two-family residences	Same as uses permitted in A-1 Agricultural District	See St. John's-on-the-Lake Subdivision Documents	No minimum	No minimum	--	--

Table 25 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations Lot Size: Minimum Area	Area Regulations Lot Size: Minimum Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
CITY OF DELAFIELD ZONING ORDINANCE (continued)							
R-6 Multiple-Family Residence	Attached multiple-family dwellings, essential services	Same as uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	2,500 square feet for efficiency units; 3,000 square feet for one-bedroom units; 4,000 square feet for two-bedroom units	100 feet	12	0.3
R-7-EH Multiple-Family Elderly Housing District	Attached multiple-family dwellings, essential services	Same uses permitted in A-1 Agricultural District	Same as RE-3 Three-Acre Rural Estate District	Same as R-6 Multiple-Family Residence District	100 feet	--	--
CBD-1 Central Business District	Convenience and general retail commercial use (see Ordinance)	Garages, off-street parking and loading areas, and residential dwellings located in the same building as a business	One- and two-family residential dwellings; multiple-family dwellings; public and semi-public buildings; automobile service stations; boat sales, service, and repair; private schools; and theaters (indoor)	4,500 square feet	45 feet	--	--
B-1 Local Business Residence District	Generally recognized retail business personal service establishments, dry cleaning, business service establishments, professional services, sales and service establishments, post offices, residential dwelling units in a commercial building, single-family residences, essential services	Structures and uses customarily incident to permitted uses	Legal nonconforming uses; cemeteries; noncommercial clubs and outdoor recreational facilities; riding academies, public, semi-public and governmental buildings; boat sales, service and repairs; quarrying and mineral extraction	5,000 square feet	100 feet	--	--
B-1A Business and Limited Residence District	Uses similar to those in the B-1 Local Business Residence District (see Zoning Ordinance)	Structures and uses customarily incident to permitted uses	Same as B-1 Local Business Residence District	10,000 square feet	100 feet	--	--
B-2 Local Business District	Same as B-1 District	Structures and uses customarily incident to permitted uses	Same as B-1 Business Residence District, drive-in restaurants	15,000 square feet	120 feet	--	--
B-3 Local and Highway Business District	Same as B-3 District, amusement establishments, animal hospitals, auction rooms, blueprinting, garden supplies, hotels, medical laboratories, motels, offices, printing establishments, research labs, private schools, taxidermists, and other similar uses	Structures and uses customarily incident to permitted uses	Same as B-2 District, dumps, land fills, incinerators, pool halls and dance halls	20,000 square feet	120 feet	--	--

Table 25 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations Lot Size: Minimum Area	Area Regulations Lot Size: Minimum Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
CITY OF DELAFIELD ZONING ORDINANCE (continued)							
B-4 General Business District	Same as B-3 District, warehousing, wholesaling and distribution operations, and permitted uses in the M-1 Industrial District	Garages, off-street parking and loading areas, parking structures	Same as B-3 District, sales and service of mopeds	20,000 square feet	120 feet	26	0.8
B-5 Office and Research Commercial District	Professional offices, business offices and office research uses	Essential services, off-street parking and loading areas	Same as B-1 District	40,000 square feet	120 feet	--	--
M-1 Limited Industrial District	Wholesale and warehouse activities and light industrial uses	Garages, off-street parking and loading areas, office storage, and power supply	Same as B-4 District	1 Acre	150 feet	13	0.4
Subtotal	--	--	--	--	--	58	1.7
VILLAGE OF CHENEQUA ZONING ORDINANCE							
Residence District	Single-family dwellings, municipal utilities and buildings, churches and temples, schools, parks and country clubs, farming uses	Accessory private garages and barns	None	2 Acres	150 feet	32	1.0
Subtotal	--	--	--	--	--	32	1.0
VILLAGE OF OCONOMOWOC LAKE ZONING ORDINANCE							
R-1 Single-Family Residence	One-family dwelling use	Storage parking facilities, nurseries, farming and gardening, private swimming pools and private emergency shelters	Municipal and/or public utility buildings, churches, school, and and nonprofit clubs	3 Acres	250 feet	--	--
R-2 Single-Family Residence	One-family dwelling use	Same as R-1 Single-Family Residential District	Same as R-1 Single-Family Residential District	2 Acres	200 feet	48.0	1.4
R-3 Single-Family Residence District	One-family dwelling use	Same as R-1 Single-Family Residence District	Same as R-1 Single-Family Residence District	1 Acre	150 feet	10	0.3
Subtotal	--	--	--	--	--	58	1.7
TOWN OF SUMMIT ZONING ORDINANCE							
RCE Country Estate District	Single-family dwellings, public parks and recreation areas, crop tree farming and horticulture, public utility facilities	Private garages, guest houses, boathouses, occupations, private residential, outdoor recreation facilities	Public and private schools, churches and religious institutions, public administrative offices and service buildings, private lodges and clubs, commercial development and historic restorations, country inns, country restaurants, nursing and rest homes for the aged, summer theaters, public utility offices, and commercial riding stables	3 Acres	300 feet	--	--
RRE Rural Estate District	Any use permitted in the RCE District	Any use permitted in the RCE District	Any conditional use permitted in the RCE District	2 Acres	200 feet	--	--
R-1 Country Home District	Any use permitted in the RCE District	Any use permitted in the RCE District	Any conditional use permitted in the RCE District	1 Acre	200 feet	--	--

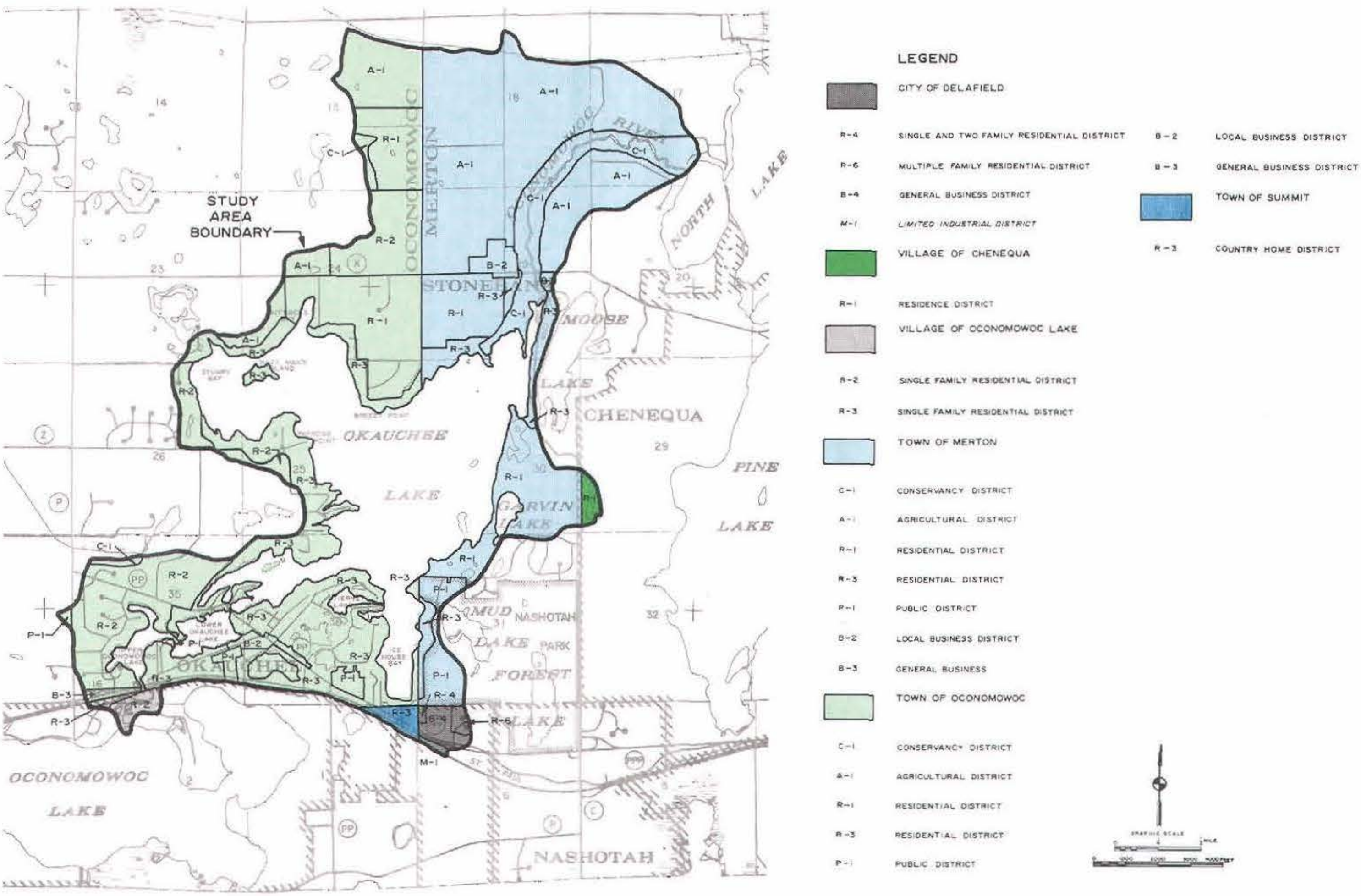
Table 25 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations Lot Size: Minimum Area	Area Regulations Lot Size: Minimum Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
TOWN OF SUMMIT ZONING ORDINANCE (continued)							
R-2 Country Home District	Any use permitted in the RCE District	Any use permitted in the RCE District	Any conditional use permitted in the RCE District	3/4 Acre	150 feet	--	--
R-3 Country Home District	Any use permitted in the RCE District	Any use permitted in the RCE District	Any conditional use permitted in the RCE District	1/2 Acre	120 feet	26	0.8
C-1 Neighborhood Convenience District	Any use permitted in the RCE District except residential use only in conjunction with and accessory to another permitted principal use, retail shops, business and professional offices and studios	Business garages, off-street parking and loading areas	Automobile service stations, drive-in establishments serving food or beverages	12,000 square feet; (sewered) 20,000 square feet (unsewered)	80 feet (sewered) 120 feet (unsewered)	--	--
C-2 Local Service Center District	Banks, savings and loan offices, commercial entertainment facilities, laundromats, post offices, restaurants, taverns, dental and medical clinics, commercial photography, advertising and art studios	Any accessory use as permitted in the C-1 District	Any conditional use permitted in the C-1 District, animal hospitals, appliance and small machinery repair establishments	9,000 square feet (sewered) 20,000 square feet (unsewered)	60 feet (sewered) 100 feet (unsewered)	--	--
C-3 General Commercial Center District	General merchandizing establishments, printing and publishing houses and related activities, hotels and transportation terminals	Signs, billboards and other similar advertising media	Lumber and building supply yards, experimental testing and research galleries, general warehousing, service and sales establishments	9,000 square feet (sewered) 20,000 square feet (unsewered)	60 feet (sewered) 100 feet (unsewered)	--	--
I Industrial District	Manufacture, assembly, processing and fabrication plants, general warehousing	Office, storage, power supply and other such uses normally auxiliary to the principal industrial operation	Quarrying, animal hospitals, kennels, junk or salvage yards	1 Acre	150 feet	--	--
A Agricultural District	Any use permitted in the RCE Country Estate District, outdoor recreational facilities	Any accessory use as permitted by RCE District	Any conditional use permitted in the RCE District, hog, goat, or or fur farms, animal hospitals, kennels, dairy processing plants, quarrying	2 Acres	250 feet	--	--
WF Wetland and Floodplain District	Grazing, harvesting of wild crops, hunting and fishing, tree farms, dams and hydroelectric power stations, recreational facilities	Recreation facilities and and structures	Public, private commercial and private noncommercial group outdoor recreational facilities	No minimum	No minimum	--	--
Subtotal	--	--	--	--	--	26	0.8
Direct Drainage Area Total	--	--	--	--	--	3,366	100.0

Source: Waukesha County Park and Planning Commission and SEWRPC.

Map 19

EXISTING ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1980



Source: SEWRPC.

Aquatic Plant Management

Records of aquatic plant management were not maintained prior to 1950. Aquatic plant management which was first recorded for Okauchee Lake in 1950, can be categorized as macrophyte harvesting, chemical macrophyte control, and chemical algae control.

Macrophyte Harvesting: The first known organized macrophyte harvesting program on Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes was conducted by the Town of Oconomowoc, which harvested from 1963 to 1977. Since 1977, the Okauchee Lake Management District has been conducting a harvesting program. As of 1980, the Lake District had two harvesters, a barge and shore loader. Essentially, the total shorelines of all three lakes, usually within 20 to 30 feet of shore, are harvested approximately three to five times per year.[1] The harvesting is conducted jointly with a macrophyte chemical control program,

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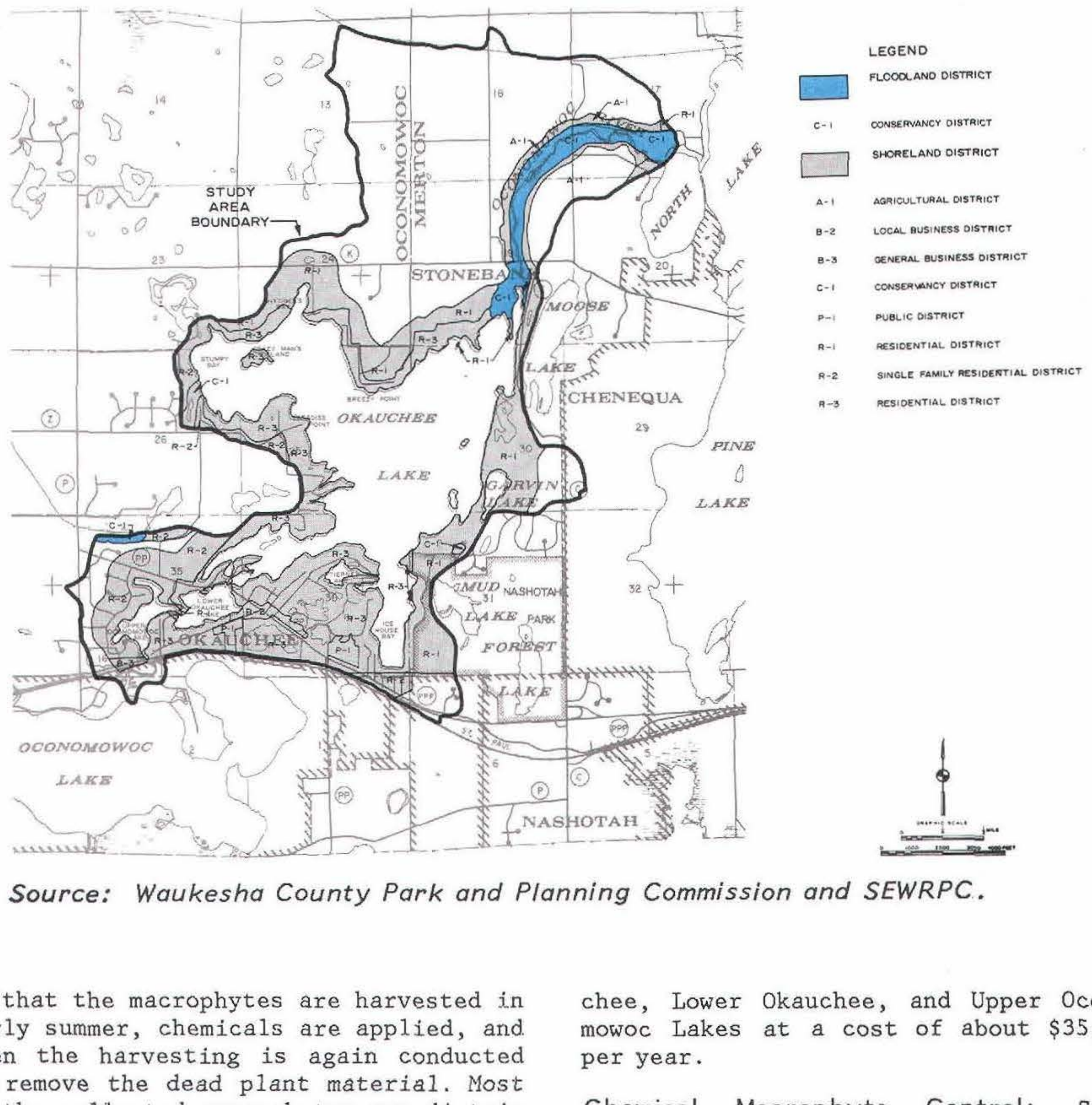
[1]*Kay Matschnig, Secretary, Okauchee Lake Management District, provided this information on May 27, 1980.*

Map 20

EXISTING FLOODLAND AND SHORELAND ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1970



Source: Waukesha County Park and Planning Commission and SEWRPC.

in that the macrophytes are harvested in early summer, chemicals are applied, and then the harvesting is again conducted to remove the dead plant material. Most of the collected macrophytes are distributed to greenhouses, farmers, and lake property owners. However, during, and for two weeks following, the use of macrophyte control chemicals, the macrophytes are disposed of by a private disposal firm and taken to a sanitary landfill. For the years 1977, 1978, and 1979, an average of 650 cubic yards of macrophytes were harvested from Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes at a cost of about $35,000 per year.

Chemical Macrophyte Control: Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Even prior to this date, chemicals had been used to control aquatic plant growth in lakes and streams. In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in Madison, Wisconsin. By the 1930's, sodium arsenite was widely used for aquatic plant control, and no other chemicals were applied in significant amounts to control macrophytes in the lakes. Records on sodium arsenite applications were not maintained prior to 1950. As indicated in Table 26, approximately 181,580 pounds of sodium arsenite was applied to Okauchee Lake from 1950 through 1966. As shown in Table 27, Okauchee Lake has received the second largest amount of sodium arsenite in the State.

The sodium arsenite was usually sprayed (Figure 10) within 200 feet of the shoreline. Treatment typically occurred between mid-June and mid-July. The amount of sodium arsenite used was usually calculated to result in a concentration of about 10 parts per million of sodium arsenite in the treated lake water. Most of the sodium arsenite remained in the water column for less than 120 days. The arsenic residue was naturally converted from a highly toxic trivalent form to a relatively less toxic--and less biologically active--pentavalent form. Much of the arsenic residue was deposited in the lake sediments. Algae, diatoms, and macrophytes have been known to concentrate arsenic in their tissue up to levels exceeding

Table 26

CHEMICAL CONTROL OF AQUATIC PLANTS IN OKAUCHEE LAKE: 1950-1979

Year	Algae Control				Macrophyte Control				
	Acres Treated	Cooper Sulfate	Blue Vitriol	Cutrine or Cutrine-+	Sodium Arsenite	2,4-D	Diquat	Endothall	Aquathol
1950	--	--	--	--	8,280 lbs.	--	--	--	--
1951	--	--	--	--	13,300 lbs.	--	--	--	--
1952	--	--	--	--	12,120 lbs.	--	--	--	--
1953	--	--	--	--	2,760 lbs.	--	--	--	--
1954	--	--	--	--	2,180 lbs.	--	--	--	--
1955	--	--	--	--	3,400 lbs.	--	--	--	--
1956	--	--	--	--	1,440 lbs.	--	--	--	--
1957	--	--	--	--	3,904 lbs.	--	--	--	--
1958	114.4	--	800 lbs.	--	20,656 lbs.	--	--	--	--
1959	283.6	--	500 lbs.	--	23,400 lbs.	--	--	--	--
1960	346.3	--	1,895 lbs.	--	24,120 lbs.	--	--	--	--
1961	237	--	--	--	11,780 lbs.	--	--	--	--
1962	319.3	--	--	--	10,440 lbs.	--	--	--	--
1963	240	--	--	--	26,100 lbs.	--	--	--	--
1964	162.5	2,100 lbs.	--	--	11,700 lbs.	--	--	--	--
1965	97.5	700 lbs.	--	--	3,300 lbs.	--	--	--	--
1966	97	1,100 lbs.	--	--	2,700 lbs.	--	--	--	--
1967	0.1	20 lbs.	--	--	--	--	--	--	--
1968	67.6	500 lbs.	--	--	--	5 gals.	15.5 gals.	--	24 gals.
1969	64.4	--	--	2 gals.	--	--	7 gals.	58 gals.	--
1970	106.9	330 lbs.	--	--	--	270 lbs.	11.5 gals.	16 gals.	--
1971	40.3	291 lbs.	--	--	--	10 gals.	--	--	735 lbs.
1972	44.3	--	--	--	--	20 gals.	--	--	150 gals.
1973	3.8	--	--	--	--	--	1 gal.	--	12 gals.
1974	9.3	--	--	--	--	22 gals.	--	11 gals.	--
	--	--	--	--	--	47 lbs.	--	379 lbs.	--
1975	25.4	105.9 lbs.	--	23 gals.	--	23 gals.	--	56 gals.	--
	--	--	--	--	--	78 lbs.	--	--	--
1976	100.6	--	--	68.2 gals.	--	269 gals.	--	14.8 gals.	--
	--	--	--	--	--	70 lbs.	--	--	--
1977	75	--	--	148 gals.	--	242 gals.	--	34 gals.	--
1978	93.8	--	--	181.2 gals.	--	129.5 gals.	--	48.2 gals.	--
	--	--	--	--	--	5 lbs.	--	70 lbs.	--
1979	134.9	--	--	116 gals.	--	174 gals.	--	71.5 gals.	--
	--	--	--	--	--	--	--	400 lbs.	--
Total	2,664	5,146.9 lbs.	3,195 lbs.	538.4 gals.	181,580 lbs.	894.5 gals. 470 lbs.	35 gals.	309.5 gals. 849 lbs.	186 gals. 735 lbs.

NOTE: Values include chemicals applied to Lower Okauchee and Upper Oconomowoc Lakes.

Source: Wisconsin Department of Natural Resources.

Table 27

LAKES RECEIVING THE 10 LARGEST AMOUNTS OF SODIUM ARSENITE IN WISCONSIN FOR AQUATIC MACROPHYTE CONTROL: 1950-1969

Lake	County	Amount of Sodium Arsenite (pounds)
Pewaukee	Waukesha	334,232
Okauchee	Waukesha	181,580
Big Cedar.	Washington	179,164
Pine.	Waukesha	129,337
Fowler Lake[a]	Waukesha	87,456
Nagawicka	Waukesha	87,214
La Belle	Waukesha	77,858
Onalaska	La Crosse	64,676
Shangrila (Benet) . . .	Kenosha	59,020
Browns.	Racine	56,600
Total	--	1,257,137[b]

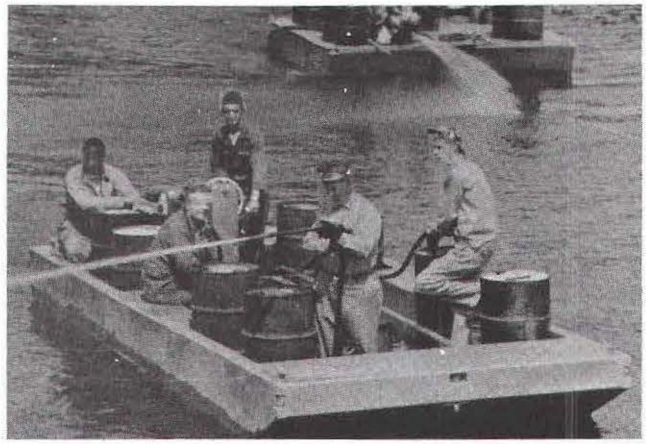
[a] *Includes application of sodium arsenite to the Oconomowoc River near Fowler Lake.*

[b] *The 1,257,137 pounds of sodium arsenite applied to these lakes constitutes 57 percent of the total amount of sodium arsenite applied to a total of 167 lakes and streams in Wisconsin during the period 1950 to 1969.*

Source: Wisconsin Department of Natural Resources.

Figure 10

PROCEDURE FOR APPLICATION OF SODIUM ARSENITE TO AN INLAND LAKE FOR AQUATIC MACROPHYTE CONTROL



Source: Wisconsin Department of Natural Resources.

2,000 micrograms per gram (ug/g) dry weight. However, biomagnification of arsenic through the food chain has not been known to occur. Analyses of fish tissue from some treated lakes by the Wisconsin Department of Natural Resources in 1960 and in 1971 indicated no excessive levels of arsenic.

When it became apparent that arsenic was accumulating in the sediments of treated lakes, the use of sodium arsenite was discontinued in Okauchee Lake in 1966, and in the entire State in 1969. The application and accumulation of arsenic were concluded to present potential health hazards to human and aquatic life. In drinking water supplies, arsenic is suspected of being carcinogenic and has been known to cause skin cancer and brain, liver, kidney, and bone marrow damage. Under certain conditions, arsenic may leach to and contaminate the groundwater, especially in sandy soils.

During anaerobic conditions, arsenic may be released from the bottom sediments to the water. In this way, some arsenic continues to be "flushed out" of Okauchee Lake through the outlet. In addition, the arsenic-laden sediments are continually being covered by new sediments. Therefore, the level of arsenic in the water and in the surface sediments may be expected to decrease with the passage of time. Table 28 sets forth measured arsenic levels in Okauchee Lake for selected years from 1962 through 1978. The U. S. Environmental Protection Agency drinking water standard for arsenic is 0.05 milligram per liter (mg/l).

As shown in Table 26, 2,4-D, Diquat, Endothal, and Aquathol also have been applied to Okauchee Lake to control aquatic macrophytes. All of these chemicals were applied since 1968. All aquatic plant control chemicals currently used must be approved by the U. S. Environmental Protection Agency and the Wisconsin Department of Natural Resources. The federal Insecticide, Fungicide, and Rodenticide Act as amended in 1972 requires that all pesticides be registered. Separate records of chemical

Table 28

MEASURED ARSENIC LEVELS IN OKAUCHEE LAKE FOR SELECTED YEARS 1962-1978

Sampling Date	Arsenic Concentration (mg/l)
April 1962.......	0.07
May 1962........	0.06
February 1963...	0.09
November 1964 ..	0.20
November 1966 ..	0.07
February 1967...	0.05
May 1968........	0.04
April 1969.......	0.02
April 1970.......	0.01
April 1971.......	0.01
June 1978	0.01

Source: Wisconsin Department of Natural Resources and SEWRPC.

treatment are not maintained by the Wisconsin Department of Natural Resources for Lower Okauchee and Upper Oconomowoc Lakes. It is likely that the amounts reported for Okauchee Lake include chemicals applied to these two smaller lakes. Map 21 shows the extent of application of aquatic plant control (macrophytes and algae) chemicals for the period of 1976 through 1979.

The advantages of chemical use are the relatively low cost; and the ease, speeds and convenience of application. In addition, officials of the Okauchee Lake Management District indicated that controlling aquatic macrophytes through harvesting was not as effective during periods when chemical applications were curtailed. Disadvantages associated with chemical control include the following:

1. Although the short-term, lethal effects of chemicals are relatively well known, potential long-term, sublethal effects--especially on fish and fish-food organisms--are relatively unknown.

2. The elimination of macrophytes reduces their competition with algae for light and nutrients. Thus increased algae blooms may develop.

3. In cases where dead plant material is not removed from the lake, the nutrients contained in the decomposing plant material will be released to the water. Decomposition of the plant bodies also consumes dissolved oxygen and increases the potential for fish kills.

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

5. Adverse impacts on other aquatic organisms may be expected. Diquat has been shown to kill the zooplankton Daphnia (water fleas) and Hyalella (scuds) at the level applied for macrophyte control. Both Daphnia and Hyalella are important fish foods, and Daphnia is the primary food for the young of nearly all fish species.

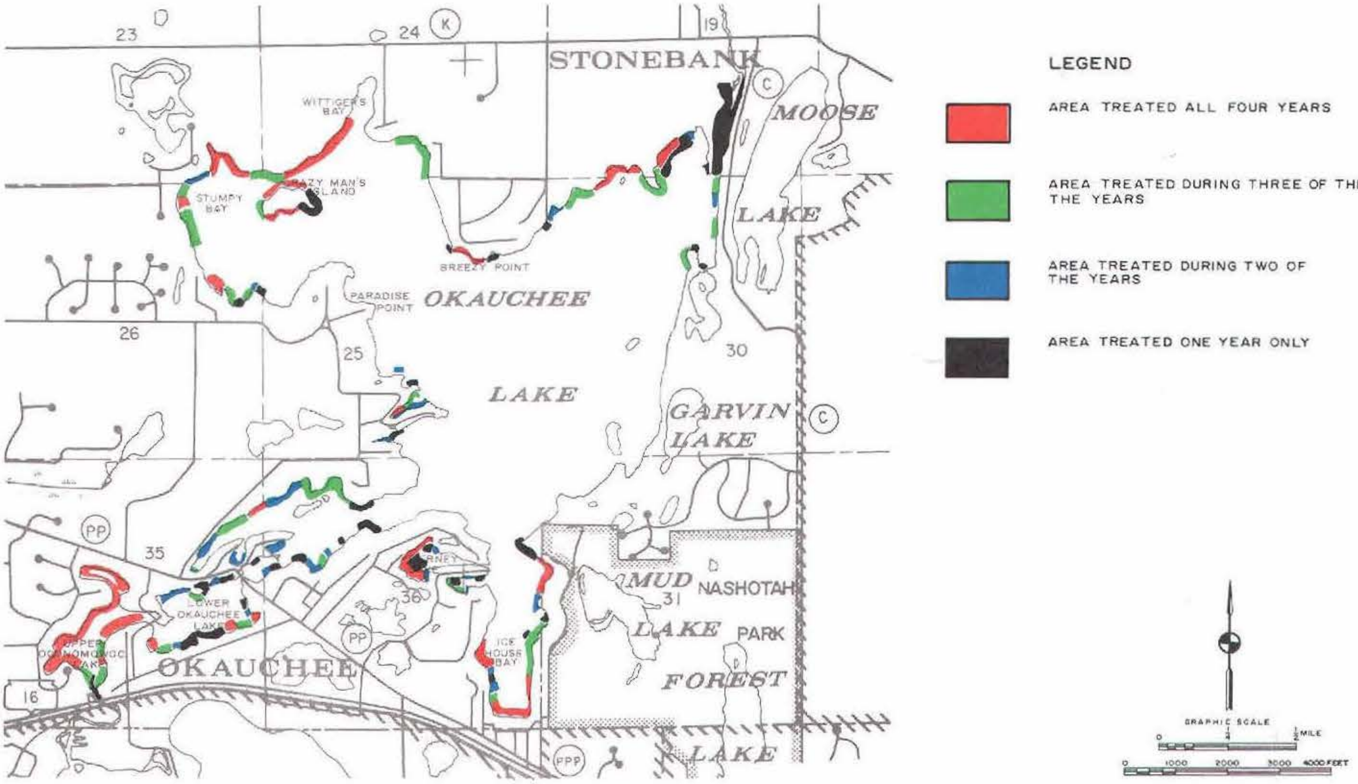
Chemical Algae Control: Table 26 indicates that copper sulfate, Blue Vitriol, Cutrine, and Cutrine-plus were applied to Okauchee Lake as early as 1953 for algae control. Many of the disadvantages of chemical macrophyte control discussed above apply to chemical algae control as well. In additon, copper, the active ingredient in algicides, may accumulate in the bottom sediments. Excessive levels of copper are toxic to fish and benthic animals.

GOVERNMENT AGENCIES WITH WATER QUALITY MANAGEMENT RESPONSIBILITIES

A number of local, state, and federal agencies have potential water quality management responsibilities for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. These agencies include an Inland Lake Protection and Rehabilitation District, a town sanitary district,

Map 21

AREAS CHEMICALLY TREATED FOR THE CONTROL OF AQUATIC PLANTS IN OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1976-1979



Source: Wisconsin Department of Natural Resources and SEWRPC.

the civil town, cities and villages, the County, the County Soil and Water Conservation District, the Regional Planning Commission, the Wisconsin Department of Natural Resources, the Wisconsin Department of Health and Social Services, the University of Wisconsin-Extension, the U. S. Environmental Protection Agency, the U. S. Department of Agriculture, Soil Conservation Service, and the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service. A detailed discussion is presented in Chapter 6, Volume One, SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000. However, the role of each of these agencies is briefly discussed below.

Inland Lake Protection and Rehabilitation Districts

Inland lake protection and rehabilitation districts are special purpose units of government created pursuant to Chapter 33 of the Wisconsin Statutes. In its initial declaration of intent, the Wisconsin Legislature summarized the underlying philosophy behind the creation of these special purpose districts:

> The legislature finds environmental values, wildlife, public rights in navigable waters, and the public welfare are threatened by the deterioration of public lakes; that the protection and rehabilitation of the public inland lakes of this state are in the best interest of the citizens of this state; that the public health and welfare will be benefited thereby; that the current state effort to abate water pollution will not undo the eutrophic and other deteriorated conditions of many lakes; and that the positive public duty of this state as trustee of waters requires affirmative steps to protect and enhance this resource and protect environmental values.

Inland lake protection and rehabilitation districts are formed at the local level. The district organizers, who may be any local property owners, propose appropriate boundaries encompassing the riparian property and as much of the lake watershed as deemed necessary. Once the district boundary has been so proposed, the organizers must obtain a petition signed by at least 51 percent of the property owners or by the owners of at least 51 percent of the land within the proposed district boundaries. The petition is presented to the county board which holds a hearing after notifying all property owners in the proposed district. Following the hearing, the county board may form an inland lake protection and rehabilitation district.

The lake district has powers to enter into contracts; own property; disburse money; and to bond, borrow, and levy special assessments to raise money. Its specific lake management powers include:

1. Study existing water quality conditions and determine the causes of existing or expected future water quality problems.

2. Control aquatic macrophytes, algae, and swimmer's itch.

3. Implement lake rehabilition techniques, including aeration, diversion, nutrient removal or inactivation, selective discharge, dredging, sediment covering, and drawdown.

4. Construct and operate water level control structures.

5. Control nonpoint source pollution.

The districts do not have police powers but may ask counties, towns, villages, or cities to enact ordinances necessary to improve or protect the lake. The governing body of a lake district is a board of commissioners, which consists of:

- Three property owners from within the district, elected by all property owners within the district,

- A county board member who is also a Soil and Water Conservation District supervisor, who is nominated by the supervisors of the Soil and Water Conservation District and is appointed by the County Board, and

- A representative appointed by the governing body of the town, village or city having the highest assessed evaluation within the district.

In 1975, a lake protection and rehabilitation district was formed for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. The district encompasses 706 acres or 21 percent of the total direct lake drainage area, as shown on Map 10.

Sanitary Districts

Sanitary districts may be created under Section 66.30 of the Wisconsin Statutes to plan, construct, and maintain centralized sanitary sewerage systems. Town sanitary districts have limited authority to construct and maintain storm sewer systems and provide garbage and refuse collection and disposal. Such districts have also been used as an organizational vehicle for lake macrophyte harvesting.

Towns

Towns have authority to undertake a wide variety of activities with respect to the abatement of pollution from both point and nonpoint sources. Towns that contain both urban and rural areas generally have elected to establish separate sanitary and utility districts for the provision of services to urban development, particularly including sanitary sewer and storm water management services. Towns may also undertake stream and lake improvements and watershed protection projects.

Cities and Villages

Cities and villages possess authority to implement both urban point and nonpoint source pollution abatement plans. Cities and villages possess general home rule authority and have specific authority to construct, operate, and maintain a sanitary sewerage system. In addition, cities and villages have authority to convey and treat storm waters, including construction, operation, and maintenance of urban storm water conveyance, storage, and treatment facilities. Cities and villages can undertake nonpoint source pollution abatement activities in conjunction with traditional public works activities, including litter and leaf control, animal waste control, and street sweeping and cleaning. Thus, cities and villages are granted all of the powers required to implement the point and nonpoint source pollution abatement elements of the plan in urban areas. Those powers may be exercised in the promulgation of construction erosion control ordinances, the construction and operation of storm water management systems, the development and enforcement of urban sanitation and refuse control ordinances, and the construction, operation, and maintenance of sanitary sewerage systems and attendant sewage treatment works.

Counties

Counties are authorized to engage in soil and water conservation projects, lake and river improvements, property acquisitions, water protection, and solid waste management. In addition, counties may regulate nonpoint source pollution through their planning, zoning, subdivision, building, and health code authorities. Counties are also important to the functioning of the soil and water conservation districts. Not only are such districts fiscally dependent upon county boards, but in effect the districts are governed by a county board committee. In implementation of the Okauchee Lake water quality management plan, therefore, it would be necessary for the Waukesha County Board and the County Soil and Water Conservation District to work together in a fully integrated effort.

Soil and Water Conservation Districts

Soil and water conservation districts, as authorized under Section 92.05 of the Wisconsin Statutes, have the authority to develop plans for the conservation of soil and water resources and for the prevention of soil erosion. In addition, the districts have authority to request the County Board of Supervisors to adopt special land use regulations that would implement such plans in unincorporated areas. Such adoption, however, requires a referendum in which a simple majority of the eligible electors who voted, and were residents of the area affected, approve the proposed regulations. Soil and water conservation districts have the authority to acquire--through eminent domain proceedings--any property or rights therein for watershed protection, soil and water conservation, flood prevention works, and fish and wildlife conservation and recreational works.

Regional Planning Commissions

In its role as a coordinating agency for water pollution control activities within southeastern Wisconsin, the Regional Planning Commission utilizes the locally adopted and certified regional plan elements as a basis for review of federal and state grants in aid, discharge permits, and sanitary sewer extensions. The Commission provides technical assistance pertaining to water quality management topics, and further promotes plan implementation through community assistance planning services, as appropriate. In addition, the Commission stands ready to provide a forum for the discussion of intergovernmental issues which may become critical to the orderly and timely implementation of water quality management projects. These indirect plan implementation functions must be distinguished from the plan implementation responsibilities of the other management agencies, through whose direct actions the plans are converted to reality.

Wisconsin Department of Natural Resources

The responsibility for water pollution control in Wisconsin is centered in the Wisconsin Department of Natural Resources. The basic authority and accompanying responsibilities relating to the water pollution control functions of the Department are set forth in Chapter 144 of the Wisconsin Statutes. Under this chapter, the Department is given broad authority to prepare as well as to approve or endorse water quality management plans; to establish water use objectives and supporting water quality standards; to review and approve all plans and specifications for components of sanitary sewerage systems; to conduct research and demonstration projects on sewerage and waste treatment matters; to operate an examining program for the certification of sewage treatment plant operators; to order the installation of centralized sanitary sewerage systems; to review and approve the creation of joint sewerage systems and metropolitan sewerage districts; to regulate water level elevations; and to administer a financial assistance program for the construction of pollution prevention and abatement facilities, or for the application of land management measures. The Wisconsin Statutes also authorize the Department to consider conformance with an approved areawide water quality management plan when reviewing locally proposed sanitary sewer extensions. This permissive authority is in addition to the Department's mandatory review for engineering soundness and for relation to public health and safety.

Under Chapter 147 of the Wisconsin Statutes, the Department is given broad authority to establish and carry out a pollutant discharge elimination program in accordance with the policy guidelines set forth by the U. S. Congress under the federal Water Pollution Control Act. Pursuant to this authority, the Department has established a waste discharge permit system. No permit may be issued by the Department for any discharge from a point source of pollution that is in conflict with any areawide water quality management plan approved by the Department. Also under this authority, the Department has rule-making powers to establish effluent limitations, water quality-related limitations, performance standards related to classes or categories of pollution, and toxic and pretreatment effluent standards. All permits issued by the Department must include conditions that waste discharges are to meet, in addition to effluent limitations, performance standards, effluent prohibitions, pretreatment standards, and any other limitations needed to meet the adopted water use objectives and supporting water quality standards. As appropriate, the permits may include a timetable for appropriate action on the part of the owner or operator of any point source waste discharge. The Wisconsin Department of Natural Resources has established a normal operating level for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes ranging from 872.60 to 873.71 feet NGVD.

Wisconsin Department of Health and Social Services, Division of Health

In performing its functions relating to the maintenance and promotion of public health, the Wisconsin Division of Health is charged with the responsibility of regulating the installation and operation of private septic tank sewage disposal systems. The Division reviews plats of all land subdivisions not served by public sanitary sewerage systems and may object to such plats if onsite sanitary waste disposal facilities are not properly provided for in the plat layout.

University of Wisconsin-Extension

The Extension Service operates on a contractual basis with counties to provide technical and educational assistance within the counties. Of particular importance to implementation of the areawide water quality management plan is the provision of technical assistance by the Extension Service to county soil and water conservation districts, county boards, and county zoning and planning committees. In addition, the Extension Service is well equipped to provide educational services, especially in the areas of nonpoint source pollution and sludge management.

U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency has broad powers under the federal Water Pollution Control Act to administer federal grants-in-aid for the construction of publicly owned waste treatment works and related sewerage facilities; to promote and fund areawide waste treatment planning and management; to set and enforce water quality standards, including effluent limitations, through the establishment of water use objectives and supporting water quality standards and through the conduct of water quality inventories and inspection and monitoring programs; and to establish a national pollutant discharge elimination system. The Environmental Protection Agency, thus, acts as the key federal water pollution control agency and must approve all basin and areawide water quality management plans as certified to it by appropriate state agencies.

U.S. Department of Agriculture, Soil Conservation Service

The U.S. Department of Agriculture, Soil Conservation Service, administers resource conservation and development projects under Public Law 566 and provides technical and financial assistance through soil and water conservation districts to landowners in the planning and construction of measures for land treatment, agricultural water management, and flood prevention, and for public fish, wildlife, and recreational development. The Soil Conservation Service also conducts detailed soils surveys and provides interpretations as a guide to the use of soil survey data in local planning and development. The technical assistance programs of the Soil Conservation Service are of great importance to implementation of the areawide water quality management plan.

U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service

The U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, administers the federal Agricultural Conservation Program (ACP), which provides grants to rural landowners in partial support of carrying out approved soil, water, woodland, wildlife, and other conservation practices. These grants are awarded under yearly and long-term assistance programs, providing guaranteed funds for carrying out approved conservation work plans. Grants from the federal Agricultural Conservation Program are important to implementation of the areawide water quality management plan. In addition, the Agricultural Stabilization and Conservation Service has relatively new authority under Section 208(J) of the federal Water Pollution Control Act to administer a cost-sharing grant program for the purpose of installing and maintaining agricultural measures found needed to control nonpoint source pollution.

PRIVATE ACTION FOR WATER POLLUTION CONTROL

The foregoing discussion deals exclusively with water quality management by units and agencies of government. Direct action may also be taken, however, by private individuals or organizations to effectively abate water pollution. As shown later in the "Alternative Water Quality Management Measures" chapter, some of the most important, yet least costly, management practices can be readily carried out by individual citizens. In addition, most of the activities of the agencies previously discussed require the cooperation and support of individual citizens and of citizen groups in order to be effectively implemented.

Chapter VII

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS

The Regional Planning Commission adopted areawide water quality management plan, as set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, recommends water use objectives and supporting water quality standards for all major lakes and streams in the Region. The water use objectives recommended for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, as well as for the Oconomowoc River are full recreational use and support of a healthy warmwater fishery. The water quality standards which support these objectives are set forth in Table 29. Standards are recommended for temperature, pH, dissolved oxygen, fecal coliform, residual chlorine, un-ionized ammonia nitrogen, and total phosphorus.

The total phosphorus standard of 0.02 milligram per liter (mg/l) applies to lakes during spring turnover, when the lakes are not stratified and maximum vertical mixing is occurring. The achievement of this recommended standard is expected to prevent excessive macrophyte and algae growths in most lakes, although lake rehabilitation techniques may also be required to avoid seasonal problems associated with the recycling of phosphorus from the bottom sediments. Excessive total phosphorus levels stimulate large growths of algae and possibly aquatic macrophytes, which interfere with recreational use. As these plant masses die and decompose, dissolved oxygen depletions may result which also threaten the survival of fish and aquatic life. Although many factors are involved, one pound of phosphorus may produce from 1,000 to 10,000 pounds wet weight of aquatic plant material. Upon the decomposition of this amount of

Table 29

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

Parameter	Standard
Maximum Temperature	$89^{\circ}F$[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 5°F for streams and 3°F for lakes.*

[b] *Dissolved oxygen and temperature standards apply to streams and 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 monthly geometric mean of 400 per 100 ml in more than 10 percent of all samples during any month.*

[d] *The values presented for lakes are the critical total phosphorus concentrations which apply only 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 a body of water shall not be present in such amounts as to interfere with public rights in waters of the State. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the State. Materials producing color, odor, taste, or unsightliness shall not be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[f] *Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. The determination of the toxicity of a substance shall be based upon the available scientific data base. References to be used in determining the toxicity of a substance shall include, but not be limited to, Quality Criteria for Water, EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976, and Water Quality Criteria 1972. EPA R3-73-003, National Academy of Engineering, U. S. Government Printing Office, Washington, D. C., 1974. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, or undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in Water Quality Criteria 1972 and Standard Methods for the Examination of Water and Wastewater, 14th Edition. American Public Health Association, New York, 1975, or other methods approved by the Department of Natural Resources.*

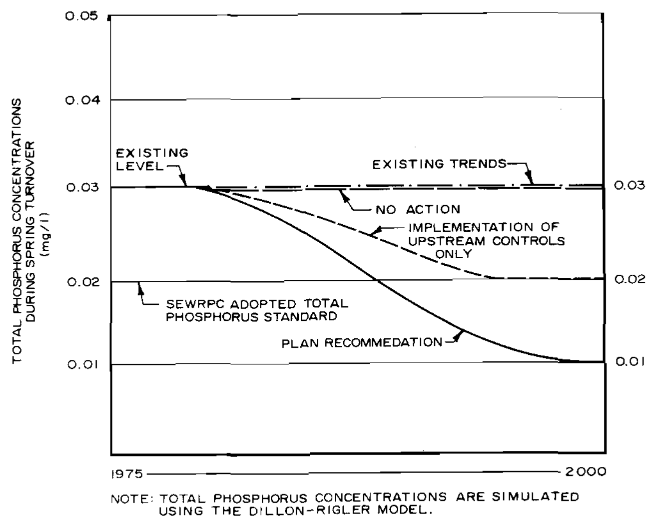
Source. SEWRPC.

plant material generated from one pound of phosphorus, 100 pounds or more of dissolved oxygen would be consumed.

The phosphorus concentration in the lake is directly related to the phosphorus load contributed to the lake via tributary runoff and atmospheric sources, although some recycling of phosphorus from the lake bottom sediments may also occur. Figure 11 indicates the total phosphorus concentrations expected to occur in Okauchee Lake during spring turnover under alternative water quality management actions in the lake watershed, as estimated with the Regional Planning Commission's water quality simulation model. Failure to implement any management measures in the lake watershed may be expected to result in continued excessive phosphorus levels, and a resulting decrease in water quality and water use potential. Complete implementation of the plan recommendations, including watershed management measures and in-lake management techniques, set forth in this report is estimated to result in the achievement of the phosphorus standard of 0.02 mg/l and subsequently to provide water quality suitable for a full range of recreational use opportunities and for support of a healthy warmwater fishery.

Figure 11

TOTAL PHOSPHORUS LEVELS IN OKAUCHEE LAKE UNDER ALTERNATIVE POLLUTION CONTROL ACTIONS



Source: SEWRPC.

Chapter VIII

ALTERNATIVE WATER QUALITY MANAGEMENT MEASURES

INTRODUCTION

Potential measures for water quality management of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes include point and nonpoint source pollution control measures and lake rehabilitation techniques. Point source pollution control measures consist of the design, construction, and operation of sanitary sewerage systems. Nonpoint source pollution control measures consist of the improved management of both urban and rural land uses to reduce pollutants discharged to the lake by direct overland drainage, by drainage through natural or man-made channels, and by groundwater inflow. Lake rehabilitation techniques either directly treat the symptoms of lake eutrophication, such as macrophyte harvesting, or alter the characteristics of the lake basin which may be interfering with the achievement of water use objectives, such as limited dredging of bottom sediments.

In developing alternative water quality management measures, it was assumed that the recommendations set forth in the adopted areawide water quality management plan for the Oconomowoc River drainage area upstream of Okauchee Lake would be implemented. Accordingly, the recommendations in this report deal primarily with water quality management measures in the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, or within the lake basins themselves.

POINT SOURCE POLLUTION CONTROL

As recommended in the regional sanitary sewerage system plan, adopted by the Commission in 1974, the Oconomowoc sewage treatment plant would serve as a regional facility to provide wastewater treatment service to the Oconomwoc-Lac La Belle, Oconomowoc Lake, Okauchee Lake, North Lake, Pine Lake, Beaver Lake, and Silver Lake sewer service areas. That recommendation was reaffirmed in the regional water quality management plan adopted by the Commission in 1979.

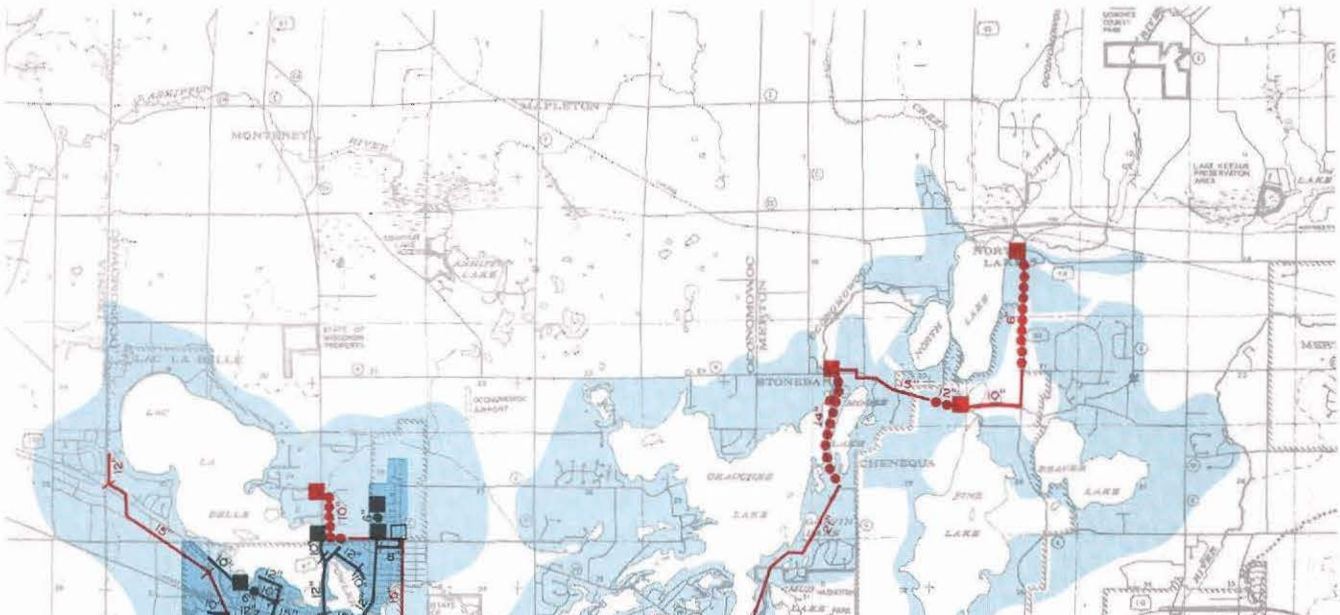
In 1978, the wastewater treatment facility serving the City of Oconomowoc was upgraded to provide secondary waste treatment, tertiary waste treatment, and auxiliary waste treatment for effluent disinfection, and was expanded to provide an average hydraulic design capacity of 4.0 million gallons per day (mgd). It is anticipated that the extension of service to existing and proposed urban development around Lac La Belle, Okauchee Lake, North Lake, Pine Lake, Beaver Lake, Silver Lake, and Oconomowoc Lake and the flow from the existing and proposed sewer service area of the City of Oconomowoc will require an average hydraulic capacity of 3.1 mgd by 1985. Final extension of sanitary sewer service to urban development around Lac La Belle, Okauchee Lake, Pine Lake, Beaver Lake, North Lake, and Silver Lake may be expected to require an average hydraulic design capacity at the City of Oconomowoc sewage treatment plant of 6.5 mgd by the year 2000. Therefore, additional capacity may be expected to be required at the Oconomowoc facility before the year 2000. The proposed sewer service area and trunk sewer system are shown on Map 22. As of 1975, there were no known industrial point sources of wastewater requiring treatment or elimination in the area tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes or to streams tributary to the lakes.

NONPOINT SOURCE POLLUTION CONTROL

Nonpoint sources of water pollution include urban sources such as runoff from residential, commercial, indus-

Map 22

RECOMMENDED SANITARY SEWERAGE SYSTEM PLAN FOR THE OCONOMOWOC-LAC LA BELLE, OCONOMOWOC LAKE, OKAUCHEE LAKE, NORTH LAKE, PINE LAKE, BEAVER LAKE, AND SILVER LAKE SEWER SERVICE AREAS--MIDDLE ROCK RIVER SUBREGIONAL AREA: 2000



Source: SEWRPC.

trial, transportation, and recreational land uses, construction activities, and septic tank systems; and rural sources such as runoff from cropland, pasture, and woodland, livestock wastes, and atmospheric contributions.

The water quality analyses presented previously in this report indicate that a reduction in nutrient loads from nonpoint sources in the tributary area will be needed to meet the recommended water use objectives and supporting water quality standards. Alternative nonpoint source control measures are set forth in Table 30. The specific practices applicable to that portion of the drainage area near STH 16 south of Ice House Bay is presented in Appendix B as a separate analysis, in accordance with requests of the Okauchee Lake Management District Commission. About a 30 percent reduction in the existing nonpoint source loads from the drainage area directly tributary to Okauchee Lake is needed to meet the recommended water use objectives and supporting standards.

LAKE REHABILITATION TECHNIQUES

Although preventing further deterioration in lake water quality conditions, the reduction of nutrient inputs to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes alone should not be expected to result in the elimination of existing water quality problems. In mesotrophic or eutrophic lakes, especially in the presence of anaerobic conditions in the hypolimnion such as occur in Okauchee Lake, significant amounts of phosphorus may be released from the existing sediments to the overlying water column. Furthermore, in all three lakes, macrophytes may continue to proliferate, rooting in the nutrient-rich bottom sediments, regardless of the nutrient content of the overlying water. The water quality improvements expected from a reduced nutrient input may be inhibited or prevented by these conditions. If this occurs, or if other characteristics of the lake result in restricted water use potential, the application of lake rehabilitation techniques should be considered.

The applicability of specific lake rehabilitation techniques is highly dependent on lake characteristics. The success of any lake rehabilitation technique can seldom be guaranteed since the state-of-the-art is still in the early stages of development. Because of the relatively high cost of applying most techniques, a cautious approach to implementing lake rehabilitation techniques is recommended. Certain lake rehabilitation techniques should be applied only to lakes in which: 1) nutrient inputs to the lake have been reduced to below the critical level; 2) there is a high probability of success; and 3) the possibility of adverse environmental impacts is minimal.

Alternative lake rehabilitation and in-lake management measures discussed below include hypolimnetic aeration, dredging, sediment covering, drawdown, nutrient inactivation, dilution/flushing, selective discharge, macrophyte harvesting, algae harvesting, chemical controls, and fish management. All cost figures related to the measures discussed are presented in January 1980 dollars.

Hypolimnetic Aeration

The purpose of hypolimnetic aeration is to provide oxygen to the hypolimnion of a stratified lake without disrupting the stratification. Lower Okauchee and Upper Oconomowoc Lakes are too shallow to thermally startify during summer and, therefore, do not contain a true hypolimnion. The hypolimnion of Okauchee Lake underlies about 420 acres, or about 35 percent of the lake surface area. During some portions of the summer, the entire volume of the hypolimnion was found to have dissolved oxygen levels of less than 2.0 milligrams per liter (mg/l). To provide hypolimnetic aeration, typically the bottom water is air-lifted up a vertical tube, with oxygenated water returned to the hypolimnion, as shown in Figure 12 and on Map 23. Aeration of the hypolimnion increases the decomposition of organic matter and promotes sorption of phosphorus by the hydrous oxides of iron and manganese present in the lake bottom sediments. The result is that the concentration of phosphorus in the bottom waters may be substantially reduced and oxygen levels improved, resulting in an improved habitat for fish and aquatic life. Hypolimnetic aeration also provides additional habitat for zooplankton, which can seek refuge from feeding fish during the day in the dark bottom lake waters and migrate toward the surface at night to graze on algae.

Table 30

GENERALIZED SUMMARY OF METHODS AND EFFECTIVENESS OF NONPOINT SOURCE POLLUTION ABATEMENT MEASURES

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	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	2-5	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	2-5	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	10-30	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 $2,300 and the cost of an alternative system is $4,500. The annual maintenance cost of a disposal system is $45. A holding tank would cost $1,300 with an annual operation and maintenance cost of $1,200. However, because septic system management is an existing function necessary for the preservation of public health and the maintenance of drinking water supplies, these costs are not included as part of the areawide water quality maintenance plan
	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	30-50	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 $38,000. The cost of the operation and maintenance of a sweeper is about $10 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	2-5	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 $25 per ton of leaves

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Urban (continued)	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	2-5	Determine curb miles for street sweeping; vary percent of urban area 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 $8
	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 chapter 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
	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	2-5	Increase current expenditures by approximately 15 percent. The annual cost per person is about $4
	Parking lot storm water 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	5-10	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 storm water detention and treatment facilities is estimated at $9,000 per acre of parking lot area, with an annual operation and maintenance cost of about $100 per acre.
	Onsite storage—residential	Remove connections to sewer systems; construct onsite storm water storage measures for subdivisions	5-10	Remove roof drains and other connections to sewer system wherever needed; use lawn aeration if applicable; apply dutch drain storage facilities to 15 percent of residences. The capital cost would approximate $200 per house, with an annual maintenance cost of about $10

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Urban (continued)	Storm water storage—urban	Store storm water runoff from urban land in surface storage basins or, where necessary, subsurface storage basins	10-35	Design all storage facilities for a 1.5 inch of 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 storm water storage would range from $1,000-$10,000 per acre of tributary drainage area, with an annual operation and maintenance cost of about $20-$40 per acre
	Storm water 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 storm water following storage	10-50	To be applied only in combination with storm water storage facilities above; general cost estimates for microstrainer treatment and ozonation were used; same costs were applied to existing urban land and proposed new urban development. Storm water treatment has an estimated capital cost of from $900-$7,000 per acre of tributary drainage area, with an average annual operation and maintenance cost of about $35 per acre
Rural	Conservation practices	Includes such practices as strip cropping, contour plowing, crop rotation, pasture management, critical area protection, grading and terracing, grassed waterways, diversions, wood lot management, fertilization and pesticide management, and chisel tillage	Up to 50	Costs for Soil Conservation Service (SCS)-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 $0.30-$14 per acres of rural land, with an average annual operation and maintenance cost of from $2-$4 per rural acre

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Rural (continued)	Animal waste control system	Construct stream bank 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	50-75	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 $90 per animal unit and $10 per animal unit, respectively. The capital cost of a liquid and slurry storage facility is about $425 per animal unit, with an annual operation and maintenance cost of about $30 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	50-75	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 about $250 per tributary acre, with an annual operation and maintenance cost of $10 per acre
	Bench terraces	Construct bench terraces, thereby reducing the need for many other conservation practices on sloping agricultural land	75-90	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 $625 per acre, with an annual operation and maintenance cost of $45 per acre

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
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 contact 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 to for every 50,000 population. The cost of one person, materials, and support is estimated at $33,000 per year
	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	20-40	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 $2,200 and $400 per acre under construction, respectively
	Materials storage and runoff control facilities	Enclose industrial storage sites with diversions; divert runoff to acceptable outlet or storage facility; enclose salt piles and other large storage sites in crib and dome structures	5-10	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 $1,100 per acre of industrial land. Material storage control costs are estimated at $30 per ton of material
	Stream protection measures	Provide vegetative buffer zones along streams to filter direct pollutant runoff to the stream; construct stream bank protection measures, such as rock riprap, brush mats, tree revetment, jacks, and jetted willow poles where needed	5-10	Apply a 50-foot-wide vegetative buffer zone on each side of 15 percent of the stream length; apply stream bank 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	0-3	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 evaluated for each watershed. 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 estimation of costs of specific practices for any one watershed. 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.*

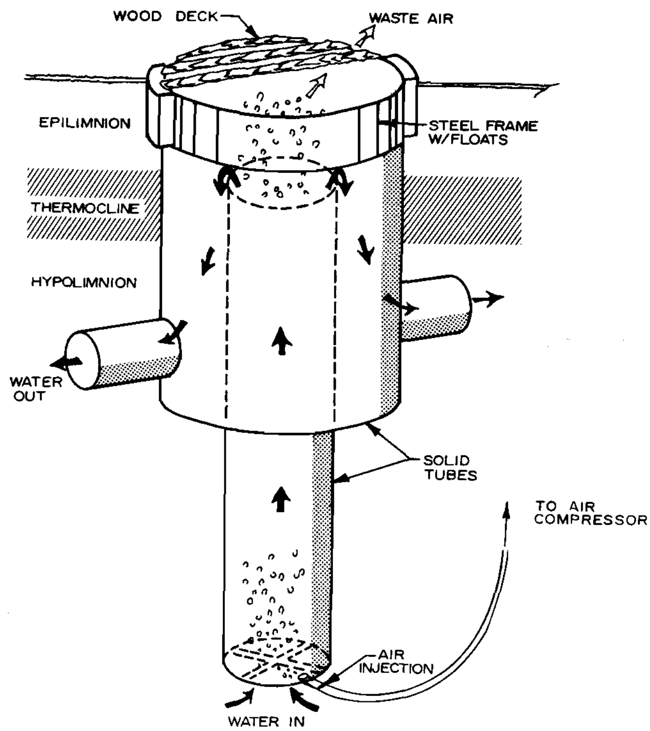
[b] *For a more detailed description of pollution control measures for diffuse sources, see SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control for Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff.*

[c] *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.*

Source: SEWRPC.

Figure 12

TYPICAL HYPOLIMNETIC AERATION SYSTEM FOR AN INLAND LAKE



Source: Adapted by SEWRPC from A.W. Fast, "The Effects of Artificial Aeration on Lake Ecology," U.S. EPA Water Pollution Control Research Series, 16010EXE, 1971.

Increased zooplankton populations can effectively reduce certain species of algae.

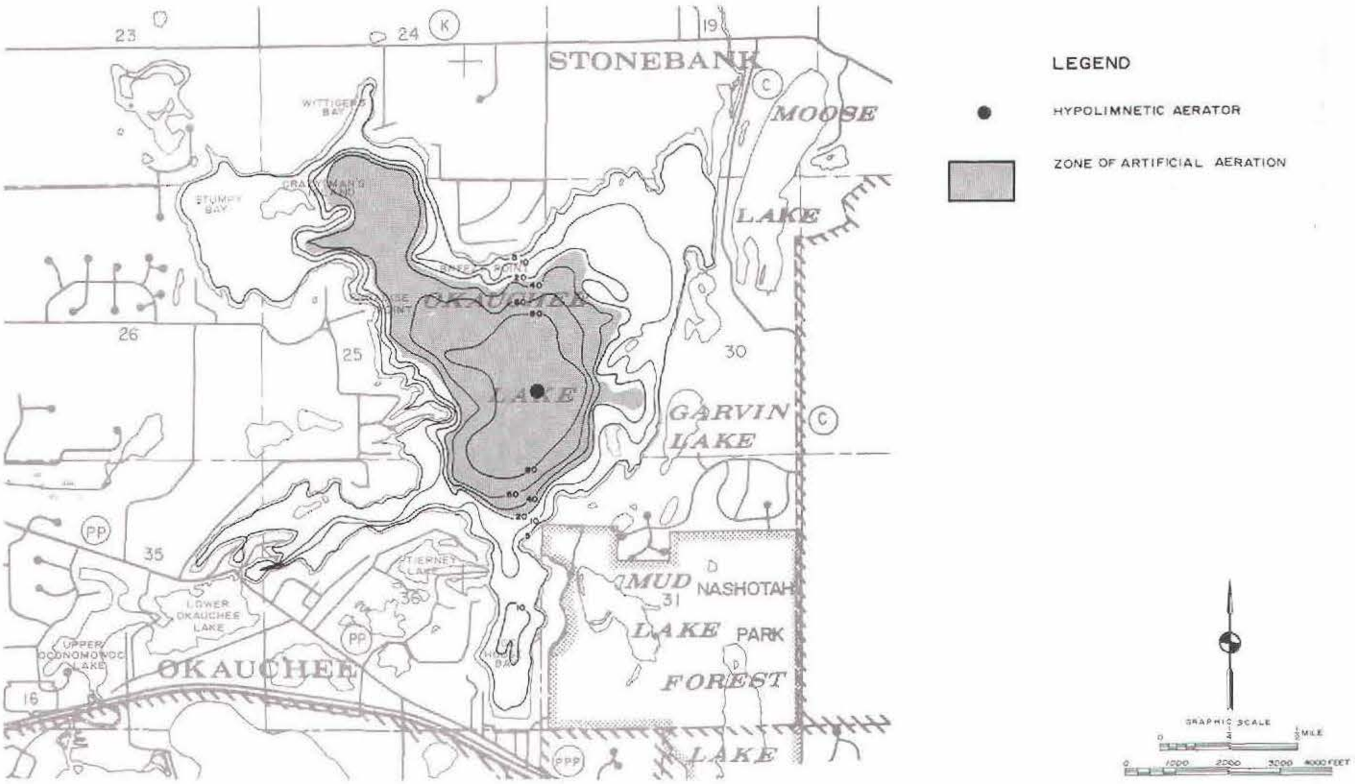
Hypolimnetic aeration in Okauchee Lake would involve a capital cost of about $300,000, with an annual operation and maintenance cost of about $15,000. It is unlikely that the effects of nonpoint source pollution control measures in the lake watershed alone would--at least for some years--substantially improve dissolved oxygen conditions in the hypolimnion. Therefore, hypolimnetic aeration could be implemented even prior to the control of nonpoint pollution sources, in order to provide additional and more immediate water quality improvement.

Measures for Controlling Sediment Effects on Water Column and Macrophyte Growth

Dredging, sediment covering, and drawdown for sediment consolidation serve to either deepen the lake or to modify the bottom sediments so they are less likely to release nutrients to the water column or support excessive macrophyte growth. Because of the relatively high cost of these practices, and the temporary disruption to the lake community which occurs when these practices are implemented on a large scale, these practices are more appropriate for Lower Okauchee and Upper Oconomowoc Lakes, being warranted on only a very limited scale for Okauchee Lake. If actions to reduce nutrient inflows are not fully effective in reducing the in-lake nutrient concentration, then additional sediment controls could be considered. Drawdown of Okauchee Lake itself is not practical because of the large amount of flow contributed to the lake by the Oconomowoc River and because diverting the Oconomowoc River around the lake--a distance of at least five miles--is not practical. However, drawdown of Lower Okauchee and Upper Oconomowoc Lakes may be considered. Total successful drawdown of Lower Okauchee and Upper Oconomowoc Lakes would require that the Oconomowoc River be temporarily diverted around the two lakes. Diversion of the Oconomowoc River around Lower Okauchee and Upper Oconomowoc Lakes is technically possible by the construction of a diversion channel, about 6,000 feet in length, south of the two lakes as shown on Map 24. The channel would be constructed about nine feet deep, with grass-lined slopes, a bottom width of 25 feet, and a top width of 45 feet. The cost of the diversion channel would approximate $3.5 million. In addition, there would be significant environmental costs which would have to be carefully considered. The construction of a diversion channel would require the purchase and removal of about four houses, construction of five new bridges, and changes in local floodland regulations. Following the temporary diversion of the Oconomowoc River around the the two lakes, Lower Okauchee and Upper Oconomowoc Lakes

Map 23

PLAN ALTERNATIVE FOR PLACEMENT OF HYPOLIMNETIC AERATION SYSTEM IN OKAUCHEE LAKE AND THE ZONE OF ARTIFICIAL AERATION



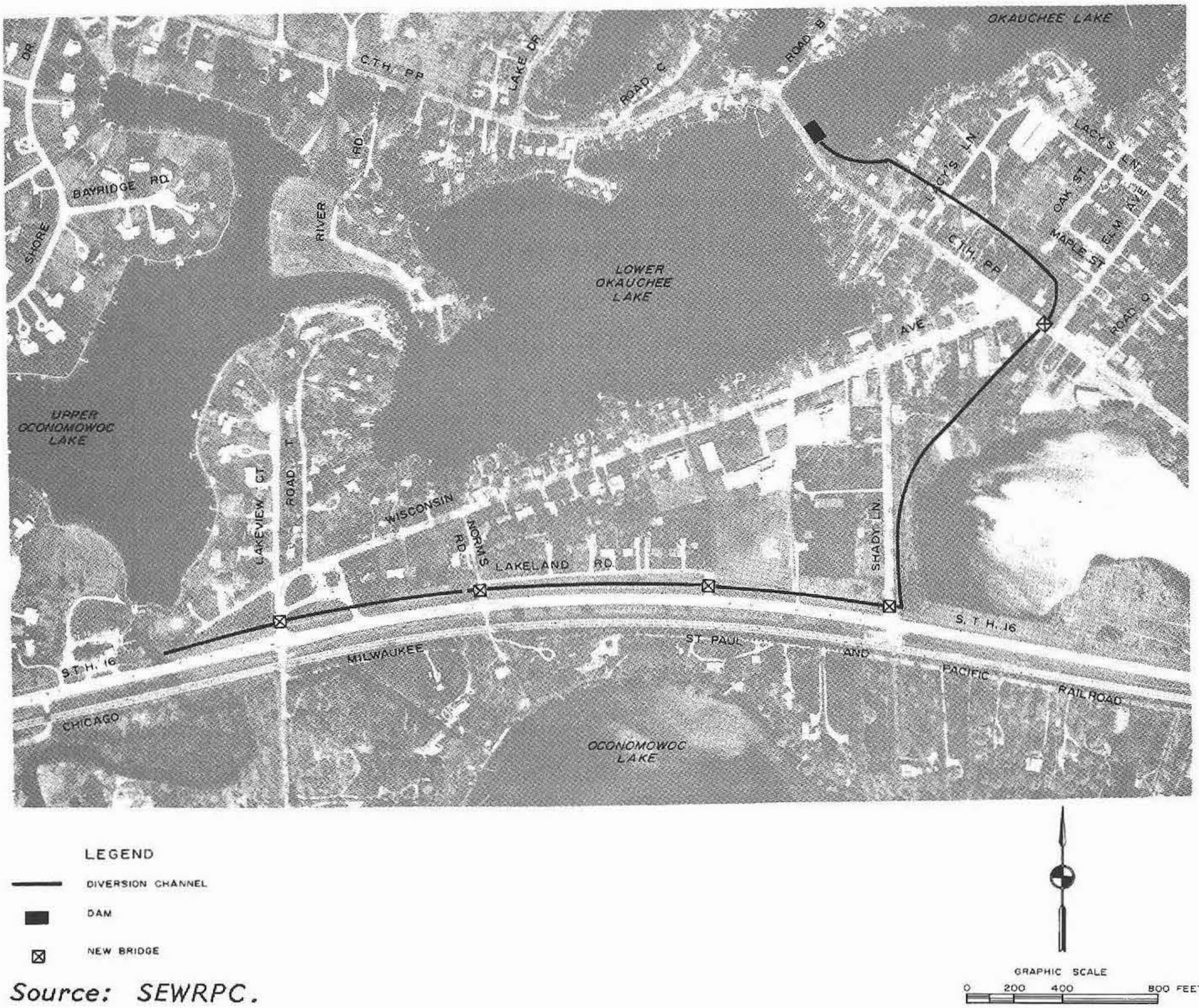
Source: SEWRPC.

could be totally drained by opening the floodgates of the Upper Oconomowoc Lake outlet. The water level of Okauchee Lake would not be affected by this alternative. The drawdown could increase the depth of these relatively shallow lakes by up to one foot. Greater increases in depth could be expected for Lower Okauchee Lake because of the greater organic content of its bottom sediments, compared to Upper Oconomowoc Lake. The organic sediments, upon drying, are more likely to consolidate. The consolidated sediments could be expected to reduce macrophyte growths, reduce nutrient release from the bottom sediments, and reduce turbidity caused by the resuspension of soft, flocculent bottom sediments. The drawdown would occur over winter and may need to be periodically repeated. Drawdown of Lower Okauchee and Upper Oconomowoc Lakes and a nine-foot drawdown of Okauchee Lake could also be accomplished without the construction of a diversion channel by only opening the Upper Oconomowoc Lake floodgates. However, under this alternative, Okauchee Lake would require 110 to 210 days to refill to normal lake levels.

Dredging and covering the bottom sediment with sand and/or a plastic lining could be useful on a limited scale to eliminate excessive macrophyte growths in localized areas. Dredging with an hydraulic dredge would cost about $2.00 per cubic yard of bottom sediment removed. The principal areas which may be expected to benefit from dredging activities are Ice House Bay, Tierney Lake, the Tierney Lake channel, and Upper Oconomowoc Lake, as shown on Map

Map 24

PLAN ALTERNATIVE FOR THE DIVERSION OF THE OCONOMOWOC RIVER AROUND LOWER OKAUCHEE LAKE AND UPPER OCONOMOWOC LAKE

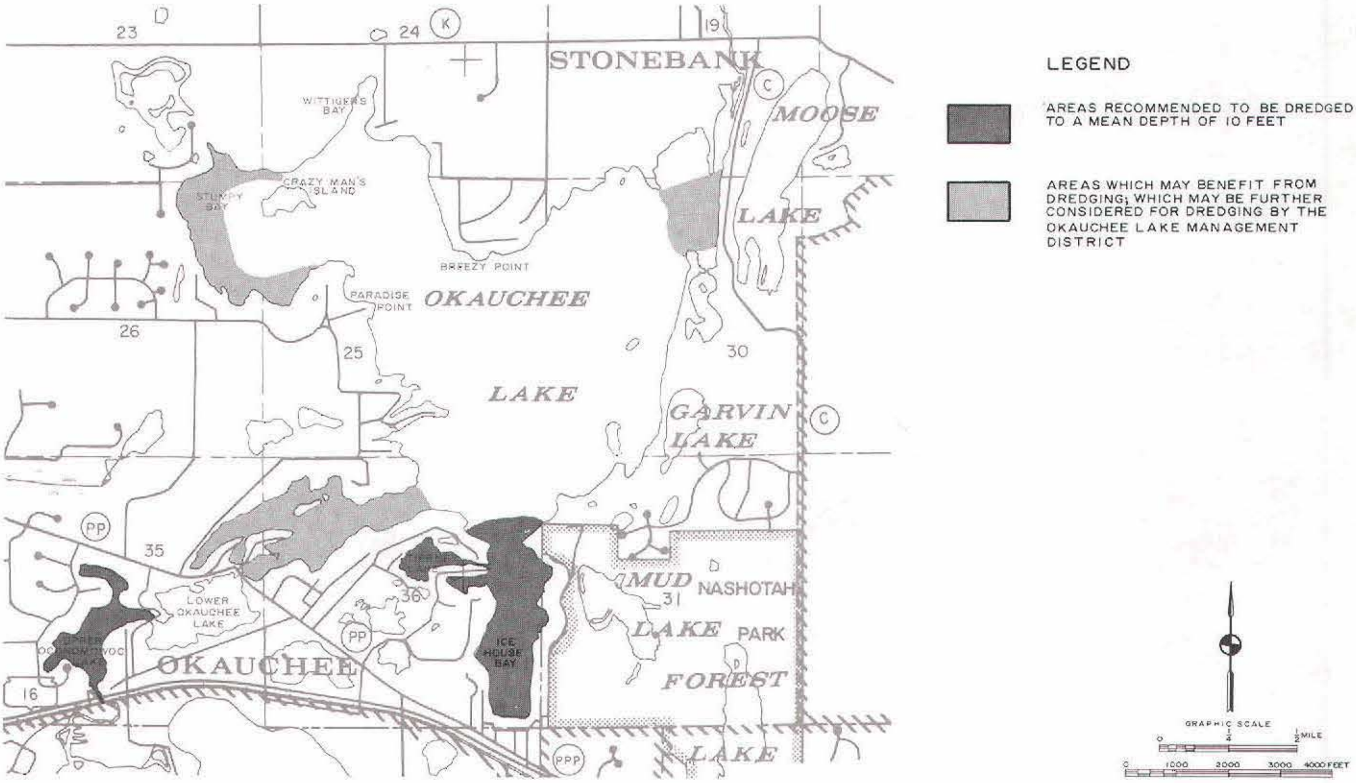


Source: SEWRPC.

25. Dredging Ice House Bay and Upper Oconomowoc Lake to a mean depth of 15 feet, and Tierney Lake and the Tierney Lake channel to a mean depth of 10 feet would involve a total capital cost of about $2.9 million. This new depth should eliminate macrophyte growths over large portions of the areas. As an alternative proposal, dredging all of these areas to a mean depth of about 10 feet would cost about $1.25 million, but would provide a lower reduction in macrophyte growths. However, macrophyte growths would still be significantly reduced over existing levels under this limited dredging alternative, and recreational opportunities would not be expected to be impaired by growth of macrophytes at the water surface--based upon the existing relationship of macrophyte growth to water depth in various areas of the lake.

Map 25

PLAN ALTERNATIVE FOR DREDGING ICE HOUSE BAY, TIERNEY LAKE, THE TIERNEY LAKE CHANNEL, AND UPPER OCONOMOWOC LAKE

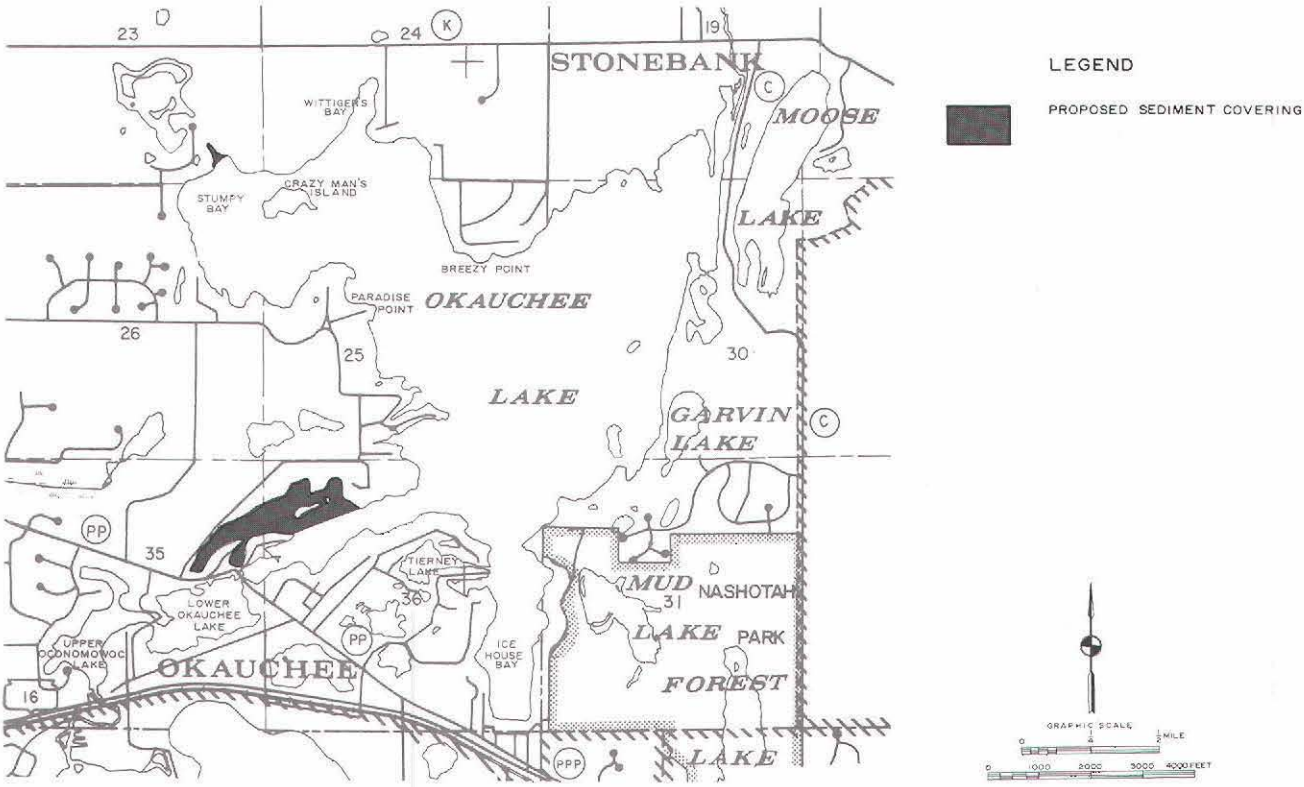


Source: SEWRPC.

Areas of Okauchee Lake near the Oconomowoc River inlet and outlet, and the northwest portion of Okauchee Lake also include shallow water areas which may benefit from dredging. However, the existing macrophyte harvesting program is believed to provide adequate control of macrophytes near the lake outlet and the northwest portion of Okauchee Lake. These areas could be further considered for dredging by the Okauchee Lake Management District at a future date. The potential dredging area located near the inlet encompasses about 24 acres. Dredging in this area to provide an average water depth of 8 feet would require removal of about 116,000 cubic yards of material at a cost of $290,000. Based on the sediment loading rate to Okauchee Lake from the Oconomowoc River and the accumulation of sediment as a consequence of decomposition of vegetation in the potential dredging area, the dredged area should not refill with silt and debris to its present depth for a period of from 50 to 70 years. It should be noted that the Okauchee Lake inlet lies within a valuable wildlife habitat which could be seriously disturbed by the dredging activity. Moreover, the presence of macrophyte growth at the lake inlet may serve to filter out some

Map 26

PLAN ALTERNATIVE FOR SEDIMENT COVERING FOR OKAUCHEE LAKE



Source: SEWRPC.

of the larger organic and inorganic materials entering the lake via the Oconomowoc River.

Prior to the actual dredging of Okauchee Lake, the effect of the arsenic residue from sodium arsenite applications--made to the lake to control macrophyte growths--on groundwater quality at the disposal sites would need to be investigated. The effect of dredging on the habitat and spawning areas of a threatened fish species, the pugnose shiner, would also need to be assessed prior to dredging. For areas not dredged which do experience excessive macrophyte growths, sediment covering could be used to provide a bottom substrate less suitable for macrophyte growth and less likely to release phosphorus to the waters. Sediment covering would cost about $2,000 per acre, or about $82,000 for the areas totaling about 41 acres, as shown on Map 26.

Nutrient Inactivation

The purpose of nutrient inactivation is to: 1) change the form of a nutrient to make it unavailable to plants; 2) remove the nutrient from the photic (light-penetrated) zone; and 3) prevent release or recycling of potentially available nutrients from the lake sediments. Nutrient inactivation of phosphorus, which is usually accomplished by application of aluminum or other metallic salt, can be conducted for the entire lake--if nutrients from the epilimnion as well as the hypolimnion are to be removed--or for just the hypolimnion--if only nutrients from the hypolimnion are to be removed. Nutrient inactivation is most applicable to lakes which have long hydraulic residence times or in which recycling of phosphorus from the bottom sediements is significant. The hydraulic residence time of Okauchee Lake is moderate--about 10 months--and there is no indication that the amounts of phosphorus being released from the bottom sediments are having significant water quality effects. However, nutrient inactivation may be an effective technique for removing nutrients from the water comumn of Okauchee Lake, if combined with watershed management practices to reduce external phosphorus loads to the lake. The application of nutrient inactivation to the entire Okauchee Lake would cost aboug $120,000; application to the hypolimnion would only cost about $42,000. The treatment could need to be repeated periodically. The hydraulic residence times of Lower Okauchee and Upper Oconomowoc Lakes are too short--only about four to six days--to allow for successful inactivation of the nutrients.

Dilution/Flushing

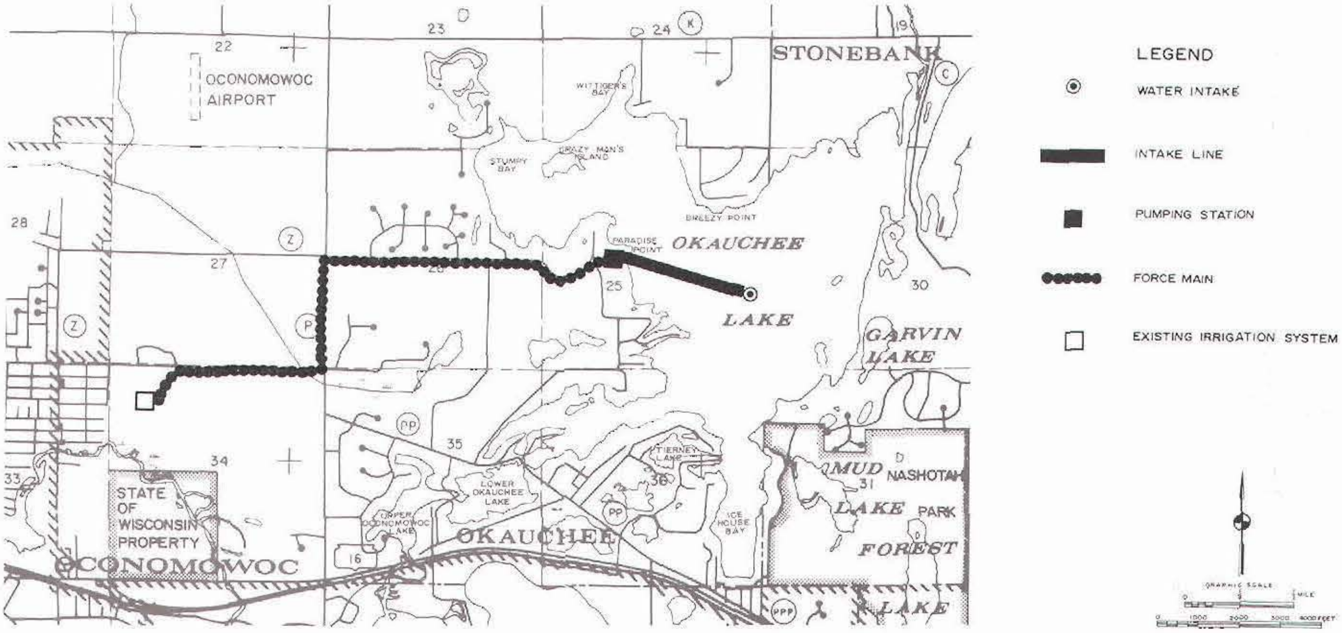
Dilution/flushing is intended to alleviate excessive algal growths and associated problems by reducing nutrient levels within a lake through the replacement of nutrient-rich waters with nutrient-poor waters, thereby flushing phytoplankton and the nutrients contained therein from the lake. Lake restoration projects have attempted nutrient dilution by two procedures: 1) pumping water out of the lake, thus permitting the increased inflow of nutrient-poor groundwater; and 2) routing additional quantities of nutrient-poor surface waters into the lake. Dilution/flushing is most applicable for lakes which have very long hydraulic residence times, so that significant natural flushing does not occur, or where the lake has received excessive pollutant loadings which have resulted in a highly eutrophic condition. In the latter case, once the pollution source has been removed, dilution/flushing may be effective in reducing the time of water quality improvement in the lake. Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes are not highly eutrophic lakes and do not have excessive hydraulic residence times. Therefore, dilution/flushing would not be expected to result in a significant increase in water quality conditions in the lakes.

Selective Discharge

Selective discharge has been employed to substantially improve the dissolved oxygen levels near the bottom of a lake and to increase the nutrient output from a lake by up to 25 percent. This technique involves releasing anaerobic, nutrient-rich water from the hypolimnion during summer stratification. This technique may be applicable for Okauchee Lake, but is not applicable for Lower Okauchee or Upper Oconomowoc Lakes, which are too shallow to stratify. Typically, the technique is readily employed in lakes with suitable outlet controls, but water may also be pumped from the hypolimnion and discharged downstream. Pumping from one site in the hypolimnion the equivalent of one-half of the volume of the hypolimnion of Okauchee Lake each summer, would require a capital cost of about $860,000 and an average annual operation and maintenance cost of about $40,000. The water quality impacts may be expected to be favorable. In order to avoid the adverse effects associated with discharging nutrient-rich, oxygen-poor water into the Oconomowoc River, the cost assumes discharge to a suitable agricultural irrigation system, two and one-half miles west of the lake, for surface discharge of the water, as depicted on Map 27. If an irrigation system closer to the lake could be developed, the cost of the project could be reduced. Prior to discharge via the irrigation system, it would be necessary to determine the degree to which arsenic

Map 27

PLAN ALTERNATIVE FOR THE SELECTIVE DISCHARGE OF WATER FROM OKAUCHEE LAKE



Source: SEWRPC.

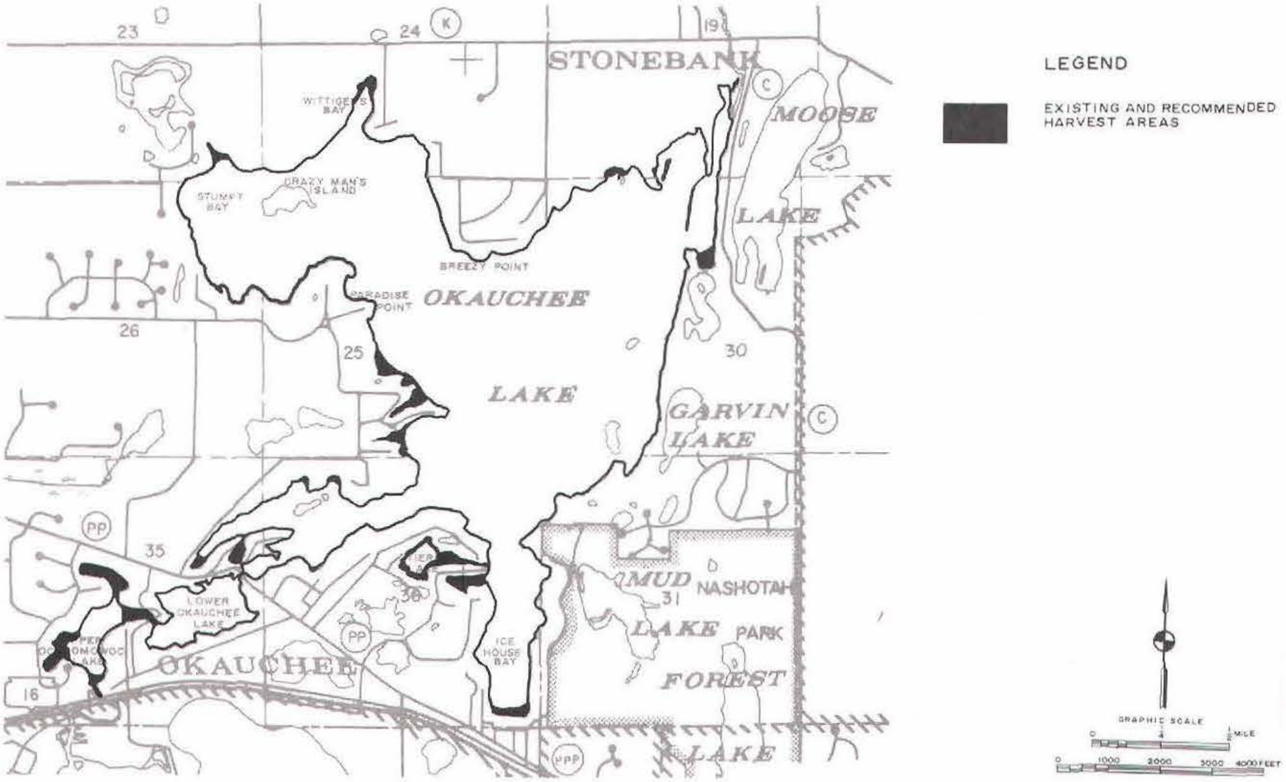
residues--from historical applications of sodium arsenite for macrophyte control--are released to the lake water during anaerobic conditions, and what effect this arsenic would have on the irrigated vegetation and underlying groundwater quality.

Aquatic Plant Harvesting

The macrophyte harvesting practices currently conducted on Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes could be continued to provide desired open water areas. Upon implementation of the point and nonpoint source controls in the watershed, macrophyte growths can be expected to either remain stable or perhaps slightly decrease in the future. Currently, two harvesters are used by the Lake Management District to harvest about 320 acres per year. An additional harvester could be used to provide additional control of macrophytes and perhaps reduce the need for the use of chemicals. A new harvester with a seven-foot cutting width, a shore conveyor, and a trailer would cost about $70,000. The current harvesting of the areas shown on Map 28 provides sufficient macrophyte control for the lakes as a whole. An additional harvester could be used to provide more frequent control of macrophytes in the bay areas, which generally contain shallow water without a moving current. The additional harvester would entail an additional estimated annual operation and maintenance cost of about $15,000. The current program removes about 400 pounds of phosphorus from the lakes each year. This removal of phosphorus could be increased by about 50 percent, to about 600 pounds per year, if an additional harvester were purchased. Because macrophytes utilize nutrients from the bottom sediments, it is unlikely that all of this phosphorus would contribute to the water quality problems of the lake except in the support of the macrophytes themselves. It may be expected, however, that a continuing macrophyte harvesting program would eventually result in a

Map 28

EXISTING AND RECOMMENDED MACROPHYTE HARVESTING IN OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES: 1979



Source: SEWRPC.

decrease in the accumulation of nutrient- and organically-rich bottom sediments.

Algae harvesting has seldom been used for large-scale, in-lake applications. The only practical system currently developed involves filtration of the lake water through a screen system such as a microstrainer. A pump and microstrainer system designed to treat about one-half of the water in Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes each summer would entail a capital cost of about $5.7 million and an annual operation and maintenance cost of about $70,000. In addition to the aesthetic improvements, harvesting of the algae at this rate could remove an estimated 200 pounds of phosphorus from the lakes annually.

Chemical Control of Algae and Macrophytes

Chemical control of algae and macrophytes is currently practiced on Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. Chemical control alone, or in combination with harvesting is not recommended over the long term unless other practices--such as harvesting, sediment covering, dredging, or land management practices intended to reduce nutrient levels--prove to be impractical or ineffective. This recommendation is based upon the evaluation of chemical control of macrophytes presented in Chapter VI. All chemical treatment programs require a permit from the Wisconsin Department of Natural Resources; and treatment of areas over one acre requires supervision by Wisconsin Department of Natural Resources staff.

Chemical control of both algae and macrophytes at the existing application levels--at which about 395 acres in Okauchee Lake are treated--entails a cost of about $12,000 per year.

Fish Management

A well-balanced fish community is established in Okauchee Lake. Alternative future management efforts include:

1. Identifying and seeking protection for the best remaining fish habitat and spawning areas in the lake, including areas along the Oconomowoc River upstream of Okauchee Lake by the local Lake Management District or the Wisconsin Department of Natural Resources.

2. Additional stocking of northern pike, walleye, and other species, as appropriate, by the Wisconsin Department of Natural Resources, to provide continued game fish resources.

3. Development of a periodic fish surveillance program for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes by the Wisconsin Department of Natural Resources, including a specific schedule for periodic fishing surveys.

4. Conduct of a creel census (a survey of sport fishing) by the Wisconsin Department of Natural Resources to determine the composition of the angler catch and the numbers of each species harvested. This information could be correlated to the relative abundance of each species to determine if over-harvest is taking place.

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Chapter IX

RECOMMENDED PLAN

INTRODUCTION

This chapter, building on the land use, land and water management, biological and water quality inventory findings; pollution source analyses; land use and population forecasts; and alternative water quality management plan evaluations, presents a recommended management plan and its projected costs for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. The plan sets forth the recommended means for: 1) providing water quality conditions suitable for the maintenance of fish and aquatic life; 2) reducing the severity of existing nuisance problems due to excessive weed growths which constrain or preclude intended water uses; and 3) improving opportunities for water-based recreational activities. The primary water-based recreational activities on the lake are fishing, swimming, and pleasure boating. An analysis of the status and condition of these recreational activities indicated that the lakes support a viable warm water fishery, but swimming and boating opportunities are hampered to a certain extent by excessive macrophyte growth. Consequently, a portion of the recommended management plan and the alternatives is directed more toward improving swimming and pleasure boating opportunities and, to a lesser degree, toward the maintenance and improvement of other uses on Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes.

The plan recommendations were developed through an evaluation of the many tangible and intangible factors bearing upon water pollution control for these lakes. The primary emphasis of the plan is placed, however, upon the degree to which the water use objectives are met, and upon the cost-effectiveness of the recommended measures and of alternatives thereto. The plan development process involved review of preliminary drafts of the recommended plan by the Okauchee Lake Management District and by other government officials.

LAND USE

A basic element of sound water quality management for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes is the sound use of the lands lying in the drainage area tributary to the three lakes. The type and locations of future urban and rural 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 forms of land management; and ultimately, the water quality condition of the lakes.

The basis for the land use recommendations set forth in this report is the adopted regional land use plan, as set forth in SEWRPC Planning Report No. 25, A Regional Land Use Plan and A Regional Transportation Plan for Southeastern Wisconsin: 2000. The regional land use plan--as shown in graphic summary form on Map 14--recommends that some additional urban land use development occur primarily at low densities in the lake drainage area through the year 2000.

The prime agricultural lands located north of Okauchee Lake are recommended to be preserved in agricultural use. Certain lands immediately surrounding the three lakes, the land along the Oconomowoc River, and a few small, scattered areas are recommended to be permanently preserved in essentially natural, open uses as environmental corridor.

The regional land use plan can be an effective tool for water quality preservation and enhancement only if local action is taken to adopt and implement the plan. The Towns of Oconomowoc and Merton, together with Waukesha County, have primary authority for local land use planning and plan implementation in relatively large portions of the Okauchee Lake, Lower Okauchee Lake, and Upper Oconomowoc Lake direct drainage area. In addition, the City of Delafield, the Villages of Chenequa and Oconomowoc Lake, and the Town of Summit have local land use planning authority for the very small portions of the drainage area which lie within these civil divisions.

ZONING ORDINANCE MODIFICATION

As noted in Chapter V, an abundance of valuable natural resource base features are located within the Okauchee Lake direct drainage area. In order for the existing zoning ordinances to be an effective tool for the preservation of these natural resource features, as recommended in the water quality management plan for Okauchee Lake, certain modifications to the ordinances are required. As previously noted, the responsible officials in Waukesha County and in the six civil divisions located within the Okauchee Lake direct drainage area should critically review the existing zoning ordinances and accompanying zoning district maps and amend and modify the ordinances and district maps as necessary to better preserve and enhance the existing natural resource base in the direct drainage area.

The following zoning districts and attendant regulations should be considered for inclusion in any modification of the existing ordinances and district maps. The areas of land which should be placed in each of the zoning districts are shown on Map 29, are quantified by civil divisions in Table 31, and are compared with existing zoning practices in Table 32.

Lowland Conservancy District

A Lowland Conservancy District should be used to preserve, protect, and enhance wetland areas of the direct drainage area. No new urban development would be permitted in this district. It is proposed that 193 acres, or about 6 percent of the direct drainage area, be included in a Lowland Conservancy District. The 193 acres are located in the Town of Merton and the Village of Oconomowoc Lake, both within Waukesha County.

The existing C-1 Conservancy District applied in the Town of Merton is deemed adequate to protect approximately 166 acres of wetlands and can continue to be used for this purpose. However, a Lowland Conservancy District should be included in the Village of Oconomowoc Lake zoning ordinance as a new zoning district to protect the approximately 27 acres of wetland currently zoned for residential uses which are located within the direct drainage area.

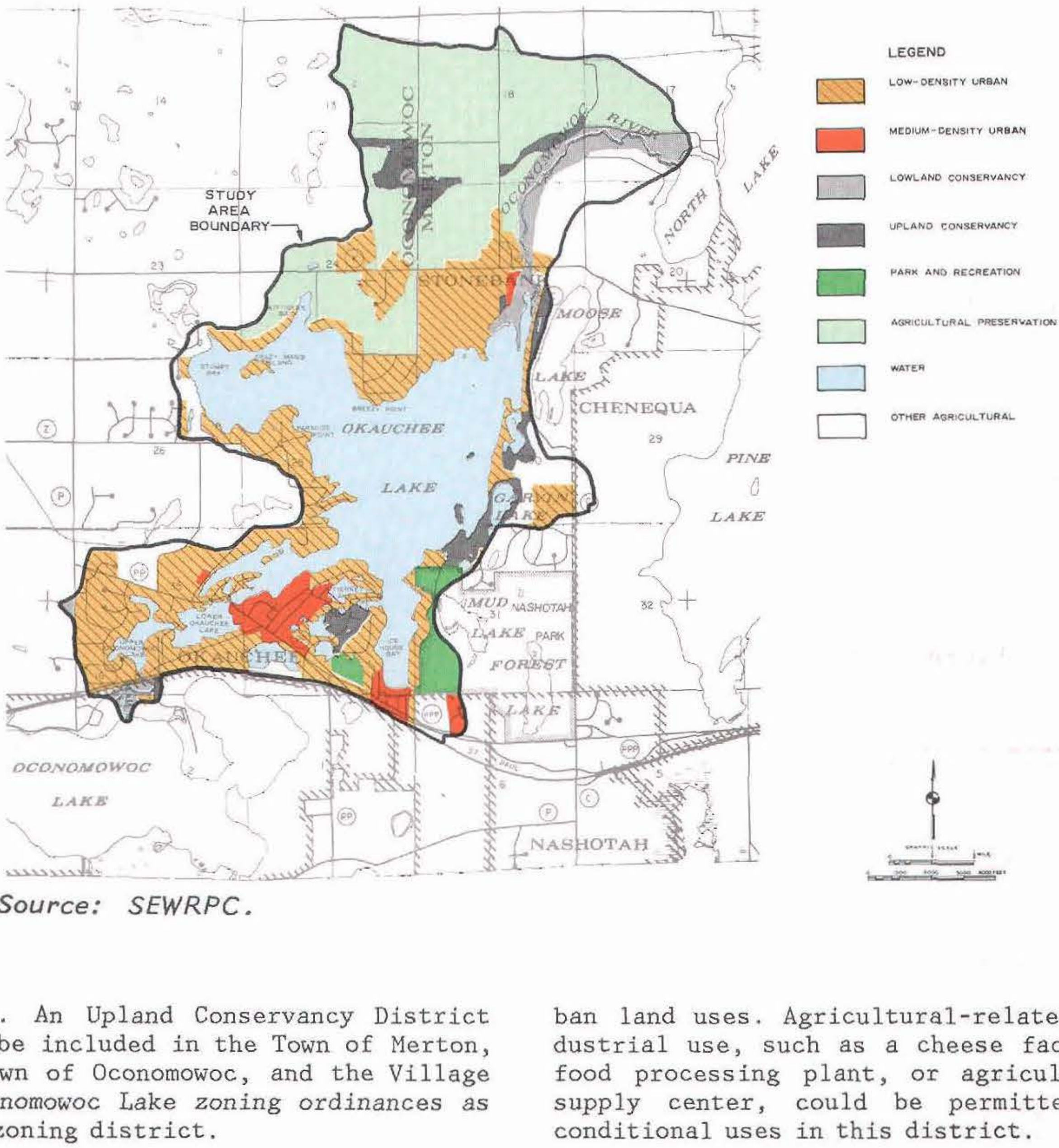
Upland Conservancy District

An Upland Conservancy District should be used to preserve, protect, and enhance the remaining significant woodlands, related scenic areas, and marginal farmlands of the direct drainage area, while allowing for rural estate type residential development that would help to maintain the rural character of portions of the Okauchee Lake drainage area. It is proposed that 215 acres, or about 6 percent of the direct drainage area, be included in an Upland Conservancy District. The 215 acres are located in the Towns of Merton and Oconomowoc and the Village of Oconomowoc Lake, all within Waukesha County.

Under the existing zoning ordinances administered within the direct drainage area, approximately 42 acres of the total 215 acres proposed for inclusion in an Upland Conservancy District are currently included in agricultural districts, one acre is currently in a conservancy district, and the remaining 172 acres are included in residential dis-

Map 29

PROPOSED ZONING DISTRICTS FOR THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES



Source: SEWRPC.

tricts. An Upland Conservancy District would be included in the Town of Merton, the Town of Oconomowoc, and the Village of Oconomowoc Lake zoning ordinances as a new zoning district.

Agricultural Preservation District

An Agricultural Preservation District should be used to preserve and enhance lands within the direct drainage area historically used for agricultural purposes. Such a district should provide for a minimum parcel size of 35 acres, in order to preserve workable farm units, and should prohibit the intrusion of urban land uses. Agricultural-related industrial use, such as a cheese factory, food processing plant, or agricultural supply center, could be permitted as conditional uses in this district.

About 1,115 acres, or about 33 percent of the direct drainage area, should be included in the Agricultural Preservation District. The 1,115 acres are located in the Towns of Merton and Oconomowoc, in Waukesha County.

Under existing ordinances administered within the direct drainage area, 291

Table 31

PROPOSED ZONING MODIFICATIONS BY CIVIL DIVISION IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

Civil Divisions	Proposed Zoning Districts														Total Direct Tributary Drainage Area	
	Lowland Conservancy		Upland Conservancy		Park and Recreation		Agricultural Preservation		General Agriculture		Low-Density Residential		Medium-Density Residential			
	Acres	Percent of Drainage Area	Acres	Percent of Drainage Area	Acres	Percent of Drainage Area	Acres	Percent of Drainage Area	Acres	Percent of Drainage Area	Acres	Percent of Drainage Area	Acres	Percent of Drainage Area	Acres	Percent
Town of Oconomowoc	--	--	69	2.1	20	0.6	447	13.3	94	2.8	859	25.5	101	3.0	1,590	47.3
Village of Oconomowoc Lake	27	0.8	14	0.4	--	--	--	--	--	--	17	0.5	--	--	58	1.7
Village of Chenequa	--	--	--	--	--	--	--	--	32	1.0	--	--	--	--	32	1.0
City of Delafield	--	--	--	--	--	--	--	--	40	1.2	--	--	18	0.5	58	1.7
Town of Merton	166	4.9	132	3.9	88	2.6	668	19.8	234	6.9	309	9.2	5	0.2	1,602	47.5
Town of Summit	--	--	--	--	--	--	--	--	--	--	9	0.3	17	0.5	26	0.8
Total	193	5.7	215	6.4	108	3.2	1,115	33.1	400	11.9	1,194	35.5	141	4.2	3,366	100.0

Source: SEWRPC.

Table 32

SUMMARY OF PROPOSED ZONING MODIFICATIONS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

Proposed Zoning Districts	Existing Zoning Classifications (acres)				Total Acres	Percent of Directly Tributary Drainage Area
	General Conservancy	Agriculture	Residential	Other[a]		
Lowland Conservancy...	166	--	27	--	193	5.7
Upland Conservancy...	1	42	172	--	215	6.4
Park and Recreation....	--	--	6	102	108	3.2
Agricultural Preservation..	9	810	291	5	1,115	33.1
General Agriculture...	6	172	186	36	400	11.9
Low-Density Residential...	9	8	1,122	55	1,194	35.5
Medium-Density Residential...	--	--	121	20	141	4.2
Total	191	1,032	1,925	218	3,366	100.0

[a] Includes Business, Manufacturing, and Park and Recreation Districts.

Source: SEWRPC.

acres of the total 1,115 acres are currently included in residential districts, 9 acres are included in conservancy districts, 5 acres are included in a business district, and the remaining 810 acres are included in agricultural districts. These agricultural districts, however, permit residential development on lots of three acres or more in size in both the Town of Merton and the Town of Oconomowoc and are, in fact, residential use and not Agricultural Preservation Districts. An Agricultural Preservation District should be included in the Town of Merton, the Town of Oconomowoc, and the Waukesha County zoning ordinances as a new zoning district.

General Agricultural District

A General Agricultural District should be used to preserve and protect open space lands in areas having marginal farmland value, while at the same time allowing for estate-type residential development that maintains the rural character of the countryside. Such a district should provide for a minimum lot size of 10 acres and would permit a mixture of farm site and estate-type residential uses.

It is proposed that 400 acres, or about 12 percent of the direct drainage area, be included in a General Agricultural District. The 400 acres are located in the Town of Merton and Oconomowoc, the City of Delafield, and the Village of Chenequa.

Under the existing zoning ordinances administered within the direct drainage area, approximately 172 acres of the total 400 acres are included in agricultural districts, 186 acres are included in residential districts, 36 acres in business and manufacturing districts, and 6 acres in conservancy districts. The General Agricultural District should be included in the Towns of Merton and Oconomowoc, the City of Delafield, and the Village of Chenequa zoning ordinances as a new zoning district.

Low-Density Urban and Medium-Density Urban Residential Districts

Low- and Medium-Density Urban Residential Districts are used to preserve and protect existing and proposed residential areas within a physical environment that is healthy, safe, convenient, and attractive. About 1,194 acres, or about 36 percent of the direct drainage area, should be included within a Low-Density Urban Residential District. About 141 acres, or 4 percent of the direct drainage area, should be included within a Medium-Density Urban Residential District. The Commission defines low-density urban residential land use as approximately 0.7 to 2.2 dwelling units per net residential acre, and medium-density urban residential land use as approximately 2.3 to 6.9 dwelling units per net residential acre.

Under the existing zoning ordinances administered within the direct drainage area, 1,243 acres are in residential districts, 75 acres are in park, business, and manufacturing districts, 9 acres are in general conservancy districts, and 8 acres are in agricultural districts.

Park and Recreation District

A Park and Recreation District should be used to properly zone existing recreation land uses in the direct drainage area and to protect them from possible encroachment by other less desirable or incompatible land uses. This category would prohibit the conversion of a private recreational site to urban or other incompatible uses without town approval. About 108 acres, or about 3 percent of the direct drainage area, should be included in this district.

Under existing zoning ordinances administered within the direct drainage area, approximately 102 acres of the 108 acres proposed to be zoned for park and recreation use are currently included in public districts, and six acres are currently included in residential districts. The Park and Recreation District would be included in the Town of Merton and the Town of Oconomowoc zoning ordinances as a new zoning district and would necessitate the modification of the P-1 Public District presently included in the existing aforementioned zoning ordinances. Thus, only existing and proposed public and private park and outdoor recreation sites would be placed in the Park and Recreation District, while governmental and institutional land uses in the towns could be retained in the existing P-1 Public Districts.

NONPOINT SOURCE POLLUTION CONTROL AND LAKE MANAGEMENT

The water quality management plan for the lakes must address methods for reducing the nutrient loading to the lake from nonpoint sources, and techniques for related water quality rehabilitation. A described below, the implementation of nonpoint source controls and lake rehabilitation techniques require urban nonpoint source control practices, agricultural land management practices, and increased regulation of certain land management activities. Technical and financial assistance from state and federal units of government will also be required to implement such practices and regulations.

Okauchee Lake Management District

It is recommended that the Okauchee Lake Management District, formed under the provisions of Chapter 33, Wisconsin Statutes, serve as the lead agency in the continued study and management of the Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. In addition to its important role in the implementation of specific management measures, it is recommended that the District coordinate the plan implementation activities of local and state agencies and private citizens within the lake drainage area.

It is also recommended that the Lake District conduct a continuing in-lake water quality sampling program to assess the effects of implemented lake management measures. This sampling program should consist at least of the measurement of soluble and total phosphorus; nitrite- and nitrate-nitrogen; ammonia nitrogen; organic nitrogen; chlorophyll-a_; and water clarity, and the development of temperature and dissolved oxygen profiles at least twice each summer and once each spring turnover. These data should be obtained at the deepest point in the lakes. In addition, a sediment sampling and analysis program to evaluate the depths of chemical residues should also be initiated. Lake freeze-up and thaw dates, as well as snow cover conditions, should be recorded annually. Precipitation and water level should also be recorded on a weekly basis. Such a data collection program would have an estimated cost of about $900 per year. Surveys of fish, macrophytes, algae, and other biota should be conducted periodically, either by or with the technical assistance of the Wisconsin Department of Natural Resources. This evaluation should examine any possible long-term adverse effects of chemical treatment for macrophyte control.

It is also recommended that the Lake District investigate and consider coordinating regulation of water-based activities. Surveys of lake district residents conducted by the Lake District have shown the need for warning buoys, boat speed limitations, waterskiing restrictions, noise reduction, and boat type regulation. Implementation of appropriate ordinances could serve to reduce lake use conflicts.

Urban Nonpoint Source Pollution Controls

The implementation of nonpoint source controls in urban areas requires the efforts of the Waukesha County Board of Supervisors, the Waukesha County Board of Health, the Waukesha County Soil and Water Conservation District, the City of Delafield, the Villages of Chenequa and Oconomowoc Lake, and the Okauchee Lake Management District. The recommended responsibilities of each of these governmental agencies--consistent with their legal authorities under existing state and federal laws--are summarized in Table 33. The specific management issues and objectives for the methods of

Table 33

LOCAL GOVERNMENTAL MANAGEMENT AGENCIES AND RESPONSIBILITIES FOR URBAN NONPOINT SOURCE WATER POLLUTION CONTROL

Urban Nonpoint Source Management Agency	Local Land Use Planning and Zoning	Undertake Septic System Management Program	Undertake Construction Erosion Control Program	Review Public Works Maintenance Practices	Conduct Educational and Informational Program	Provide Technical Assistance	Provide Fiscal Support to Soil and Water Conservation District
Waukesha County	X	--	X	--	X	--	X
Waukesha County Board of Health	--	X	--	--	X	--	--
Waukesha County Soil and Water Conservation District	--	--	--	--	--	X	--
Okauchee Lake Management District	--	--	--	X	X	--	--
City of Delafield	X	--	X	X	X	--	--
Village of Chenequa	X	--	X	X	X	--	--
Village of Oconomowoc Lake	X	--	X	X	X	--	--
Town of Merton	X	--	--	X	--	--	--
Town of Oconomowoc	X	--	--	X	--	--	--
Town of Summit	X	--	--	X	--	--	--

Source: SEWRPC.

nonpoint source pollution control including the development of septic tank systems management programs, construction erosion programs, and development and implementation of urban land management practices, are discussed below.

Septic Tank System Management Program: The basic objective of a septic tank system management program is to ensure the proper installation, operation, and maintenance of existing septic tank systems, and of any new systems that may be required to serve existing urban development in the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. It is important that a septic tank system management program be conducted in the lake drainage area until recommended sanitary sewer service is provided.

A septic tank system management program is recommended to consist of at least the following actions to assure proper management of these septic systems which would not be eliminated by the recommended centralized sanitary sewer system:

1. The revision of the Waukesha County sanitary ordinance to include regulation of the operation and maintenance of onsite sewage disposal systems, including septic tanks, holding tanks, "mound" systems or other systems approved by the applicable state regulations.

2. The establishment through such sanitary ordinances of a regular program of inspection of onsite sewage disposal systems by the Waukesha County Board of Health. Such a program would include the visual inspection of each onsite sewage disposal system by trained individuals. The purpose of the inspection would be to identify any malfunctioning sewage disposal system. Each system should be inspected once every five years and, accordingly, one-fifth of all such systems should be inspected annually. The inspection program would result in the issuance of orders as necessary to abate improper practices and take appropriate corrective measures.

3. The continuation of an educational program whereby homeowners and developers would be advised of the rules and regulations governing the installation and operation of on-site sewage disposal systems and would be encouraged to undertake preventive maintenance measures.

Construction Erosion Control Program: It is recommended that Waukesha County, the City of Delafield, the Villages of Chenequa and Oconomowoc Lake, and the Towns of Merton, Oconomowoc, and Summit undertake steps to ensure the reduction of water pollution--particularly nutrient pollution associated with the introduction of phosphorus--as a result of soil erosion from land undergoing a change in use and related construction activity. It is recommended that these designated urban management agencies establish construction erosion control programs and review their subdivision regulations, zoning ordinances, and building codes for the inclusion of appropriate erosion control measures, in order to assure that such regulations, ordinances, and codes taken together address administrative procedures, erosion control performance standards, and enforcement provisions.

It is recommended that the ordinances be properly expanded to require the submittal of an erosion control plan by land developers and that the erosion control plan be reviewed and approved by the county Soil and Water Conservation District. It is recommended that each designated agency adopt the appropriate ordinance modifications; require the submittal of erosion control plans for all construction projects; and review such plans with technical assistance from the Soil and Water Conservation Districts, in conjunction with local municipal engineers. Further, each designated urban management agency should provide for the proper enforcement, through inspection, of the erosion control measures to be implemented. The review and evaluation of the plans and control measures implemented should be based on criteria set forth in the Soil and Water Technical Guide of the Soil Conservation Service of the U.S. Department of Agriculture. Enforcement would be through the land subdivision, zoning, and building code approval authorities of each designated management agency. Upon request, the Southeastern Wisconsin Regional Planning Commission, which has published model ordinances in Appendices H through M of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, can assist in the development of the required regulations.

Development and Implementation of Urban Land Management Practices: The development of urban nonpoint source pollution abatement practices should be a highly localized, detailed, and individualized effort. It requires highly specific knowledge of the physical, managerial, social, and fiscal considerations that affect the local landowners concerned. Accordingly, it is recommended that the Okauchee Lake Management District work with property owners to attain application of the land management practices recommended herein, as necessary to effect an approximately 25 percent reduction in urban nonpoint source pollution runoff.

It is recommended that the Lake Management District, in cooperation with the City of Delafield and the Villages of Chenequa and Oconomowoc Lake, identify the specific sources of nonpoint source pollution within the urban areas of the watershed and develop programs to implement measures to control these specific sources. These designated agencies should inventory and assess the existing land management practices and determine the extent and location of problem areas. Further, the appropriate pollution control measures for these problem areas and the estimated effectiveness and costs of these control measures should be assessed. Finally, a program for implementing and financing the recommended control measures should be developed.

It is recommended that urban nonpoint source control measures implemented, as

Table 34

LOCAL GOVERNMENTAL MANAGEMENT AGENCIES AND RESPONSIBILITIES FOR RURAL NONPOINT SOURCE WATER POLLUTION CONTROL

Rural Nonpoint Source Management Agency	Local Land Use Planning and Zoning	Develop Livestock Waste Control Program	Develop and Implement Detailed Plan for Rural Practices	Conduct Educational and Informational Program	Provide Technical Assistance	Provide Fiscal Support to Soil and Water Conservation District
Waukesha County	X	X	--	X	--	X
Waukesha County Soil and Water Conservation District	--	X	X	--	X	--
Okauchee Lake Management District	--	--	X	X	--	X

Source: SEWRPC.

applicable, throughout the drainage area tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes include: 1) a public education program to provide information on the relationship of land management practices to water quality; 2) improved street cleaning and maintenance; 3) the proper collection and disposal of leaves, grass clippings, and other vegetative debris; 4) the proper use of fertilizers, pesticides, and other lawn care measures; 5) improved refuse collection and disposal; 6) the proper vegetative management of near-shore areas; 7) the adequate maintenance of storm water drainage ditches and storm sewer systems, including discharge sites; 8) the proper disposal of litter and pet wastes; and 9) other measures as locally identified. It is recommended that a publication identifying specific residential land management practices beneficial to water quality be prepared and distributed to property owners with the assistance of the University of Wisconsin-Extension Service. It is further recommended that the designated agencies seek technical assistance in the preparation and implementation of the aforementioned detailed practices from the Waukesha County Soil and Water Conservation District, and also seek assistance in the form of public education and information programs from the Waukesha County office of the University of Wisconsin-Extension Service.

Rural Nonpoint Source Pollution Controls

The implementation of nonpoint source pollution controls in rural areas requires the cooperative efforts of the Okauchee Lake Management District, Waukesha County, and the Waukesha County Soil and Water Conservation District. The recommended responsibilitis of each governmental agency are set forth in summary form in Table 34.

As with urban nonpoint source pollution abatement practices, the development of rural nonpoint source pollution abatement practices should be a highly localized, detailed, and individualized effort. Accordingly, it is recommended that the Waukesha County Soil and Water Conservation District, in cooperation with the Okauchee Lake Management District, undertake the development of plans needed for the design of detailed rural soil and water conservation practices on each farm in the watershed. It is recommended that the Lake District be the lead agency in the preparation of such plans. As the lead agency, the Lake District should formally request that the county Soil and Water Conservation District work with the landowners to design detailed practices applicable for each land parcel for agricultural nonpoint source pollution control in the lake watershed. This should include estimates of soil loss and recommendations for specific abatement measures for each identified source. The estimated cost and effectiveness of each practice recommended should also be included. Agricultural nonpoint source pollution abatement measures which may be appropriate for use in the Okauchee Lake direct drainage area include crop rotation, conservation tillage, grassed waterways, diversions, terraces, contour strip-cropping, and livestock waste control. Some agricultural areas in the lake drainage area with relatively steep slopes are located in proximity to the lake and are particularly susceptible to erosion. They significantly harm the lake environment, and should receive priority for planning and implementation efforts. For example, the drainage area within Section 24, Township 8 North, Range 17 East, Town of Oconomowoc was identified in the lake study field survey as a potentially high pollutant-contributing area. It is envisioned that the Lake Management District would--through an intergovernmental memorandum of understanding--cooperate with the Waukesha County Soil and Water Conservation District in the necessary detailed planning.

Following the selection of detailed practices for the abatement of nonpoint source pollution in rural areas, it is recommended that the management agencies take appropriate steps to install the practices. This would include the establishment of public educational programs by the Lake District in cooperation with the University of Wisconsin-Extension Service, continued work with the farm operators, and the undertaking of actions to protect critical areas from erosion. It is further recommended that the Waukesha County Soil and Water Conservation District provide all necessary technical assistance in installing the practices.

LAKE REHABILITATION TECHNIQUES

The selection of lake rehabilitation techniques must consider local circumstances and lake management objectives. The implementation of lake rehabilitation techniques is best carried out by the Okauchee Lake Management District. Additional technical assistance from the Wisconsin Department of Natural Resources, Office of Inland Lake Renewal, will be required prior to actual implementation of a rehabilitation technique.

To control excessive growth of macrophytes in Okauchee Lake and to provide improved opportunities for recreational use, it is recommended that the Okauchee Lake Management District continue its macrophyte harvesting program. Given the frequency of harvesting currently provided by the program, it is probably not necessary to expand the existing program at this time. It is recommended that the areas shown on Map 27 continue to be harvested with mechanical macrophyte harvesters about three times per year. In future years, the areas harvested and the schedule of harvesting can be refined to provide the most cost-effective use of the harvesters. The benefits of macrophyte harvesting are that it is a reasonably economical practice, approximating the annual cost of herbicide usage; it removes plant material and nutrients from the lakes; it is effective against existing problem species such as water milfoil in Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes; and it is a highly flexible practice in that control efforts can be directed to the most severe problem areas at any specific time. Harvesting does not significantly interfere with the recreational use of the lakes, and, if properly used, does not damage fish spawning areas. The harvesting operations and the collection and disposal of the removed plant material do have a significant labor requirement.

To further control excessive macrophyte growths, particularly in the bay areas, it is recommended that the Okauchee Lake Management District investigate dredging the limited areas shown on Map 24. Preliminary analyses indicate that dredging Ice House Bay, Tierney Lake, and the Tierney Lake channel and Upper Oconomowoc Lake to mean depths of about 10 feet is feasible and would reduce macrophyte growths in severe problem areas. Dredging these areas to the recommended depths would reduce, although not eliminate, macrophyte growths in the treated areas. Based on information provided by the macrophyte surveys, macrophytes would not be expected to reach the water surface in areas with water depths greater than about five feet. The dredging would provide a long-term reduction in the growth of macrophytes in the treated areas; would reduce the consumption of oxygen by decaying plant masses; would improve the recreational use potential of these areas; would improve the water circulation in these bay areas, thereby perhaps improving dissolved oxygen levels and reducing algae growth; and would reduce the need for chemicals to control macrophytes. The cost of the recommended dredging of Ice House Bay, Tierney Lake, and Upper Oconomowoc Lake would be about $1,250,000. The Lake Management District may also consider dredging, at a future date, shallow areas near the Okauchee Lake outlet and in the northwest portion of Okauchee Lake.

To manage the fishery resources in Okauchee Lake, it is recommended that the Wisconsin Department of Natural Resources consider protecting and, if necessary, purchasing the highest quality habitat and spawning areas, as identified by Department fish and wildlife managers. The Wisconsin Department of Natural Resources can more effectively protect and manage these areas, particularly around the Okauchee Lake inlet, than can the Lake Management District. It is recommended that the Department continue the management of the northern pike and walleye fisheries, including stocking as necessary. It is recommended that the Department conduct a creel census to evaluate the angler catch and determine if overharvesting of some species is occurring. It is also recommended that the Department establish a periodic fish surveillance and sampling program for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. Under such a program, whereby a specific schedule for periodic fishery surveys would be established, the Department would be able to assess and evaluate long-term trends in the total fishery resource of the lake, not just in specific game fish species.

Hypolimnetic aeration is not recommended for Okauchee Lake at this time. The water quality problems which hypolimnetic aeration alleviates--an anaerobic hypolimnion, nutrient release from bottom sediments, and excessive algae growths--have not been identified as severe water quality problems significantly affecting beneficial uses of Okauchee Lake. Therefore, while hypolimnetic aeration is generally applicable to Okauchee Lake, the existing water quality problems do not appear to warrant its application at this time.

Other methods of controlling excessive aquatic macrophyte growths, such as sediment covering and drawdown, are technically feasible for portions of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. However, these techniques are not recommended because, while they have substantially higher costs than harvesting, they are not expected to provide substantial additional water quality or water use benefits. The benefits of covering the sediments with plastic lining, sand, or other suitable material could be short-lived if additional organic matter is deposited upon these new sediments. Drawdown of Lower Okauchee and Upper Oconomowoc Lakes, while consolidating the sediments and providing a slight increase in depth, would not, in itself, be expected to provide the level of macrophyte control which could be achieved by dredging combined with a continued harvesting program. Nutrient inactivation and selective discharge are not recommended because, while reducing the nutrient levels in the water, these techniques would not significantly reduce aquatic macrophyte growth in the lake and because the lakes flush too rapidly for nutrient inactivation to be highly effective.

Because of the unknown long-term ecological consequences of the use of chemicals to control algae and aquatic macrophytes, it is recommended that the Lake District consider severely curtailing the application of this practice in Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. Furthermore, the deposit of the dead plant material, which is not removed by subsequent harvesting techniques, upon the lake bottom releases additional nutrients to the water and serves to further contribute to the build-up of organic matter with associated macrophyte growth and reduced depth conditions. The use of chemicals is recommended only as a last resort when other plant management alternatives are not feasible. For Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, there are environmentally sound alternative methods of aquatic plant control which are feasible and cost-effective.

COST ANALYSES

Cost estimates--expressed in 1980 dollars--for recommended nonpoint source controls in the Okauchee Lake drainage area and in-lake management techniques are set forth in Table 35. The total capital cost of the recommended plan is about $1.66 million over a 20-year plan implementation period, with an average operation and maintenance cost of $50,600, resulting in a total annual average cost of $135,300. Of these totals, $706,600, or 43 percent of the capital cost; $39,300, or 78 percent of the annual operation and maintenance cost; and $77,300, or 57 percent of the total annual cost would be borne by the local units of government. The remaining costs could be borne by individual property owners or by state or federal cost-sharing programs. About $203,000, or 76 percent, of the total capital cost of the recommended watershed management measures is associated with control of erosion from construction activities, with 25 percent of the erosion control cost being borne by the public sector. The in-lake management costs include a total average annual cost of $900 for an in-lake water quality sampling program. Table 36 sets forth the estimated costs of implementing the recommended plan that could be expected to be provided by state or federal cost-sharing funds. Based on the expected 1985 population of the lake drainage area, the total average annual cost for each lake drainage area resident would be about $27, or $81 per household. The average annual local public sector cost for each lake drainage area resident would be about $15, or $46 per household.

Table 35

ESTIMATED COST OF RECOMMENDED WATER QUALITY AND LAKE MANAGEMENT MEASURES FOR OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

Water Quality or Lake Management Measure[b]	Estimated Cost 1980-2000[a]					
	Capital		Average Annual Operation and Maintenance		Total Average Annual	
	Total	Local Public Sector	Total	Local Public Sector	Total	Local Public Sector
Sanitary Sewer Service[c]	$ --	$ --	$ --	$ --	$ --	$ --
Septic Tank System Management[d]	--	--	--	--	--	--
Rural Land Management	800	--	4,500	--	4,500	--
Livestock Waste Control	64,600	--	5,500	--	8,600	--
Urban Land Management	100	100	2,600	2,600	2,600	2,600
STH 16 Construction Erosion Control	21,000	21,000	300	300	5,600	5,600
Other Construction Erosion Control	182,000	45,500	1,800	500	11,900	2,700
Watershed Management Subtotal	$ 268,500	$ 66,600	$14,700	$ 3,400	$ 33,200	$10,900
Aquatic Macrophyte Harvesting[e]	$ 140,000	$140,000	$35,000	$35,000	$ 41,700	$41,700
Dredging[f]	1,250,000	500,000	--	--	59,500	23,800
Fish Management[g]	--	--	--	--	--	--
Water Quality Sampling Program	--	--	900	900	900	900
In-Lake Management Subtotal	$1,390,000	$640,000	$35,900	$35,900	$102,100	$66,400
Total	$1,658,500	$706,600	$50,600	$39,300	$135,300	$77,300

[a] All costs are expressed in January 1980 dollars, and are rounded off to the nearest hundred.

[b] Land use plan element costs are not presented.

[c] Nearly all urban development in the drainage area directly tributary to Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes is recommended to be served by sanitary sewers by the year 2000. The sewage generated in this area would be conveyed to and treated at the City of Oconomowoc sewage treatment plant. The estimated cost for a portion of the treatment facility and major trunk sewers serving the drainage area, together with local hookup and operation and maintenance of the system includes a total capital cost of about $9.8 million, with an annual operation and maintenance cost of about $215,000.

[d] The proper maintenance and replacement of the remaining septic tank systems is recommended to help improve the water quality of Okauchee Lake. However, because septic tank systems management is an existing function necessary for the preservation of public health and the maintenance of drinking water supplies, this cost is not included in the water quality management plan. The estimated expenditures for septic system management in the Okauchee Lake drainage basin include a capital cost over the period of 1980-2000 of $450,000 with an average annual operation and maintenance cost of $5,700.

[e] It was assumed that two harvesters suitable for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes would need to be purchased prior to year 2000 in order to maintain the current level of harvesting and would cost about $70,000 each.

[f] It was assumed that 60 percent of the capital costs for dredging would be provided by the Wisconsin Inland Lake Protection and Rehabilitation Program. State funds are limited for this type of project and assistance may also be needed from the U.S. Environmental Protection Agency Section 314 Clean Lakes Grant Program.

[g] Costs for fish management will be borne by the Wisconsin Department of Natural Resources.

Source: SEWRPC.

Table 36

AVAILABLE STATE AND FEDERAL COST-SHARING FOR IMPLEMENTATION OF THE RECOMMENDED WATER QUALITY MANAGEMENT PLAN FOR OKAUCHEE, LOWER OKAUCHEE, AND UPPER OCONOMOWOC LAKES

Water Quality or Lake Management Measure	Estimated Total Cost 1980-2000		Anticipated Percent State or Federal Cost Share	State or Federal Cost-Share Program
	Capital	Annual Operation and Maintenance		
Rural Land Management Practices[a]	$ 800	$ 4,500	50-75% of capital cost, none for operation and maintenance	Federal Agricultural Conservation Program (ACP) administered by the USDA, Agricultural Stabilization and Conservation Service (ASCS) and the Soil Conservation Service (SCS)
Urban Land Management Practices[a]	100	2,600	None	--
Aquatic Macrophyte Harvesting	140,000	35,000	None	--
Limited Dredging	1,250,000	--	60% of capital cost	Department of Natural Resources, Inland Lake Rehabilitation Program
Fish Management	--	--	--	Costs for fish management will be borne by the Wisconsin Department of Natural Resources
Water Quality Sampling Program	--	900	None	--

[a]Cost-sharing and technical assistance for nonpoint source controls could also be applied for as a local priority project under the Wisconsin Fund Nonpoint Source Pollution Abatement Program administered by the Wisconsin Department of Natural Resources.

Source: SEWRPC.

Chapter X

SUMMARY

The preparation of a water quality management plan for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes was a cooperative effort by the Southeastern Wisconsin Regional Planning Commission and the Wisconsin Department of Natural Resources. The lake study included the design and conduct of a water quality sampling program--conducted from December 1976 through November 1977--and the inventory and analysis of land use, watershed characteristics, natural resource base, recreational use, and existing management practices. The objectives of the plan were to provide a level of water quality in Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes suitable for the maintenance of warmwater fish and other aquatic life, to reduce the severity of existing nuisance conditions caused by excessive macrophyte and algae growth, and to improve opportunities for water-based recreational activities.

Okauchee Lake is located within U. S. Public Land Survey Township 8 North, Range 17 East, Town of Oconomowoc, and Township 8 North, Range 18 East, Town of Merton, in Waukesha County. The lake has a surface area of 1,198 acres, a maximum depth of 115 feet, and a mean depth of 25 feet. Lower Okauchee and Upper Oconomowoc Lakes are 47 acres and 36 acres in size, respectively, and both are located entirely within Township 8 North, Range 17 East, Town of Oconomowoc. The three lakes have a combined direct tributary drainage area of 3,366 acres, or 5.26 square miles, and a total watershed area of 44,922 acres, or 70.19 square miles.

The drainage area of Okauchee Lake includes portions of the City of Delafield (0.09 square mile, or 1.24 percent); the Villages of Chenequa (0.05 square mile, or 0.69 percent) and Oconomowoc Lake (0.09 square mile, or 1.24 percent); and the Towns of Merton (3.09 square miles, or 42.56 percent), Oconomowoc (3.90 square miles, or 53.72 percent), and Summit (0.04 square mile, or 0.55 percent), all of which are located in Waukesha County.

As of 1975, the resident population of the drainage area directly tributary to the lakes was estimated by the Commission to be 4,160 persons. The type, intensity, and spatial distribution of land uses are important factors determining resource demand in the direct tributary drainage area. As of 1975, approximately 1,250 acres, or 37 percent of the 3,366-acre direct tributary drainage area, was in urban land use, with the dominant urban land use--901 acres, or 72 percent--in residential use. The remaining urban land uses--commercial, industrial, governmental and institutional, transportation, communication, utilities, and recreational--constituted about 349 acres, or 28 percent, of urban land use in the Okauchee Lake direct drainage area. Approximately 2,116 acres, or 63 percent of the direct tributary drainage area, was in rural land use, with the dominant rural land use--1,595 acres, or 75 percent--in agricultural use. Woodlands and open lands comprised about 295 acres, or 14 percent, of the rural land area. Wetlands and surface waters, excluding the surface area of Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes, accounted for 227 acres, or 11 percent, of the rural land area.

As of 1975, the sanitary and household wastewaters from the estimated 4,160 persons residing in the drainage area directly tributary to the lakes, were treated and disposed of through the use of onsite disposal systems. There are approximately 1,335 septic tank systems in the direct tributary drainage area--508 of which are located in areas covered by soils having severe or very severe limitations for the use of such systems. No holding tanks or mound systems were known to exist, as of 1975, in the direct tributary drainage area.

For the year of study, it is estimated that approximately 35,914 acre-feet of water entered Okauchee Lake. Of this total, about 24,330 acre-feet of water, or 68 percent, was contributed by inflow from the Oconomowoc River; about 6,516 acre-feet, or 18 percent, was contributed from groundwater inflow; about 3,620 acre-feet, or 10 percent, was contributed by direct precipitation on the lake surface; and about 1,448 acre-feet, or 4 percent, was contributed by surface runoff from the direct tributary drainage area. Of the total water output from Okauchee Lake--about 35,914 acre-feet--approximately 20,995 acre-feet, or 59 percent, was discharged via the Oconomowoc River; about 10,860 acre-feet, or 30 percent, left as groundwater outflow; and about 2,896 acre-feet, or 8 percent, evaporated from the surface of the lake. Further, about 1,163 acre-feet, or 3 percent, was represented by increased storage in the lake basin with a resulting higher lake level. Because of the relatively small size of Lower Okauchee and Upper Oconomowoc Lakes, the Oconomowoc River accounts for over 97 percent of both the water inputs to, and the water outputs from, these two lakes.

Monthly temperature and dissolved oxygen profiles indicate that complete mixing of Okauchee Lake is restricted during the summer by thermal stratification. The data indicated that Okauchee Lake, like other mesotrophic or eutrophic lakes in southeastern Wisconsin, experiences oxygen depletion in the hypolimnion or bottom water layer. Oxygen depletion in the hypolimnion may increase the release of phosphorus from the bottom sediments and cause fish to migrate upward in the water column where higher dissolved oxygen concentrations exist. Water clarity, as measured by a Secchi Disc, ranged from about 4.7 feet to 22.6 feet, with an average Secchi Disc depth of 9.5 feet in Okauchee Lake.

Okauchee Lake supports a relatively large and diverse fish community. Wisconsin Department of Natural Resources survey reports indicated that from 1946 through 1975, 30 different fish species were surveyed in the lake. In addition, the pugnose shiner, sampled in 1975, is currently listed by the Wisconsin Department of Natural Resources as a threatened species.

The Regional Planning Commission recommended water quality standard, for recreational use and warmwater fish and aquatic life, indicates that nuisance aquatic plant growth is likely to occur in lakes where the total phosphorus concentration exceeds 0.02 milligram per liter (mg/l) during the spring turnover. In Okauchee Lake, the mean concentration of total phosphorus in the spring was about 0.03 mg/l, which indicates that the potential for nuisance aquatic plant growths exists in the lake.

During the study year, aquatic macrophyte growth in Okauchee Lake was found to be moderate to high. Macrophytes grew on about 45 percent of the lake bottom and extended to the water's surface over approximately 20 percent of the surface area of the lake. In Lower Okauchee and Upper Oconomowoc Lakes macrophytes covered 75 to 80 percent of the lake bottoms. Analyses on the type and abundance of algae present indicated relatively low concentrations in June and July. However, nuisance "bloom" conditions occurred from late April to early May, primarily in shallow bays and along the shoreline.

It is estimated that under the existing conditions, as of 1975, the total phosphorus load to Okauchee Lake during an average year would be approximately 7,167 pounds. Of this total, about 2,900 pounds, or 40 percent, were estimated to be contributed by the Oconomowoc River. In addition, livestock operations were estimated to contribute about 1,940 pounds, or 27 percent, of the total. Malfunctioning septic tank systems contributed approximately 737 pounds, or 10 percent, of the total phosphorus load to the lake. The remaining land uses in the Okauchee Lake direct drainage area--residential, commercial, industrial, governmental and institutional, transportation, and recreational lands, construction activities, agricultural land, direct atmospheric fallout, woodlands, and other open land--contributed an estimated 1,590 pounds, or 23 percent, of the phosphorus load to the lake.

Based on the study data, Okauchee Lake was classified as mesotrophic, a term describing moderately fertile lakes which may support abundant aquatic plant growths and may support productive fisheries. Nuisance growths of algae and macrophytes may be exhibited by some mesotrophic lakes.

According to the adopted Commission land use plan, the population of the Okauchee Lake direct tributary drainage area is expected to increase 44 percent, or approximately 1,840 residents, by the year 2000. The year 2000 land use plan recommends that most new residential development in the direct tributary drainage area occur at low densities. Under the year 2000 land use plan, approximately 1,486 acres, or 44 percent, of the 3,366-acre direct tributary drainage area, would be in urban land use, with the dominant urban land use being residential, encompassing 1,085 acres, or about 73 percent, of the urban land area. Compared to 1975 land use, this represents a 19 percent increase in urban land uses and, specifically, a 20 percent increase in residential land in the direct tributary drainage area. Most of the planned development would occur on land presently in agricultural and open space land uses. According to the adopted Commission land use plan, the remaining 1,880 acres, or 56 percent, of the direct drainage area would be in a mixture of agricultural, water, wetlands, woodlands, and other open land uses.

The Commission also estimated that under year 2000 conditions, the total phosphorus load to the lake would be approximately 5,073 pounds per year, or about 30 percent less than the estimated 1975 loadings. Of this total, approximately 1,500 pounds, or 30 percent, would be contributed by the Oconomowoc River. The anticipated decrease of about 1,400 pounds in phosphorus loading from the Oconomowoc River would occur following implementation of the upstream water pollution control measures recommended in the regional water quality management plan. Further, there would also be an estimated decrease of 730 pounds of phosphorus--from about 737 pounds per year in 1975 to approximately 8 pounds per year--entering the lake from malfunctioning septic tank systems following provision of sanitary sewer service to residents of Okauchee Lake, also as recommended in the regional water quality management plan. Other major sources of phosphorus, under anticipated year 2000 conditions, would be livestock operations, representing about 1,940 pounds, or 38 percent; direct atmospheric contributions, representing 689 pounds, or 14 percent; and construction activities, representing about 409 pounds, or 8 percent. The remaining land uses in the Okauchee Lake direct drainage area--residential, commercial, industrial, governmental and institutional, transportation, recreational, agricultural lands, woodlands, and other open lands--would contribute the remaining 527 pounds, or 10 percent of the phosphorus load to the lake.

Management measures required to meet the water use objectives for Okauchee Lake must address the nonpoint source pollution controls needed. Commission estimates indicated that there would need to be a reduction of 30 percent in nonpount source phosphorus loads from the direct tributary drainage area in order to meet the recommended water use objectives and supporting standards. As noted, the provision of sanitary sewer service to the drainage area directly tributary to Okauchee Lake is recommended as a point source control measure in the adopted regional water quality management plan. This would abate a nonpoint source by eliminating all but approximately five of the septic tank systems on soils with severe or very severe limitations for such use. Sewage treatment would be provided by the City of Oconomowoc sewage treatment facility. Other nonpoint source control measures, as discussed in Chapter IX, consist of improved management of both urban and rural land uses to reduce pollutant discharges to the lake by direct overland drainage, drainage from natural or man-made channels, and by groundwater inflow. These actions would be designed to reduce the in-lake concentration of total phosphorus in Okauchee Lake during the spring turnover to the Commission-recommended standard of 0.02 milligram per liter (mg/l).

Alternative lake rehabilitation and in-lake management techniques were evaluated to examine the feasibility of conducting an in-lake management program. Techniques assessed included hypolimnetic aeration, dredging, sediment covering, drawdown, nutrient inactivation, dilution and flushing, selective discharge, macrophyte harvesting, algae harvesting, chemical controls, and fish management. As a result of these analyses, the Commission recommends that the Okauchee Lake Management District continue their macrophyte harvesting program. To further control excessive macrophyte growths, particularly in the bay areas, it is recommended that the Okauchee Lake Management District investigate dredging limited areas. Preliminary analyses indicate that dredging Ice House Bay, Tierney Lake, the Tierney Lake channel, and Upper Oconomowoc Lake to mean depths of about 10 feet is feasible. Dredging these areas to the recommended depths would reduce, although not eliminate, macrophyte growths in the treated areas. Based on information provided by the macrophyte surveys, macrophytes would not be expected to reach the water surface in areas with water depths greater than five feet. The dredging would provide a long-term reduction in the growth of macrophytes in the treated areas; would reduce the consumption of oxygen by decaying plant masses; would improve the recreational use potential of these areas; would improve the water circulation in these bay areas, thereby perhaps improving dissolved oxygen levels and reducing algae growth; and would reduce the need for chemicals to control macrophytes.

To manage the fishery resources in Okauchee Lake, it is recommended that the Wisconsin Department of Natural Resources consider protecting and, if necessary, purchasing the highest quality habitat and spawning areas, as identified by Department fish and wildlife managers. The Wisconsin Department of Natural Resources can more effectively protect and manage these areas, particularly around the Okauchee Lake inlet, than can the Lake Management District. It is recommended that the Department continue the management of the northern pike and walleye fisheries, including stocking as necessary. It is recommended that the Department conduct a creel census to evaluate the angler catch and determine if over-harvesting of some species is occurring. It is also recommended that the Department establish a periodic fish surveillance and sampling program for Okauchee, Lower Okauchee, and Upper Oconomowoc Lakes. Under such a program, whereby a specific schedule for periodic fishery surveys would be established, the Department would be able to assess and evaluate long-term trends in the total fishery resource of the lake, not just a specific game fish species.

In summary, the water quality management recommendations for Okauchee Lake were developed within the framework of the adopted regional water quality management plan for the upstream tributary areas draining to the Oconomowoc River, and include:

1. The modification of local land use zoning ordinances to bring local planning and zoning into conformance with the Commission's adopted regional land use plan.

2. The provision of sanitary sewer service to portions of the drainage area directly tributary to the

lake to provide for collection and conveyance of sanitary wastewaters with treatment and discharge at the City of Oconomowoc sewage treatment plant.

3. The implementation of nonpoint source pollution controls in both urban and rural areas, including a public education program, improved public works activities, improved urban "housekeeping" practices, improved agricultural management, and technical and financial assistance from state and federal units of government.

4. The revision of the Waukesha County Sanitary Ordinance to address the operation, maintenance, and inspection of the privately owned onsite sewage disposal systems which would not be eliminated by the proposed centralized sanitary sewerage system.

5. The implementation of construction erosion control ordinances by Waukesha County; the City of Delafield; the Villages of Chenequa and Oconomowoc Lake; and the Towns of Merton, Oconomowoc, and Summit.

6. The implementation of a continuing in-lake water quality and fishery resource monitoring and stocking program by the Okauchee Lake Management District and the Wisconsin Department of Natural Resources.

Implementation of the recommended nonpoint source pollution controls in the drainage area directly tributary to Okauchee Lake and in-lake management would entail a total capital cost of about $1.66 million, with an average annual operation and maintenance cost of about $50,600, and a total average annual cost of $135,300 over a 20-year plan period. About 76 percent of the capital cost of watershed management is associated with control of erosion from construction activities, with 25 percent of this construction erosion control cost being borne by the public sector. The in-lake management costs include a total average annual cost of $900 for an in-lake water quality monitoring program. Based on the expected 1985 population of the drainage area directly tributary to the lakes, the total average annual cost--$135,300--for each household in the drainage area would be about $81, or about $27 per resident. The average annual local public sector cost of the recommended plan is about $77,300, or about $46 for each household in the drainage area, or about $15 per resident.

Okauchee Lake is a valuable natural resource in the Southeastern Wisconsin Region. There is a delicate, complex relationship between the water quality conditions of a lake and the land uses within the directly tributary drainage area of the lake. Projected increases in population, urbanization, income, leisure time, and individual mobility forecast for the Region will result in additional pressure for development in the direct drainage area of lakes in southeastern Wisconsin and for water-based recreation on the lakes themselves. Without the adoption and administration of an effective water quality management program for Okauchee Lake, based upon comprehensive water quality management and related land use plans, the water quality protection needed to maintain conditions in Okauchee Lake suitable for recreational use and for maintenance of fish and other aquatic life will not be provided.

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APPENDICES

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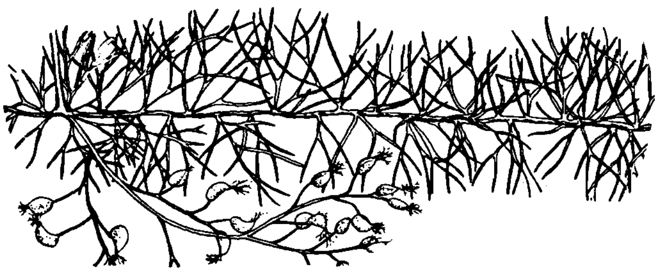
Appendix A

ILLUSTRATIONS OF REPRESENTATIVE BIOTA IN OKAUCHEE LAKE

Appendix A-1

REPRESENTATIVE MACROPHYTES FOUND IN SOUTHEASTERN WISCONSIN LAKES

BLADDERWORT (Utricularia sp.)

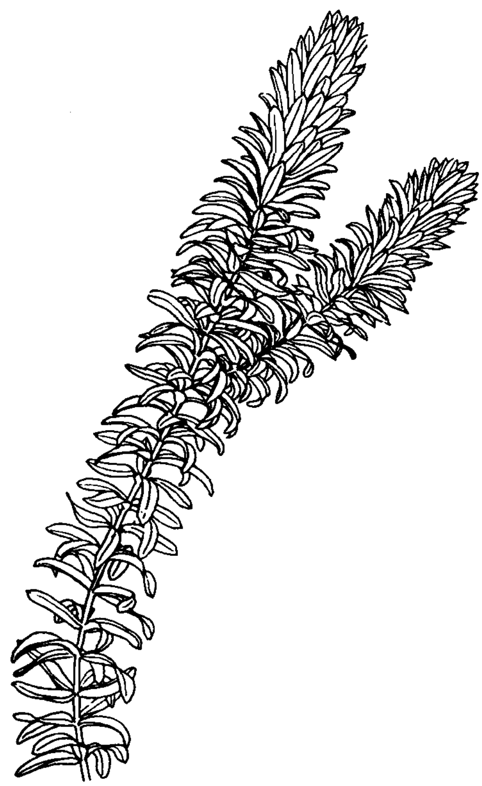


Bladderwort is a carnivorous plant which occurs in shallow ponds and lakes or on wet soils. The small bladders are traps which catch tiny animal life, particularly crustaceans. Bladderwort provides some food and cover for fish. It is never abundant enough to become a nuisance.

BUSHY PONDWEED (Najas flexilis)

Bushy pondweed is a common species in ponds, small lakes, and slow-moving streams in southeastern Wisconsin. It provides food and cover for fish. Bushy pondweed may become a nuisance during late summer in some lakes.

COMMON WATERWEED (Anacharis canadensis)



Common waterweed is a submerged plant which usually occurs in hard water. It provides cover for many small aquatic organisms which serve as food for the fish population. Waterweed is an aggressive plant and may suppress the growth of other aquatic plants.

COONTAIL (Ceratophyllum demersum)

Coontail is a submerged plant which prefers hard water. It supplies cover for shrimp and young fish and supports insects which are valuable as fish food. A heavy growth of coontail is an indication of very fertile lake conditions.

CURLY LEAF PONDWEED (Potamogeton crispus)

Curly leaf pondweed is an introduced plant species which does well in hard or brackish water which is usually polluted. However, curly leaf pondweed does provide good food, shelter, and shade for fish and is valuable for early spawning fish.

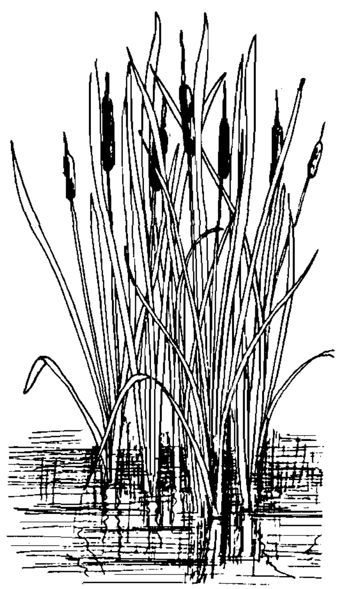
FLOATING LEAF PONDWEED (Potamogeton natans)

Floating leaf pondweed has leaves which float on the surface with the rest of the plant submerged. It provides food and shelter for fish and other aquatic species.

LARGE LEAF PONDWEED (Potamogeton amplifolius)

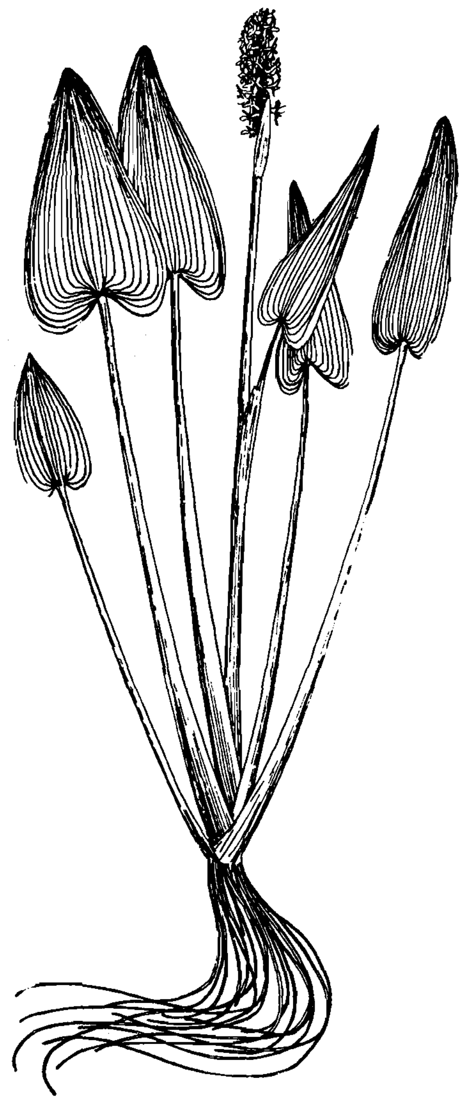
Large leaf pondweed is usually found in relatively hard water. Submersed, it supports insects and provides a good food supply for fish.

NARROW-LEAVED CATTAIL (Typha angustifolia)



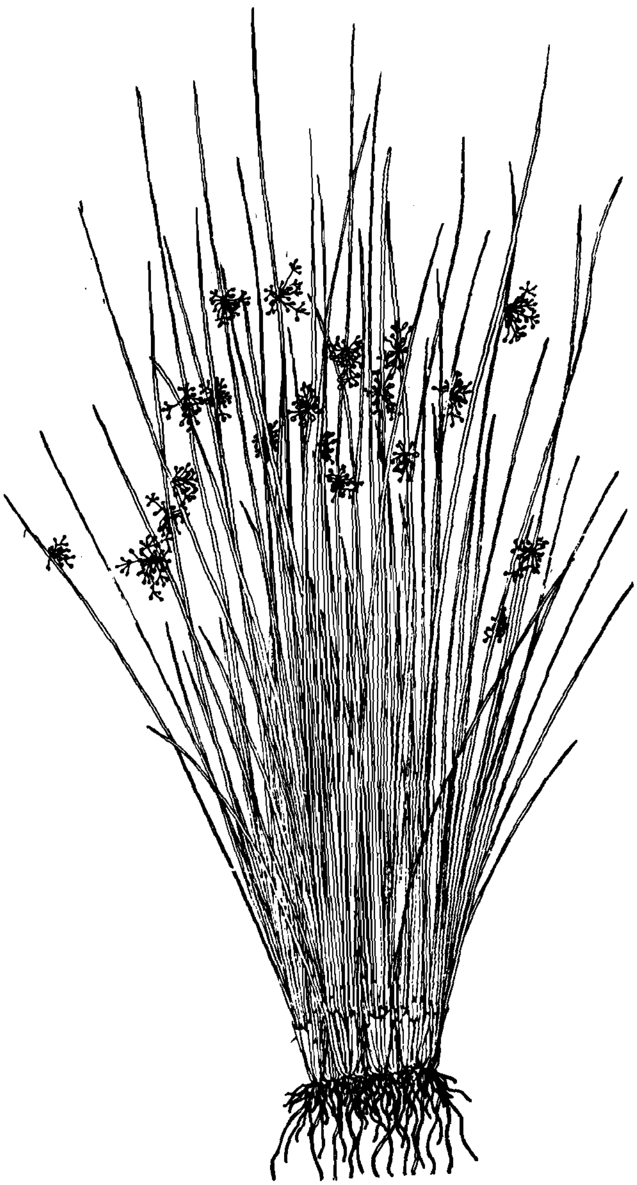
Narrow-leaved cattail may appear in almost any wet place. It is used as a spawning area for sunfish and shelter for various species of young fish, as well as a variety of other forms of wildlife. Cattails often occur in dense stands and therefore may become a nuisance.

PICKEREL WEED (Pontedera cordata)



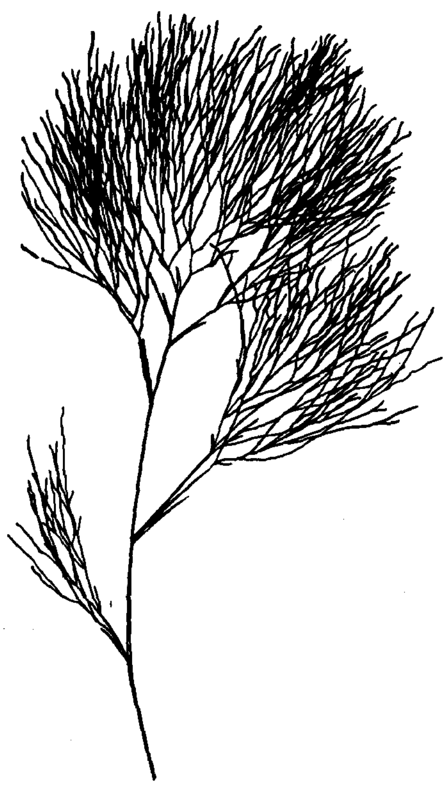
Pickerel weed is common in shallow water with muddy shores. It provides shade and shelter for fish but has only slight value as food and cover. Pickerel weed usually is not abundant enough to be a nuisance.

RUSH (*Juncus* sp.)



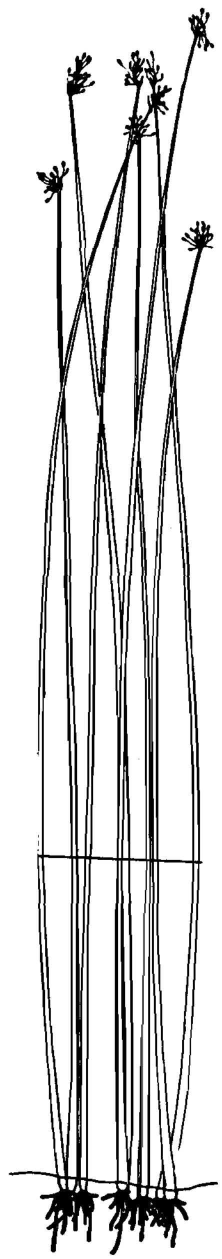
Rushes are an emergent aquatic plant with a widespread habitat which ranges from wet meadows and lakeshores to shallow pools. Thick growths of rushes often form spawning grounds for rock bass, bluegills, and other sunfish.

SAGO PONDWEED (*Potamogeton pectinatus*)



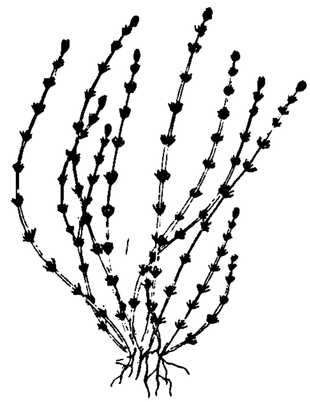
Sago pondweed is found in hard or brackish water of lakes and slow-flowing streams. Sago pondweed provides food and shelter for young trout and other fish.

SOFTSTEM BULRUSH (Scirpus validus)



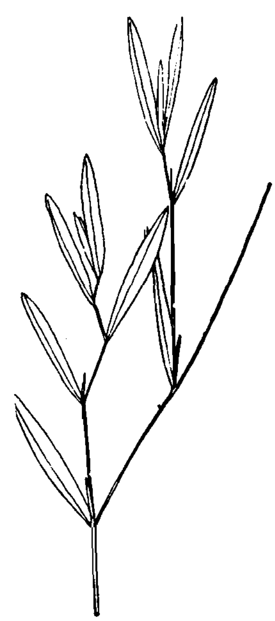
Softstem bulrush is an emergent aquatic species. It supports insects and provides food for young fish and many species of waterfowl.

STONEWORT (Chara aspera)



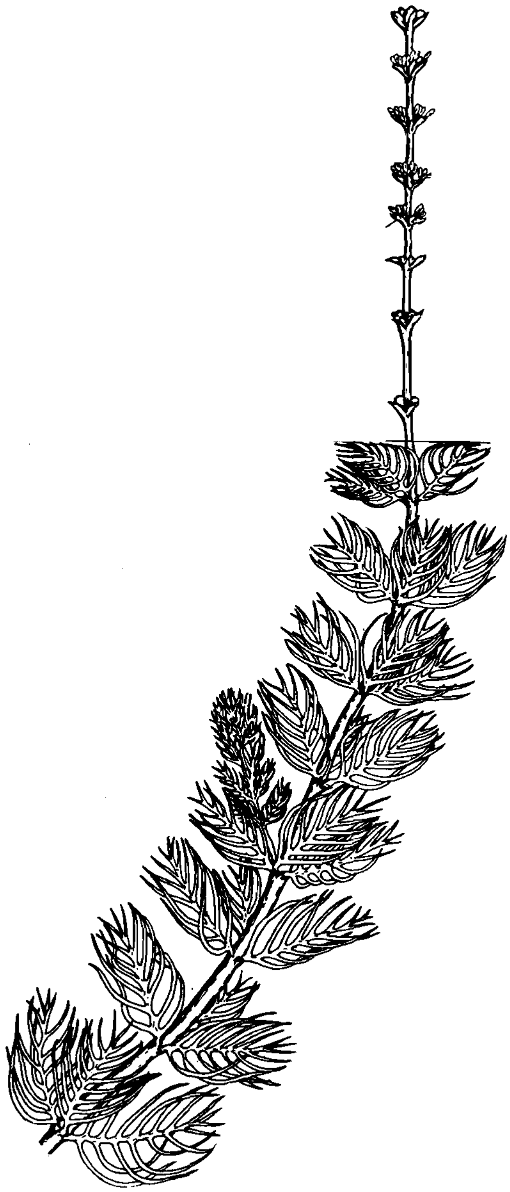
Stonewort is a type of algae which usually occurs in hard water. It provides fair cover for fish and produces excellent food for young trout, large and small mouth bass, and black bass.

VARIABLE PONDWEED (Potamogeton gramineus)



Variable pondweed is a submergent species. However, it will occasionally grow on muddy shores. Variable pondweed provides food and cover for fish.

WATER MILFOIL (*Myriophyllum exalbescens*)

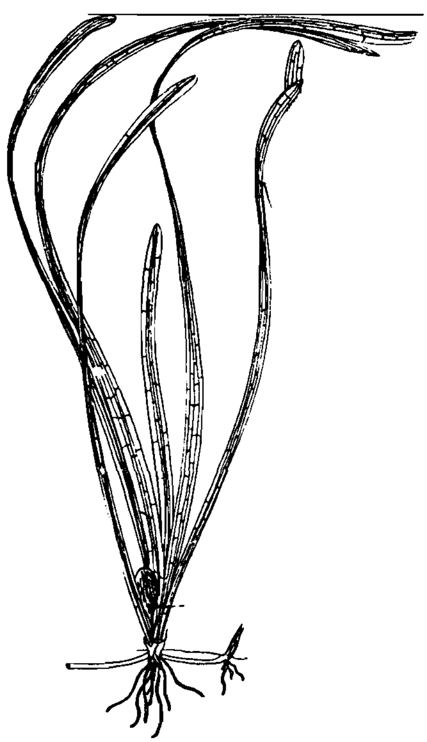


Water milfoil is a submergent plant which may cause extensive weed problems in lakes and streams. However, when not overabundant, water milfoil provides cover for fish and is a valuable food source for many forms of aquatic life.

WATER SMARTWEED (*Polygonum natans*)

Water smartweed is found along the shoreline of shallow water. It provides food and cover for fish and wildlife. Water smartweed is never abundant enough to cause aquatic nuisance problems.

WILD CELERY OR EEL GRASS (Vallisneria americana)

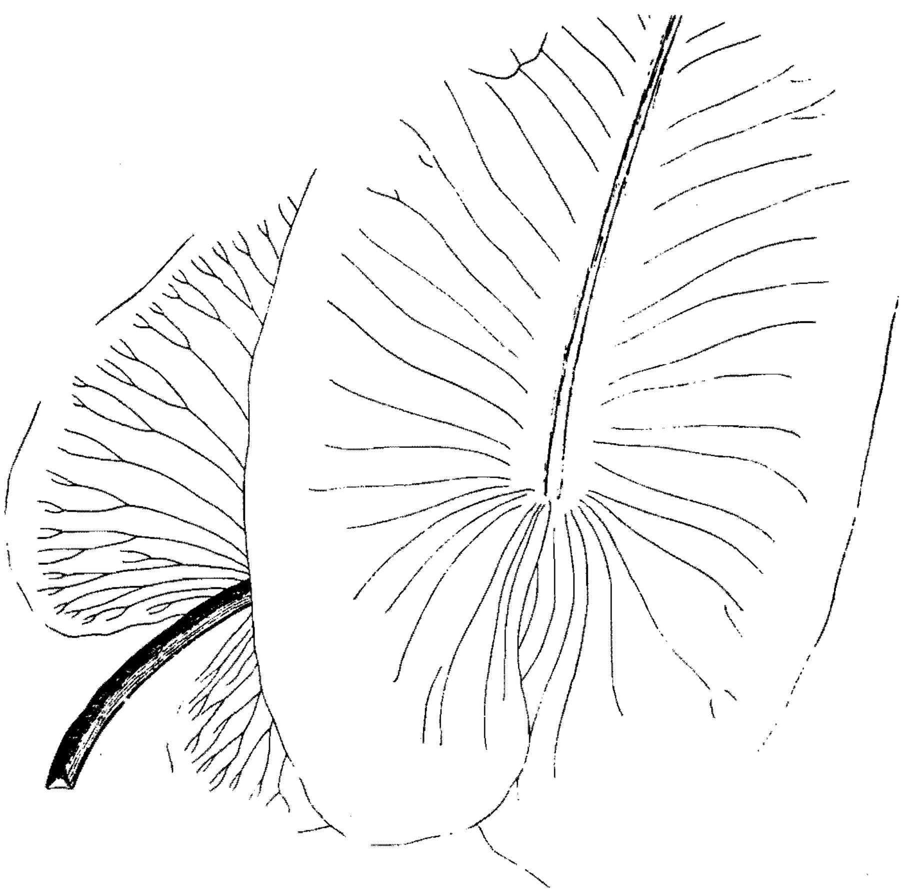


Eel grass is a submersed plant which provides shade, shelter, and food for fish. It supports insects and is a valuable food source for waterfowl. Sometimes forming dense growths, eel grass may be undesirable in swimming areas.

WILD RICE (Zizania aquatica)

Wild rice is a valuable emergent aquatic grass. Wild rice prefers clean water with low turbidity during the growing season. Wild rice is an annual grass with seeds that depend on sufficient light penetration in spring and early summer for germination. Wild rice is an important food source for many species of fish and waterfowl. It is also a food source for humans.

YELLOW WATER LILY (Nuphar variegatum)



Yellow water lily and white water lily are found in shallow portions of lakes and ponds. The leaves float on the surface of the water and algae and insects often grow under the leaves. Yellow and white water lilies provide shade and shelter for fish but may cause problems because of the extensiveness of their beds in shallow portions of lakes.

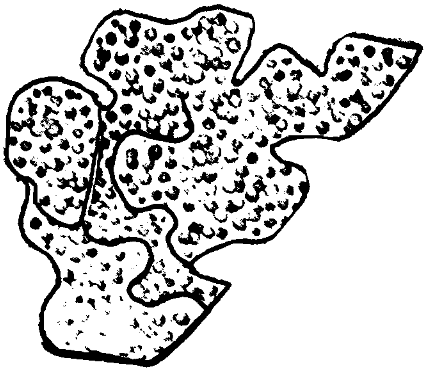
Appendix A-2

REPRESENTATIVE PHYTOPLANKTON FOUND IN SOUTHEASTERN WISCONSIN LAKES

Anabaena

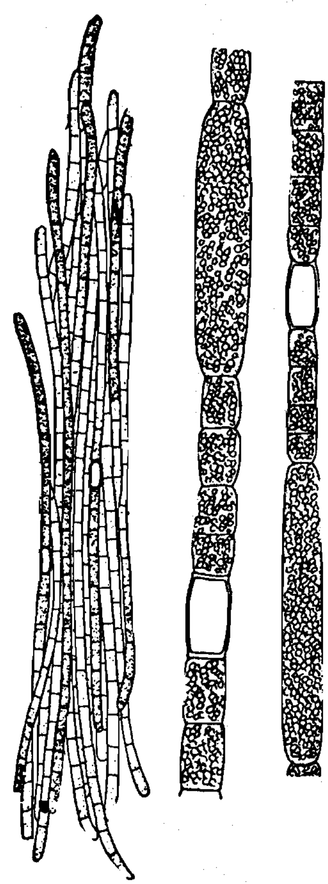
There are many individual species of the bluegreen algae, Anabaena. Some species are solitary while others form aggregated masses of indefinite shape. Anabaena seldom cause disagreeable conditions in lakes and reservoirs when they bloom, as they remain suspended throughout the water column and do not form surface scums. However, some species of Anabaena have been known to cause toxic water supplies which have caused animal fatalities.

Anacystis



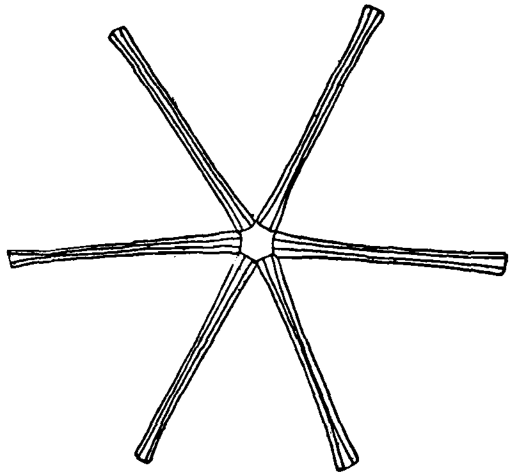
Anacystis is a loose colony of small spherical bluegreen algae cells contained in a gelatinous mass. The colony floats in the water column and is visible to the naked eye. Like Anabaena, Anacystis have been known to cause toxic water supplies.

Aphanizomenon



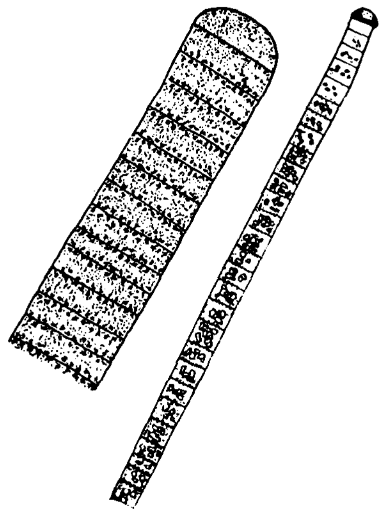
Individual cells of Aphanizomenon form strands which lie parallel in bundles and often occur so abundantly that the water appears to be filled with bits of chopped grass. The individual cells contain air spaces which give the plants great bouyancy. This accounts for the abundant growths of this bluegreen algae becoming concentrated on or near the surface where floating scum results. Dense growths may lead directly or indirectly to the death of fish through oxygen depletion or the secretion of toxins.

Asterionella



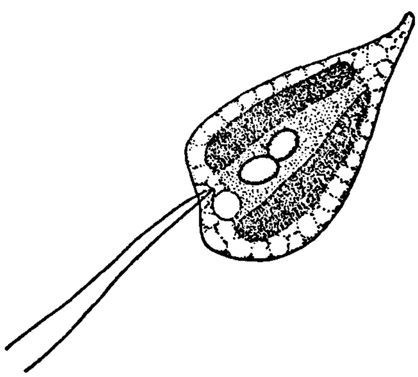
The diatom, Asterionella, usually occurs as a member of lake plankton. It prefers hard-water lakes and is readily identified by the spoke-like arrangement of the rectangular arms about a common center. Asterionella may be so abundant that lake water used for domestic water supplies may have a fishy taste.

Oscillatoria



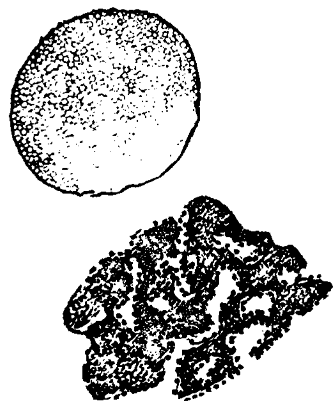
Oscillatoria is a filamentous bluegreen algae that grows in dense darkly colored clumps or mats. A characteristic of this bluegreen algae is the active oscillating movement for which it is named.

Dinobryon



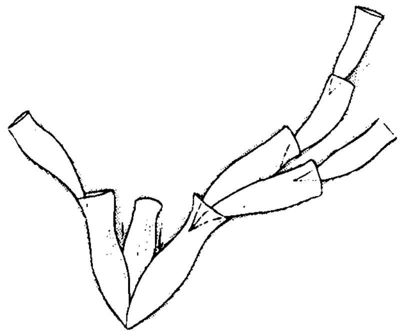
Dinobryon typically inhabit hard water lakes and, under certain conditions, may bloom. Dinobryon may produce disagreeable odors and tastes in domestic water supplies.

Microcystis



The cells of Microcystis, a bluegreen algae, are closely compacted and irregularly arranged in colonies enclosed in mucilage. Where some species of Microcystis occur, the habitat is completely dominated by this algae to the exclusion of all other forms of algae. Dense growths of Microcystis may cause oxygen depletion or secrete toxins which cause fish kills.

YELLOW GREEN ALGAE (Chrysophyta)



Many freshwater Chrysophyta are restricted to cold brooks, especially mountain streams, springs, and lakes duirng cool seasons. Most thrive in water relatively free of pollution.

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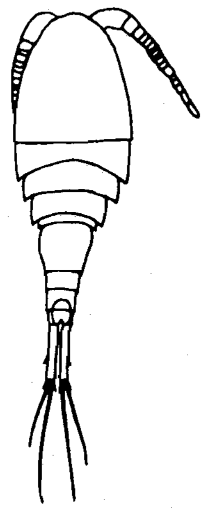
Appendix A-3

A FORM OF ZOOPLANKTON FOUND IN SOUTHEASTERN WISCONSIN LAKES

COPEPODS (Diacyclops thomasi)



A common example of copepods found in permanent bodies of water of all types from shallow ponds and marshes to lakes is Diacyclops thomasi. The adults are predaceous on other zooplankton and can injure fish fry.

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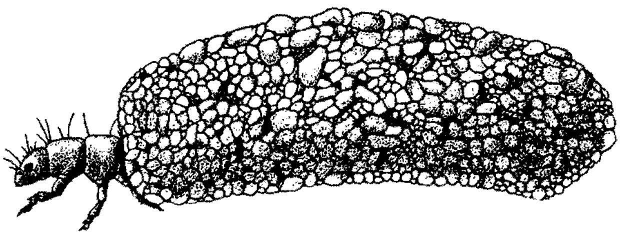
Appendix A-4

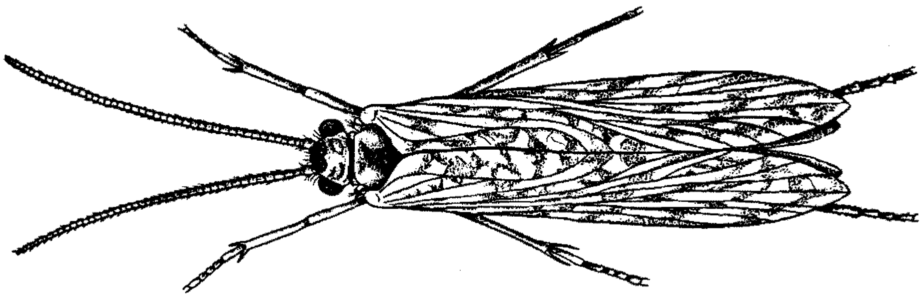
A FORM OF BENTHIC OR BOTTOM DWELLING ORGANISM FOUND IN SOUTHEASTERN WISCONSIN LAKES

CADDISFLIES (*Trichoptera*)

Caddisfly Larvae and Case



Adult Caddisfly



Caddisflies are found in most types of freshwater habitat, including streams, spring seepages, rivers, lakes, marshes, and temporary pools. Their tolerance to organic pollution varies widely, with some species being quite tolerant. Caddisflies are a food source for many species of fish.

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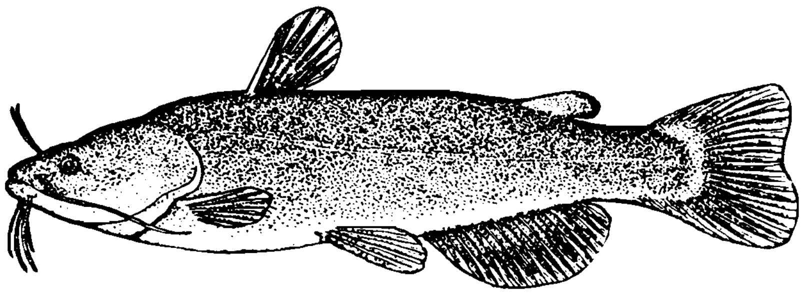
Appendix A-5

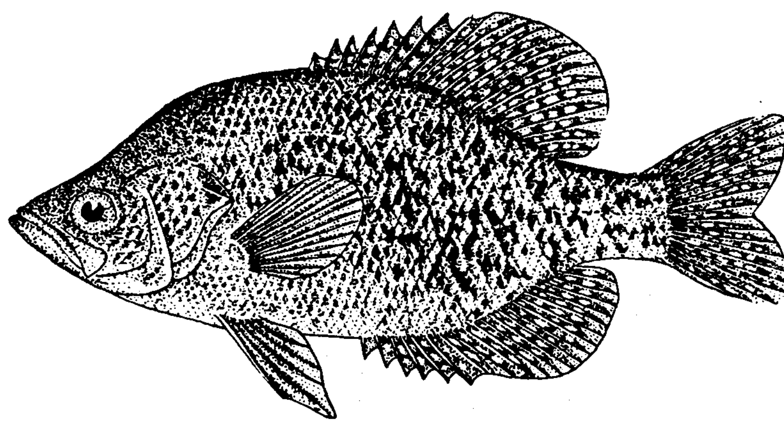
REPRESENTATIVE FISH SPECIES FOUND IN SOUTHEASTERN WISCONSIN LAKES

BLACK BULLHEAD (Ictalurus melas)



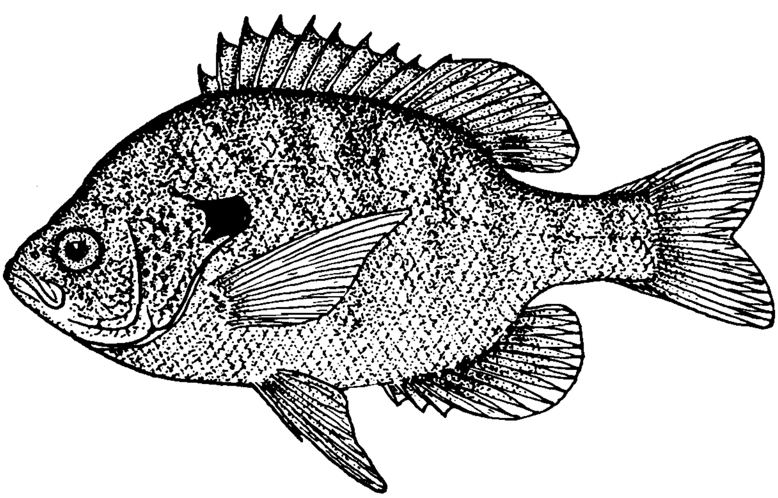
The black bullhead is common in shallow lakes and muddy streams. It nests in shallow water on either a sand or mud bottom. Bullheads are scavengers and will eat whatever food is available, such as minnows, leeches, crayfish, and amphipods.

BLACK CRAPPIE (Pomoxis nigromaculatus)



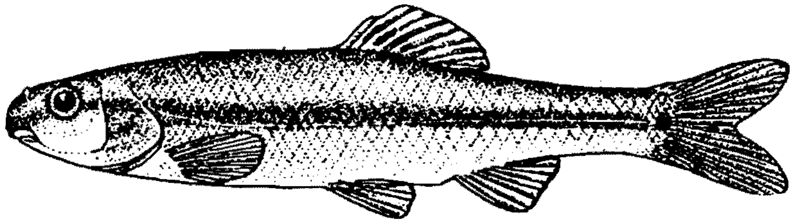
The black crappie prefers large streams and medium-sized lakes. It nests in water between three and six feet deep with a somewhat muddy bottom. Crappies feed on aquatic insects, small crustaceans, minnows, and other small fish.

BLUEGILL (Lepomis macrochirus)



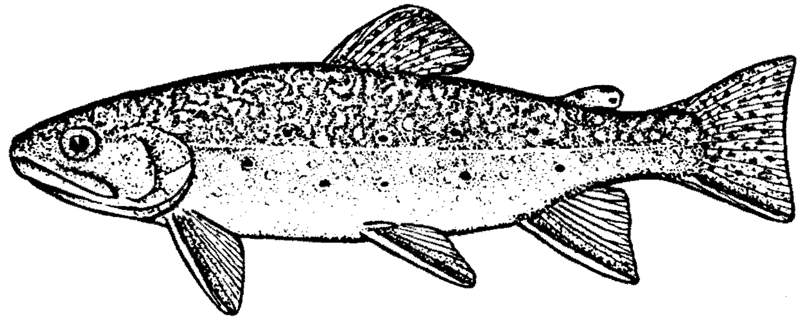
The bluegill is found in nearly all clear water lakes and streams. It nests in shallow areas with sandy bottoms; nests are often crowded together. Bluegills feed on small aquatic insects, worms, snails, and amphipods.

BLUNTNOSE MINNOW (Pimephales notatus)



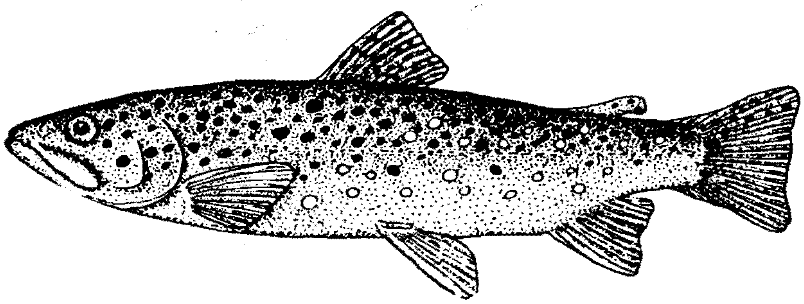
The bluntnose minnow is common in lakes and streams, but not in large rivers. The nest is built under an object, such as a rock or log. Bluntnose minnows feed mainly on algae.

BROOK TROUT (Salvelinus fontinalis)



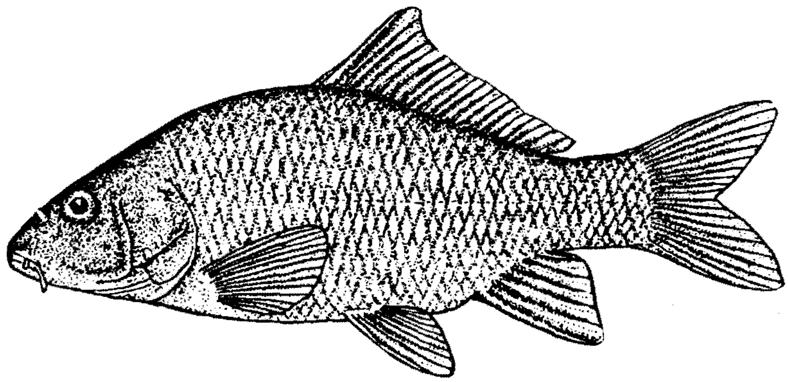
The brook trout, a native species in southeastern Wisconsin, prefers clear brooks and rivers in which the mean annual temperature rarely exceeds 50°F. The nest or redd is built on gravel bottoms in shallow riffle areas. Brook trout feed on adult aquatic insects and their larvae.

BROWN TROUT (Salmo trutta)



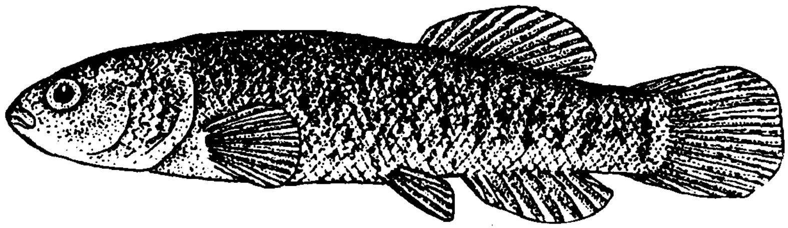
The brown trout is an introduced trout species which has become common in cold water streams. Nests or redds are built on sand and gravel bars at the mouths of tributaries. Young brown trout feed on small crustaceans and aquatic insects. Adults eat small fish, snails, crayfish, and terrestrial insects.

CARP (Cyprinus carpio)



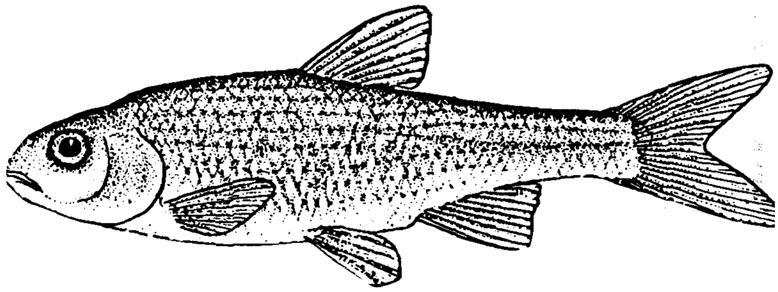
The carp is an introduced species which is tolerant of low dissolved oxygen conditions and prefers warm waters, with shallow mud-bottom lakes. Carp eat a wide variety of food. The uprooting of vegetation during feeding results in suspension of bottom sediments into the water column and a loss of aquatic plant beds which other fish species depend on.

CENTRAL MUDMINNOW (Umbra limi)



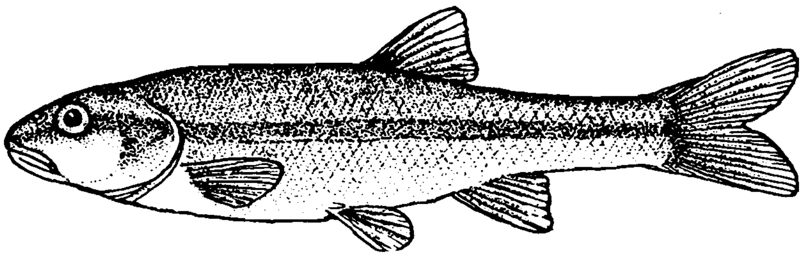
The central mudminnow prefers bog habitats, ditches, and streams with mud bottoms supporting dense aquatic vegetation. Spawning occurs in late spring and early summer. Mudminnows feed on insects, small crustaceans, and worms.

COMMON SHINER (Notropis cornutus)



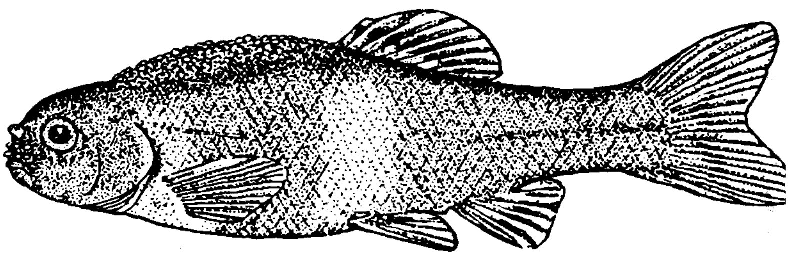
The common shiner occurs in habitats ranging from intermittent streams to large rivers and lakes. Common shiners are a forage fish that have value as a food source for game species. Shiners feed on small insects, crustaceans, and some algae.

CREEK CHUB (Semotilus atromaculatus)



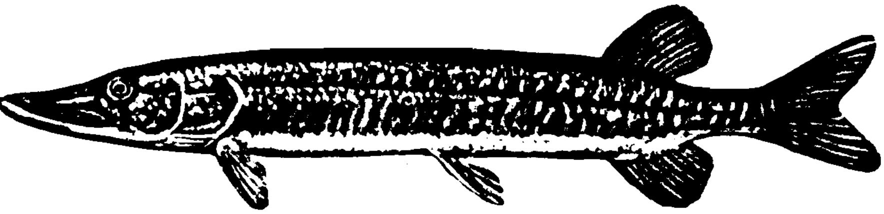
The creek chub prefers small streams and rivers but occasionally is found in lakes and large rivers. Creek chubs are quite common in beaver dam pools and may compete with trout for food. Chubs feed on all types of insects, amphipods, vegetation, and other, smaller fish.

FATHEAD MINNOW (Pimphales promelas)



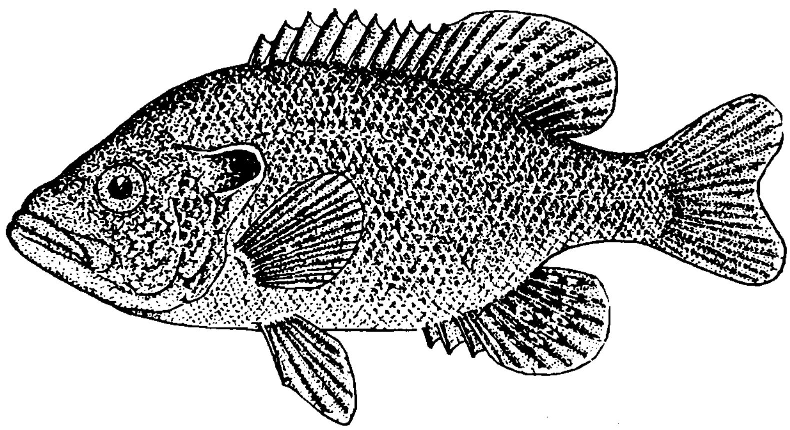
The fathead minnow prefers shallow lakes, ponds, and ditches. Nests are built on the underside of sticks, boards, and rocks in water between 3 and 12 inches deep. The fathead minnow can withstand very low oxygen conditions and, therefore, are very tolerant to pollution. Young fathead minnows feed on algae, while adults feed on a variety of aquatic insects, worms, and plants. The fathead minnow is a forage species and serves as a food source for many types of game fish.

GRASS PICKERAL (Esox americanus vermiculatus)



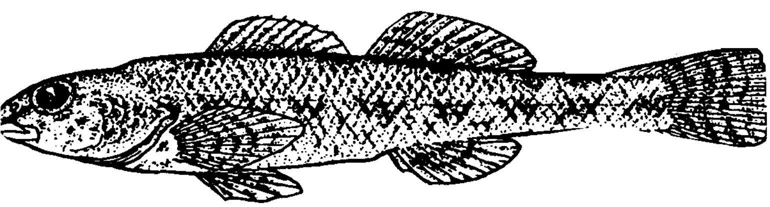
The grass pickerel is common in weedy portions of lakes and rivers. Pickerels are predators and as such feed almost exclusively on other fish. Grass pickerel are too small to have much value as a game fish.

GREEN SUNFISH (Lepomis cyanellus)



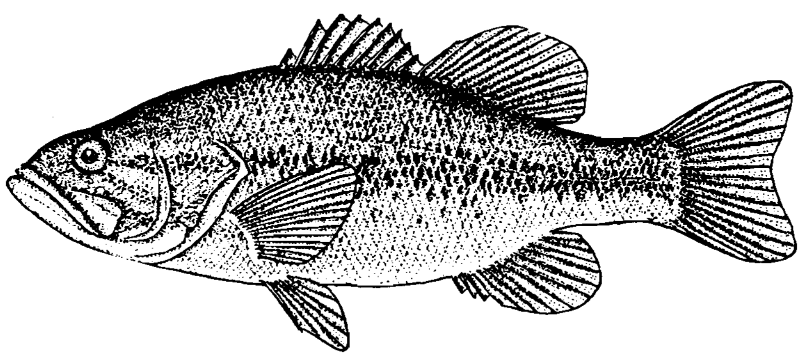
The green sunfish prefers small, shallow lakes and is common in creeks. Green sunfish feed on aquatic insects and any flying insects that happen to fall into the water. Large numbers of stunted adults may occur in some lakes and as such may decrease the viability of the existing fishery.

JOHNNY DARTER (Etheostoma nigrum)



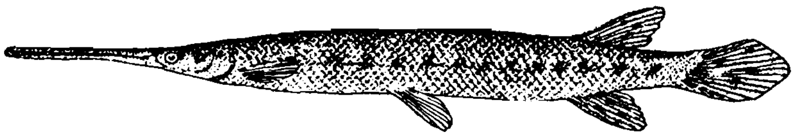
The johnny darter occurs in relatively clean lakes and streams. Nests are built under sticks and stones. The johnny darter feeds on algae and small, immature insects.

LARGEMOUTH BASS (Micropterus salmoides)



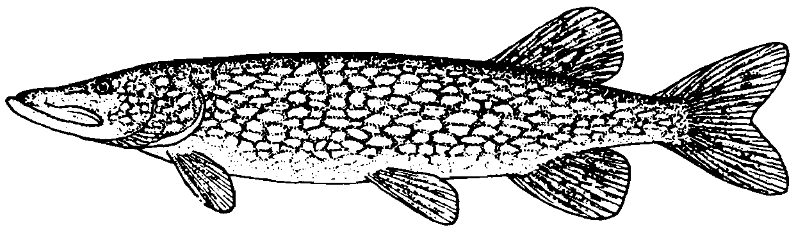
The largemouth bass prefers small- to medium-sized hardwater lakes with clear water, sandy shores, and marginal weed beds. The largemouth bass is carnivorous and as an adult feeds on perch, minnows, and small sunfish.

LONGNOSE GAR (Lepisosteus osseus)



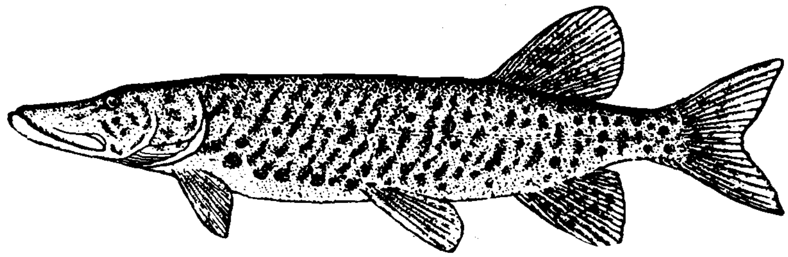
The longnose gar is a warmwater fish that often can tolerate surface waters which are too polluted for other species. Gars feed on game and forage fish and in some instances may alter fish populations enough to damage a fishery resource.

NORTHERN PIKE (Esox lucius)



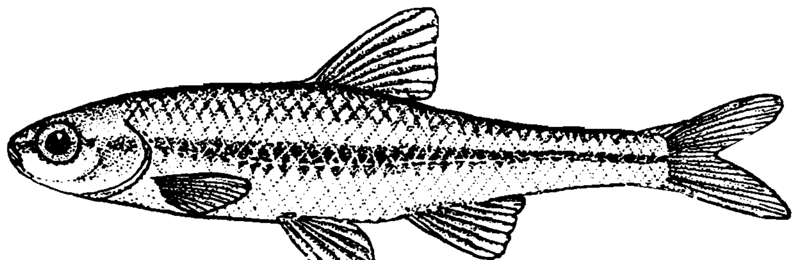
The northern pike is common in southeastern Wisconsin lakes. It feeds on a variety of fish, including perch, small suckers, sunfish, and even smaller northern pike. Spawning occurs immediately after the ice melts in April or early May in wetlands adjacent to lakes and streams.

MUSKELLUNGE (Esox masquinongy)



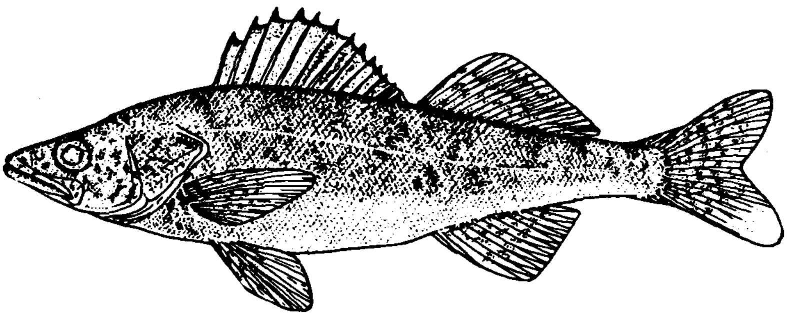
The muskellunge is common in lakes but is seldom abundant because it requires a large area of water to supply enough food for its voracious appetite. Spawning occurs in early May in tributary streams and shallow lake channels. Muskellunge are strictly carnivorous, feeding primarily on perch and suckers. A hydrid strain (tiger muskie) is stocked in many lakes in southeastern Wisconsin.

PUGNOSE SHINER (Notropis anogenus)



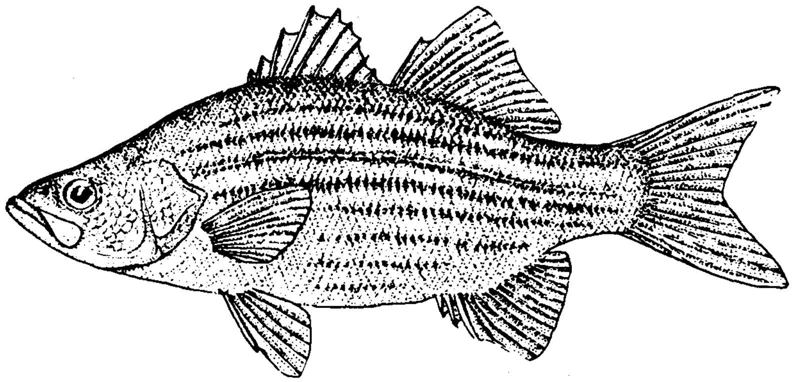
The pugnose shiner is threatened in Wisconsin. This small fish—up to two inches in length—prefers weedy waters in streams and lakes. Little is known about its life history as it is one of the rarest shiners. Changes by man in streams, rivers, and lakes have been responsible for its disappearance and resulting inclusion on the threatened species list in Wisconsin.

WALLEYE (Stizostedion vitreum vitreum)



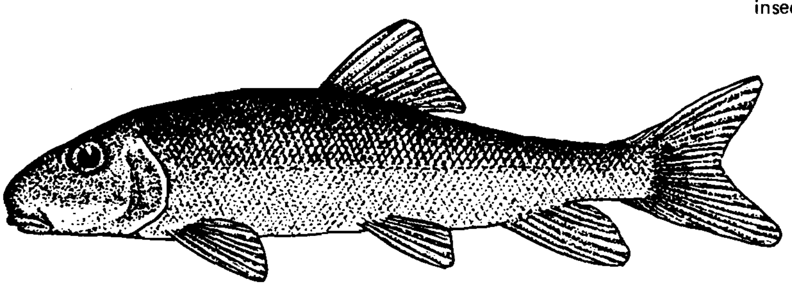
The walleye prefers clean and moderately warm to cold lakes and rivers. Spawning occurs in early spring on sand bars and shoals. Walleye feed on small minnows, small bullheads, and leeches. Walleye are a very desirable game fish.

WHITE BASS (Morone chrysops)



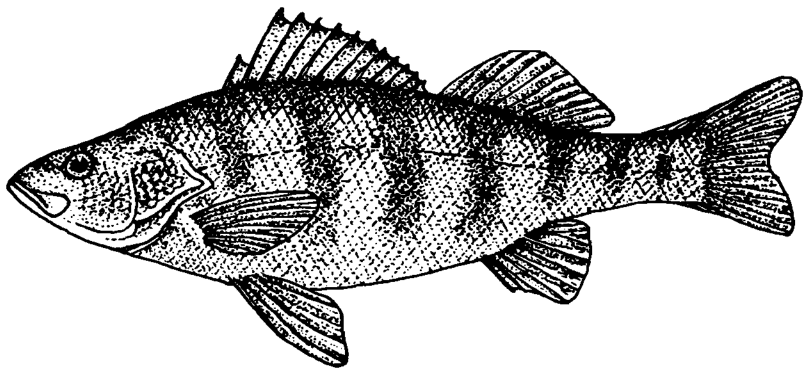
The white bass occurs in large rivers and connected lakes. White bass usually travel in large schools near the surface. Eggs are scattered randomly on shallow bars and gravelly reefs. White bass feed on insects and small fish.

WHITE SUCKER (Catostomus commersoni)



The white sucker occurs in almost every permanent body of fresh water, from small streams to large lakes. White suckers have an important role in cleaning lakes and streams. White suckers are a forage species and serve as a food source for many other species of fish.

YELLOW PERCH (Perca flavescens)



Yellow perch are schooling fish common to lakes and streams which do not experience winter kills. Eggs are deposited in a gelatinous, ribbonlike bank over submerged aquatic plants or branches. Perch are predaceous and feed on minnows, aquatic insects, crayfish, leeches, and snails. In addition, perch may compete with other game fish for food and space if populations get too large.

Appendix B

ANALYSIS OF STORM WATER MANAGEMENT ALTERNATIVES FOR STH-16 DRAINAGE AREA AT ICE HOUSE BAY, OKAUCHEE LAKE

INTRODUCTION

One specific site at which nonpoint pollution control practices were clearly identified as necessary was the area lying south of Okauchee Lake along that portion of STH 16 extending easterly approximately 2,300 feet from the intersection with CTH PP. The area drains to Ice House Bay at the foot of Jaeckles Boulevard. With the reconstruction of this portion of the highway partially completed in 1979, local residents reported severe storm water management problems, including localized street flooding, damage to private property due to the flooding, and significant contributions of sediment and associated pollutants to Ice House Bay.

At the request of the Okauchee Lake Management District Commissioners, the problems and a series of alternative measures to alleviate the problems were analyzed jointly by the staffs of the Wisconsin Departments of Transportation and Natural Resources, the Waukesha County Soil and Water Conservation District, and the Regional Planning Commission. This appendix presents the results of those analyses, and includes an identification of the existing problems, an evaluation of the depth and volume of sediment deposited in Ice House Bay, a quantification of the estimated peak rates of storm water runoff from the tributary area, and an identification and analysis of potential measures to resolve the problems. The analyses took place in two phases. The first phase consisted of an identification of the existing storm water management problems and of the historic changes which have occurred in land use and in the storm water drainage system which serves the area. The second phase consisted of the identification and analysis of alternative storm water management measures for abating the problems of the area.

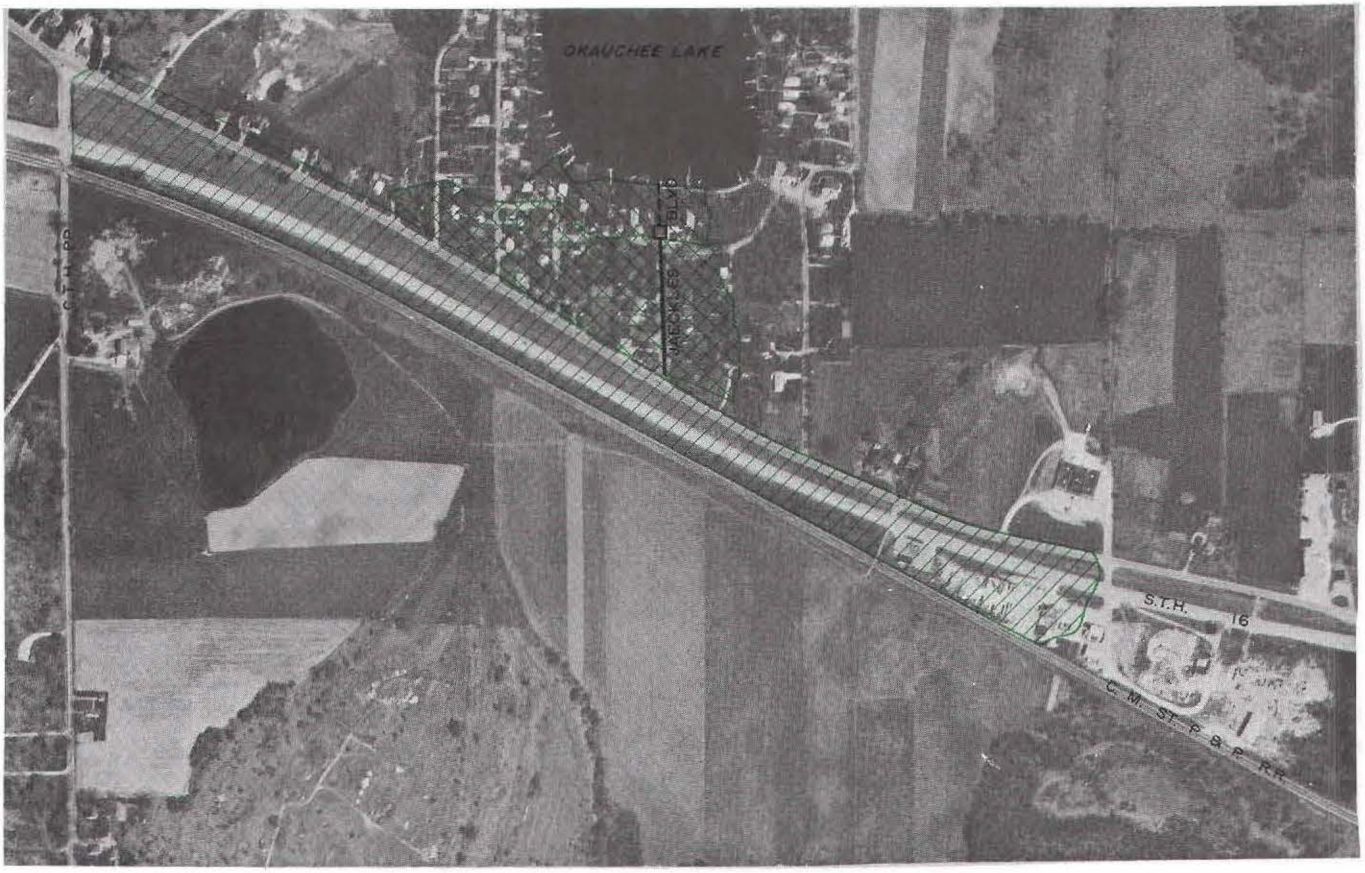
BACKGROUND AND PROBLEM IDENTIFICATION

In order to provide an understanding of the existing storm water management system serving the area which drains to Ice House Bay at the foot of Jaeckles Boulevard, and the existing storm water management problems in that area, the existing system was analyzed and the development decisions leading to the existing situation were reviewed. The principal features and components of the storm water management system for the drainage area are illustrated on Maps B-1 and B-2. Table B-1 summarizes selected characteristics of the storm water management system serving the area under existing and historic conditions. The results of these analyses may be summarized as follows:

1. The Wisconsin Department of Transportation (WisDOT), in converting STH 16 from a two-lane to a four-lane divided limited access highway, undertook a major highway reconstruction project in portions of the Towns of Oconomowoc, Summit, Merton, and Delafield. Prior to reconstruction in 1978, the drainage area concerned discharged into a 24-inch diameter storm sewer constructed of corrugated metal culvert pipe (CMCP) located on the west side of Jaeckles Boulevard, as shown on Map B-1. The drainage area of approximately 26 acres tributary to this storm sewer is also shown on Map B-1. As indi-

Map B-1

STORM WATER MANAGEMENT FACILITIES IN THE STH 16 AREA NEAR ICE HOUSE BAY, OKAUCHEE LAKE BEFORE 1978-1979 CONSTRUCTION



LEGEND

- DIRECT DRAINAGE TO OKAUCHEE LAKE
- AREA TRIBUTARY TO CATCH BASIN AT THE FOOT OF JAECKLES BOULEVARD, BEFORE 1978–1979 CONSTRUCTION
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CORRUGATED METAL CULVERT PIPE STORM SEWER ON WEST SIDE OF JAECKLES BOULEVARD, BEFORE 1978 - 1979 CONSTRUCTION
- 24 INCH CORRUGATED METAL CULVERT PIPE STORM SEWER
- 29 INCH BY 18 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- CATCH BASIN

GRAPHIC SCALE

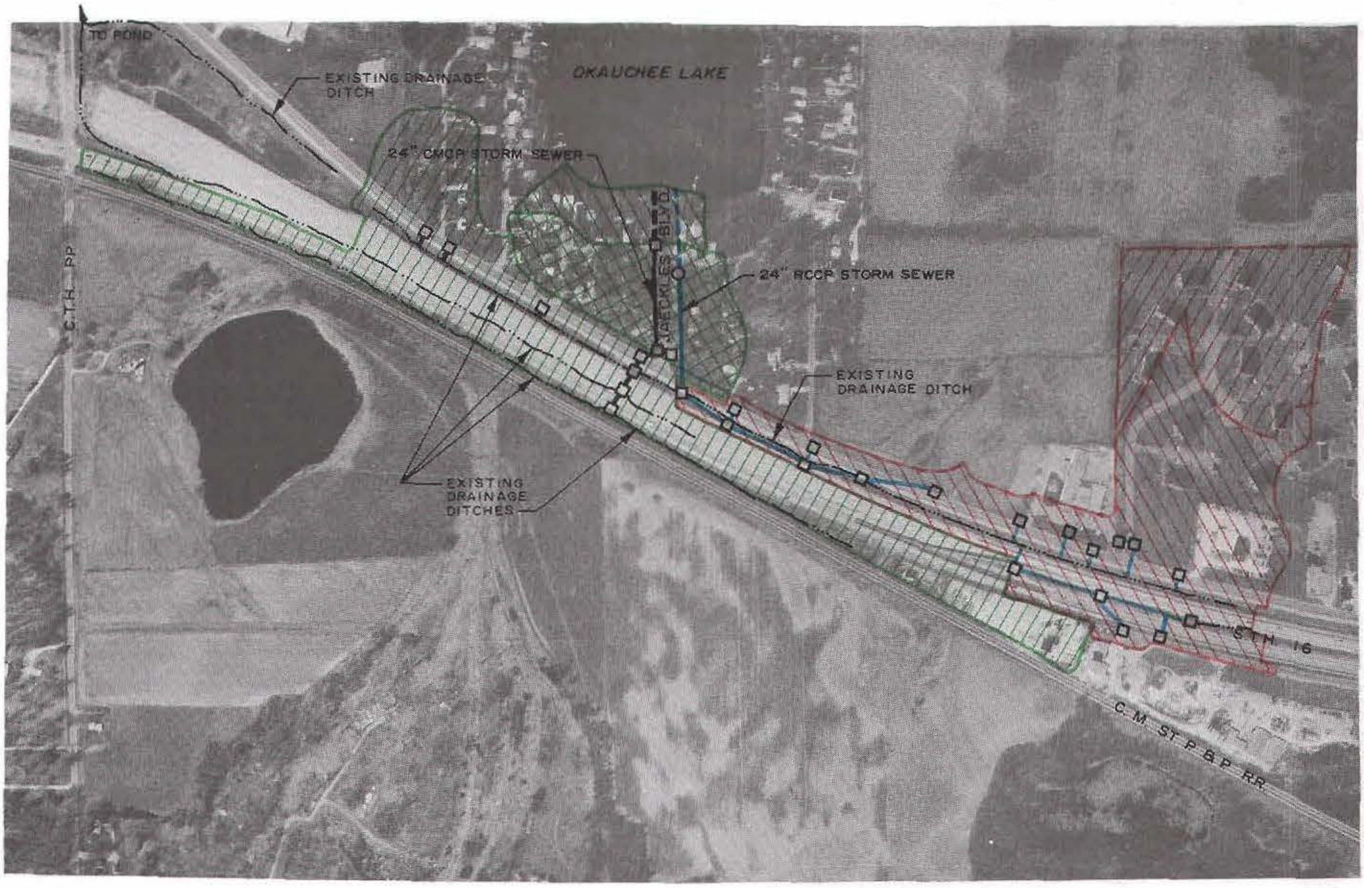
0 400 800 FEET

Source: SEWRPC.

cated in Table B-1, the peak rate of storm water runoff from the 26-acre drainage area for a 25-year recurrence interval storm event--normally used by the WisDOT for the design of this type of drainage improvement--was estimated at 16.2 cubic feet per second (cfs). The 24-inch diameter CMCP storm sewer terminates about 200 feet from Ice House Bay, at which point storm water is presently conveyed to Ice House Bay by a 29-inch by 18-inch storm sewer constructed of corrugated metal pipe arch (CMPA) having a peak hydraulic capacity of

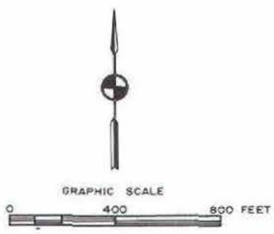
Map B-2

STORM WATER MANAGEMENT FACILITIES IN THE STH 16 AREA NEAR ICE HOUSE BAY, OKAUCHEE LAKE AFTER 1978 CONSTRUCTION



LEGEND

- DIRECT DRAINAGE TO OKAUCHEE LAKE
- AREA TRIBUTARY TO CATCH BASIN AT THE FOOT OF JAECKLES BOULEVARD, AFTER 1978-1979 CONSTRUCTION
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CORRUGATED METAL CULVERT PIPE STORM SEWER ON WEST SIDE OF JAECKLES BOULEVARD, AFTER 1978-1979 CONSTRUCTION
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH REINFORCED CONCRETE PIPE STORM SEWER ON EAST SIDE OF JAECKLES BOULEVARD, AFTER 1978-1979 CONSTRUCTION
- ADDITIONAL 9 ACRES ADDED TO TRIBUTARY AREA PRIOR TO 1978 CONSTRUCTION
- STORM SEWER TRIBUTARY TO 29 INCH BY 18 INCH CORRUGATED METAL PIPE ARCH STORM SEWER ON WEST SIDE OF JAECKLES BOULEVARD
- STORM SEWER TRIBUTARY TO 28 INCH BY 20 INCH CORRUGATED METAL PIPE ARCH STORM SEWER ON EAST SIDE OF JAECKLES BOULEVARD
- 29 INCH BY 18 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- 28 INCH BY 20 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- CATCH BASIN
- MANHOLE



Source: SEWRPC.

Table B-1

SELECTED CHARACTERISTICS OF THE STORM WATER MANAGEMENT SYSTEM FOR THE DRAINAGE AREA DIRECTLY TRIBUTARY TO ICE HOUSE BAY AT JAECKLES BOULEVARD: HISTORIC AND CURRENT (1980) CONDITIONS

		Drainage System Component Hydraulic Capacity, 25-Year Recurrence Interval Flow Estimates and Acreage of Tributary Area								
		24-Inch Diameter Storm Sewer (CMCP) Along West Side of Jaeckles Boulevard			Channel (Pre-1965), or 29" x 18" Storm Sewer (CMPA) at Foot of Jaeckles Boulevard			24-Inch Diameter Storm Sewer (RCCP) and 28" x 20" Storm Sewer (CMPA) Along East Side of Jaeckles Boulevard		
Date	Description	Estimated Hydraulic Capacity (cfs)	Estimated Flow (cfs)	Tributary Area (acres)	Estimated Hydraulic Capacity (cfs)	Estimated Flow (cfs)	Tributary Area (acres)	Estimated Hydraulic Capacity (cfs)	Estimated Flow (cfs)	Tributary Area (acres)
1941-1965.....	After west pipe was installed discharging to a rip-rapped ditch at the foot of Jaeckles Boulevard	19.0	16.2	26.0	19.0	16.2	35.2 (26.0 + 9.2)	--	--	
1965-1977.....	After west pipe was installed discharging to storm sewer with 29" x 18" corrugated metal pipe arch storm sewer	19.0	16.2	26.0	7.5	23.8	35.2 (26.0 + 9.2)	--	--	--
1978-Present..	After first stage of STH 16 reconstruction but based on topography prior to development of the Vista Park Subdivision	19.0	17.7	20.0	7.5	27.6	27.0	35.0	31.8	23.0
1978-Present..	After first stage of STH 16 reconstruction based on topography after development of the Vista Park Subdivision	19.0	17.7	20.0	7.5	27.6	27.0	35.0	39.8	32.0

Note: All design data obtained from Wisconsin Department of Transportation.

Source: Wisconsin Department of Transportation and SEWRPC.

only about 7.5 cfs. This 29-inch by 18-inch CMPA storm sewer was installed in 1965, replacing an open drainage ditch in the same location. As shown on Map B-1, an additional 9.2 acres of land adjacent to Jaeckles Boulevard was also drained directly to the 29-inch by 18-inch CMPA storm sewer.

In a discussion of possible causes for the storm water system failures as a result of a series of precipitation events in 1979, local residents indicated, and the WisDOT staff concurred, that the previous topography and drainage characteristics of the tributary area--prior to the 1978 construction project--had served to retain and store storm water, thereby reducing the peak rate of flows delivered to the undersized 29-inch by 18-inch CMPA storm sewer at the foot of Jaeckles Boulevard during a major storm event. The available data indicated that in the past--prior to the highway reconstruction project--storm water damage was prevented in part by the natural retention capacity of the drainage system. In addition, it was indicated that a lack of regular maintenance on the storm water drainage system upstream from the 29-inch by 18-inch CMPA storm sewer may have resulted in a reduced capacity of the upstream components of the drainage system to deliver storm water to the culvert. This is believed to have prevented the maximum flow rates from reaching the 29-inch by 18-inch CMPA storm sewer at the foot of Jaeckles Boulevard, resulting instead in the water being backed up in the pre-1978 STH 16 right-of-way itself, upstream from the inlet to the storm sewer where flooding problems were experienced after the 1978 reconstruction of STH 16.

2. Upon completion of the 1978 reconstruction project, the tributary drainage area was modified, as shown on Map B-2, with the area tributary to the then-existing 24-inch diameter CMCP storm sewer being reduced from approximately 26.0 acres to approximately 20.0 acres. In addition, approximately 7.0 acres of land adjacent to Jaeckles Boulevard was drained directly to the 29-inch by 18-inch CMPA storm sewer, as shown on Map B-2.

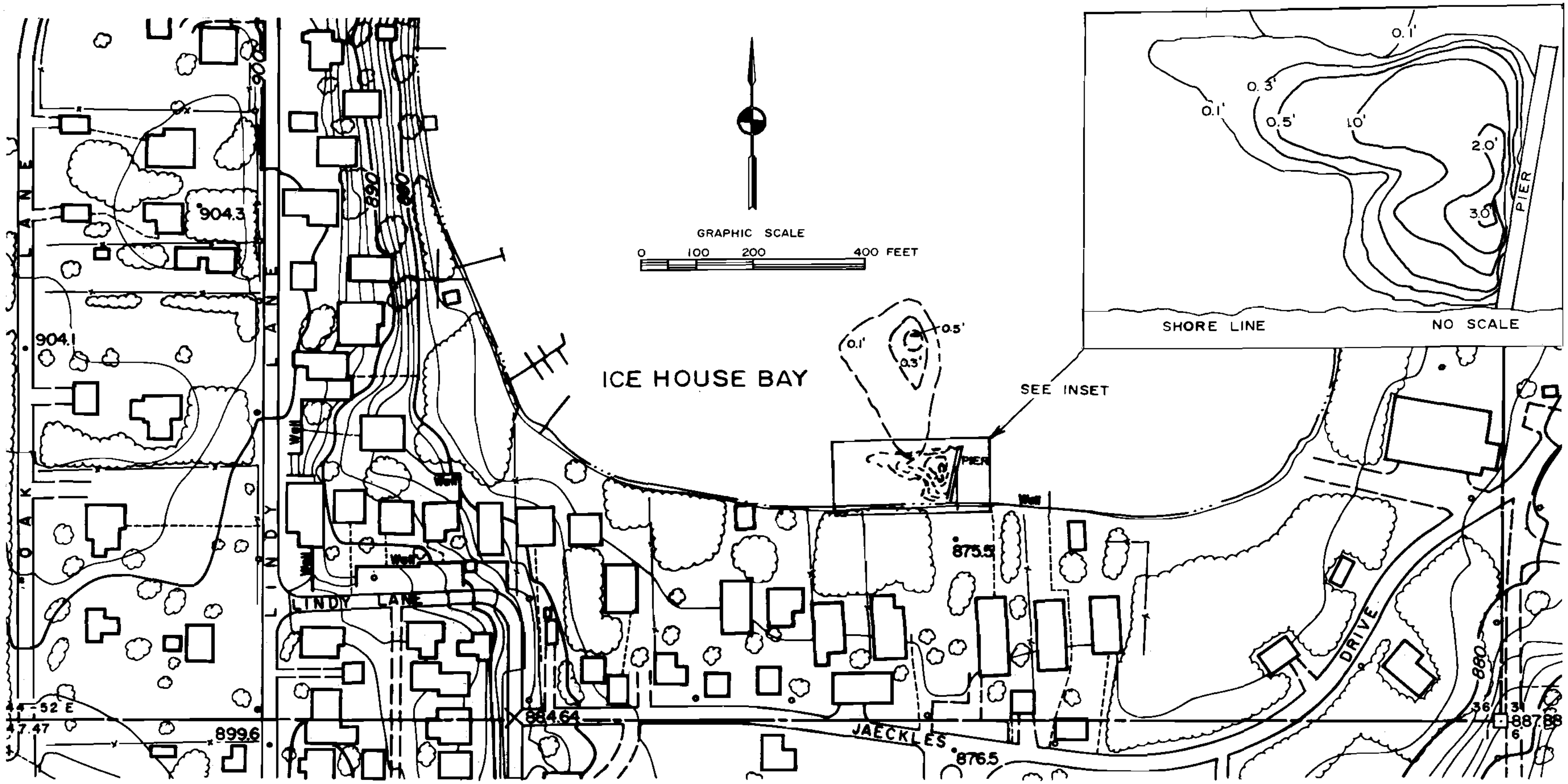
   As part of the 1978 reconstruction project, a new 24-inch diameter storm sewer constructed of reinforced concrete culvert pipe (RCCP) was laid along the eastern side of Jaeckles Boulevard parallel to the existing 24-inch diameter CMCP storm sewer from the STH 16 frontage road to a point about 250 feet south of Ice House Bay. At this point, a new 28-inch by 20-inch CMPA storm sewer was installed to convey storm water to the shoreline of Ice House Bay, adjacent to the point of discharge of the 29-inch by 18-inch CMPA storm sewer located to the west. This new sewer was designed to drain approximately 23.0 acres, as shown on Map B-1, and was designed to convey an estimated 31.8 cfs peak flow during a 25-year recurrence interval storm event. The actual capacity of the new storm sewer, as constructed, is estimated to have been 35.0 cfs. Thus, a total of about 50.0 acres was then tributary to Ice House Bay at the point of discharge. Immediately following initial construction of this new 24-inch diameter RCCP storm sewer, and prior to completion of the STH 16 reconstruction project, two major storm events occurred. At the time, the installation of soil erosion control measures--including re-vegetation of the construction area--had not been completed. These events were estimated by WisDOT staff to have been greater than 50-year recurrence interval events. The resulting flooding damage to property and the sediment load to Ice House Bay aroused significant public concern, and resulted in a request to the Okauchee Lake Management District to address this problem. That agency, in turn, contacted the Wisconsin Department of Natural Resources (DNR) and WisDOT.

3. At the request of the DNR, WisDot-District 2 obtained a series of sediment core samples on January 25 and March 6, 1980, in order to identify the depth and distribution of the sediments derived from the storm water runoff from the STH 16 project area. The results are reported in a WisDOT staff file memorandum dated April 21, 1980, from Mr. Lewis H. Updike, Civil Engineer. As indicated on Map B-3, an estimated 175 cubic yards of sediment were deposited at depths ranging up to 3.0 feet and over an area of about 0.5 acre. At an interagency meeting held on July 8, 1980, the WisDot staff, with the concurrence of the DNR Southeast District staff, agreed to seek to have the contractor remove approximately 110 cubic yards of sediment from that area shown on Map B-3 having a sediment deposit of greater than 0.1 foot in depth.

4. Upon further analysis of the storm water drainage system, it became apparent that a series of development decisions in the areas tributary to the newly constructed 24-inch diameter RCCP storm sewer on the east side of Jaeckles Boulevard had resulted in approximately 32.0 acres--rather than the 23.0 acres originally assumed in the design--being tributary to this storm sewer. This incremental tributary area of about 9.0 acres is shown on Map B-2. Table B-1

Map B-3

SURVEYED SEDIMENTATION IN ICE HOUSE BAY AT THE FOOT OF JAECKLES BOULEVARD



Source: Wisconsin Department of Transportation.

reflects the increased peak flow estimated to be associated with this new condition. As shown, the estimated peak flow during the 25-year recurrence interval storm event increased by 8.0 cfs, from 31.8 cfs to 39.8 cfs. This flow exceeds the 35.0 cfs design capacity of the 24-inch diameter RCCP storm sewer.

5. Based upon the investigations and analyses conducted, it was concluded that a combination of several factors, including the occurrence of storms larger than the design storms, lack of construction erosion control practices, and local action to install a culvert pipe in place of an open ditch, thereby reducing the hydraulic capacity of the drainage system on the west side of Jaeckles Boulevard, together were the causes of the flooding and sediment problems associated with the drainage area adjacent to Jaeckles Boulevard and Ice House Bay.

ALTERNATIVES ANALYSIS

As an outgrowth of these analyses which identified the existing problems, the Okauchee Lake Management District requested that the Commission staff, as part of the ongoing Okauchee Lake management plan, review the existing problems and identify alternative measures which could be considered to abate the identified problems. In response to this local concern, an analysis was conducted of several alternative courses of action. These alternatives are intended to reduce the nonpoint source pollutant loadings to the lake significantly, as well as to reduce the threat of storm water damage.

More specifically, a systems analysis was conducted for the purpose of: 1) determining volumes and rates of storm water runoff and pollutant loadings associated with that runoff; 2) identifying alternatives for reducing the nonpoint source pollutant loads to the lake; 3) identifying possible locations or sites for the storm water management system components of each alternative; and 4) estimating the cost--as well as other considerations--associated with each alternative. The analysis was made in sufficient depth to permit comparison of alternatives. However, more detailed engineering will be needed prior to implementation of a selected alternative.

As noted, the analysis conducted and the alternatives considered were directed chiefly toward reducing the pollutant loads to Okauchee Lake from nonpoint sources. However, most of the structural components of the alternatives will also affect the hydraulics of the storm water drainage system serving the area under consideration. Thus, the impact of the alternatives on the hydraulics of the drainage system and the related flooding problems were also considered in the analysis.

The alternatives considered consisted of storm water storage and conveyance components, as well as of basic land management practices. The storage-oriented components of the alternatives were sized to control 2.3 inches of runoff, which corresponds to approximately a five-year recurrence interval precipitation event with a minimum antecedent dry period of from 12 to 24 hours and minimum subsequent dry period of from 12 to 24 hours. Analyses indicate that only limited additional benefit for control of pollutants would be obtained by sizing storage-sedimentation facilities for larger recurrence interval storms.[1]

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[1]*See SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff.*

Design of the conveyance-oriented components of the alternatives was based upon a 25-year recurrence interval precipitation event, in order to be consistent with the basis of design used by the Wisconsin Department of Transportation in sizing the STH 16 storm water drainage system into which the alternative components are to be integrated. Refinements in the storage capacity should be considered in subsequent final designs to optimize the size of the storage facilities in relation to other components of this storm water drainage system. The estimates of pollutant loadings and of levels of control associated with data developed for the regional water quality management plan are documented in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, Volume One, Inventory Findings, and Volume Two, Alternative Plans, and presented in more detail in SEWRPC Technical Report No. 18, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff.

As part of the analysis, drainage areas were delineated and measured on, where available, 1" = 100' scale 2' contour interval topographic maps and, where such maps were not available, on 1" = 400' ratioed and rectified aerial photographs. The drainage area delineations were field-checked in order to reflect properly land development decisions made through January 1981, and thus represent further refinements to the delineations of the drainage limits utilized in previous analyses.

The Commisision analyzed four action alternatives for reducing the identified problems in the STH 16 area near Ice House Bay, as well as a "No Action" alternative. The principal components of these alternatives are shown on Maps B-4, B-5, and B-6. The principal features and costs of these alternatives are summarized in Table B-2, and each alternative is briefly described below.

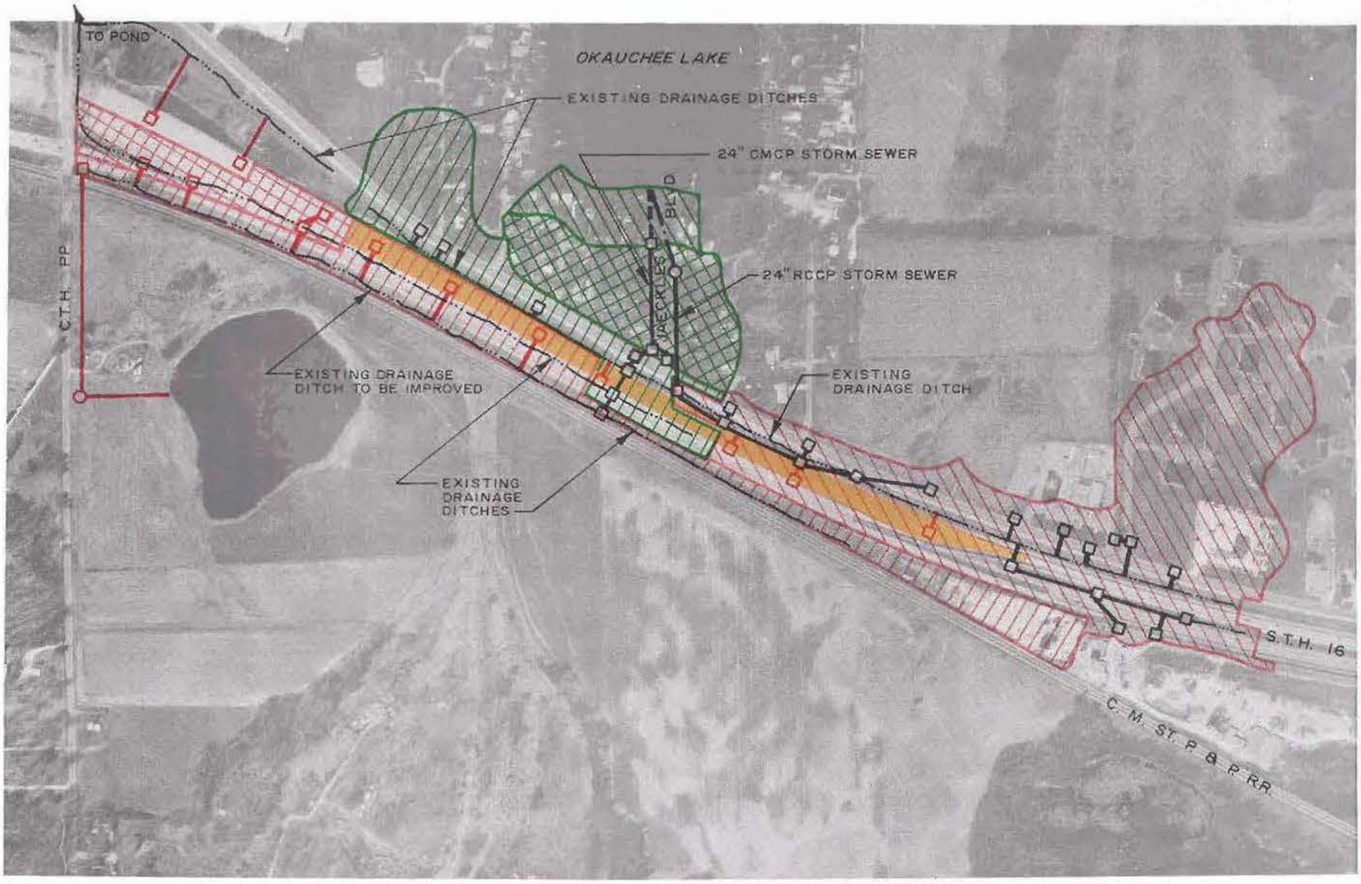
Alternative 1: "No Action" Beyond Planned Highway Drainage Design Changes

The first alternative is considered the "No Action" alternative. This alternative incorporates committed storm water management proposals that are included in the current WisDOT designs for STH 16 which would be installed when the remaining segment of the proposed STH 16 reconstruction is completed. At that time the WisDOT would incorporate into the construction project certain conventional storm water management practices provided for under the highway improvement design. As presently planned by WisDOT, the drainage pattern in the area would be modified as shown on Map B-4, including diverson of storm water from about 12.7 acres of the 46.0-acre area now tributary to Ice House Bay via the two 24-inch storm sewers located at the intersection of Jaeckles Boulevard and the STH 16 frontage road. Following construction, about 33.3 acres would be drained to these two storm sewers. Erosion controls would be provided during and after construction. These components of the alternative would be implemented at the time that funding for the next phase of the STH 16 construction project became available. The principal components of this alternative are shown on Map B-4. Under this alternative no additional construction erosion control measures would be provided for in the interim period until the next phase of the STH 16 reconstruction project.

It should be noted that during the interim period until the next phase of the STH 16 project, storm water runoff from approximately 46.0 acres of land would continue to be discharged to Okauchee Lake through the existing drainage system. Of this total drainage area, approximately 6.9 acres presently have no vegetative cover and have a high potential for erosion due to the previous construction activity. On the next phase of highway reconstruction, the drainage system would be modified to divert a portion of the drainage area to

Map B-4

ALTERNATIVE 1: "NO ACTION" AND ALTERNATIVE 2: SHORT TERM MEASURES TO PROVIDE IMMEDIATE NONPOINT SOURCE POLLUTION CONTROLS FOR THE STH 16 DRAINAGE AREA AT ICE HOUSE BAY, OKAUCHEE LAKE



LEGEND

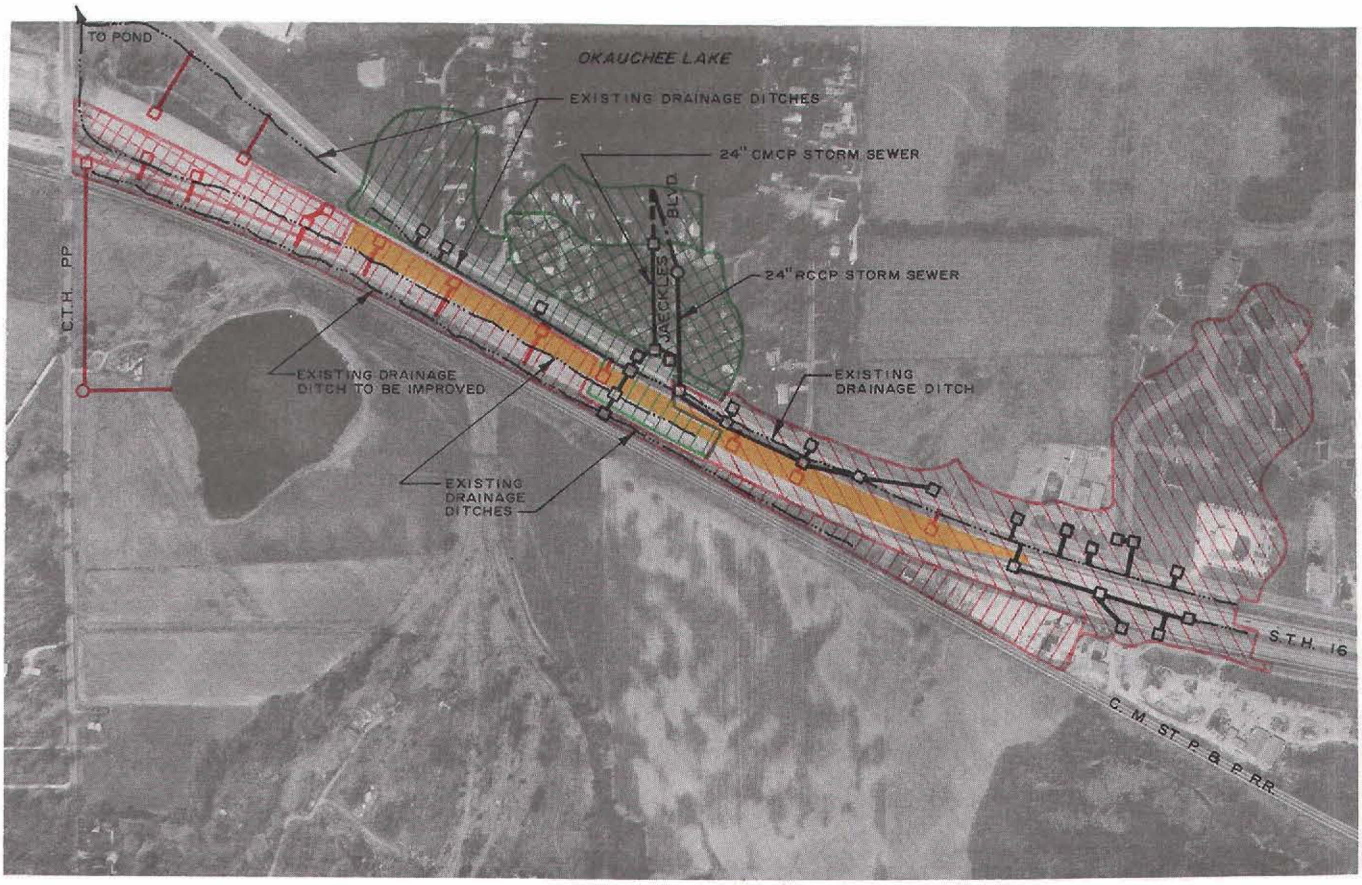
- DIRECT DRAINAGE TO OKAUCHEE LAKE
- AREA TRIBUTARY TO CATCH BASIN AT THE FOOT OF JAECKLES BOULEVARD, AFTER 1978-1979 CONSTRUCTION
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CORRUGATED METAL CULVERT PIPE STORM SEWER ON THE WEST SIDE OF JAECKLES BOULEVARD FOLLOWING PROPOSED CONSTRUCTION OF S.T.H. 16 TO C.T.H. PP
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CONCRETE CULVERT PIPE STORM SEWER ON EAST SIDE OF JAECKLES BOULEVARD FOLLOWING PROPOSED CONSTRUCTION OF S.T.H. 16 TO C.T.H. PP
- AREA CURRENTLY DRAINED TO OKAUCHEE LAKE TO BE DIVERTED TO AN INTERNALLY DRAINED POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD AT C.T.H. PP AS DESIGNATED UNDER ALTERNATIVES 1 & 2
- AREA CURRENTLY DRAINED TO POND NORTH OF S.T.H. 16 AT CTH PP TO BE DIVERTED TO AN INTERNALLY DRAINED POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD AT C.T.H. PP AS DESIGNATED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION DESIGN
- OPEN CUT AND FILL AREA THAT WOULD REQUIRE SEEDING AND EROSION CONTROL UNDER ALTERNATIVE 2
- EXISTING STORM SEWER
- PROPOSED STORM SEWER DESIGNED FOR FUTURE COMPLETION OF S.T.H. 16
- EXISTING 29 INCH BY 18 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- EXISTING 28 INCH BY 20 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- EXISTING CATCH BASIN
- EXISTING MANHOLE
- PROPOSED CATCH BASIN
- PROPOSED MANHOLE

GRAPHIC SCALE
0 400 800 FEET

Source: SEWRPC.

Map B-5

ALTERNATIVES 3 AND 3A: IN-BASIN STORM WATER STORAGE MEASURES TO PROVIDE LONG TERM NONPOINT SOURCE POLLUTION CONTROLS FOR THE STH 16 DRAINAGE AREA AT ICE HOUSE BAY, OKAUCHEE LAKE



LEGEND

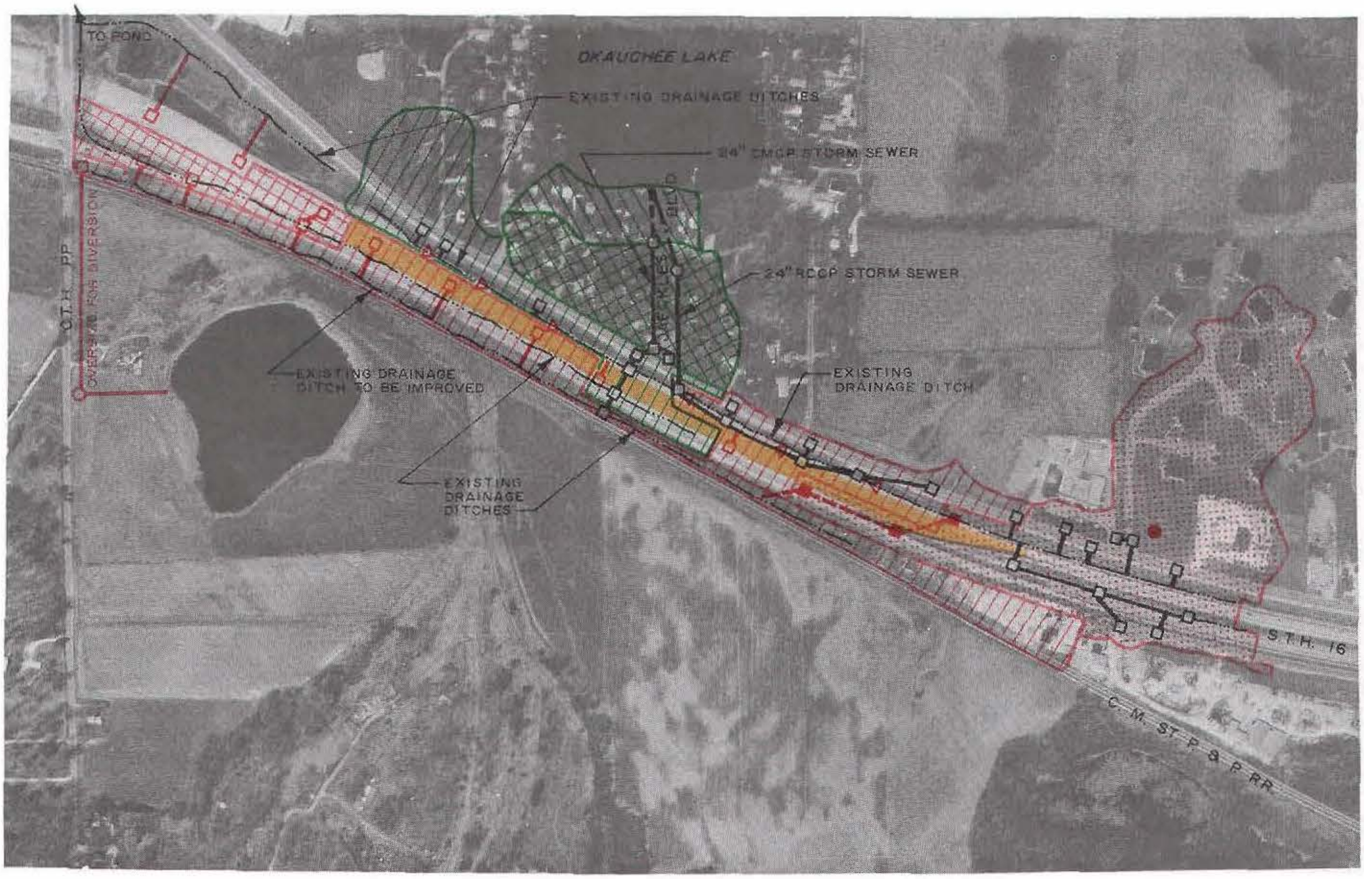
- DIRECT DRAINAGE TO OKAUCHEE LAKE
- AREA TRIBUTARY TO CATCH BASIN AT THE FOOT OF JAECKLES BOULEVARD, AFTER 1978 - 1979 CONSTRUCTION
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CORRUGATED METAL CULVERT PIPE STORM SEWER ON THE WEST SIDE OF JAECKLES BOULEVARD FOLLOWING PROPOSED CONSTRUCTION OF S.T.H. 16 TO C.T.H. PP
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CONCRETE CULVERT PIPE STORM SEWER ON EAST SIDE OF JAECKLES BOULEVARD FOLLOWING PROPOSED CONSTRUCTION OF S.T.H. 16 TO C.T.H. PP
- AREA CURRENTLY DRAINED TO OKAUCHEE LAKE TO BE DIVERTED TO AN INTERNALLY DRAINED POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD AT C.T.H. PP AS DESIGNATED UNDER ALTERNATIVES 1 & 2
- AREA CURRENTLY DRAINED TO POND NORTH OF S.T.H. 16 AT C.T.H. PP TO BE DIVERTED TO AN INTERNALLY DRAINED POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD AT C.T.H. PP AS DESIGNATED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION DESIGN
- OPEN CUT AND FILL AREA THAT WOULD REQUIRE SEEDING AND EROSION CONTROL
- EXISTING STORM SEWER
- PROPOSED STORM SEWER DESIGNED FOR FUTURE COMPLETION OF S.T.H. 16
- EXISTING 29 INCH BY 18 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- EXISTING 28 INCH BY 20 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- EXISTING CATCH BASIN
- EXISTING MANHOLE
- PROPOSED CATCH BASIN
- PROPOSED MANHOLE
- PROPOSED STORMWATER DETENTION BASIN
- PROPOSED STORMWATER CHECK DAM

GRAPHIC SCALE
0 400 800 FEET

Source: SEWRPC.

Map B-6

ALTERNATIVE 4: DIVERSION WITH LIMITED IN-BASIN STORAGE MEASURES TO PROVIDE LONG TERM NONPOINT SOURCE POLLUTION CONTROLS FOR THE STH 16 DRAINAGE AREA AT ICE HOUSE BAY, OKAUCHEE LAKE



LEGEND

- DIRECT DRAINAGE TO OKAUCHEE LAKE
- AREA TRIBUTARY TO CATCH BASIN AT THE FOOT OF JAECKLES BOULEVARD, AFTER 1978 - 1979 CONSTRUCTION
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CORRIGATED METAL CULVERT PIPE STORM SEWER ON THE WEST SIDE OF JAECKLES BOULEVARD FOLLOWING PROPOSED CONSTRUCTION OF S.T.H. 16 TO C.T.H. PP
- AREA TRIBUTARY TO OKAUCHEE LAKE THROUGH A 24 INCH CONCRETE CULVERT PIPE STORM SEWER ON EAST SIDE OF JAECKLES BOULEVARD FOLLOWING PROPOSED CONSTRUCTION OF S.T.H. 16 TO C.T.H. PP
- AREA CURRENTLY DRAINED TO OKAUCHEE LAKE TO BE DIVERTED TO AN INTERNALLY DRAINED POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD AT C.T.H. PP AS DESIGNATED BY THE EXISTING DEPARTMENT OF TRANSPORTATION DESIGN
- AREA CURRENTLY DRAINED TO POND NORTH OF S.T.H. 16 AT C.T.H. PP TO BE DIVERTED TO AN INTERNALLY DRAINED POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD AT C.T.H. PP AS DESIGNATED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION DESIGN
- *ADDITIONAL AREA TO BE DIVERTED UNDER ALTERNATIVE 4 TO INTERNALLY DRAINED* POND SOUTH OF THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC RAILROAD AT C.T.H. PP
- OPEN CUT AND FILL AREA THAT WOULD REQUIRE SEEDING AND EROSION CONTROL
- EXISTING STORM SEWER
- PROPOSED STORM SEWER
- EXISTING 29 INCH BY 18 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- EXISTING 28 INCH BY 20 INCH CORRUGATED METAL PIPE ARCH STORM SEWER
- EXISTING CATCH BASIN
- EXISTING MANHOLE
- PROPOSED CATCH BASIN
- PROPOSED MANHOLE
- PROPOSED STORMWATER DETENTION BASIN
- PROPOSED STORMWATER CHECK DAM
- PROPOSED DIVERSION SEWER
- PROPOSED DIVERSION CATCH BASIN

GRAPHIC SCALE
0 400 800 FEET

Source: SEWRPC.

Table B-2

PRINCIPAL FEATURES AND COSTS OF STORM WATER MANAGEMENT ALTERNATIVES FOR THE STH 16 DRAINAGE AREA AT ICE HOUSE BAY, OKAUCHEE LAKE

	Hydraulic Discharge									
	Estimated Tributary Area (acres)			Estimated Maximum Storm Water Discharge Rate (cubic feet per second)				Estimated Annual Average Total Discharge Volume (million gallons)		
				West[b]		East[c]				
Alternative Number	West[b]	East[c]	Total	5-Year	25-Year	5-Year	25-Year	West[b]	East[c]	Total
1 "No Action"										
Pre-Construction STH 16 to CTH PP[d]...	22.2	23.8	46.0	24.8	33.6	20.3	28.0	4.2	4.1	8.3
Post-Construction STH 16 to CTH PP[e]...	7.4	25.9	33.3	10.0	13.6	24.9	34.3	1.1	3.3	4.4
Total	--	--	--	--	--	--	--	--	--	--
2 Interim Erosion Control and Storm Water Management Measures										
Pre-Construction STH 16 to CTH PP[d]..	22.2	23.8	46.0	23.1	31.8	19.8	27.3	2.9	2.7	5.6
Post-Construction STH 16 to CTH PP[e]..	7.4	25.9	33.3	10.0	13.6	24.9	34.3	1.1	3.3	4.4
Total	--	--	--	--	--	--	--	--	--	--
3 Maximum In-Basin Storage										
Pre-Construction STH 16 to CTH PP[d]...	22.2	23.8	46.0	23.1	31.8	19.8	27.3	2.9	2.7	5.6
Post-Construction STH 16 to CTH PP[e]...	7.4	25.9	33.3	9.6	13.1	21.4	28.2	1.1	3.0	4.1
Total	--	--	--	--	--	--	--	--	--	--
3A Limited In-Basin Storm Water Storage										
Pre-Construction STH 16 to CTH PP[d]..	22.2	23.8	46.0	23.1	31.8	19.8	27.3	2.9	2.7	5.6
Post-Construction STH 16 to CTH PP[e]..	7.4	25.9	33.3	9.6	13.1	21.4	28.2	1.1	3.0	4.1
Total	--	--	--	--	--	--	--	--	--	--
4 Diversion With Limited In-Basin Storm Water Storage										
Pre-Construction STH 16 to CTH PP[d]..	22.2	23.8	46.0	23.1	31.8	19.8	27.3	2.9	2.7	5.6
Post-Construction STH 16 to CTH PP[e]..	7.4	5.4	12.8	9.6	13.1	8.2	11.4	1.1	0.7	1.8
Total	--	--	--	--	--	--	--	--	--	--

Table B-2 (continued)

Alternative Number	Estimated Total Annual Pollutant Loading Potential to Ice House Bay				Estimated Cost[a]			Economic Analysis Estimates[a]					
	Total Sediment Loading (tons/year)	Percent Reduction[g]	Total Phosphorus Loading (pounds/year)	Percent Reduction[g]	Total Capital Cost	Annual Operation and Maintenance	20-Year Average Annual Operation and Maintenance	Present Worth (1980-2000) Capital	Present Worth (1980-2000) Operation and Maintenance	Present Worth (1980-2000) Total	Equivalent Annual Cost (1980-2000) Capital	Equivalent Annual Cost (1980-2000) Operation and Maintenance	Equivalent Annual Cost (1980-2000) Total
1 "No Action"													
Pre-Construction STH 16 to CTH PP[d]...	490	--	350	--	$ --[f]	$ --[f]	$ --[f]	$ --[f]	$ --[f]	$ --[f]	$ --[f]	$--[f]	$ --[f]
Post-Construction STH 16 to CTH PP[e]...	175	--	34	--	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]
Total	--	--	--	--	--	--	--	--	--	--	--	--	--
2 Interim Erosion Control and Storm Water Management Measures													
Pre-Construction STH 16 to CTH PP[d]..	245	50	74	79	21,000	1,100	275	21,000	4,500	25,500	1,980	420	2,400
Post-Construction STH 16 to CTH PP[e]..	175	0	34	0	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]	--[f]
Total	--	--	--	--	21,000	--	275	21,000	4,500	25,500	1,980	420	2,400
3 Maximum In-Basin Storage													
Pre-Construction STH 16 to CTH PP[d]...	245	50	74	79	21,000	1,100	275	21,000	4,500	25,500	1,980	420	2,400
Post-Construction STH 16 to CTH PP[e]...	100	43	28	18	254,000	6,500	4,875	181,100	42,200	223,300	17,100	4,000	21,100
Total	--	--	--	--	275,000	--	5,150	202,100	46,700	248,800	19,080	4,420	23,500
3A Limited In-Basin Storm Water Storage													
Pre-Construction STH 16 to CTH PP[d]...	245	50	74	79	21,000	1,100	275	21,000	4,500	25,500	1,980	420	2,400
Post-Construction STH 16 to CTH PP[e]...	140	20	31	9	21,900	1,000	750	15,600	6,500	22,100	1,470	610	2,080
Total	--	--	--	--	42,900	--	1,025	36,600	11,000	47,600	3,450	1,030	4,480
4 Diversion With Limited In-Basin Storm Water Storage													
Pre-Construction STH 16 to CTH PP[d]...	245	50	74	79	21,000	1,100	275	21,000	4,500	25,500	1,980	420	2,400
Post-Construction STH 16 to CTH PP[e]...	65	63	14	59	68,200	1,500	1,125	48,600	9,700	58,300	4,590	910	5,500
Total	--	--	--	--	$ 89,200	--	$ 1,400	$ 69,600	$14,200	$ 83,800	$ 6,570	$1,330	$ 7,900

[a]Cost data are based upon January 1980 dollars.
[b]Designates area tributary to the west 24" diameter CMCP storm sewer at Jaeckles Boulevard and Frontage Road.
[c]Designates area tributary to the east 24" diameter RCCP storm sewer at Jaeckles Boulevard and Frontage Road.
[d]Designates the existing drainage conditions prior to construction of the remaining segment of STH 16 to CTH PP but after the alternative measures are in place. For cost analysis purposes, it was assumed the project would be completed by 1986.
[e]Designates the proposed drainage condition after completion of STH 16 to CTH PP (estimated to be in 1986).
[f]These costs are common to all alternatives and for comparison purposes, are not shown.
[g]Computed against loading resulting from alternative No. 1.

Source: SEWRPC

the small, internally drained pond located south of the Chicago, Milwaukee, St. Paul & Pacific Railroad Company (the Milwaukee Road) and east of CTH PP, resulting in a reduction of about 12.7 acres in the area tributary to the two 24-inch storm sewers at the intersection of Jaeckles Boulevard and the STH 16 frontage road. At that time conventional erosion control practices, including the planting of vegetative cover, would also be implemented, abating the high erosion potential in the area. For purposes of estimating comparable costs for the alternatives, it was assumed that the next phase of STH 16 improvement project would be completed by 1986.

Under Alternative 1, the average annual loading of sediment and phosphorus contributed to Okauchee Lake from the drainage area being analyzed is estimated to approximate 490 tons and 350 pounds, respectively, until completion of the next phase of the STH 16 reconstruction project. The total annual average storm water volume discharged from the drainage area to Okauchee Lake is estimated to be 8.3 million gallons, occurring in about 46 events. The maximum discharge rates from the drainage area tributary to the 24-inch diameter CMCP storm sewer on the west side of Jaeckles Boulevard are estimated to be 24.8 cfs for a five-year recurrence interval rainfall event, and 33.6 cfs for a 25-year recurrence interval event. The maximum discharge rates from the area tributary to the 24-inch diameter RCCP storm sewer on the east side of Jaeckles Boulevard are estimated to be 20.3 cfs for a five-year recurrence interval rainfall and 28.0 cfs for a 25-year recurrence interval event.

Following completion of the next phase of the STH 16 reconstruction project, the average annual loadings from the drainage area may be expected to approximate 175 tons of sediment and 34 pounds of phosphorus to the lake, reductions of 64 and 91 percent, respectively, from existing conditions. The annual average storm water volume discharged from the drainage area to Okauchee Lake under those conditions is estimated to total 4.4 million gallons, a reduction of 47 percent from existing conditions. The maximum discharge rates at that time from the area tributary to the west storm sewer are estimated to be 10.0 cfs for a five-year recurrence interval event and 13.6 cfs for a 25-year recurrence interval event, while the maximum discharge rates from the drainage area tributary to the east storm sewer are estimated to be 24.9 cfs for a five-year recurrence interval event and 34.3 cfs for a 25-year recurrence interval event.

The monetary costs associated with Alternative 1 are common to all the alternatives analyzed and are therefore not included for comparison purposes in the analysis.

Alternative 2: Interim Erosion Controls and Storm Water Management Measures

The second alternative considered is similar to Alternative 1 with the addition of limited storm water storage and nonpoint source pollution control measures to reduce existing erosion and associated pollution loadings within the drainage area. These measures are directed toward reducing the relatively high pollutant loads during the interim period until the completion of the next phase of the STH 16 reconstruction project. These interim measures consist of erosion control procedures, such as covering with topsoil and seeding exposed soil areas; critical area protection; and provision of temporary checkdams as sediment traps and storage areas in drainageways. These measures are designed to prevent additional erosion of exposed and unprotected cut and fill areas along STH 16 within this lake drainage area. In addition, these measures are designed to enhance the retention of storm water within the direct drainage system during the period until the completion of the next phase of the STH 16 reconstruction project. The principal components of this alternative are shown on Map B-4. Specific locations of the temporary check-dams are not shown as they would be more appropriately located in an onsite investigation of existing field conditions. Selected characteristics and costs of the storm water management measures included under this alternative are shown on Table B-2.

Under this alternative, the area tributary to Okauchee Lake both prior to and after the completion of the next phase of the STH 16 reconstruction project would be the same as set forth above for Alternative 1. It is estimated that the average annual loadings of sediment and phosphorus contributed to Okauchee Lake from the drainage area being analyzed would be 245 tons and 74 pounds, respectively, prior to the completion of the next phase of the STH 16 reconstruction project. When compared to the pollutant loadings estimated for the same time period under the previously discussed "No Action" alternative, this would represent 50 percent and 79 percent reductions in sediment and total phosphorus loads, respectively. Prior to the completion of the next phase of the STH 16 reconstruction project, it is estimated that the total average annual storm water volume discharged from the drainage area to Okauchee Lake will be 5.6 million gallons, occurring in 46 events, and representing a reduction of 32 percent from the volume estimated to be discharged for the same period under the "No Action" proposal described in Alternative 1. The maximum storm water discharge rates from the drainage area tributary to the west storm sewer are estimated to be 23.1 cfs for a five-year recurrence interval rainfall event and 31.8 cfs for a 25-year recurrence interval event. The maximum discharge rates from the area tributary to the east sewer are estimated to be 19.8 cfs for a five-year recurrence interval event and 27.3 cfs for a 25-year event.

Following completion of the next phase of the STH 16 reconstruction project, the pollutant loads and storm water discharge quantities from the drainage area are expected to be the same as estimated under Alternative 1, since no additional storm water management measures are included under this alternative for this period of time.

The estimated capital cost associated with the interim nonpoint source pollution control measures is $21,000, including topsoil placement, with an average annual operation and maintenance cost over a 20-year period of $275. If further field studies indicate adequate vegetative cover can be established without topsoil placement, the capital cost would be reduced to about $5,000. These operation and maintenance costs would only be incurred until the completion of the next phase of the STH 16 reconstruction project. Based upon the assumption that the next phase of the highway reconstruction will take place by 1986 and using an annual interest rate of 7 percent, an amortization period of 20 years, and an analysis period of 20 years, the equivalent annual cost of construction and operation and maintenance of these interim measures is estimated at $2,400.

Alternative 3: Maximum In-Basin Storm Water Storage

Alternative 3 includes the same interim erosion controls as Alternative 2, and the permanent installation of additional storm water detention facilities. As shown on Map B-5, these additional facilities would consist of a surface storm water detention basin with a capacity of 3.6 acre-feet to be constructed adjacent to the STH 16 frontage road at the Vista Park subdivision; a series of eight channel check-dams designed to provide additional storage of storm water and to decrease the velocity of storm water within the channelized collection systems, thus trapping sediment particles that would be otherwise transported through the conveyance system; and a subsurface sediment trap between the westbound lane of STH 16 and the north frontage road at Jaeckles Boulevard to provide additional sediment collection prior to storm water discharge to Okauchee Lake. This alternative requires high levels of maintenance because of the maximized pollutant trapping efficiency. The cost for maintenance has been estimated and is shown in Table B-2. As part of the implementation actions, it would be necessary under this alternative to identify an appropriate agency to carry out this maintenance, considering present maintenance of roadway drainage systems and other storm water management practices for the area. Selected characteristics and cost of the storm water management measures included under this alternative are shown in Table B-2.

Under this alternative, the area tributary to Okauchee Lake both prior to and after the completion of the next phase of the STH 16 reconstruction project would be the same as set forth above for Alternatives 1 and 2. It is estimated that the average annual loadings of sediment and phosphorus contributed to Okauchee Lake from the drainage area being analyzed would be 245 tons and 74 pounds, respectively, for the period prior to the completion of the next phase of STH 16 reconstruction project. When compared to the pollutant loadings estimated for the same time period under the "No Action" plan previously discussed as Alternative 1, this would represent reductions of 50 percent in sediment and 79 percent in phosphorus loads. The total average annual storm water volume discharged from the drainage area to Okauchee Lake is estimated to be 5.6 million gallons, occurring in 46 events, representing a reduction of 32 percent from the volume estimated to be discharged for the same period under the "No Action" plan. These reductions in pollutant and hydraulic loadings are the same as those estimated to be achieved under Alternative 2, since the measures proposed for this time frame are the same. The maximum storm water discharge rate from the drainage area is also estimated to be the same as was estimated under Alternative 2 for that period of time prior to completion of the highway reconstruction project.

Following the completion of the next phase of the STH 16 reconstruction project, it is estimated that the average annual loadings from the drainage area would be 100 tons of sediment and 28 pounds of phosphorus. This represents reductions of 43 percent in sediment and 18 percent in total phosphorus loads from the loadings that would result from using the conventional storm water management control measures set forth in Alternatives 1 and 2 for the same period. Following completion of the STH 16 reconstruction project, it is estimated that the total average annual storm water volume discharged from the drainage area to Okauchee Lake would be 4.1 million gallons, or about 7 percent less than estimated for the same time period under Alternatives 1 and 2. The maximum storm water discharge rates from the drainage area tributary to the west storm sewer are estimated to be 9.6 cfs for a five-year recurrence interval event and 13.1 cfs for a 25-year recurrence interval event. The maximum rates of storm water discharge from the area tributary to the east storm sewer are estimated to be 21.4 cfs for a five-year recurrence interval storm event and 28.2 cfs for a 25-year event.

The estimated capital cost associated with the Alternative 3 storm water management measures is $275,000, with an average annual operation and maintenance cost of $5,150. Using an annual interest rate of 7 percent, an amortization period of 20 years, and an analysis period of 20 years, the equivalent annual cost of construction and operation and maintenance of this alternative is estimated at $23,500.

Alternative 3A: Limited In-Basin Storm Water Storage

Alternative 3A is the same as Alternative 3, as shown on Map B-5, except that the subsurface sediment trap proposed to be located between the westbound lane of STH 16 and the frontage road at Jaeckles Boulevard--and the associated high maintenance costs--would be eliminated. Selected characteristics and costs of this alternative are shown in Table B-2.

Under this alternative, the area tributary to Okauchee Lake both prior to and after the completion of the next phase of the STH 16 reconstruction project would be the same as set forth above for Alternatives 1, 2, and 3. Under the proposal for Alternative 3A, the estimated average annual loadings of sediment and phosphorus contributed to Okauchee Lake, as well as the estimated storm water volume discharged and the storm water hydraulic flow rates from the drainage area being analyzed, would be the same as estimated for Alternatives 2 and 3 for that period prior to the completion of the next phase of the STH 16 reconstruction project.

Following the completion of the next phase of the STH 16 reconstruction project, the average annual loadings from the drainage area would be 140 tons of sediment and 31 pounds of phosphorus. This would represent reductions of 20 percent in sediment and 9 percent in total phosphorus loads from the loadings that would result from using the conventional storm water management control measures set forth in Alternatives 1 and 2 for the same period of time. The total average annual storm water volume discharged from the drainage area to Okauchee Lake is estimated at 4.1 million gallons, which is about 7 percent less than estimated for the same time period under Alternatives 1 and 2. The maximum storm water discharge rates from the drainage area tributary to the west storm sewer are estimated to be 9.6 cfs for a five-year recurrence interval event and 13.1 cfs for a 25-year recurrence interval event. The maximum storm water discharge rates from the area tributary to the east storm sewer are estimated to be 21.4 cfs for a five-year recurrence interval storm event and 28.2 cfs for a 25-year event.

The estimated capital cost associated with Alternative 3A nonpoint source pollution control measures is $42,900, with an average annual operation and maintenance cost of $1,025. Using an annual interest rate of 7 percent, an amortization period of 20 years, and an analysis period of 20 years, the equivalent annual cost of construction and operation and maintenance of this alternative is estimated at $4,480.

Alternative 4: Diversion With Limited In-Basin Storm Water Storage

Alternative 4 provides for the same interim erosion controls as Alternatives 2, 3, and 3A, and for the permanent installation of storm water detention facilities to divert storm waters from approximately 21.7 acres of the subwatershed away from discharge to Ice House Bay into an internally drained pond south of the Chicago, Milwaukee, St. Paul & Pacific Railroad and east of CTH PP. As shown on Map B-6, these facilities would consist of a surface storage basin with a capacity of 1.4 acre-feet to be constructed adjacent to the STH 16 frontage road at the Vista Park subdivision; a series of six channel check-dams designed to provide additional storage of storm water and to decrease the velocity of storm water within the channelized collection system, thus trapping sediment particles that would otherwise be transported through the conveyance system; and a 30-inch diameter storm water diversion sewer to be constructed approximately 1,000 feet east of Jaeckles Boulevard within the STH 16 right-of-way. The diversion would require that a storm sewer planned by

WisDOT to be installed at the CTH PP intersection with STH 16 be increased in size to handle the additional diverted storm water. The principal components of this alternative are shown on Map B-6. Selected characteristics and costs of this alternative are shown in Table B-2.

Under this alternative, the area tributary to Okauchee Lake prior to and after the construction of the next phase of STH 16 would be 46.0 acres and 12.8 acres, respectively. The estimated average annual loadings of sediment and phosphorus contributed to Okauchee Lake, as well as the estimated storm water volume discharged and the storm water hydraulic flow rates from the drainage area being analyzed, would be the same as estimated for Alternatives 2, 3, and 3A for the period prior to the completion of the next phase of the STH 16 reconstruction project. Following the completion of the next phase of the STH 16 reconstruction project, it is estimated that the average annual loadings from the drainage area would be 65 tons of sediment and 14 pounds of phosphorus. For the same time period, this would represent reductions of 63 percent in sediment and 59 percent in total phosphorus loads from the loadings that would result from using the conventional storm water management control measures set forth in Alternatives 1 and 2. As shown in Table B-2, the storm water management measures included under Alternative 4 also may be expected to provide a reduction in the pollutant loadings for the same time period when compared to Alternatives 3 and 3A. It is estimated that the total average annual storm water discharged from the area to Okauchee Lake would be 1.8 million gallons, which is a 59 percent reduction from the volume estimated for the same time period under Alternatives 1 and 2. The total annual volume estimated to be discharged is also less than estimated under Alternatives 3 and 3A, as shown in Table B-2. The maximum storm water discharge rates from the drainage area tributary to the west storm sewer are estimated to be 9.6 cfs for a five-year recurrence interval event and 13.1 cfs for a 25-year recurrence interval event. The maximum storm water discharge rates from the area tributary to the east storm sewer are estimated to be 8.2 cfs for a five-year recurrence interval storm event and 11.4 cfs for a 25-year storm event. This alternative will require an analysis of legal implications such as the potential need for a further drainage easement from CTH PP east to the point of discharge.

The capital cost associated with the interim nonpoint source pollution control measures is estimated at $89,200, with an average annual operation and maintenance cost of $1,400. Using an annual interest rate of 7 percent, an amortization period of 20 years, and an analysis period of 20 years, the equivalent annual cost of construction and operation and maintenance of this alternative is estimated at $7,900. It should be noted that this alternative cost assumes the full cost of a storm sewer from Station 186+00 on STH 16 to Station 181+00 consisting of 550 feet of 30-inch storm sewer and the incremental cost of providing additional storm sewer capacity at CTH PP to the internally drained pond.

Comparison of Alternatives and Recommended Plan

Four basic storm water management alternatives were developed to reflect varying degrees of nonpoint source pollution control for the area draining to Ice House Bay in the vicinity of STH 16. The components of each of these alternatives also have an impact on the hydraulics of the drainage systems serving this area. Each alternative was considered to have two phases, the first phase being the interim period until the next phase of reconstruction of STH 16 is completed. The second phase of each alternative would address long term measures to be implemented during the construction of the remaining portion of STH 16 within the drainage area. The principal features of these alternatives are summarized in Table B-2.

A total annual phosphorus loading from the drainage area directly tributary to Okauchee Lake of about 1,300 pounds was proposed in the lake management plan, in order to attain the established water use objectives. In order to limit the phosphorus load to that level, basic land management practices were recommended for both urban and rural lands in the drainage area. These measures would be designed to achieve about a 30 percent reduction in pollutant loadings from nonpoint sources other than construction sites and livestock operations. A pollutant reduction of about 90 percent was recommended from those sources. Construction erosion control practices were also generally recommended.

When evaluating water quality impacts, it should be noted that the data presented in Table B-2 only address the level of control expected for sediment and phosphorus. However, loadings of other pollutants--including heavy metals and pesticides--which are associated with fine sediments may also be expected to be reduced under all of the control alternatives. The degree of removal of other pollutants may be assumed to be approximately proportional to the percent removal of sediments. With regard to water quality impacts, it can be noted by review of the data in Table B-2 that significant reductions in pollutant loads can be achieved by implementing the interim storm water management measures set forth in Alternative 2. These same interim measures were also included as a component of Alternatives 3, 3A, and 4. Because of the relatively low cost associated with these interim measures, the significant reduction in pollutant loads, and the previous recommendations for implementation of erosion control measures, it is recommended that the short term measures described in Alternative 2 be implemented as phase one of the recommended plan. The beneficial impacts of these interim (or phase one) components on the hydraulics of the existing system are minimal, as can be noted by review of the data in Tables B-1 and B-2. Interim erosion control measures are not expected to resolve hydraulic capacity problems that will still exist in the 24-inch CMCP storm sewer and the 29-inch by 18-inch CMPA storm sewer located on the west side of Jaeckles Boulevard for storms with a recurrence interval of 25 years or longer. The other major hydraulic elements of the drainage area appear to have adequate capacity for design storms up to a 25-year recurrence interval.

With regard to that period following completion of the next section of the STH 16 reconstruction project, a review of the pollutant loading data indicates that the most substantial reductions in nonpoint source loads may be expected under the proposal set forth in Alternative 4. A substantially lower degree of protection would be afforded by the proposals set forth under Alternatives 3 and 3A. Since the cost associated with Alternative 3 is substantially higher than the cost of Alternative 4, Alternative 3 was not given further consideration. Although the proposals set forth in Alternative 3A are less costly than those in Alternative 4, Alternative 4 offers improved pollutant removal benefits. However, a review of the magnitude of the amount of pollutant removed by these alternatives compared to the total loading--less than 2 percent of the planned phosphorus loading--to Okauchee Lake indicates that it would be difficult to justify the costs involved in these alternatives. However, it is suggested that the WisDOT review the design of the proposed next phase of reconstruction of STH 16 to determine the maximum amount of drainage area which could be diverted from Ice House Bay with little or no increase in the construction costs for the drainage system.

Thus, the proposed action can be considered to be a two-phase project, with the first phase being the establishment of interim short term erosion controls in the drainage areas. These controls would consist of developing vegatative cover on all areas with exposed soil and the installation and maintenance of temporary check-dams as water and sediment traps in drainage ways. The second phase of the proposed action would consist of the permanent installation of facilities to direct storm waters from Ice House Bay to an internally drained pond south of the Chicago, Milwaukee, St. Paul & Pacific Railroad and east of CTH PP. It is recommended that these facilities be incorporated into the design as part of the drainage system for the STH 16 project and be so designed by the WisDOT as to provide for the maximum practical degree of diversion.

Following construction of the recommended plan elements, the drainage system problems which exist in the area would be significantly reduced. All the components would have capacity to handle a 25-year recurrence interval storm, with one exception. That exception would be the 29-inch by 18-inch CMPA storm sewer at the lower end of the west pipe in Jaeckles Boulevard. It is estimated that the existing capacity of that storm sewer segment is approximately 7.5 cfs. The estimated 25-year peak flow from the area tributary to the 24-inch CMCP storm sewer in the west side of Jaeckles Boulevard is 13.6 cfs. However, this flow rate may be reduced if the WisDOT more detailed analysis concludes that additional area could be diverted from draining to Ice House Bay. This peak flow is transferred directly to the 29-inch by 18-inch CMPA storm sewer at the foot of Jaeckles Boulevard, which has a hydraulic capacity of only 7.5 cfs. If no major change in drainage area is planned, it is recommended that a parallel CMPA storm sewer segment be installed at the foot of Jaeckles Boulevard in order to resolve this problem. That pipe would consist of approximately 200 feet of 29-inch by 18-inch CMPA storm sewer segment, with an estimated hydraulic capacity of 7.5 cfs. These parallel storm sewer segments will more closely match the capacity of the upstream 24-inch CMCP storm sewer.