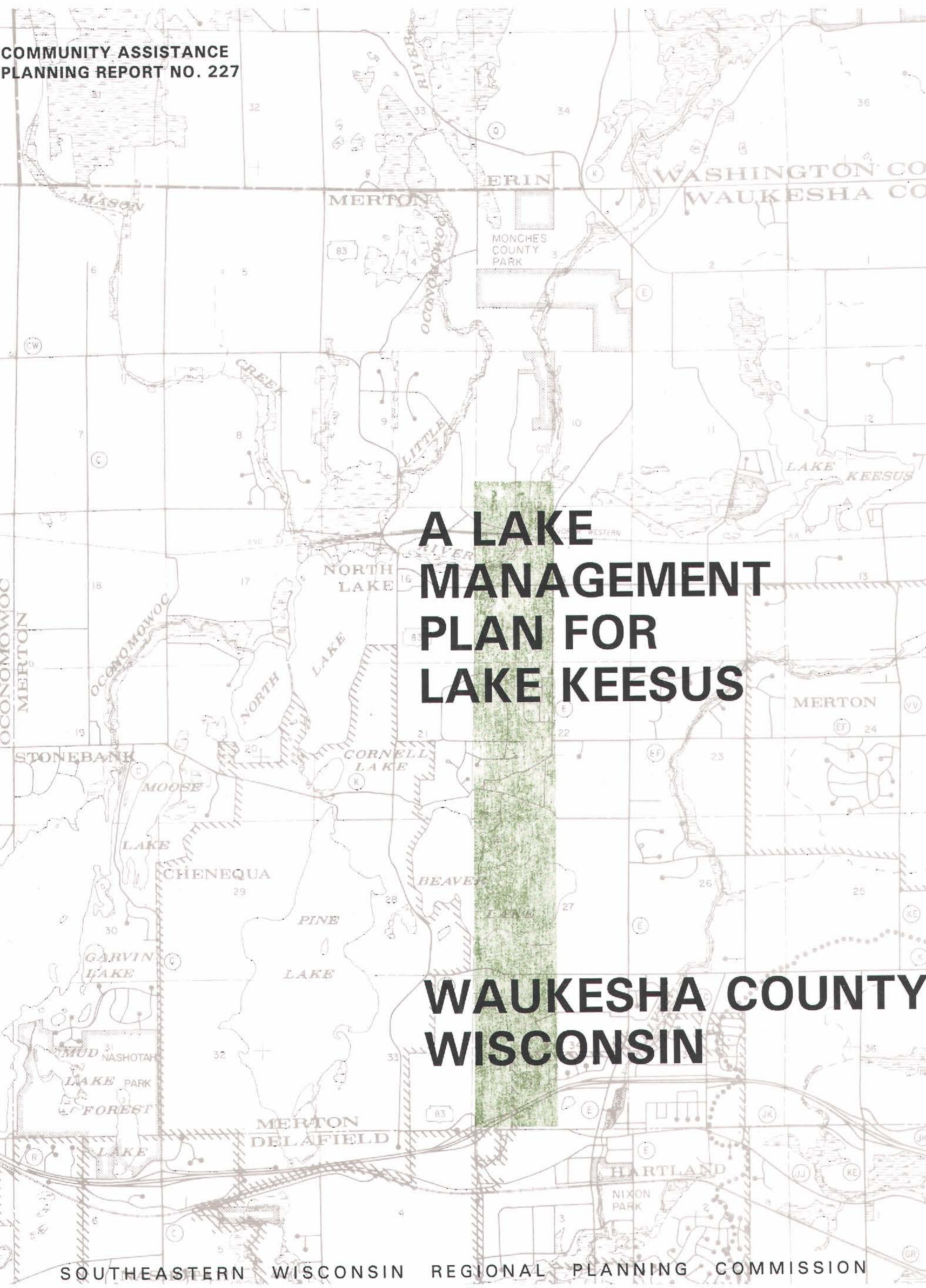
COMMUNITY ASSISTANCE
PLANNING REPORT NO. 227



A LAKE MANAGEMENT PLAN FOR LAKE KEESUS

WAUKESHA COUNTY WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgment is due to Dr. Calvin Gander, Chairman of the Water Quality Committee, and Ms. Fay Franz, Chairman of the Weed Harvesting Committee, for their contributions to the conduct of this study and the preparation of this report.

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

COMMUNITY ASSISTANCE PLANNING REPORT
NUMBER 227

A LAKE MANAGEMENT PLAN FOR LAKE KEESUS

WAUKESHA COUNTY, WISCONSIN

Prepared by the

Southeastern Wisconsin Regional Planning Commission
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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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June 25, 1998

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

Over the past several years, the Southeastern Wisconsin Regional Planning Commission and others, at the request of the Lake Keesus Protection and Rehabilitation District, have been conducting lake management-related data collection and analysis efforts. These efforts have now been integrated into a lake management plan for Lake Keesus, which plan addresses the water quality, recreational use, and natural resource problems of the Lake. The preparation of the plan was a cooperative effort by the Lake Keesus Protection and Rehabilitation District, the U.S. Geological Survey, the Wisconsin Department of Natural Resources, the Waukesha County Department of Parks and Land Use, and the Southeastern Wisconsin Regional Planning Commission.

This report documents the recommended lake management plan. The report describes the physical and biological characteristics of Lake Keesus and its watershed; the quality of the Lake waters and the factors affecting that quality, including land use and management practices; the recreational use of the Lake; and the shoreline conditions around the Lake. The report concludes with a set of recommended management measures.

The plan presented in this report is intended to provide a guide to the making of development decisions concerning the wise use and management of Lake Keesus as an aesthetic and recreational asset of immeasurable value. Accordingly, adoption of the plan presented herein by all concerned water use management agencies is urged. The Regional Planning Commission stands ready to assist the various units and agencies of government concerned in adopting and carrying out the plan recommendations over time.

Respectfully submitted,

Philip C. Evenson

Philip C. Evenson
Executive Director

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Chapter I

INTRODUCTION

Lake Keesus is a 237-acre drained lake, located on a tributary to the Oconomowoc River within U.S. Public Land Survey Sections 11, 12, 13, and 14, Township 8 North, Range 18 East, Town of Merton, Waukesha County. The Lake offers a variety of water-based recreational opportunities and is the focus of the lake-oriented community surrounding the Lake. However, during recent years, the Lake has experienced various management problems, including excessive plant and algae growth, recreation user conflicts and limitations, and fluctuating water levels. In addition, concerns have been raised regarding variable water quality conditions, the need to protect environmentally sensitive areas and to prevent the invasion of exotic plant species.

Seeking to improve the usability of Lake Keesus, and to prevent deterioration of the natural assets and recreational potential of the Lake, the residents of the watershed, in 1991, formed the Lake Keesus Management District, a special-purpose unit of government. The Lake Keesus Advancement Association, a private-sector organization, created in 1930, also continues to be active in lake management-related matters. The Lake Keesus Management District has undertaken a program to evaluate water quality conditions and identify specific management measures needed to improve the water quality and recreational use potential of Lake Keesus. This program involved the conduct of a hydrologic and water quality monitoring program conducted by the U.S. Geological Survey from October 1990 through September 1995 to determine the existing water budget and water quality of the Lake. A lake resident opinion and information survey was also conducted in 1991 by the University of Wisconsin-Extension Service. In addition, an aquatic plant survey and management plan was prepared during 1994 by a private consultant under contract to the Lake Keesus Management District.[1] This plan was subsequently reviewed and refined by Commission staff based upon the District's experience in its implementation. The programs were funded, in part, under the lake management planning grant program provided Chapter NR 119 (currently Chapter NR 190) of the *Wisconsin Administrative Code*. During 1995, plans were prepared by the Lake Keesus Management District, Town of Merton, and Wisconsin Department of Natural Resources for developing a public recreational boating access site on the southeastern shore of Lake Keesus under the provision of Chapter NR 190 of the Wisconsin Administrative Code. The boat ramp and parking facilities are expected to be constructed during 1998.

This lake management plan represents an ongoing commitment by the Lake Keesus Management District to sound environmental planning. This plan was prepared by the Regional Planning Commission in cooperation with the District, and it incorporates the data and analyses developed in the aforementioned lake management-related studies. As part of this planning effort, a field survey was made of the Lake to supplement the 1991 aquatic plant survey, and a recreational boating-use survey was conducted. The report presents feasible alternative in-lake measures for enhancing the water quality conditions and for providing opportunities for safe and enjoyable use of the Lake. More specifically, this report describes the physical, chemical, and biological characteristics of the Lake and pertinent related characteristics of the tributary watershed, as well as the feasibility of various watershed and in-lake management measures which may be applied to enhance the water quality conditions, biological communities, and recreational opportunities of the Lake.

The primary objectives which this plan is intended to achieve are: 1) to contribute to the overall conservation and wise use of Lake Keesus through the environmentally sound management of vegetation, fishes, and wildlife populations in and around the Lake; 2) to provide the potential for high-quality, water-based recreational experiences by residents and visitors to the Lake; and 3) to effectively control the severity of nuisances resulting from the recurring excessive aquatic macrophyte and algal growths in portions of the Lake Keesus basin to facilitate the conduct of water-based recreational activities, to improve the aesthetic value of the Lake, and to enhance its resource value. This plan should serve as a practical guide over time for achieving these objective in a technically sound manner.

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[1]*Aron & Associates,* Lake Keesus Aquatic Plant Management Plan, *October 1994.*

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Chapter II

PHYSICAL DESCRIPTION

INTRODUCTION

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

WATERBODY CHARACTERISTICS

Lake Keesus is located immediately north of the Village of Merton and northeast of North, Beaver and Pine Lakes in the Town of Merton, Waukesha County, as shown on Map 1. Lake Keesus was formed as the Michigan and Green Bay Lobes of the continental glacier retreated from Southeastern Wisconsin approximately 12,500 years ago, during the late Wisconsin stage of glaciation. The Lake, like many others in the Region, lies in a depressed area of this interlobate, or "kettle moraine," area that is characterized by unconsolidated glacial sediments consisting predominantly of silty-clay till and sandy outwash deposits. These glacial sediments, ranging in thickness from 100 to 200 feet, are underlain by Silurian dolomite and are overlain by organic deposits formed after glaciation.

Lake Keesus is a drained lake with extensive shallow areas and a single, deep basin. Basic hydrographic and morphometric data on the Lake are presented in Table 1. The Lake has a surface area of 237 acres with a maximum depth of about 42 feet. Water depths under about 50 percent of the lake area are less than 15 feet. Water depths under the other approximately 50 percent of the Lake all are between 15 and 42 feet. Lake Keesus has a shoreline length of 5.3 miles, and a shoreline development factor of 2.5, indicating that the Lake shoreline is irregular and is about 2.5 times as long as that which a circular lake of the same area would have. The Lake has a volume of approximately 3,958 acre-feet. The bathymetry of the Lake is illustrated in Map 2.

An unnamed intermittent tributary draining a two-square-mile area north of the Lake constitutes the major inflow to the Lake, supplemented by surface runoff from the direct drainage area of the Lake and direct precipitation onto the lake surface. The Lake discharges to a tributary of the Oconomowoc River, as shown on Map 2. The lake outflow is uncontrolled, and drains through an extensive area of wetland situated west of Marquardt's Bay located on the western side of Lake Keesus. The outflow stream joins the Oconomowoc River approximately 1.5 miles downstream of the western shoreline of Lake Keesus. The confluence of the outflow stream and the Oconomowoc River is located about 1.5 miles upstream of North Lake. The Oconomowoc River passes through North Lake, Okauchee Lake, Oconomowoc Lake, Fowler Lake, and Lac La Belle before ultimately discharging into the Rock River in the Town of Ixonia, east of the City Watertown, in Jefferson County, about 20 miles downstream from Lake Keesus.[1]

A survey of lake bottom substrate within the littoral zone of Lake Keesus was conducted in 1994 by Aron &

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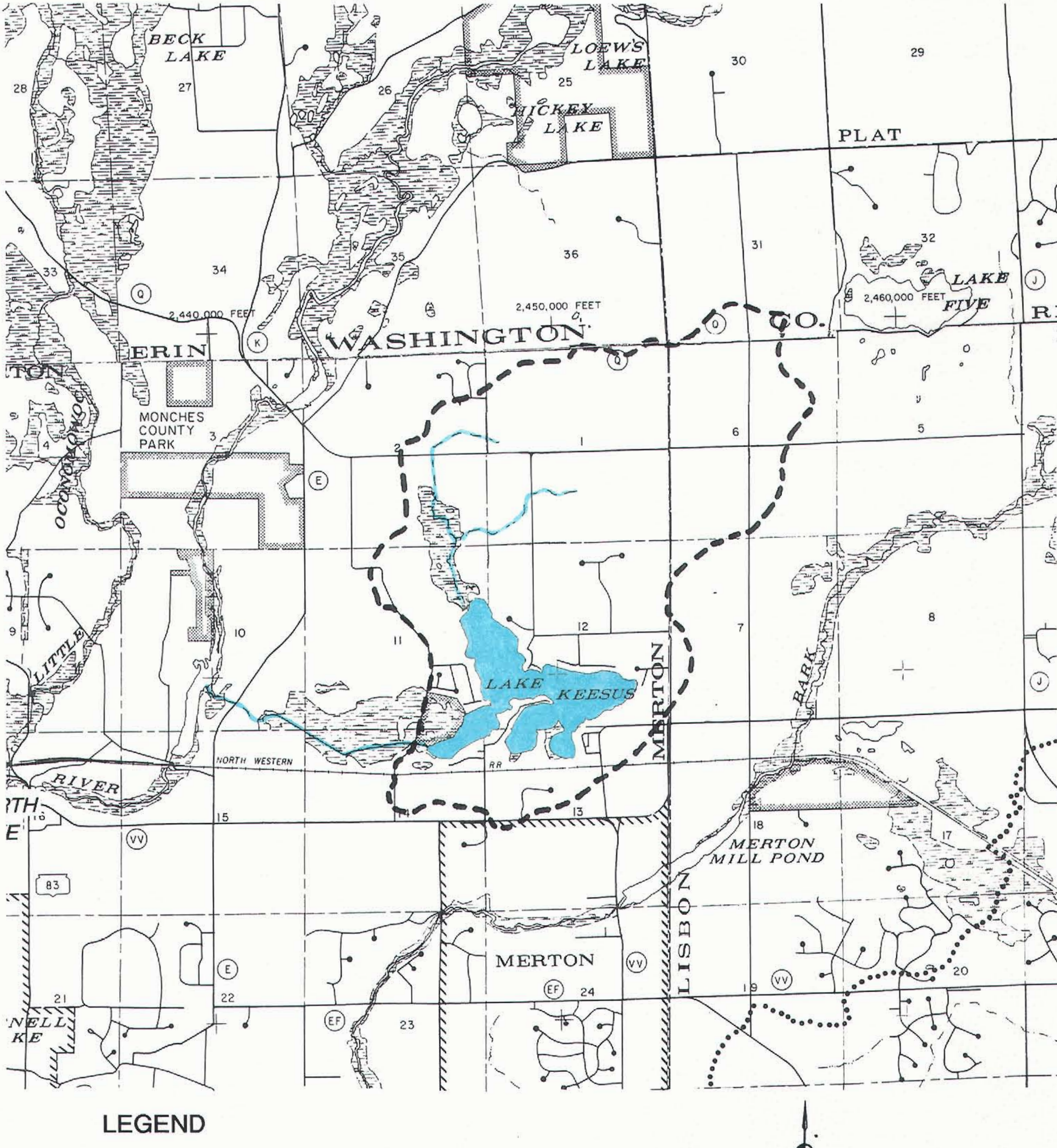
[1] *Comprehensive lake management plans have been prepared for the Oconomowoc River chain-of-lakes and have been published as SEWRPC Community Assistance Planning Report No. 47,* A Water Quality Management Plan for Lac La Belle, Waukesha County, Wisconsin, *December 1980; SEWRPC Community Assistance Planning Report No. 53,* A Water Quality Management Plan for Okauchee Lake, Waukesha County, Wisconsin, *August 1981; SEWRPC Community Assistance Planning Report No. 54,* A Water Quality Management Plan for North Lake, Waukesha County, Wisconsin, *July 1982; SEWRPC Community Assistance Planning Report No. 181,* A Water Quality Management Plan for Oconomowoc Lake, Waukesha County, Wisconsin, *March 1990; and SEWRPC Community Assistance Planning Report No. 187,* A Management Plan for Fowler Lake, Waukesha County, Wisconsin, *March 1994.*

Map 1

LAKE KEESUS TRIBUTARY DRAINAGE AREA



LEGEND

TOTAL TRIBUTARY AREA FOR LAKE KEESUS

Source: SEWRPC.

Table 1

HYDROGRAPHY AND MORPHOMETRY OF KEESUS LAKE

Parameter	Measurement
Size	
Area of Lake	237 acres
Drainage Area	2,660 acres
Lake Volume	3,958 acre-feet
Hydraulic Residence Time[a]	2 years
Shape	
Length of Lake	1.1 miles
Length of Shoreline	5.3 miles
Width of Lake	0.9 mile
Shoreline Development Factor[b]	2.5
Depth	
Portion of Lake Less than Five Feet	22 percent
Portion of Lake between 5 and 15 Feet	28 percent
Portion of Lake between 15 and 25 Feet	12 percent
Portion of Lake between 25 and 30 Feet	13 percent
Portion of Lake between 30 and 40 Feet	23 percent
Portion of Lake More than 40 Feet	2 percent
Mean Depth	16.7 feet
Maximum Depth	42 feet

[a] *The "hydraulic residence time" is estimated as the time period for a 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.*

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

Associates and is shown on Map 3. The littoral zone is defined as the shoreland zone in which aquatic plant growth occurs, extended from the ordinary high water mark to about 10 feet in depth. Of the surveyed bottom sediments, 62 percent was covered by muck, 33 percent by rubble, and 5 percent by sand. The depths of the soft sediments were not measured, but are likely to exceed four feet in the western embayments.

The shoreline of Lake Keesus is almost entirely developed for residential uses, with the exception of the wetland areas located adjacent to the southern embayments, which are in open space use, and the areas located adjacent to northern embayment, which are surrounded by a privately owned camp.

Erosion of shorelines results in the loss of land, damage to shoreland infrastructure, and interference with access and lake use. Such erosion is usually caused by wind-wave erosion, ice movement, and motorized boat traffic. A survey of the Lake Keesus shoreline, conducted during the summer of 1995 by Commission staff, identified existing shoreline protection conditions around this lake, as shown on Map 4. About 1.5 miles, or 30 percent of the shoreline of Lake Keesus, were found to be in a natural condition, while the remaining 3.8 miles were found to be protected by some type of shore protection structure, including bulkheads, vertical walls, revetments, sloping stonewalls, and areas where riprap had been used to stabilize the shoreline. Most of the observed shoreline protection measures were in a good state of repair.

WATERSHED CHARACTERISTICS

The drainage area tributary to Lake Keesus totals about 2,660 acres, or about 4.2 square miles, including about two square miles north of the Lake which drains through an intermittent stream and wetland complex to the Lake, as shown on Map 1. Lake Keesus has a watershed-to-lake area ratio of 11:1.

Map 5 reproduces the 1874 plat map for the Lake Keesus area.

Soil Types and Conditions

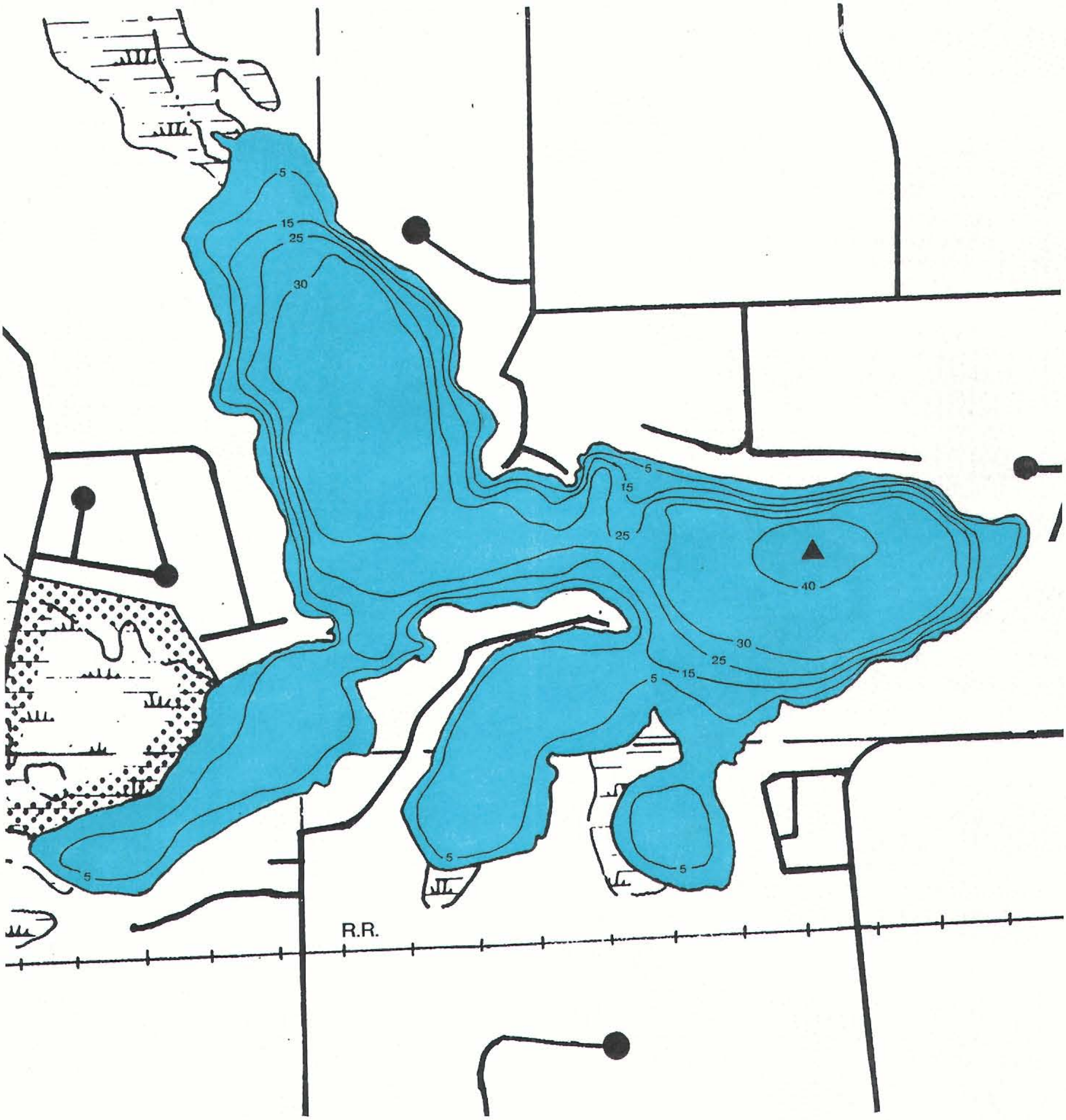
Soil type, land slope, and land use and management practices are among the more important factors determining lake water quality conditions. Soil type, land slope, and vegetative cover are also important factors affecting the rate, amount, and quality of stormwater runoff. The soil texture and the shape and stability of aggregates of soil particles—expressed as soil structure—influence the permeability, infiltration rate, and erodibility of soils. Land slopes are also important determinants of stormwater runoff rates and of susceptibility to erosion.

The U.S. Soil Conservation Service under contract to the Southeastern Wisconsin Regional Planning Commission completed a detailed soil survey of the entire seven-county planning region, including the Lake Keesus area in 1966.[2] The soil survey contained interpretations for planning and engineering applications and for suitability for various types of urban land uses, as well as for

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

Map 2

BATHYMETRIC MAP OF LAKE KEESUS

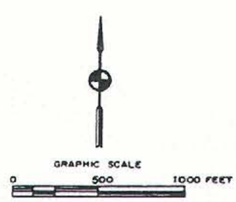


LEGEND

▲ SAMPLING SITE LOCATION

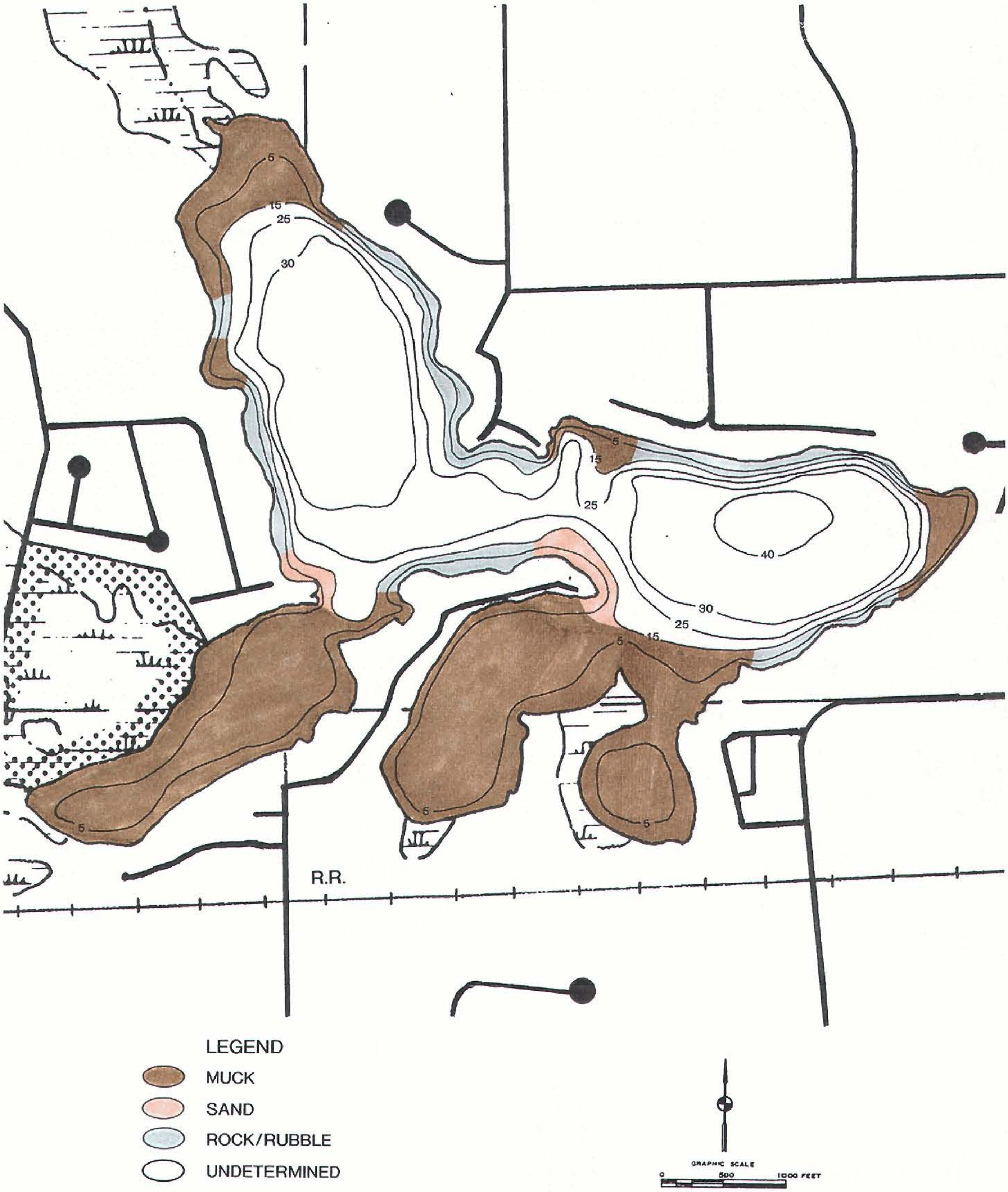
15 WATER DEPTH CONTOUR IN FEET

Source: U.S. Geological Survey and SEWRPC.



Map 3

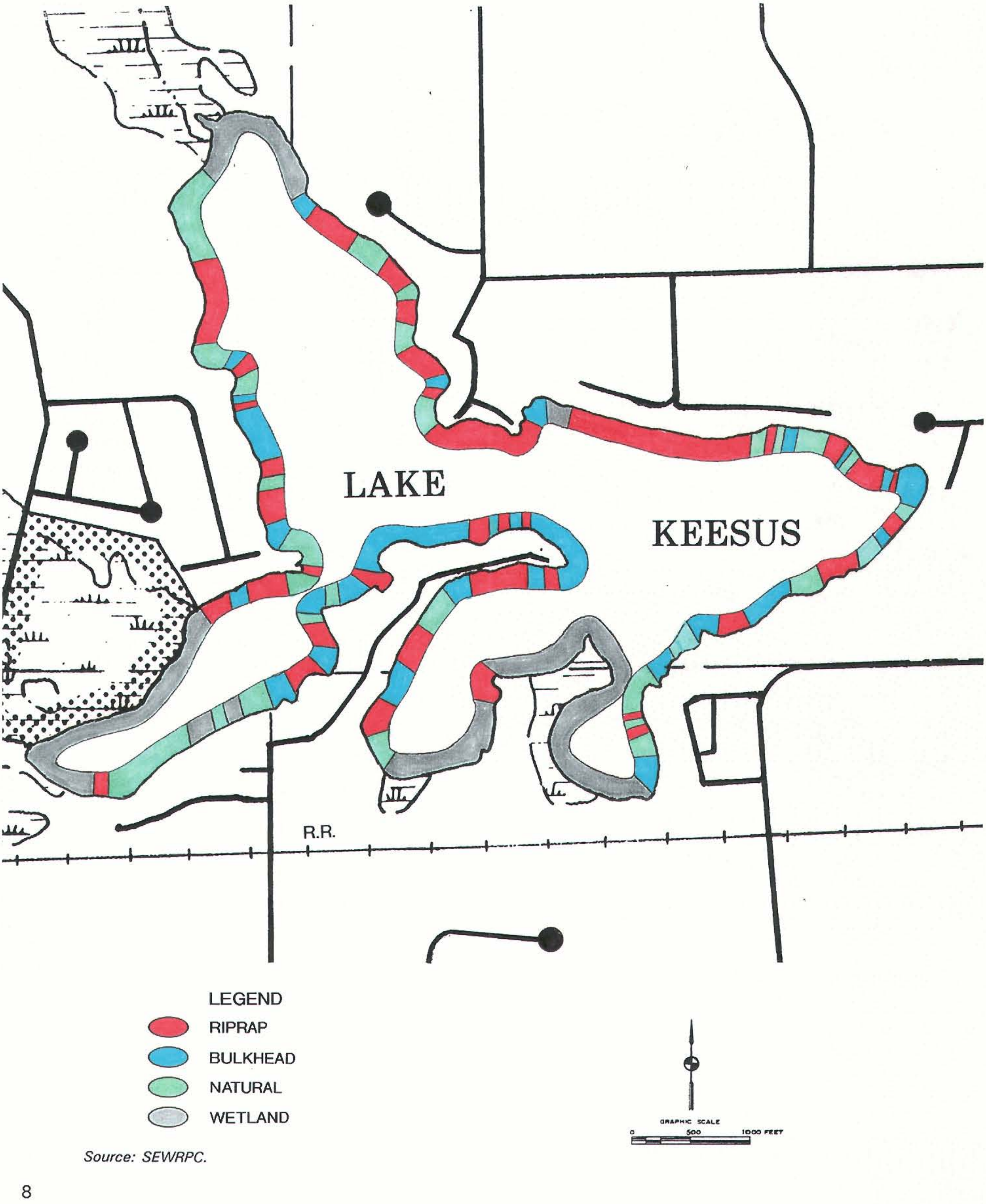
BOTTOM SUBSTRATE FOR LAKE KEESUS: 1994



Source: Aron & Associates and SEWRPC.

Map 4

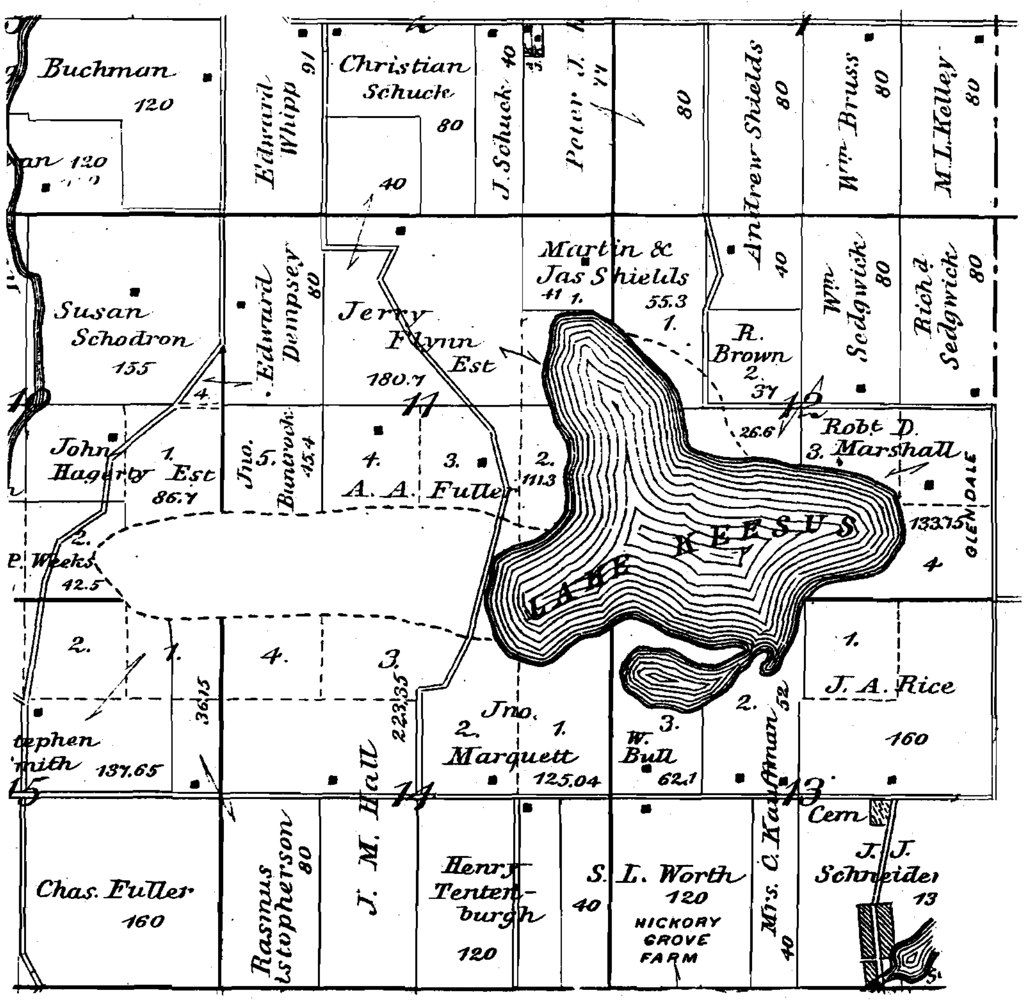
SHORELINE CONDITIONS ON LAKE KEESUS: 1995



Source: SEWRPC.

Map 5

HISTORIC UNITED STATES PLAT MAP FOR LAKE KEESUS AREA: 1874



Source: Waukesha County 1874 Plat Book by Balliet and Volk.

agricultural applications. Using the regional soil survey, an assessment was made of hydrologic characteristics of the soils in the drainage area of Lake Keesus. The suitability of the soils for urban residential development was assessed using three common development scenarios: development with conventional onsite sewage disposal systems; development with alternative onsite sewage disposal systems; and development with public sanitary sewers.

Soils within the drainage area of Lake Keesus were categorized into four main hydrologic soil groups, as well as an "other" category, as indicated in Table 2. The areal extent of these soils and their locations within the watershed are shown on Map 6. About 73 percent of the Lake Keesus drainage area is covered by the moderately well-drained soils.

As already noted, the regional soil survey included interpretations of the suitability of the mapped soils for various types of urban and rural development. The suitability ratings of the various soils for use of onsite sewage disposal systems were updated by the Regional Planning Commission based upon the soil characteristics determined by the detailed soil surveys and the experience of County and State technicians responsible for overseeing the location and design of such systems. The new ratings reflect the current soil and site specifications

Table 2

GENERAL HYDROLOGIC SOIL TYPES WITHIN THE KEESUS LAKE DRAINAGE AREA

Group	Soil Characteristics	Study Area Extent (acres)	Percent of Total
A	Well drained Very rapidly to rapid permeability Low shrink-swell potential	0.0	0.0
B	Moderately well drained Texture intermediate between coarse and fine Moderately rapid to moderate permeability Low to moderate shrink-swell potential	1,943.7	73.1
C	Somewhat poorly drained to poorly drained High water table for part or most of the year Mottling, suggesting poor aeration and lack of drainage, generally in A to C horizons	376.8	14.2
D	Very poorly drained High water table for most of the year Organic or clay soils Clay soils having high shrink-swell potential	102.0	3.8
- -	Hydrologic soil group not determined	2.6	0.1
Water	- -	234.9	8.8
- -	Total	2,660.2	100.0

Source: SEWRPC.

set forth in Comm 83—formerly Chapter ILHR 83—of the *Wisconsin Administrative Code.*

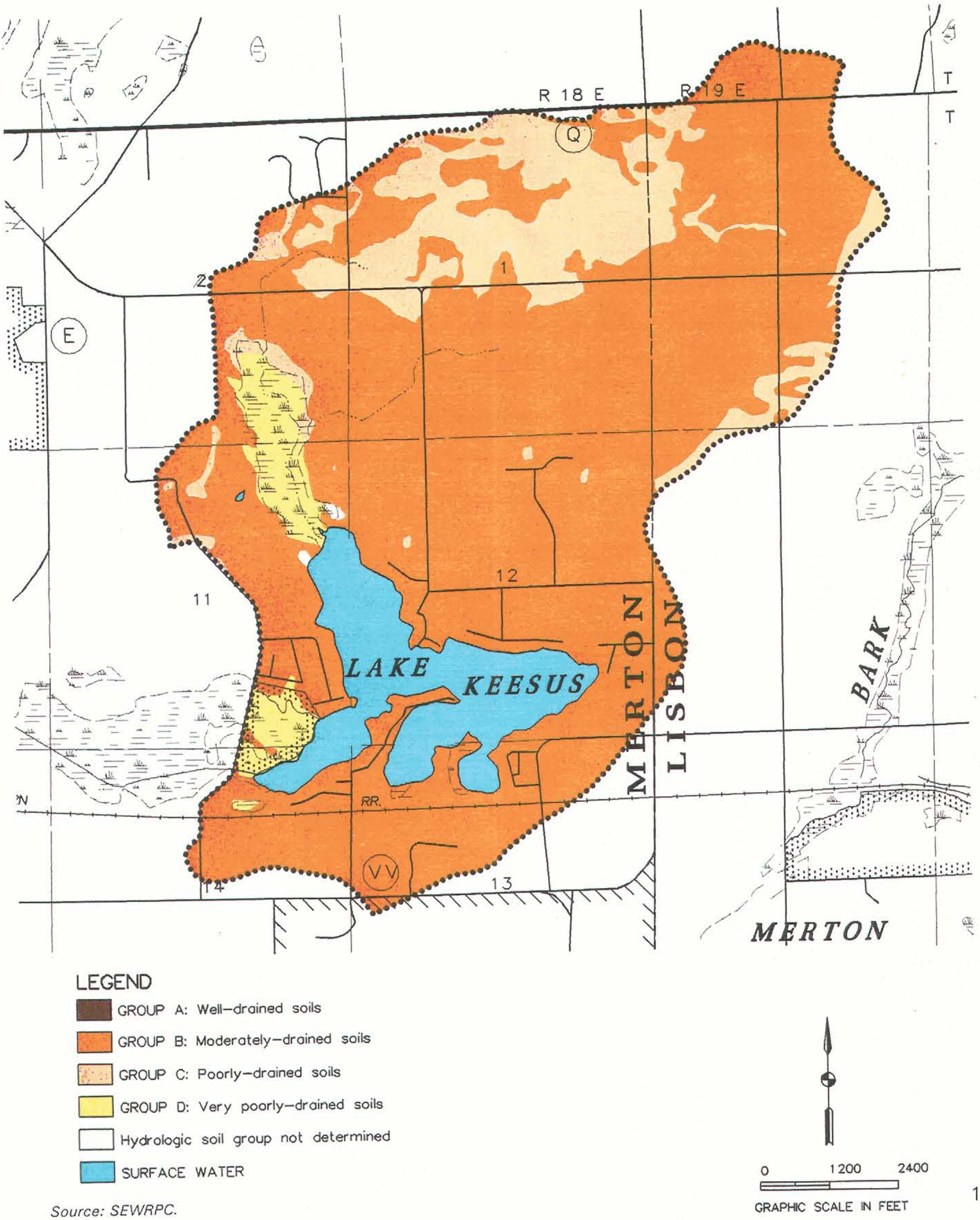
With respect to residential development utilizing conventional onsite sewage disposal systems, as shown on Map 7, about 51 percent of the drainage area tributary to Lake Keesus is covered by soils suitable for such development, and about 8 percent by soils unsuitable for such development. The soil suitability could not be determined without further field study for 33 percent of the land in the drainage area, and less than 0.1 percent could not be classified. Nearly all of the residential shoreline development around Lake Keesus is underlain by soils which fall into the category whereby no determination could be made without further field study.

Using alternative onsite sewage disposal systems, such as mound systems, as shown on Map 8, yields additional land which may be suitable for urban residential development: about 72 percent of the drainage area tributary to Lake Keesus is covered by soils suitable for such development and about 6 percent by soils unsuitable for such development. The soil suitability could not be determined without further field study for about 22 percent of the tributary drainage area and less than 0.1 percent could not be classified. Nearly all of the shoreline residential development around Lake Keesus is underlain by soils which fall into the category whereby no determination could be made without further field study.

Soil limitations for residential development utilizing sanitary sewer service are shown on Map 9. About 75 percent of the drainage area tributary to Lake Keesus is covered by soils suitable for such development and about 16 percent by soils unsuitable for such development. About 9 percent of the area, including most of the lakeshore residential lands, is covered by unclassified soils. As of 1995, the Lake Keesus drainage area was not served by public sanitary sewers, although the provision of public sanitary sewer service to the Lake

Map 6

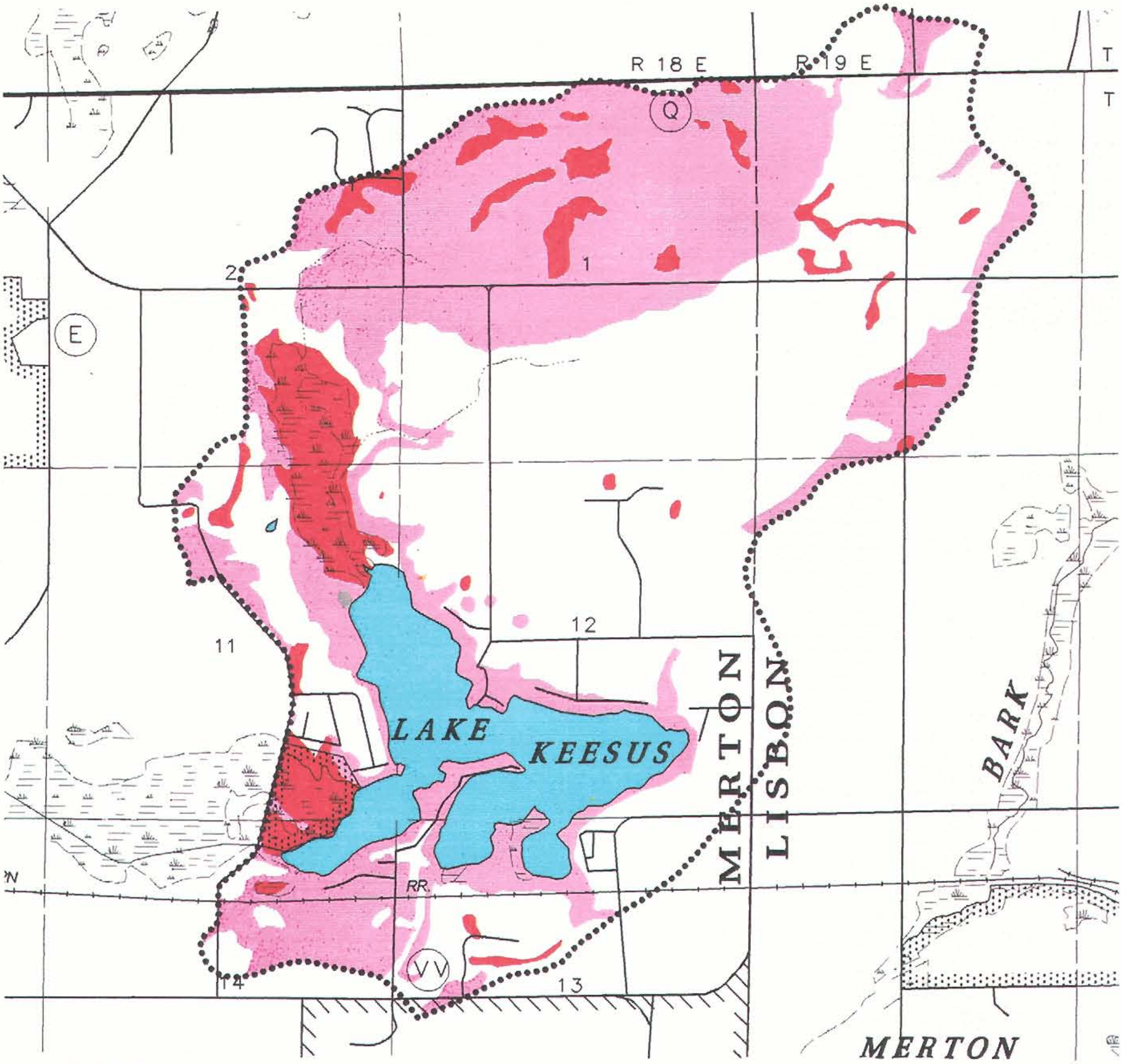
HYDROLOGIC SOIL GROUPS WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS



Source: SEWRPC.

Map 7

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



LEGEND

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

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

SUITABLE: Areas covered by soils having a high probability of meeting the criteria of Chapter ILHR 83 of the Wisconsin Administrative Code governing conventional onsite sewage disposal systems.

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

SURFACE WATER

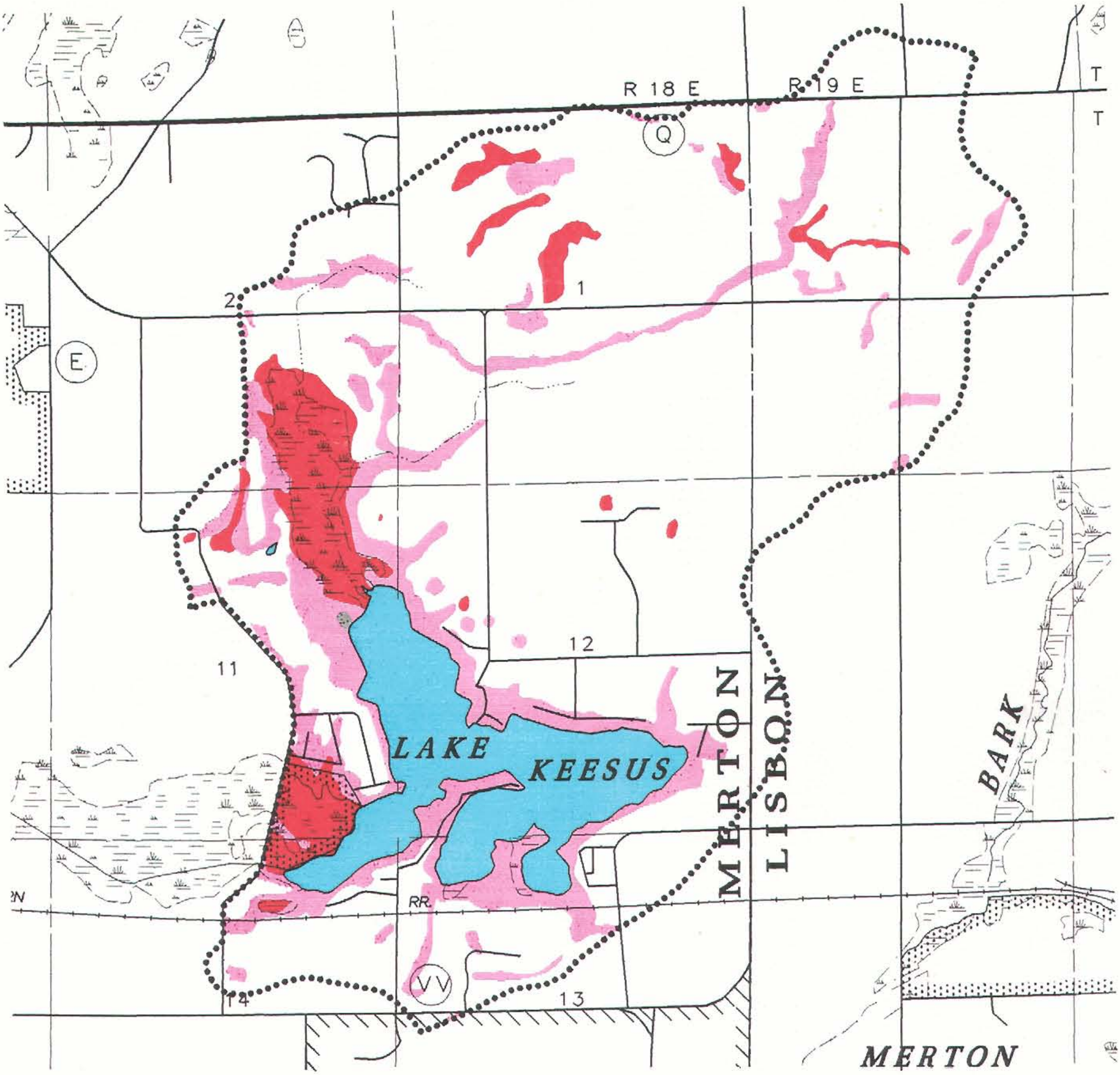
0 1200 2400

GRAPHIC SCALE IN FEET

Source: SEWRPC.

Map 8

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



LEGEND

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

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

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

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

SURFACE WATER

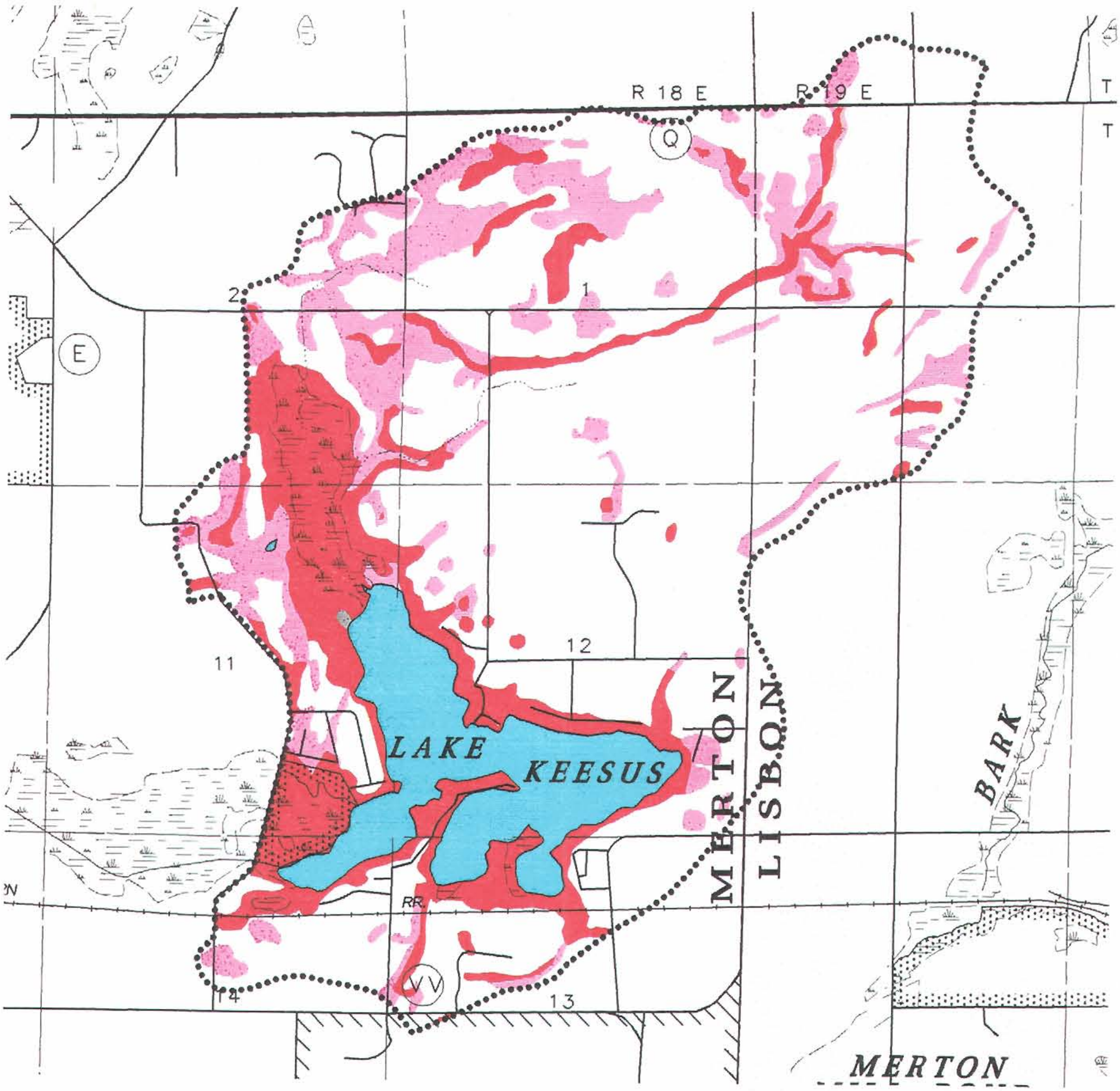
0 1200 2400

GRAPHIC SCALE IN FEET

Source: SEWRPC.

Map 9

SUITABILITY OF SOILS WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS FOR RESIDENTIAL DEVELOPMENT WITH PUBLIC SANITARY SEWER SERVICE



LEGEND

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

0 1200 2400

GRAPHIC SCALE IN FEET

Source: SEWRPC.

Keesus urban area is to be investigated in the preparation of a sanitary sewerage system plan for northwestern Waukesha County.[3]

LAKE HYDROLOGY

Long-term average monthly air temperature and precipitation values for the Lake Keesus area are set forth in Table 3. In addition, Table 3 provides monthly air temperature and precipitation data for 1994 during the period that lake hydrology and water quality data were obtained for use in this report. Table 3 also provides runoff data for both periods—long-term and 1994—derived from U.S. Geological Survey flow records for the Oconomowoc River, station number 05425500, at Watertown, Jefferson County, Wisconsin. Groundwater levels were not measured during this study.

The mean summer and winter temperatures of 67.3°F and 24.9°F at Oconomowoc are similar to those of other recording locations in Southeastern Wisconsin. Mean annual precipitation at Oconomowoc is 30.90 inches. More than one-half of the normal yearly precipitation falls during the growing season, from May to September. Runoff rates are generally low during this period because evapotranspiration rates are high, vegetation cover is abundant, and soils are not frozen. Normally, about 15 percent of the summer precipitation is expressed as surface runoff, but intense summer storms occasionally produce high runoff. Peak runoff usually occurs during winter and early spring, when about 40 percent of the annual precipitation, in the form of snowmelt and/or rain, falls on frozen ground.

As Table 3 indicates, in 1994 precipitation was 2.28 inches, or 5 percent, below the long-term average at Oconomowoc. In June, July and August, the wettest months, 4.20, 6.36, and 4.06 inches of precipitation were experienced, respectively, or 0.60, 2.60, and 0.13 inches above the long-term average. This abundant precipitation was off-set by below normal precipitation during much of the remainder of the year. However, the net result of the three months of relatively heavy rainfall, combined with lower precipitation in the remainder of the year, resulted in near normal runoff volumes in 1994 at the U.S. Geological Survey streamflow gauge located on the Rock River at Watertown.

Although groundwater levels were not measured during this study, the slope of the water table indicates that groundwater flows occur from northeast to southwest across the lake area, similar to the surface water drainage pattern.[4]

Water Budget

Based on available data, an average annual water budget for Lake Keesus was computed and is set forth in Figure 1. During the 12-month period from October 1993 through September 1994, an estimated 2,092 acre-feet of water entered the Lake. Approximately 1,527 acre-feet, or 73 percent, of the known inflow was contributed by runoff from the drainage area directly tributary to the Lake and the 2.0 square miles tributary to the intermittent stream and wetland complex tributary to the north end of the Lake. The remaining 565 acre-feet, or 27 percent, of the known inflow came from direct precipitation onto the Lake surface. An estimated 1,950 acre-feet of water was lost from the Lake, including 1,377 acre-feet, or about 71 percent, via the outlet, and about 573 acre-feet, or 29 percent, by evaporation from the lake surface. Flows were not measured, but groundwater inflow was assumed to equal groundwater outflow. The net change in water storage volume in Lake Keesus was assumed to be 142 acre-feet, or approximately one-half foot, during the year.[5]

The hydraulic residence time, or the time required for a volume equivalent to the full volume of the Lake to enter the lake basin, was approximately two years, during both the study period and an average year. The hydraulic residence time is important in determining the expected response time of a lake to increased or decreased nutrient and pollutant loadings. The smaller the lake volume and/or greater the rate of inflow, the shorter the hydraulic residence time will be, and the more quickly the lake will respond to changes in nutrient or pollutant loadings. The residence time of Lake Keesus implies that the water quality of the Lake will be resistant to rapid changes in these rates, and will be strongly influenced by the quality of water running off the land surface.

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[3]*Black & Veatch,* A Sanitary Sewerage System Plan for the Northwestern Waukesha County Area, *Draft, in preparation.*

[4]*U.S. Geological Survey Water Resources Investigation Open File Report 79-43, Water Table Map of Waukesha County, Wisconsin, May 1979.*

[5]*U.S. Geological Survey Open-File Report No. 95-190,* Water-Quality and Lake-Stage Data for Wisconsin Lakes, Water Year 1994, *1995, p. 69.*

Table 3

LONG-TERM AND 1994 STUDY YEAR TEMPERATURE, PRECIPITATION, AND RUNOFF DATA FOR THE KEESUS LAKE AREA

Temperature													
Air Temperature Data (°F)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	15.3	19.4	31.9	45.4	57.5	66.7	71.7	71.8	60.1	49.0	35.5	21.4	45.5
1994 Mean Monthly	9.4	14.5	33.6	47.8	56.5	69.1	69.8	69.4	63.6	51.8	40.3	29.7	46.3
Departure from Long-Term Mean	-5.8	-4.9	1.7	2.4	-1.0	2.4	-1.9	-2.4	3.5	2.8	4.8	8.3	0.8

Precipitation														
Precipitation Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Total
Long-Term Mean Monthly	0.99	0.94	1.87	2.76	2.86	3.60	3.76	3.93	3.88	2.52	2.12	1.67	2.57	30.90
1994 Mean Monthly	1.62	2.62	0.83	1.26	1.30	4.20	6.36	4.06	1.56	0.63	3.21	0.97	2.38	28.62
Departure from Long-Term Mean	0.63	1.68	-1.04	-1.50	-1.56	0.60	2.60	0.13	-2.32	-1.89	1.09	-0.70	-0.19	-2.28

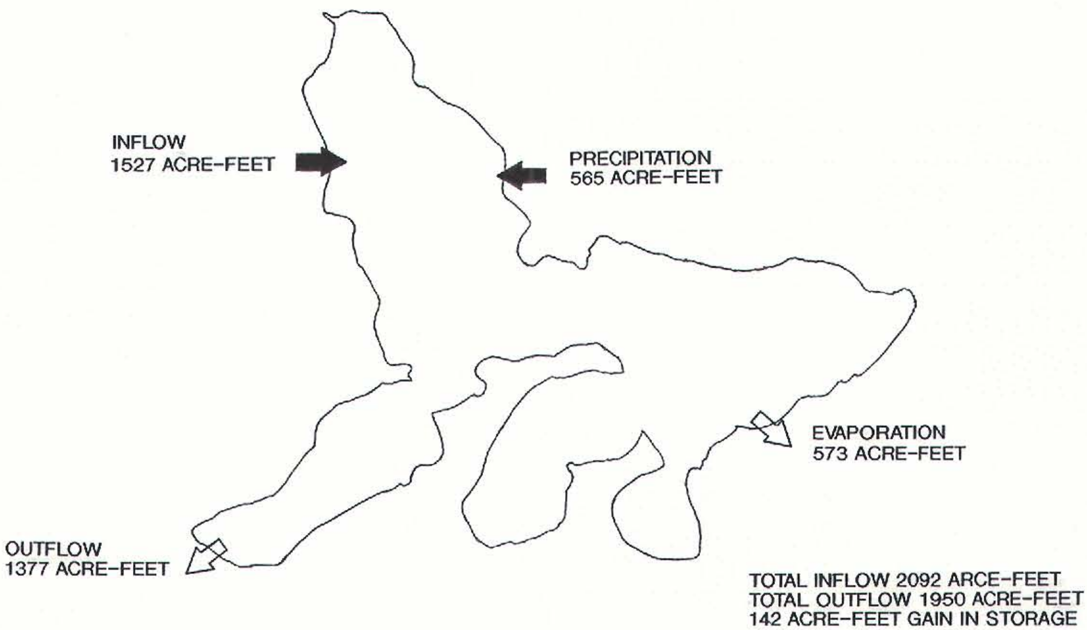
Runoff													
Runoff Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	0.13	0.15	0.39	0.58	0.31	0.18	0.15	0.10	0.11	- -[a]	- -[a]	- -[a]	- -[a]
1994 Mean Monthly	0.16	0.61	1.89	1.06	0.36	0.16	0.60	0.23	0.10	- -[a]	- -[a]	- -[a]	- -[a]
Departure from Mean Monthly	0.03	0.46	1.5	0.48	0.05	-0.02	0.45	0.13	-0.01	- -[a]	- -[a]	- -[a]	- -[a]

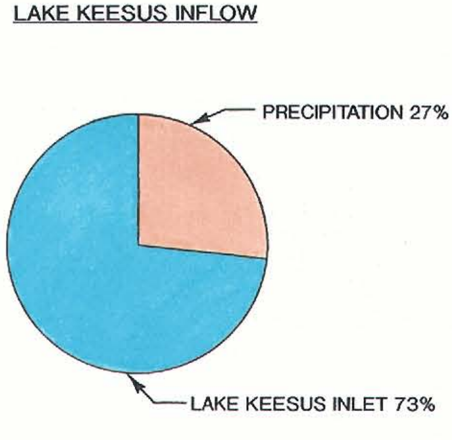
[a] *Data not available.*

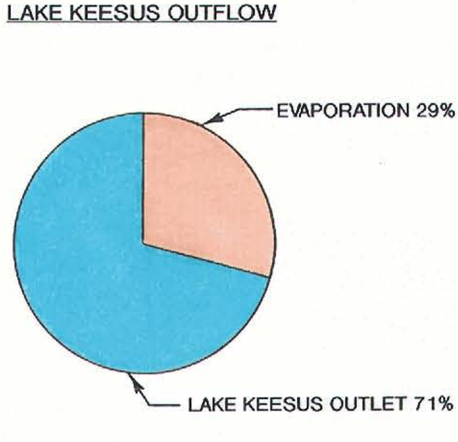
Source: National Oceanic and Atmospheric Administration and U.S. Geological Survey.

Figure 1

HYDROLOGIC BUDGET FOR LAKE KEESUS: 1993-1994







Source: SEWRPC.

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Chapter III

HISTORICAL, EXISTING, AND PLANNED LAND USE AND POPULATION

INTRODUCTION

Water pollution problems, recreational use conflicts, and deterioration of the natural environment are all primarily a function of the human activities within the drainage area of a waterbody, as are the ultimate solutions to these problems. This is especially true with respect to lakes which are highly susceptible to deterioration by human activities because of relatively long pollutant retention times, and because of the variety of often conflicting uses to which lakes are subject. Furthermore, urban development is often concentrated in the direct drainage areas and around the shorelines of lakes, where there are no intermediate stream segments to attenuate pollutant runoff and loadings. Accordingly, the population levels and land use and management in the tributary drainage area of a lake must be important considerations in any lake management efforts.

CIVIL DIVISIONS

The geographic extent and functional responsibilities of civil divisions and special-purpose units of government are important factors related to land use and management, since these local units of government provide the basic structure of the decision-making framework within which land use development and redevelopment must be addressed. Superimposed on the Lake Keesus drainage area are the local civil division boundaries shown on Map 10. The drainage area tributary to Lake Keesus is located primarily in the Towns of Lisbon and Merton in Waukesha County; but also includes small portions of the Towns of Erin and Richfield in Washington County, and of the Village of Merton in Waukesha County. The area and proportion of the drainage area lying within each jurisdiction concerned, as of 1990, is set forth in Table 4.

POPULATION

As indicated in Table 5, the resident population of the drainage area tributary to Lake Keesus has increased steadily since 1960, with the largest increase occurring between 1970 and 1980. The 1990 resident population of the drainage area, estimated at 970 persons, is about 45 percent greater than the estimated 1960 population. Population forecasts prepared by the Regional Planning Commission, as a basis for the preparation of the adopted regional land use plan,[1] indicate, as shown in Table 5, that the resident population of the drainage area tributary to Lake Keesus may be expected to remain relatively stable to the year 2010 at a level between 980 and 1,090 persons.

As indicated in Table 5, the number of resident households in the drainage area tributary to Keesus Lake also increased steadily since 1960. The number of resident households in the area may be expected to increase from about 330 households in 1990, to about 360 households by the year 2010.

In addition to the year-round resident population and households, there were, as of 1990, about 100 seasonal residents and 40 seasonal housing units within the drainage area tributary to Lake Keesus.

Land Use

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

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

Significant urban development began to occur in the drainage area tributary to Lake Keesus in the early 1900s. Map 11 and Table 6 indicate the historical urban

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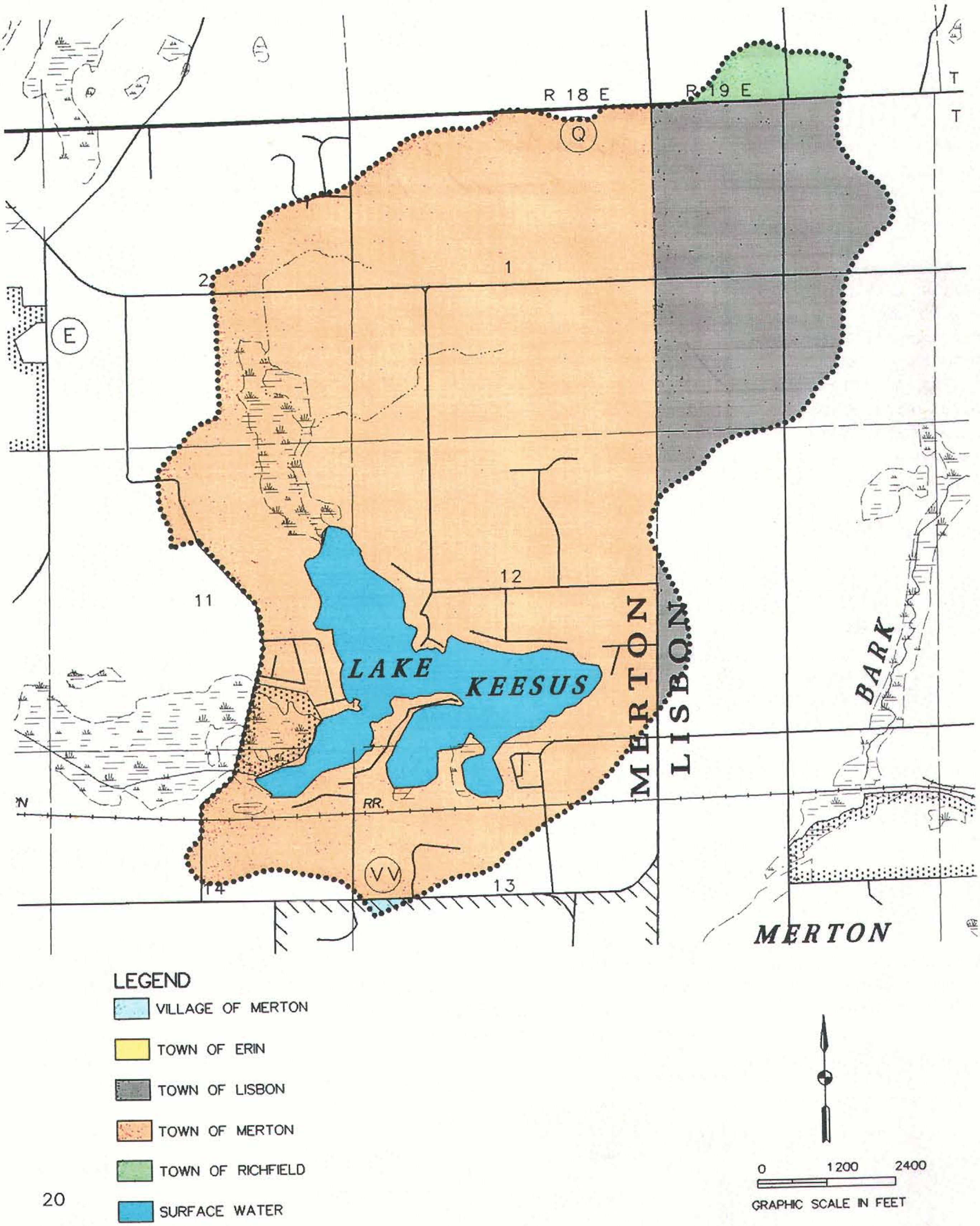
[1] *SEWRPC Planning Report No. 40,* A Regional Land Use Plan for Southeastern Wisconsin—2010, *January, 1992.*

Map 10

CIVIL DIVISION BOUNDARIES WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS



Source: SEWRPC.

Table 4

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

Civil Division	Civil Division Area within Study Area (acres)	Percent of Study Area within Civil Division	Percent of Civil Division within Study Area
Town of Erin	<1	<1	<1
Town of Richfield	45	2	<1
Town of Lisbon	484	18	2
Town of Merton	2,129	80	12
Village of Merton	2	<1	<1
Total	2,660	100	- -

Source: SEWRPC.

growth pattern in the tributary drainage area since 1920. The most rapid increase in urban land use development occurred between 1980 and 1985, when almost 162 acres of the drainage area were converted from rural to urban land uses. The rate of urban development in the drainage area tributary to Keesus Lake decreased to about 37 acres between 1985 and 1990.

The existing land use pattern in the Lake Keesus tributary drainage area, as of 1990, is shown on Map 12 and is quantified in Table 7. As indicated in Table 7, by about 1990, about 445 acres, or about 17 percent of the drainage area, were devoted to urban land uses. The dominant urban land use was residential, encompassing 297 acres, or about 67 percent of the area in urban use. As of 1990, about 2,215 acres, or about 83 percent of the drainage area tributary to Lake Keesus, were still devoted to rural land uses. About 1,690 acres, or about 76 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface water, including the surface area of Lake Keesus, accounted for approximately 525 acres, or about 24 percent of the area in rural uses.

Under year 2010 conditions, no significant changes in land use conditions within the drainage area tributary to Lake Keesus are envisioned in the regional land use plan, although some infilling of existing platted lots and some backlot development may be expected to occur. In addition, the redevelopment of properties and the reconstruction of existing single-family homes may be expected on lakeshore properties. Recent surveillance indicates that some large-lot subdivision development is also occurring in the area—generally north and east of Center Oak Road and which was not envisioned in the recommended regional plan. If this trend continues, much of the open space areas remaining in the drainage area will be replaced, over time, with large-lot urban development.

Under the full buildout condition envisioned under the Waukesha County development plan[2] completed in 1996, most of the undeveloped lands outside the environmental corridors and other environmentally sensitive areas could potentially be developed for low-density and suburban-density residential uses. This development could occur in the form of residential clusters on smaller lots, and, thereby, preserve portions of the remaining open space, and, thus, reduce impacts on the Lake.[3]

EXISTING ZONING REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. As already noted, the Lake Keesus drainage area includes portions of the Towns of Erin, Lisbon, Merton, and Richfield, and Village of Merton. The Towns of Lisbon and Merton are under the jurisdiction of Waukesha County and its Zon-

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

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

Table 5

HISTORIC AND FORECAST RESIDENT POPULATION AND HOUSEHOLD LEVELS WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS: 1960-2010[a]

Year	Number of Residents	Number of Households
1960	670	180
1970	700	190
1980	930	290
1990	970	330
2010 Intermediate-Growth Centralized Regional Plan	980	360
2010 High-Growth Decentralized Alternative	1,090	380

[a]*Study area approximated using whole U.S. Public Land Survey one-quarter sections.*

Source: SEWRPC.

Table 6

EXTENT OF URBAN GROWTH WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS: 1920-1990

Year	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]
1920	15	15
1940	58	73
1963	22	95
1975	60	155
1980	162	317
1985	155	472
1990	37	509

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

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

ing Ordinance, while the Towns of Erin and Richfield are under the jurisdiction of Washington County and its Zoning Ordinance. The Village of Merton, Waukesha County, administers its own zoning ordinance. The current generalized zoning districts applicable to the drainage area tributary to Lake Keesus, as provided for under the current zoning regulations are shown on Map 13.

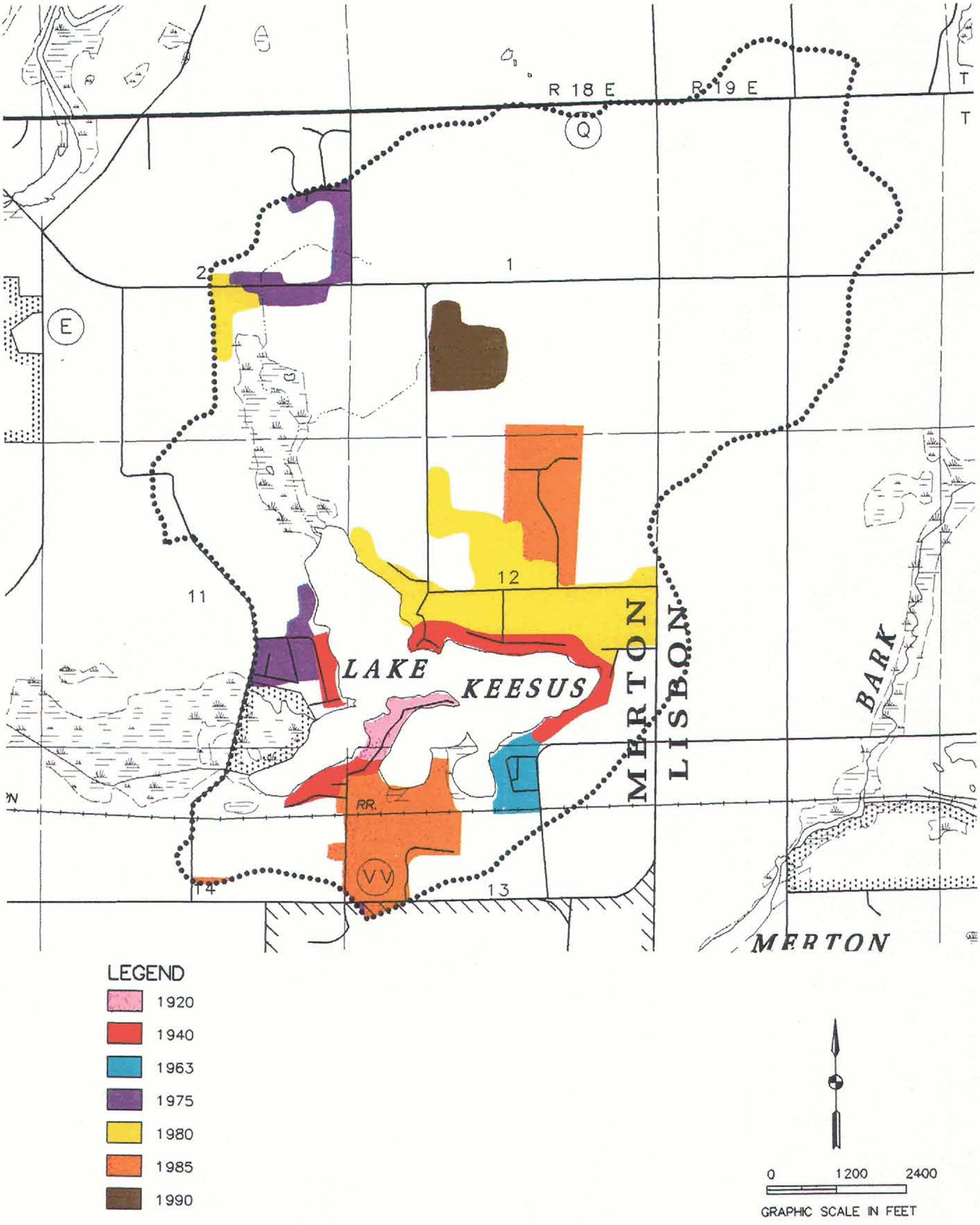
In addition to the comprehensive zoning ordinances administered in the Lake Keesus drainage area, both the Waukesha County and Washington County Boards of Supervisors exercise special-purpose shoreland and floodland zoning in the drainage area. These special-purpose zoning ordinances, prepared pursuant to the requirements of the Wisconsin Water Resources Act of 1965 (Chapter 30, *Wisconsin Statutes*), impose special land use regulations on all unincorporated 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 shoreland and floodland protection zoning ordinances are similar in content in both Waukesha and Washington Counties, and include regulations intended to protect waterways and the attendant shorelines.

Other pertinent land use and management regulations include wetland and shoreland protection ordinances. Chapters 23 and 330 of the *Wisconsin Statutes* require that counties regulate the use of all wetlands five acres or larger located in the shoreland areas of unincorporated municipalities within 300 feet of a stream and 1,000 feet of a lake, or to the landward side of the floodplain, whichever is greater. Wetland maps for Waukesha and Washington Counties were prepared for the Wisconsin Department of Natural Resources by the Regional Planning Commission in 1981. In accordance with Chapter NR 115 of the *Wisconsin Administrative Code*, Waukesha and Washington Counties have amended their shoreland zoning regulations and attendant maps to preclude further loss of wetlands in the shoreland areas.

The existing zoning ordinances have proven to be relatively effective in protecting the wetlands and water resources of the Lake Keesus drainage area. Nevertheless, some concern has been expressed by residents of the area over the widespread development of large-lot development on former agricultural lands in the vicinity of the Lake. In addition, infilling and replacement of existing housing with larger structures, especially within the shoreland surrounding Lake Keesus has, to a limited extent, taken place. Such redevelopment of the watershed and lakefront may be undesirable from the point of view of water quality protection—as it generally results in a greater area of impervious surface, increased runoff, and increased pollutant loading. This may be accom-

Map 11

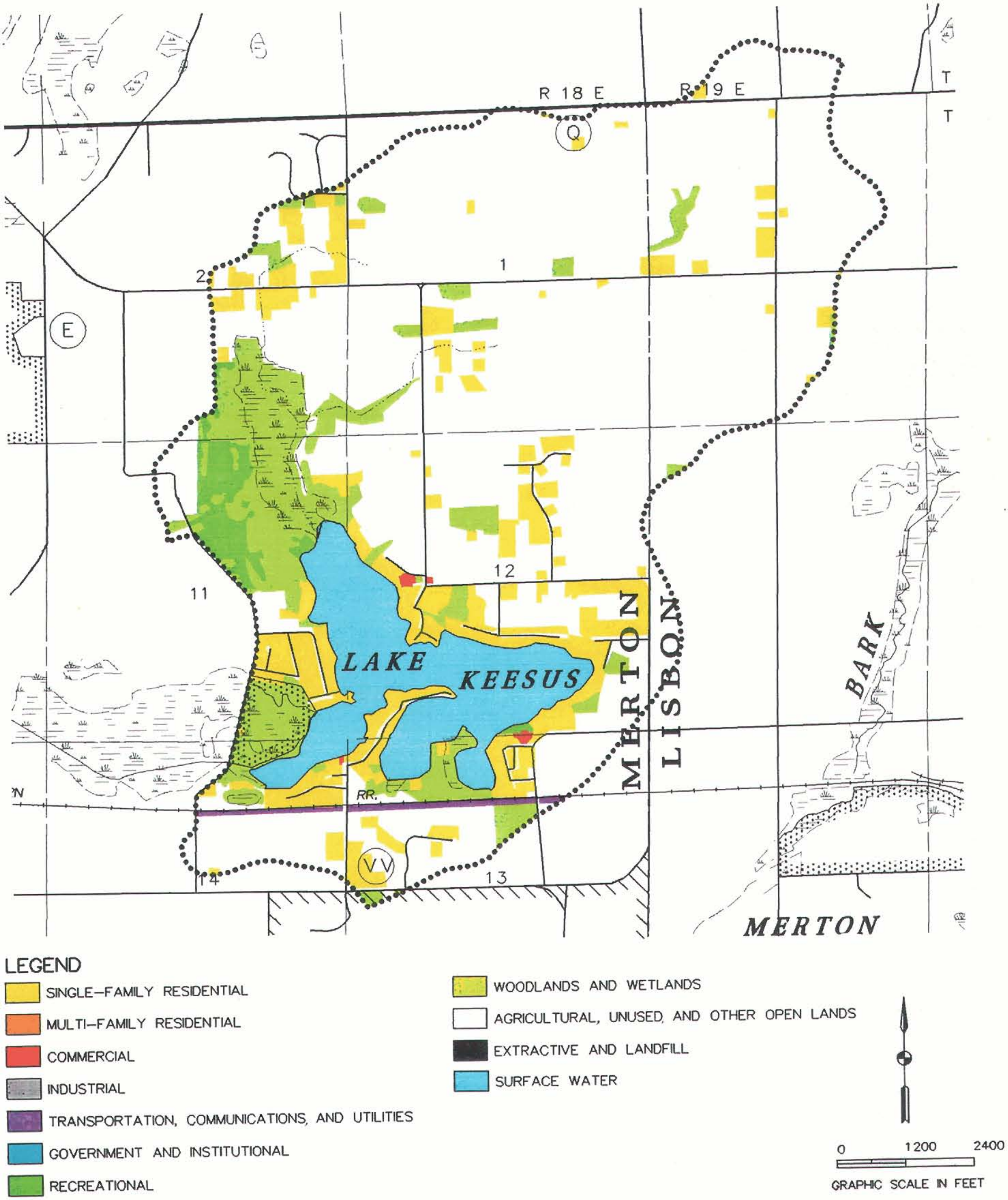
HISTORIC URBAN GROWTH WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS: 1920-1990



Source: SEWRPC.

Map 12

EXISTING LAND USES WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS: 1990



Source: SEWRPC.

Table 7

EXISTING LAND USE WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS: 1990

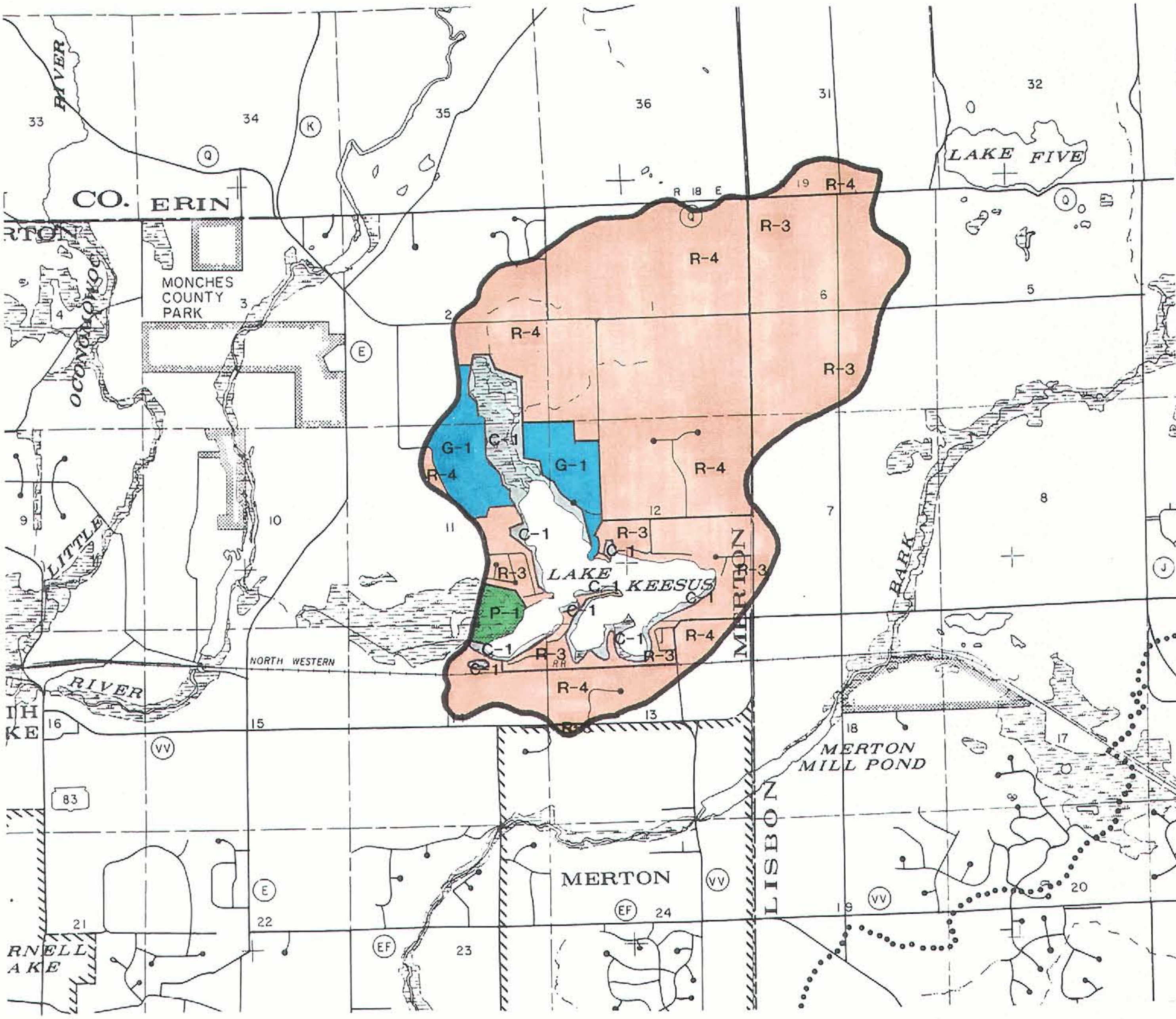
Land Use Categories	Acres	Percent of Major Category	Percent of Total Tributary Drainage Area
Urban			
Residential	297	67	11
Commercial	2	<1	<1
Transportation, Communication, and Utilities	102	23	4
Recreation	44	10	2
Subtotal	445	100	17
Rural			
Agricultural	1,690	76	63
Woodlands	166	7	6
Wetlands	118	5	4
Water	241	12	9
Subtotal	2,215	100	83
Total	2,660	- -	100

Source: SEWRPC.

panied by the year-round use of formerly seasonal lakefront properties—often resulting in an over-loading of onsite sewage disposal systems. Control of shoreland redevelopment, and the related intensification of use, is not specifically addressed in the existing zoning codes, although new construction may be required to meet specific compliance and inspection requirements for onsite sewage disposal systems.

Map 13

EXISTING ZONING DISTRICTS WITHIN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS: 1995



LEGEND

RESIDENTIAL

GOVERNMENTAL

PARK

OTHER RURAL LAND

WATER

ZONING DISTRICTS

R-3 LOW-DENSITY RESIDENTIAL

R-4 SUBURBAN-DENSITY RESIDENTIAL

G-1 GOVERNMENT/INSTITUTION

C-1 LOWLAND CONSERVANCY

P-1 PARK

GRAPHIC SCALE 0 2000 4000 FEET

Source: SEWRPC.

Chapter IV

WATER QUALITY

INTRODUCTION

The earliest definitive data on water quality conditions in Lake Keesus were collected by the Wisconsin Department of Natural Resources in the early 1960s.[1] Other sources of information on the historical water quality conditions in Lake Keesus include the results of monitoring studies conducted by the Wisconsin Department of Natural Resources from 1973 through 1975, and by the U.S. Geological Survey (USGS) from 1991 through 1995. These data all indicate that water quality conditions in Lake Keesus were relatively good at the times of those studies and that there was little evidence of excessive pollution.

However, residents of Lake Keesus have expressed concerns about trends in water quality conditions, and, in 1990, the Lake Keesus Management District decided that a water quality study was necessary to provide background information on the Lake. The U.S. Geological Survey, in cooperation with the Lake Keesus Management District, conducted a comprehensive water quality monitoring program for Lake Keesus from April 1991 through September 1995.[2] This study involved the determination of physical, chemical, and biological characteristics of the Lake's water, including dissolved oxygen and water temperature profiles, pH, specific conductance, water clarity, nutrient, and chlorophyll-a concentrations. In addition to these data, the USGS collected information on lake levels and the basic hydrology of the Lake. A private consultant was engaged to conduct an aquatic plant survey of the Lake in 1994.[3] The Southeastern Wisconsin Regional Planning Commission staff subsequently conducted generalized surveys of the aquatic plants in the Lake during 1995 and 1996 to assess any changes in conditions which occurred after the initial aquatic plant survey in 1994, and consequently, to refine the aquatic plant inventory and management plan recommendations accordingly, as presented in Chapters V and VIII, respectively.

The in-lake water quality monitoring investigations were funded by the Wisconsin Department of Natural Resources and the Lake Management District under the Lake Management Planning Grant Program provided for under Chapter NR 190 of the *Wisconsin Administrative Code*. The data obtained through that program and the earlier investigation were used in the development of this lake management plan, which has also been funded in part through the Wisconsin Department of Natural Resources Lake Management Planning Grant Program.

EXISTING WATER QUALITY CONDITIONS

The data collected during the study period 1991 through 1995 were used to determine water quality conditions in the Lake and to characterize the suitability of the Lake for recreational use and the support of fish and aquatic life. Water quality samples were taken from the main basin of the Lake once per season during the 1991 through 1995 monitoring period. The primary sampling station was located at the deepest point in the Lake, as shown on Map 2. These findings are summarized in Table 8 and Figure 2. More detailed information on these water quality data, including locations and procedures, may be found in reports published by the U.S. Geological Survey.[4]

Thermal Stratification

Thermal and dissolved oxygen profiles for Lake Keesus are shown in Figure 3. Water temperatures ranged from

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[1] *Wisconsin Conservation Department,* Surface Water Resources of Waukesha County, *1963.*

[2] *U.S. Geological Survey Water-Data Reports WI-91-1 through WI-94-2,* Water Resources Data - Wisconsin, Water Year 1991 *through* Water Year 1994, *published annually, March 1992 through March 1995; U.S. Geological Survey Open-File Reports 95-190 and 96-168,* Water-Quality and Lake-Stage Data for Wisconsin Lakes, Water Year 1994 *and* Water Year 1995, *published annually, 1995 and 1996.*

[3] *Aron & Associates,* Lake Keesus Aquatic Plant Management Plan, *October 1994.*

[4] *U. S. Geological Survey, op. cit.*

Table 8

SEASONAL WATER QUALITY DATA FOR LAKE KEESUS: 1991-1995

Water Quality Parameter	Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
Water Temperature (°C)						
Range	2.5-4.0	3.5-4.5	8.0-10.0	6.5-8.5	17.5-26.5	7.5-9.5
Mean	3.1 (3)	4.1 (3)	8.4 (5)	7.3 (5)	24.2 (16)	8.0 (16)
Dissolved Oxygen (mg/l)						
Range	10.9-13.1	1.0-8.8	10.1-12.9	6.7-10.8	8.0-10.5	0-0.6
Mean	12.4 (3)	3.7 (3)	11.7 (5)	9.8 (5)	8.6 (16)	0.2 (16)
Specific Conductivity (μmhos/cm at 25°C)						
Range	351-400	365-445	346-399	364-397	326-401	371-537
Mean	379 (3)	416 (3)	368 (5)	374 (5)	356 (16)	435 (16)
pH (standard units)						
Range	8.0-8.6	7.3-7.7	7.8-8.4	7.9-8.3	7.9-8.8	7.0-7.5
Mean	8.3 (3)	7.6 (3)	8.3 (5)	8.2 (5)	8.2 (16)	7.2 (16)
Secchi Disk (feet)						
Range	--	--	6.6-10.2	--	3.6-15.8	--
Mean			9.0 (5)		10.5 (16)	
Turbidity (Nephelometric turbidity units)						
Range	--	--	1.0-1.5	1.1-1.6	--	--
Mean			1.4 (5)	1.5 (5)		
Nitrate Nitrogen (mg/l)						
Range	--	--	0.020-0.090	0.020-0.170	--	--
Mean			0.050 (5)	0.050 (5)		
Total Ammonia (mg/l)						
Range	--	--	0.02-0.80	0.16-0.80	--	--
Mean			0.50 (5)	0.57 (5)		
Total Nitrogen, as N (mg/l)						
Range	--	--	0.69-1.0	0.78-1.1	--	--
Mean			0.83 (5)	0.88 (5)		
Total Phosphorus, as P (mg/l)						
Range	--	--	0.022-0.034	0.023-0.048	0.011-0.024	0.310-0.736
Mean			0.025 (5)	0.028 (5)	0.013 (15)	0.506 (15)
Orthophosphorus, as PO_4P (mg/l)						
Range	--	--	<0.002-0.002	0.002-0.019	--	--
Mean			<0.002 (5)	0.004 (5)		
Calcium, as Ca (mg/l)						
Range	--	--	33-41	34-40	--	--
Mean			37 (5)	37 (5)		
Magnesium, as Mg (mg/l)						
Range	--	--	21-23	22-23	--	--
Mean			22(5)	23 (5)		
Sodium, as Na (mg/l)						
Range	--	--	5.6-7.0	5.8-7.0	--	--
Mean			6.5 (5)	6. (5)		
Potassium, as K (mg/l)						
Range	--	--	1.9-2.0	2.0-2.1	--	--
Mean			2.0 (5)	2.0 (5)		
Sulfate, as SO_4 (mg/l)						
Range	--	--	8.0-12	8.0-12	--	--
Mean			10.4 (5)	10.4 (5)		

Table 8 (continued)

Water Quality Parameter	Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
Chloride (mg/l)						
Range	- -	- -	12-16	13-17	- -	- -
Mean			14 (5)	15 (5)		
Chlorophyll a						
Range	- -	- -	8-15	- -	3-10	- -
Mean			12 (5)		3 (15)	
Iron, as Fe (μg/l)						
Range	- -	- -	<50	<50	- -	- -
Mean			<50 (5)	<50 (5)		

NOTE: Number in parentheses represents number of samples.

Source: Wisconsin Department of Natural Resources and SEWRPC.

about 2.5°C (approximately 36°F) during the winter to 26.5°C (approximately 80°F) during the summer. Complete mixing of the Lake was restricted by thermal stratification in the summer and by ice cover in the winter.

Thermal stratification is the result of differential heating of lake water and the resulting water temperature-density relationships. Water is unique among liquids because it reaches its maximum density—or weight per unit of volume—at about 39.2°F. The development of thermal stratification begins in early summer, reaches its maximum in late summer, and disappears in the fall, as illustrated diagrammatically in Figure 4. Stratification may also occur in winter under ice cover. This process is described below.

As summer begins, the lake waters absorb solar energy at the surface. Wind action, and, to some extent, internal heat-transfer mechanisms, transmit this energy to the underlying portions of the waterbody. As the upper layer of water is heated by solar energy, a physical, density barrier begins to form between the warmer surface water and the lower, heavier, colder water as illustrated by the June, July, and August profiles in Figure 3. This "barrier" is marked by a sharp temperature gradient known as the thermocline and is characterized by an approximately 1°F to 2°F drop in temperature per three feet of depth that separates the warmer, lighter, upper layer of water—called the epilimnion—from the lower layer—called the hypolimnion. Although this barrier is readily crossed by fish, provided sufficient oxygen exists, it essentially prohibits the exchange of water between the two layers. This condition, illustrated diagrammatically in Figure 5, has a great impact on both the chemistry and biology of the lake, which are also commonly stratified as a result.

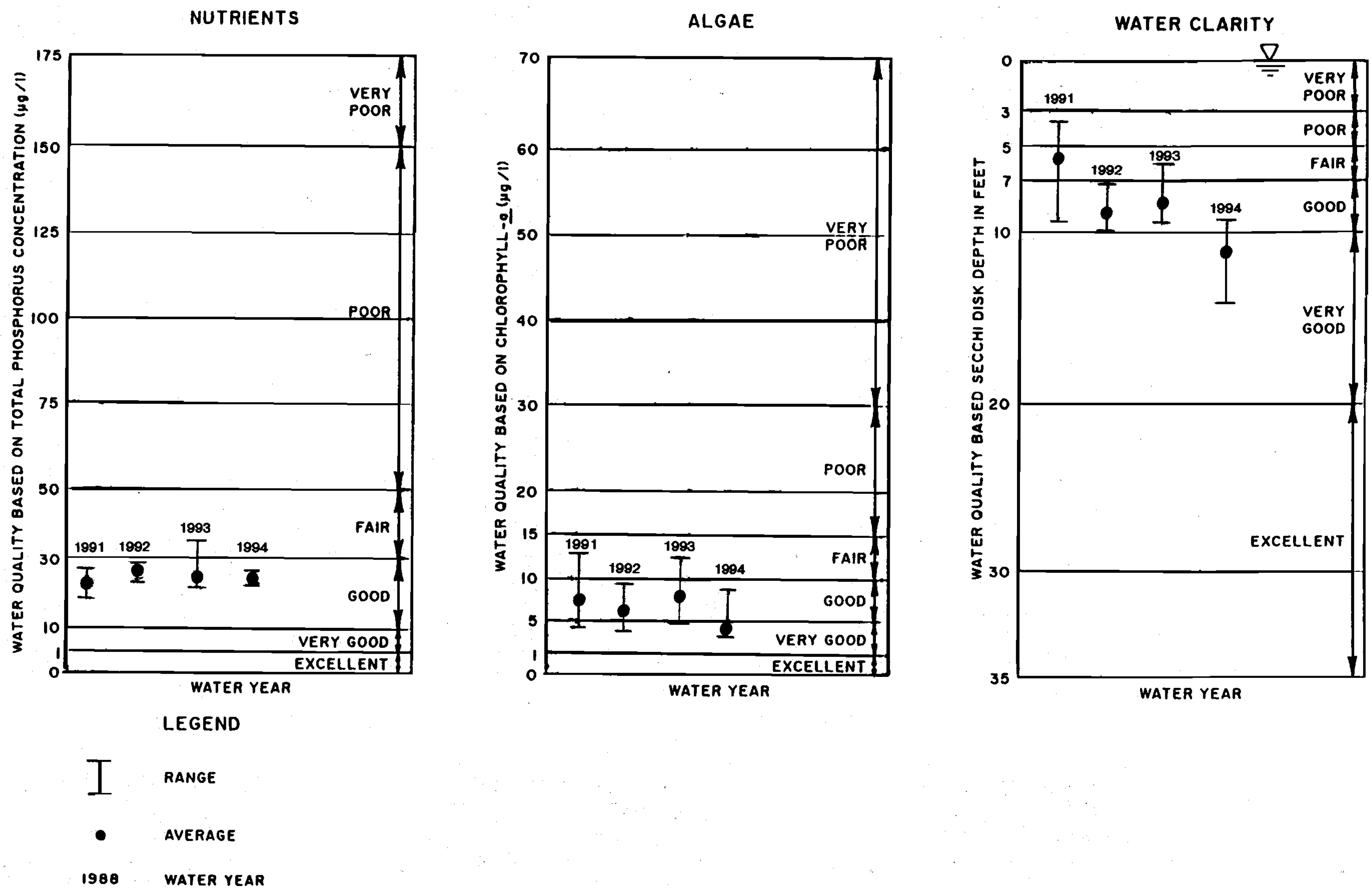
This autumnal mixing period occurs when air temperatures cool the surface water and wind action results in the erosion of the thermocline: as the surface water cools, it becomes heavier, sinking and displacing the now relatively warmer water below. The colder water sinks and mixes under wind action until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

When the water temperature drops to the point of maximum water density, 39.2°F, the waters at the lake surface become more dense than the now warmer, less dense bottom waters of the lake, and "sink" to the bottom. Eventually, the water column is cooled to the point where the surface water, cooled to 32°F and now lighter than the bottom waters which remain close to 39°F, becomes ice, covering the surface of the lake and isolating it from the atmosphere for a period of up to four months, as illustrated by the February profiles in Figure 3. Winter stratification occurs as colder, lighter waters and ice remain at the lake surface, now separated from the relatively warmer, heavier waters near the bottom of the lake.

Spring begins a reversal of this process. As the ice thaws and the upper layers of water warm, they again become more dense and begin to approach the tempera-

Figure 2

LAKE KEESUS PRIMARY WATER QUALITY INDICATORS: 1991-1994



Source: U.S. Geological Survey and SEWRPC.

Figure 3

TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR LAKE KEESUS: 1991-1995

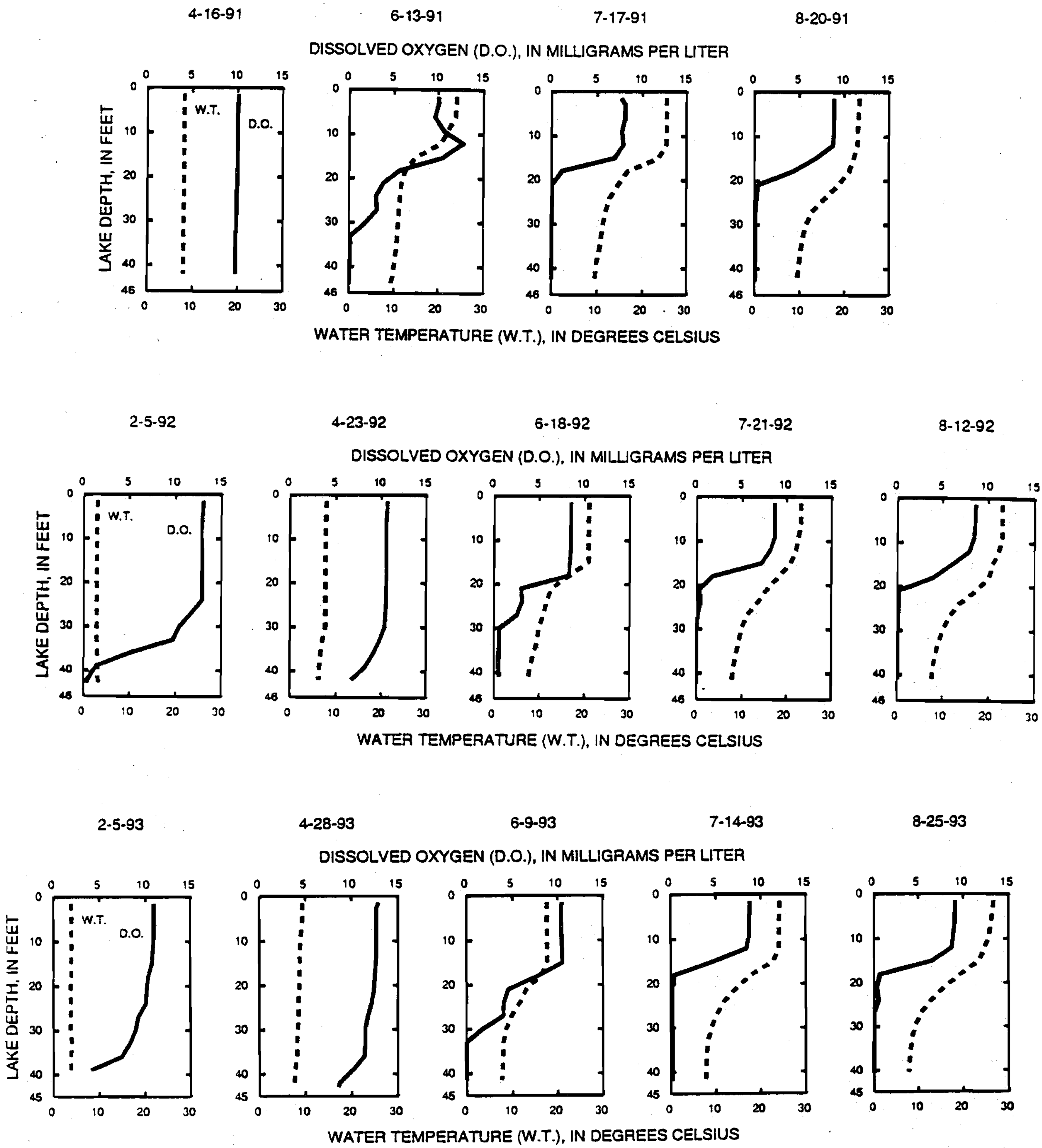
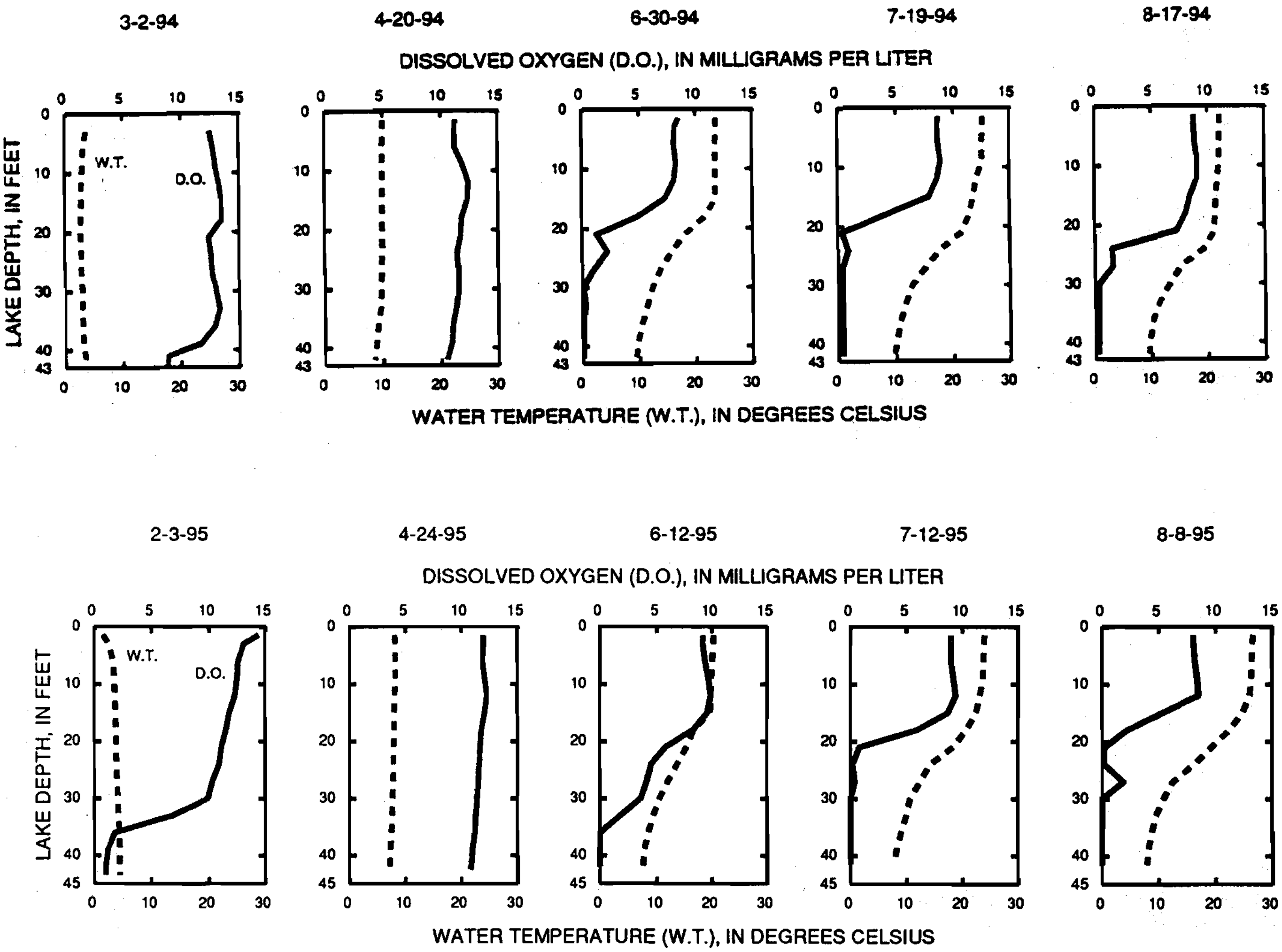


Figure 3 (continued)



Source: U.S. Geological Survey and SEWRPC.

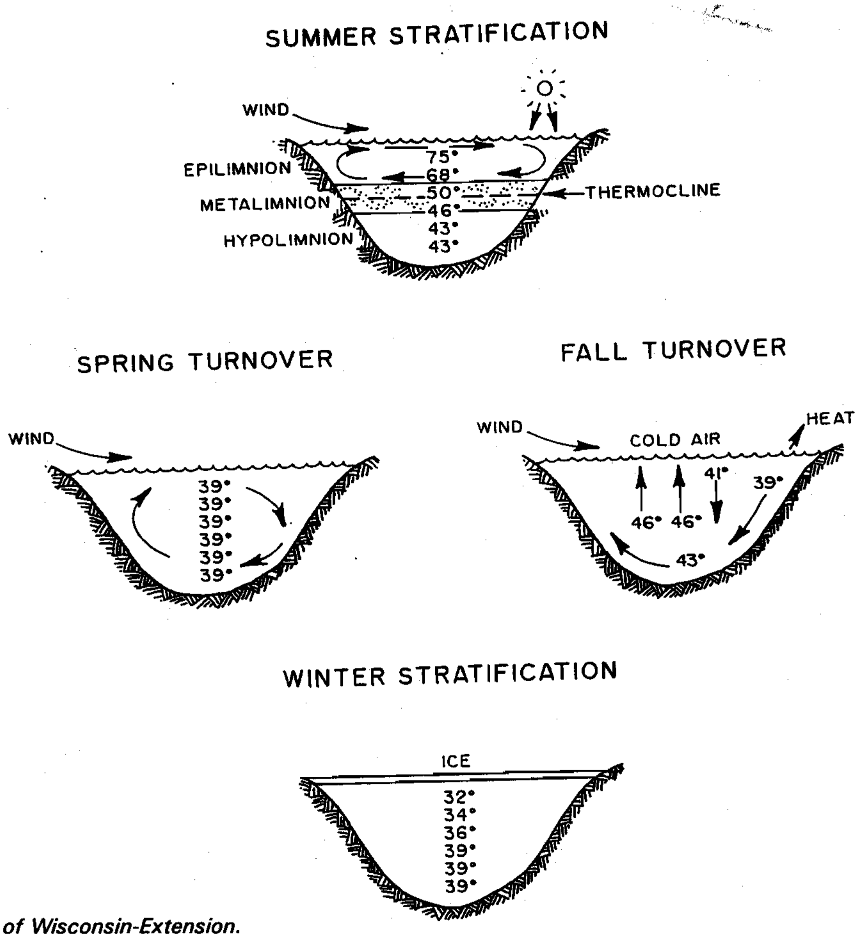
ture of the warmer, deeper waters until the entire water column reaches the same temperatures from surface to bottom. This is refereed to as "spring turnover" and usually occurs within weeks after the ice goes out, as illustrated by the April profiles in Figure 3. After spring turnover, the waters at the surface again warm and become lighter, causing them to float above the colder, deeper water. Wind and resulting waves carry some of the energy of the warmer, lighter waters to lower depths, but only to a limited extent. Thus begins the formation of the thermoclines and another period of summer thermal stratification.

Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake's ecosystem. As shown in Figure 3, dissolved oxygen levels were generally higher at the surface of Lake Keesus, where there was an interchange between the water and the atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis. Dissolved oxygen levels were lowest on the bottom of the Lake, where decomposer organisms and chemical oxidation processes—collectively known as biochemical oxygen demand—utilized oxygen in the decay process. Occa-

Figure 4

THERMAL STRATIFICATION OF LAKES



Source: University of Wisconsin-Extension.

sionally, dissolved oxygen concentrations were greatest at an intermediate depth—as shown in Figure 3 for the month of June 1991—which suggests the presence of a lens of algae at a depth that is producing oxygen through photosynthesis and elevating the measured concentration of dissolved oxygen in the surrounding water.

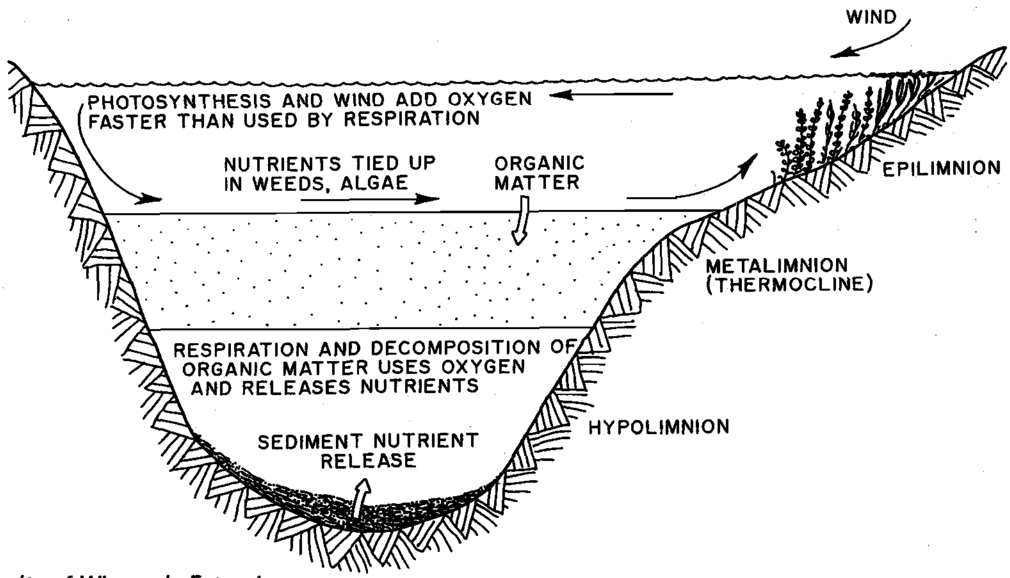
When any lake becomes thermally stratified, as described above, the surface supply of dissolved oxygen to the hypolimnion is cut off. Gradually, if there is not enough dissolved oxygen to meet the total demands from the bottom-dwelling aquatic life and decaying material, the dissolved oxygen levels in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

The hypolimnion of Lake Keesus becomes anoxic during summer stratification. During the 1991 through 1995 study period, dissolved oxygen concentrations at the bottom of the Lake fell to zero by mid-June. In most years from 1991 through 1995, dissolved oxygen concentrations dropped to below five milligrams per liter (mg/l), or the minimum level necessary to support many species of fish, at a depth of approximately 15 to 20 feet, with concentrations decreasing to zero at about 20 feet during July and August.

Fall turnover—between September and October in most years—naturally restores the supply of oxygen to the bottom waters, although hypolimnetic anoxia can be

Figure 5

LAKE PROCESSES DURING SUMMER STRATIFICATION



Source: University of Wisconsin-Extension.

reestablished during the period of winter thermal stratification. Winter anoxia is more common during years of heavy snow fall, when snow covers the ice, reducing the degree of light penetration and reducing algal photosynthesis that takes place under the ice. In Lake Keesus, however, dissolved oxygen levels at depths of less than 35 feet were found to be adequate for the support of fish throughout the winter. At the end of winter, dissolved oxygen concentrations in the bottom waters of the Lake are restored during the period of spring turnover, which generally occurs between March and May in most years.

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

In other lakes in the Region, hypolimnetic anoxia can also occur during winter stratification. Under these conditions, anoxia contributes to winter-kill of fishes.

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

Specific Conductance

Specific conductance is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. Conductivity and pH profiles for Lake Keesus are shown in Figure 6. During periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion, referred to as "internal loading." This phenomenon was more noticeable in Lake Keesus during summer stratification than during the winter. As shown in Table 9, the specific conductance of Lake Keesus during spring turnover of 1991 through 1995 ranged from 346 to 399 microSiemens per centimeter (μS/cm) at 25°C, which is within the normal range for lakes in Southeastern Wisconsin.[5]

Chloride

Chloride concentrations in Lake Keesus ranged from 12 to 17 milligrams per liter (mg/l) during spring turnover of 1991 through 1995, as shown in Table 9. The most important anthropogenic source of chlorides is believed to be street deicing salts which are rarely used in this predominantly rural watershed. The concentration of chloride measured in Lake Keesus is within the normal range for lakes in Southeastern Wisconsin.

Alkalinity and Hardness

Alkalinity is an index of the buffering capacity of a lake, or the capacity of a lake to absorb and neutralize acids. The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity because of the types of soil covering, and the bedrock underlying, the watersheds. In contrast, water hardness is a measure of the multivalent metallic ions, such as calcium and magnesium, present in the lake. Hardness is usually reported as an equivalent concentration of calcium carbonate ($CaCO^3$). Applying these measures to the study lake, Lake Keesus is a hard-water alkaline lake. During the springs of 1991 through 1995, alkalinity averaged 167 mg/l, while hardness averaged 181 mg/l, as listed in Table 9. These values were within the normal range of lakes in Southeastern Wisconsin.[6]

Hydrogen Ion Concentration (pH)

The pH is a logarithmic measure of hydrogen ion concentration on a scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, a pH below 7 indicates acidic water. In Lake Keesus, the pH was found to range between 7.0 and 8.8 standard units, as shown in Table 8. Since Lake Keesus has a high alkalinity, or buffering capacity, the pH does not fluctuate below 7 and the Lake is not susceptible to the harmful effects of acidic deposition.

Water Clarity

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

Water clarity generally varies throughout the year as algal populations increase and decrease and as the amount of inorganic suspended materials and humic coloration varies, in response to changes in weather conditions and nutrient loadings. These same factors make Secchi-disk readings vary from year to year as well. Secchi-disk readings for Lake Keesus were always greater than three feet. These values range from fair to very good water quality compared to other lakes in Southeastern Wisconsin.[7]

Chlorophyll-a

Chlorophyll-a is the major photosynthetic ("green") pigment in algae. The amount of chlorophyll-a present in the water is an indication of biomass or amount of algae in the water. Chlorophyll-a concentrations in Lake Keesus ranged from a low of 2.9 micrograms per liter (μg/l) in August 1994, to a high of 15 μg/l in April 1995. These values were within the range of chlorophyll-a concentrations recorded in other lakes in the Region[8] and indicate good water quality.

Nutrient Characteristics

Aquatic plants and algae require such nutrients as phosphorus, nitrogen, carbon, calcium, chloride, iron,

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

[6] *Ibid.*

[7] *Ibid.*

[8] *Ibid.*

Figure 6

SPECIFIC CONDUCTANCE AND pH PROFILES FOR LAKE KEESUS: 1991-1995

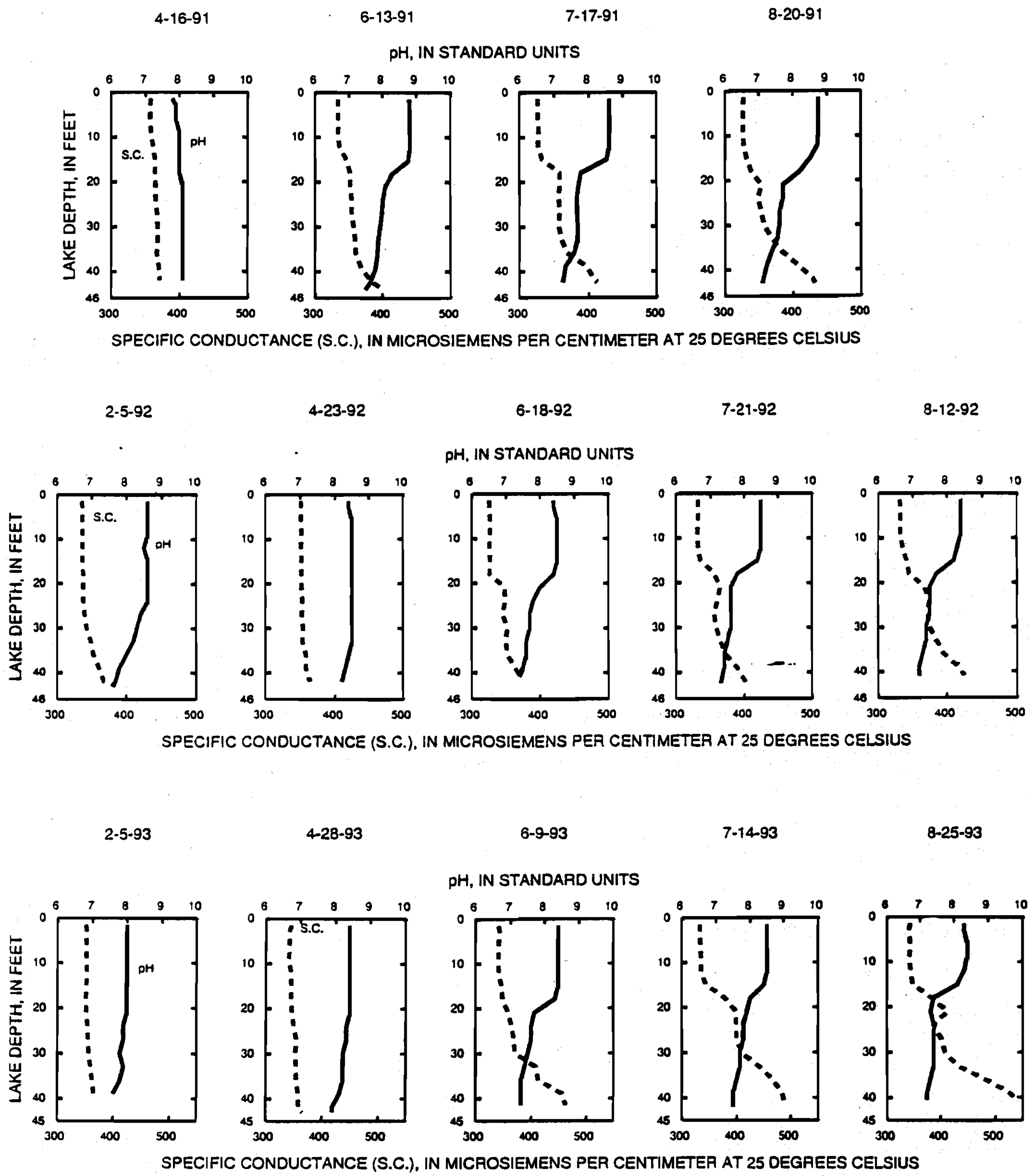
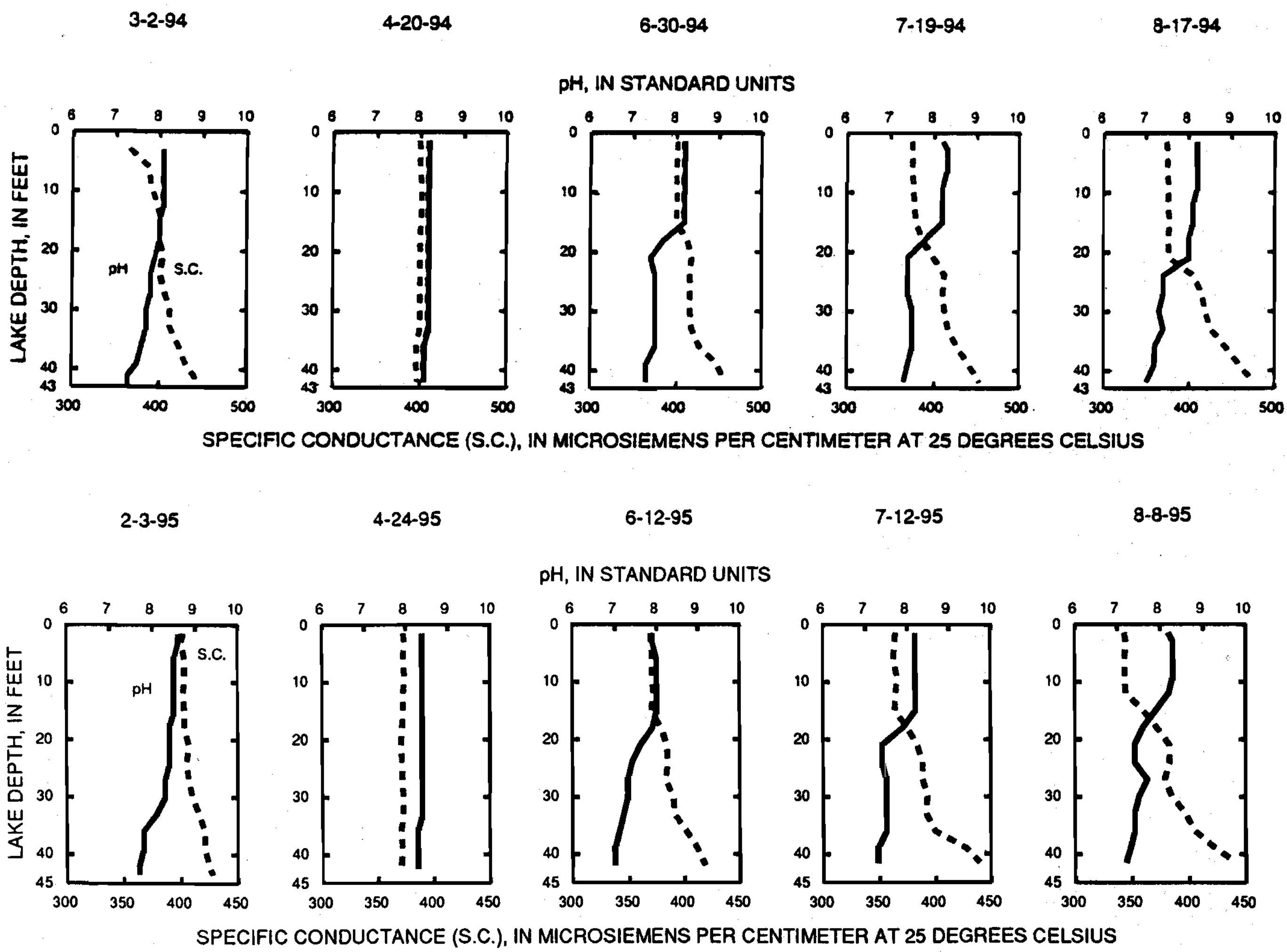


Figure 6 (continued)



Source: U.S. Geological Survey and SEWRPC.

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

The ratio of total nitrogen to total phosphorus in lake water, or the N:P ratio, can indicate which nutrient is likely to be limiting plant growth. A nitrogen-to-phosphorus ratio greater than 14 to 1 indicates that phosphorus is probably the limiting nutrient, while a ratio of less than 10 to 1 indicates that nitrogen is probably the limiting nutrient.[9] As shown in Table 10, the nitrogen-to-phosphorus ratios in spring turnover samples collected from Lake Keesus during the period 1991 through 1995 were always greater than 20. This indicates that plant production was most likely consistently limited by phosphorus. Other factors, such as light, turbulence, and

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

Table 9

LAKE KEESUS SPRING OVERTURN WATER QUALITY DATA: 1991-1995

Water Quality Parameter	April 16, 1991		April 23, 1992		April 28, 1993		April 20, 1994		April 24, 1995	
	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Depth of Sample (feet)	1.5	42	1.5	41	1.5	43	1.5	42	1.5	42
Specific Conductance(μS/cm)	358	371	351	364	346	365	399	397	373	373
pH	7.8	8.1	8.4	8.2	8.4	7.9	8.2	8.1	8.0	7.0
Water Temperature (°C)	8.2	8.1	8.0	6.5	9.5	7.5	10.0	8.5	8.0	7.0
Color (platinum-cobalt scale)	10	10	10	10	10	10	15	15	10	10
Turbidity (nephelometric turbidity units)	1.5	1.5	1.3	1.5	1.0	1.3	1.2	1.1	1.5	1.6
Secchi Disk (feet)	6.6	6.6	7.5	7.5	7.5	7.5	8.5	8.5	10.2	10.2
Dissolved Oxygen	10.1	9.8	10.7	12.9	12.9	8.6	11.3	10.5	12.1	10.8
Hardness, as $CaCO_3$	170	180	170	170	170	180	200	190	190	190
Calcium	33	34	33	35	35	36	41	40	39	39
Magnesium	22	23	22	21	21	22	23	23	23	23
Sodium	6.0	6.0	5.8	5.6	5.6	5.9	6.9	7.0	7.0	7.0
Potassium	1.88	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Alkalinity, as $CaCO_3$	165	165	160	160	160	160	180	180	170	170
Sulfate	9.0	9.0	8.0	10	10	10	12	12	11	11
Chloride	13	13	13	12	12	13	15	15	16	17
Silica	0.3	0.4	0.4	0.2	0.2	1.5	<0.2	0.3	0.0	0.1
Dissolved Solids	202	202	192	204	204	206	238	236	220	222
Nitrate/ite Nitrogen	0.02	0.03	0.03	0.16	0.16	0.17	0.09	0.08	0.02	0.02
Ammonia Nitrogen	0.152	0.160	0.11	0.02	0.02	0.24	0.03	0.08	0.04	0.07
Total Nitrogen	0.9	0.90	1.0	0.76	0.76	1.1	0.69	0.78	0.82	0.82
Total Phosphorus	0.027	0.030	0.028	0.034	0.034	0.048	0.025	0.025	0.022	0.023
Orthophosphorus	0.002	0.003	0.002	<0.002	<0.002	0.019	<0.002	0.002	<0.002	0.002
Iron (μg/l)	<50	<50	<50	<50	<50	<50	<50	<50	<10	<10
Manganese (μg/l)	<40	<40	<40	180	<40	210	<40	<40	0.9	4
Chlorophyll-a (μg/l)	13	--	9.0	--	12	--	7.9	--	15	--

Source: U.S. Geological Survey and SEWRPC.

through-flow, may also limit plant growth; these are further discussed below.

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

The Southeastern Wisconsin Regional Planning Commission recommends that total phosphorus concentrations in lakes not exceed 0.020 mg/l during the period of spring mixing or turnover. This level is considered necessary to prevent nuisance algal and macrophyte growths. During the study year the total phosphorus concentrations at spring turnover in Lake Keesus were consistently greater than 0.020 mg/l, as shown in Table 9. However, during the 1991 through 1995 study period, average total phosphorus concentration in the surface waters of Lake Keesus, based upon the data set forth in Table 8, was 0.019 mg/l, indicating good water quality.

In the hypolimnion, or bottom waters, of Lake Keesus, total phosphorus concentrations were higher, ranging from 0.023 to 0.736 mg/l, as shown in Table 8. The average bottom-water total phosphorus concentration in Lake Keesus during the study period was 0.267 mg/l.

When aquatic organisms die, they usually sink to the bottom of the lake, where they are decomposed. Phosphorus from these organisms is then either stored in the bottom sediments or rereleased into the water column. Because phosphorus is not highly soluble in water, it readily forms insoluble precipitates with calcium, iron,

Table 10

NITROGEN-PHOSPHORUS RATIOS FOR LAKE KEESUS

Date	Nutrient Levels		
	Nitrogen (mg/L)	Phosphorus (mg/L)	N:P Ratio
April 16, 1991	0.90	0.03	30
April 23, 1992	1.00	0.03	33
April 28, 1993	0.76	0.03	25
April 20, 1994	0.69	0.03	23
April 24, 1995	0.82	0.02	41

Source: U.S. Geological Survey and SEWRPC.

and aluminum under aerobic conditions and accumulates predominantly in the lake sediments. If the bottom waters become depleted of oxygen during stratification, however, certain chemical changes occur, especially the change in the oxidation state of iron from the insoluble Fe^{3+} state to the more soluble Fe^{2+} state. The effect of these chemical changes is that phosphorus becomes soluble and is more readily released from the sediments. This process also occurs under aerobic conditions, but generally at a slower rate than under anaerobic conditions. As the waters mix, this phosphorus may be widely dispersed throughout the lake waterbody and become available for algal growth. If the turnover event is slow, over several weeks, this hypolimnetic phosphorus may be readsorbed by the iron and precipitate back to the sediment. If the process is more rapid, a few days or less, some of this phosphorus is circulated into the upper waters of the lake, generally in a bio-available form, where it can be taken up very rapidly by algae.

The 1991 through 1995 data indicated that there was the potential for considerable internal loading of phosphorus from the bottom sediments of Lake Keesus. Such releases tended to occur primarily during the anaerobic periods of summer and winter stratification. When such releases did occur, however, the relatively constant surface total phosphorus concentrations and the relatively modest concentrations of chlorophyll-a observed in the Lake would suggest that the contribution of phosphorus from the bottom waters of Lake Keesus was negligible in terms of the total phosphorus load.

CHARACTERISTICS OF BOTTOM SEDIMENT

The sediments of Lake Keesus consist largely of muck, rubble, and sand, as shown on Map 3. Few data on the chemical composition of the lake sediments are available. However, it should be noted that between 1950 and 1969, 6,584 pounds of sodium arsenite were applied to Lake Keesus to control aquatic plant growth in the lake basin—see also Chapter V, Aquatic Plant Management. Sodium arsenite applications occurred annually during 1952 and 1953; the 1952 application amounted to 4,684 pounds, and the 1953 application amounted to 1,900 pounds of the chemical herbicide. No applications of sodium arsenite have taken place since the early 1950s. All of this arsenic is likely to have been retained in the Lake sediments, and, while measurements of arsenic concentration in the overlying waters were not included in the U.S. Geological Survey sampling program, it is possible that some arsenic may be released into the water column from the bottom sediments during anaerobic periods. However, any such releases should decrease with the passage of time as the arsenic residuals are buried by newly deposited sediments, and as leached arsenic is washed out of the Lake. Nevertheless, based on evidence from other Southeastern Wisconsin inland lakes, it is most likely that no significant releases of arsenic occur.

POLLUTION LOADINGS AND SOURCES

Currently, there are no known point source discharges of pollutants to Lake Keesus. Nonpoint sources of water pollution include urban sources, such as runoff from residential, transportation, construction, and recreational activities, and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems. The tributary drainage area to Lake Keesus is about 2,660 acres in size, and drains directly to the Lake without passing through any other waterbodies. The water quality of a lake is directly impacted by the contaminant inputs generated from all of the various land uses within the watershed.

In order to estimate the amount of pollution contributed by these sources to Lake Keesus, annual loading budgets for phosphorus and sediment were developed for the watershed under the study using the unit area load model. The results of that model were checked by comparison to analyses prepared by the Commission staff utilizing the Wisconsin Lakes Model Spreadsheet

(WILMS) Version 1.01, and the OECD models as described by Ryding and Rast.[10] Contaminant loads to the Oconomowoc River—the discharge from Lake Keesus—were modified for retention in Lake Keesus using the phosphorus retention model developed by Larsen and Mercier.[11]

The annual sediment load was estimated to be 380 tons, as set forth in Table 11. About 355 tons per year, or 93 percent of the total sediment load, was estimated to be contributed by runoff from rural land, and approximately 25 tons per year, or 7 percent of the total sediment load, was estimated to be contributed by runoff from urban land. Sediment transport out of Lake Keesus was estimated to be 15 tons, after accounting for in-lake retention of sediments in Lake Keesus.

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

The annual phosphorus load to Lake Keesus was estimated to be 1,530 pounds, as set forth in Table 11. Of this total, it is estimated that 1,320 pounds per year, or 93 percent of the total loading, was contributed by runoff from rural land; and 100 pounds per year, or 7 percent, was contributed by runoff from urban land. The remaining phosphorus loading was contributed by onsite sewage disposal systems. Phosphorus release from the lake bottom sediments—internal loading—may also contribute phosphorus to the Lake. However, because forecast in-lake phosphorus concentrations were always greater than the observed phosphorus concentrations, internal loading of phosphorus from the sediment phosphorus was assumed to be negligible.

As of 1990, the entire drainage area tributary to Lake Keesus was served by onsite sewage disposal systems. Approximately 334 onsite sewage disposal systems were known to exist in the drainage area of Lake Keesus in 1990. Onsite sewage disposal systems are designed to remove phosphorus by adsorption to soil in the drainfield. The removal capacity decreases with increasing soil particle size; and all soils have a fixed adsorptive capacity which will eventually become exhausted. Onsite sewage disposal systems include conventional septic tank systems, mound systems, and holding tanks. Holding tanks store wastewater temporarily until it is pumped and conveyed by tank truck to a sewage treatment plant, storage lagoon, or land disposal site. All other types of onsite sewage disposal systems discharge effluent to the groundwater reservoir.

Provided that the systems are located, installed, used, and maintained properly, the onsite sewage disposal system may be expected to operate with few problems for periods of up to about 20 to 25 years. Failure of a conventional septic tank system occurs when the soil surrounding the seepage area will no longer accept or properly stabilize the septic tank effluent. Further, not all residential areas within the drainage area tributary to Lake Keesus served by onsite sewage disposal systems are located in areas covered by soils suitable for septic tank use, as shown on Map 7, and septic system failure may result from improper location, poor installation, or inadequate maintenance.

While many older onsite sewage disposal systems may have met *Wisconsin Administrative Code* requirements when installed, these requirements have changed over the years, with the effect that many older systems no longer conform to present practices. Also, some installations, designed for vacation or seasonal use are now in use year-round and are potentially subject to overloading. The precise identification of potential septic tank problems requires a sanitary survey.

The potential need for and costs of installation of a public sanitary sewer to serve the urban development on the shoreline of Lake Keesus is currently being investigated under the northwestern Waukesha County sanitary sewer system study being undertaken by the

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[10]*S.-O. Ryding, and W. Rast, "Chapter 7. Estimating the Nutrient Load to a Waterbody," in UNESCO Man and the Biosphere Series Volume 1,* The Control of Eutrophication of Lakes and Reservoirs, *Parthenon Press, London, 1989.*

Also OECD (Organization for Economic Cooperation and Development), Eutrophication of Waters: Monitoring, Assessment and Control, *OECD, Paris, 1982.*

[11]*D.P. Larsen and H.T. Mercier, "Phosphorus Retention Capacity of Lakes,"* Journal of the Fisheries Research Board of Canada, *Volume 33:1742-1750, 1976.*

Table 11

ESTIMATED POLLUTANT LOADS TO LAKE KEESUS: 1990

Land Use	Pollutant Loads: 1990			
	Sediment (tons)	Percent	Phosphorus (pounds)	Percent
Urban				
Residential	22.6	6	75.6	5
Commercial	1.1	<1	3.5	<1
Communications and Utilities	0.5	<1	11.3	1
Recreational	0.6	<1	12.6	1
Subtotal	24.8	7	103.0	7
Rural				
Agricultural	331.1	87	1,265.2	83
Woodland	0.3	<1	5.6	<1
Wetland	0.2	<1	4.0	<1
Other	0.6	<1	13.2	1
Subtotal	354.8	93	1,319.3	84
Atmospheric	22.6	6	31.3	2
Onsite Sewage Disposal Systems	- -	- -	106.7	7
Total	379.6	100	1,529.0	100

Source: SEWRPC.

Regional Planning Commission.[12] That study considered information on problem systems provided by the Waukesha County Department of Parks and Land Use, Environmental Health Division: lot sizes, soil suitability for onsite sewage disposal systems, depth to groundwater, the age of the existing onsite system, distance from the nearest public sanitary sewer system, and costs. Based upon a preliminary evaluation completed in January 1998, that study recommended that the Lake Keesus area continue to be served by onsite sewage disposal systems in the near term. However, given the age of existing onsite systems, lot sizes, and the existence of steeply sloping lands in some areas of the shoreline, the study further recommended that urban development in the vicinity of Lake Keesus be included in the long-term planned sewer service area. Implementation of the latter recommendation, however, is likely to occur beyond the end of the present planning period, or after the year 2010. Thus, it is likely that the Lake Keesus community will continue to rely on onsite sewage disposal systems for the next 10 or more years.

Approximately 96 percent of the total phosphorus load, or 1,365 pounds, is estimated to be used by the biomass within the Lake or deposited in the sediments,[13] resulting in a net downstream transport of phosphorus of about 60 pounds, or 4 percent of the total phosphorus load to Lake Keesus. This mass is subject to modification by the Lake Keesus Management District aquatic plant harvesting program, which could remove phosphorus from the Lake.[14] This mass was not explicitly considered in this model-based analysis.

[12]*Black & Veatch,* A Sanitary Sewerage System Plan for the Northwestern Waukesha County Area, *Draft, in preparation.*

[13]*Larsen and Mercier, op. cit.*

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

The spreading of septage by a licensed waste hauler within the Lake Keesus watershed is an issue of concern to the Lake community.[15] This activity is subject to a Wisconsin Pollutant Discharge Elimination System (WPDES) permit issued by the Wisconsin Department of Natural Resources. The current permit was issued in July 1989 to Bob's Superior Sanitary, Inc., and permits the spreading of septage on five fields with a total acreage of about 47 acres, as shown in Map 14. These fields are located in U.S. Public Land Survey Sections 1 and 2 of Town 8 North, Range 18 East. In addition to the requirements of Chapter NR 113 of the *Wisconsin Administrative Code*, which requires soil injection or liming of the septage, the hauler is restricted from spreading septage on slopes steeper than 6 percent and on eroded soils or soils subject to ponding, including specified Casco, Fox, Hochheim, Houghton, Ogden, Pella, and Pistakee series soils located on the property. Further, application of septage to fields two and four is subject to the granting of written permission by neighboring residents granting a reduction in the separation distance from 1,000 feet to 500 feet; the maintenance of a 1,000 feet buffer between spreading activities and residential lands is set forth in Section NR 113.08(3)(b). A 50 feet buffer around drainage ways is also prescribed, and spreading in depressions is prohibited.

Based on field inspections conducted by Wisconsin Department of Natural Resources staff during August 1995, it was determined that the hauler was in compliance with the permit conditions. It was further indicated that the application of septage was largely confined to field three, as shown on Map 14. Inspection by Commission staff at that time further indicated that there was little possibility that septage spread in conformance with the permit requirements would result in significant pollutant loadings reaching Lake Keesus.

No groundwater samples have been obtained from the vicinity of Lake Keesus. Samples would be needed to draw any conclusions regarding the contamination of the groundwater with phosphorus and other substances. It should be noted, however, that the results obtained during groundwater sampling programs conducted on other lakes within Waukesha County would indicate that the volume of groundwater in the water budgets of the area lakes is low and that any nutrient and contaminant loadings from this source would be effectively masked by the much larger loads carried by the surface drainage channels.

RATING OF TROPHIC CONDITION

Lakes are commonly classified according to their degree of nutrient enrichment or trophic status. The ability of a lake to support a variety of recreational activities and healthy fish and aquatic life communities is often correlated to the degree of nutrient enrichment that has occurred. There are three terms usually used to describe the trophic status of a lake: oligotrophic, mesotrophic, and eutrophic. Oligotrophic lakes are nutrient-poor lakes. These lakes characteristically support relatively few aquatic plants and often do not contain productive fisheries. Because of the naturally fertile soils and the intensive land use practices employed in the State, there are relatively few oligotrophic lakes in Southeastern Wisconsin. Mesotrophic lakes are moderately fertile lakes that support abundant aquatic plant growths and may support productive fisheries. Nuisance growths of algae and weeds are usually not exhibited by mesotrophic lakes. Many of the cleaner lakes in Southeastern Wisconsin are classified as mesotrophic. Eutrophic lakes are defined as nutrient-rich lakes. These lakes are often characterized by excessive growths of aquatic weeds and/or experience frequent algal blooms. Many eutrophic lakes support very productive fisheries. In shallow eutrophic lakes, fish winterkills may also be common. Many of the more polluted lakes in Southeastern Wisconsin are classified as eutrophic. Extremely eutrophic lakes may be described by a further descriptor, hypertrophic or hypereutrophic.

Several numerical "scales," based on one or more water quality parameters, have been developed to define the trophic condition of a lake. Because trophic state is actually a continuum from very nutrient poor to very nutrient rich, a numerical scale is useful for comparing lakes and for evaluating trends in water quality conditions. Care must be taken, however, that the particular scale used is appropriate for the lake to which it is applies. In this case, two indices specific to Wisconsin lakes have been used; namely, the Vollenweider-OECD open-boundary trophic classification system, shown in

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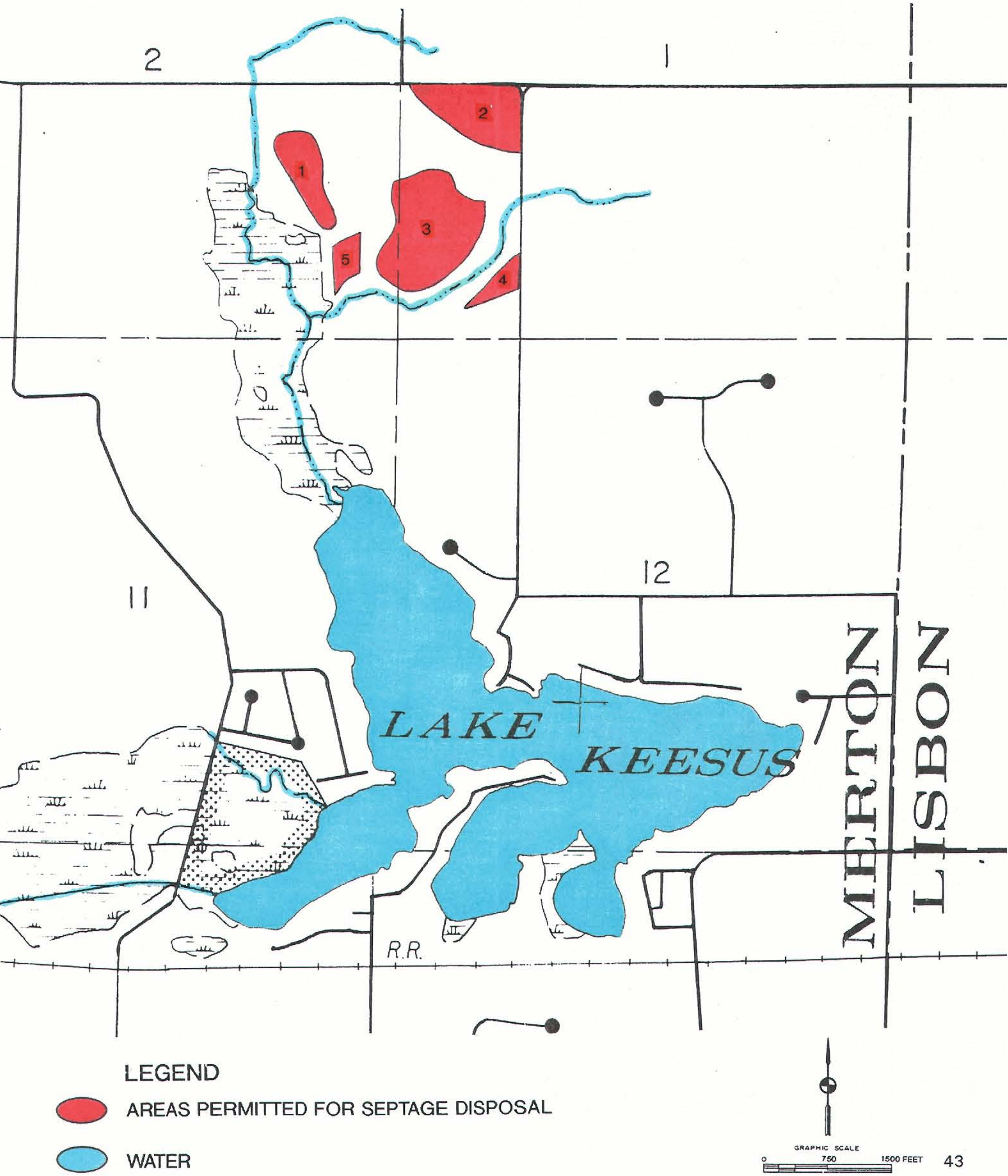
[15]*University of Wisconsin-Extension,* Public Opinion of Water Use and Quality in Lake Keesus (Merton, Waukesha County, Wisconsin), *1991.*

Map 14

AGRICULTURAL FIELDS NEAR LAKE KEESUS PERMITTED FOR LAND SPREADING OF SEPTAGE: 1995



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 7,[16] and the Carlson Trophic State Index (TSI), shown in Figure 8.[17] The Wisconsin Trophic State Index value (WTSI) is a refinement of the Carlson TSI designed to account for the greater humic acid content—brown water color—present in Wisconsin lakes, and has been adopted by the Wisconsin Department of Natural Resources for use in lake management investigation. The WTSI values for Lake Keesus are shown in Figure 9.[18]

Using the Vollenweider trophic system and applying the data in Table 8, Keesus Lake would be classified as being mesotrophic, based on the total phosphorus concentration, as shown in Figure 6. Based on the chlorophyll-a concentration, the Lake would be classified as being between a mesotrophic and eutrophic state and based on Secchi-disk readings the Lake would be classified as being eutrophic, as shown in Figure 6. While these indicators result in widely varying lake trophic state classifications, it may be concluded that Lake Keesus should be classified as a mesotrophic lake, or a lake with acceptable water quality for most uses.

Trophic State Index

The Trophic State Index assigns a numerical trophic condition rating based on Secchi-disk transparency and total phosphorus and chlorophyll-a concentrations. The Trophic State Index ratings for Lake Keesus generally ranged from about 40 to 60, respectively, over the study period as a function of sampling date, as shown in Figure 7. Subsequently, the original Trophic State Index developed by Carlson has been modified for Wisconsin lakes by the Wisconsin Department of Natural Resources using data on 184 lakes throughout the State.[19] The Wisconsin Trophic State (WTSI) varied similarly as a function of sampling date, as shown in Figure 7. Based on these Trophic State Index ratings, Lake Keesus may be classified as mesotrophic.

SUMMARY

Lake Keesus represents a typical hard-water, alkaline lake that has not been subjected to high levels of pollution. Physical and chemical parameters measured during the study period—with the exception of water clarity—indicated that the water quality is within the "good" range, compared to other regional lakes. However, total phosphorus levels were found to be generally above the level considered to cause nuisance algal and macrophytic growths. Summer and winter stratification was observed in Lake Keesus. During summer stratification, the Lake waters below about 20 feet were found to be devoid of oxygen while the upper waters remained well oxygenated and supported a healthy fish population (see Chapter V). Winterkill was not a problem in Lake Keesus because dissolved oxygen levels were found to be adequate for the support of fish throughout the winter at depths above 35 feet. Internal releases of phosphorus from the bottom sediments were observed but were not considered to be a problem in Lake Keesus.

As of 1997, there were no known point sources of pollutants in the Lake Keesus watershed. Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. Sediment and phosphorus loadings from the watershed were estimated.

In 1995, the total annual phosphorus load to Lake Keesus was estimated to be about 1,425 pounds. Runoff from the rural lands contributed the largest amount of phosphorus, 93 percent of the total phosphorus load, with the runoff from urban land contributing 7 percent of the total phosphorus load. Approximately 1,365 pounds, or 96 percent, of the total phosphorus loading is estimated to remain in the Lake by conversion to biomass or through sedimentation, resulting in a net transfer of about 60 pounds, or 4 percent, of phosphorus downstream. Onsite sewage disposal systems were considered to contribute a further 10 to 110 pounds of phosphorus to the Lake annually.

Based on the OECD trophic state model and the Trophic State Index ratings calculated from Lake Keesus data, Lake Keesus may be classified as a mesotrophic lake.

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[16] *OECD (Organization for Economic Cooperation and Development),* Eutrophication of Waters: Monitoring, Assessment and Control, *Paris, 1982; S.-O. Ryding and W. Rast,* The Control of Eutrophication in Lakes and Reservoirs, *UNESCO/MAB Series 1, Parthenon Press, 1989; and H. Olem and G. and Flock,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *U.S. Environmental Protection Agency Report EPA-440/4-90-006, Office of Water (WH-553), Washington, D.C., August 1990.*

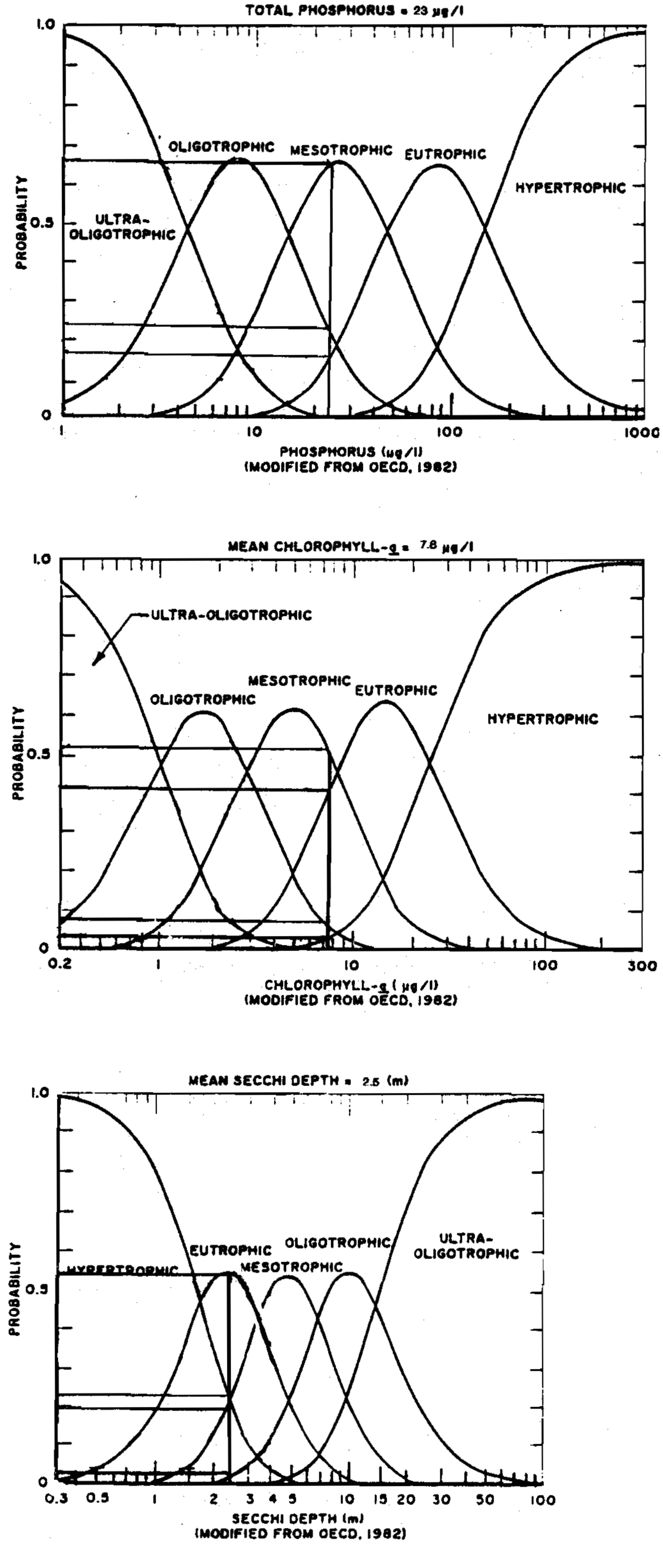
[17] *R.E. Carlson, "A Trophic State Index for Lakes,"* Limnology and Oceanography, *Vol. 22, No. 2, 1977.*

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

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

Figure 7

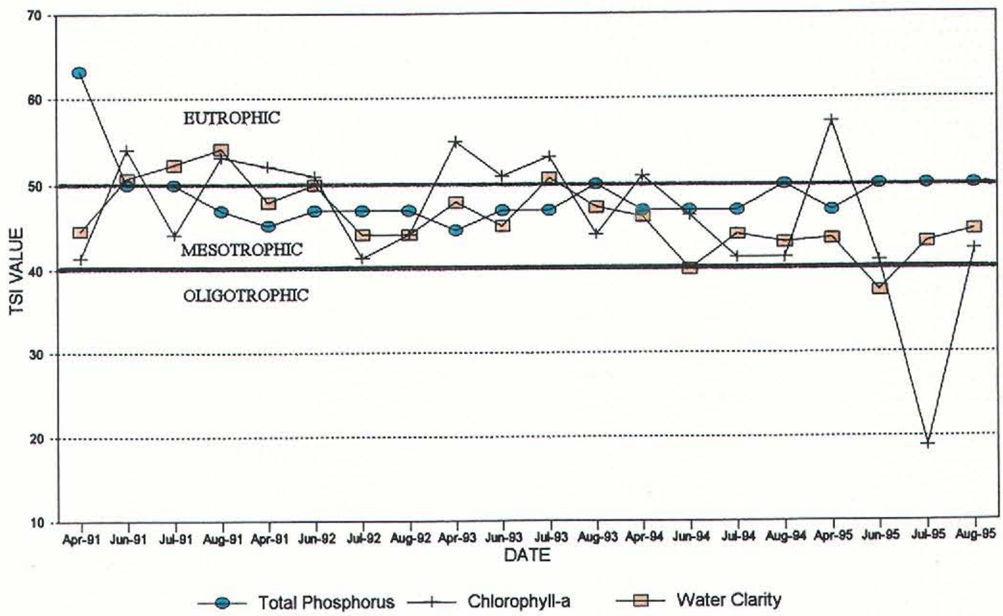
TROPHIC STATE CLASSIFICATION OF LAKE KEESUS BASED UPON THE VOLLENWEIDER MODEL



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

Figure 8

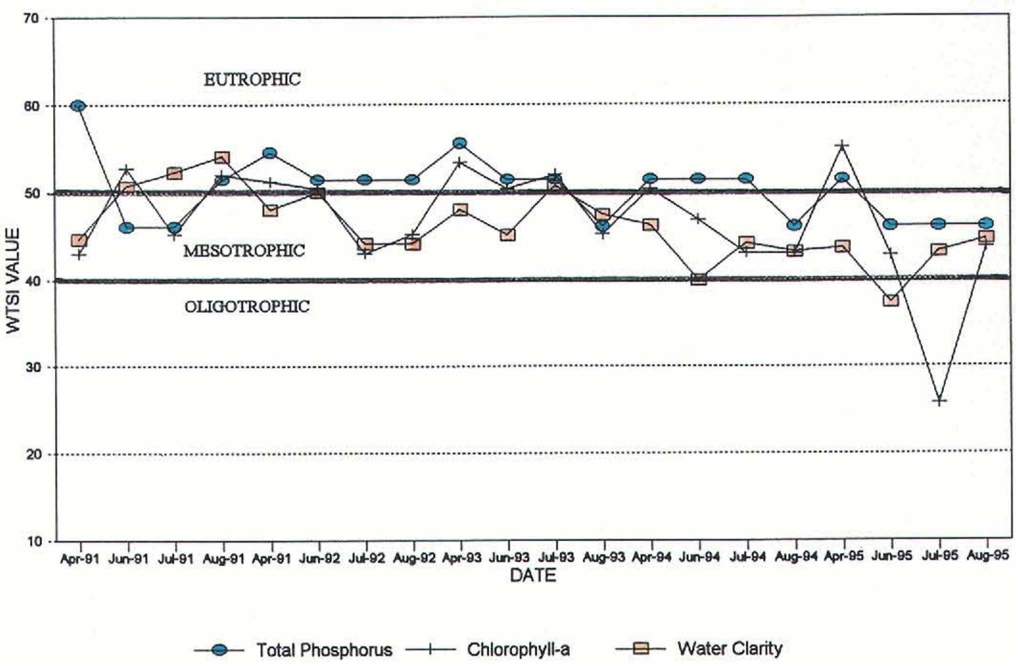
CARLSON'S TROPHIC STATUS INDEX FOR LAKE KEESUS: 1991-1995



Source: SEWRPC.

Figure 9

WISCONSIN TROPHIC STATUS INDEX FOR LAKE KEESUS: 1991-1995



Source: SEWRPC.

Chapter V

AQUATIC BIOTA AND ECOLOGICALLY VALUABLE AREAS

INTRODUCTION

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

AQUATIC PLANTS

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

Aquatic Macrophytes

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

To document the types and relative abundances of aquatic macrophytes in Lake Keesus, an aquatic plant survey was conducted by Aron & Associates, consultant to the District, during June 1994. The Regional Planning Commission staff also conducted lake inspection surveys in 1995 and 1996 to refine the aquatic plant survey data and note changes which occurred in the distribution of plants. The aquatic plant survey was designed to determine species composition. A species list, compiled from the results of this aquatic plant survey, is set forth in Table 12.

During the 1994 survey, 21 species of aquatic plants were identified, many of which were common to abundant. Species that have the potential to interfere with the recreational and aesthetic use of the Lake, such as *Myriophyllum spicatum, Ceratophyllum demersum*, and *Potamogeton crispus*, were found to be present in the Lake, all but the latter being described as common. Plant growth occurred throughout the Lake in up to 12 feet of water depth. Musk grass—*Chara* spp., wild celery—*Vallisneria americana*—and flat-stemmed pondweed—*Potamogeton zosteriformis* were the dominant species in many areas of the main basin. *Ceratophyllum demersum* and *Myriophyllum spicatum* were more common in the main lake basin in the deeper waters, greater than three feet in depth. *Myriophyllum spicatum* was particularly common in the southern embayments where the soils had the organic character favored by these plants. The distribution of the plant communities, as determined in the 1994 survey, is shown on Map 15.

Table 12

AQUATIC PLANT SPECIES PRESENT IN LAKE KEESUS AND THEIR POSITIVE ECOLOGICAL SIGNIFICANCE

Aquatic Plant Species Present	Ecological Significance[a]
Ceratophyllum demersum (coontail)	Provides good shelter for young fish, and supports insects valuable as food for fish and ducklings
Chara vulgaris (muskgrass)	Excellent producer of fish food, especially for young trout, bluegills, and small and largemouth bass; stabilizes bottom sediments; and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis (waterweed or Elodea)	Provides shelter and support for insects valuable as fish food
Lemna minor (lesser duckweed)	Provides important food for wildfowl and attracts small aquatic animals
Myriophyllum spicatum (Eurasian water milfoil)	None known
Najas flexilis (bushy pondweed)	Stems, foliage, and seeds are important wildfowl food and produces good food and shelter for fish
Nuphar sp. (yellow water lily)	Leaves, stems, and flowers are eaten by deer; roots eaten by beavers and porcupines; seeds eaten by wildfowl; leaves provide harbor to insects, in addition to shade and shelter for fish
Nymphaea sp. (white water lily)	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrats; roots eaten by beaver, deer, moose, and porcupine
Potamogeton amplifolius (large-leaf pondweed)	Provides food and shelter for fish, supports insects eaten by fish, and provides food for ducks
Potamogeton crispus (curly-leaf pondweed)	Provides food, shelter, and shade for some fish and food for wildfowl
Potamogeton foliosus (leafy pondweed)	Provides important food for wildfowl and food and shelter for fish
Potamogeton friesii (Fries pondweed)	Provides food for ducks
Potamogeton illinoensis (Illinois pondweed)	Provides some food for ducks and shelter for fish
Potamogeton natans (floating-leaf pondweed)	Provides good food for ducks late in the season
Potamogeton pectinatus (sago pondweed)	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton praelongus (whitestem pondweed)	Provides food for ducks and feeding grounds for muskellunge and trout
Potamogeton strictifolius (stiff pondweed)	None known
Potamogeton zosteriformis (flatstem pondweed)	Provides some food for ducks
Sagitarria sp. (arrowhead)	Provides food for ducks, muskrats, porcupines, beavers, and fish and provides shelter for young fish
Utricularia vulgaris (bladderwort)	Provides good food and cover for fish
Vallisneria americana (water celery or eel grass)	Provides good shade and shelter, supports insects, and is valuable fish food

[a] *Information obtained from A Manual of Aquatic Plants by Norman C. Fassett and Guide to Wisconsin Aquatic Plants, Wisconsin Department of Natural Resources.*

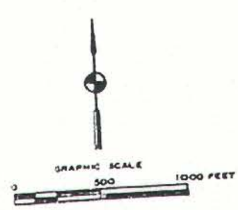
Source: SEWRPC.

Map 15

AQUATIC PLANT COMMUNITY DISTRIBUTION IN LAKE KEESUS: 1994

LEGEND

- COONTAIL, CURLY-LEAF PONDWEED, BUSHY PONDWEED, NATIVE PONWEEDS, MUSKGRASS, EEL GRASS, ELODEA, AND EURASIAN WATER MILFOIL
- COONTAIL, NATIVE PONDWEEDS, ARROWHEAD, BLADDERWORT, AND EURASIAN WATER MILFOIL
- COONTAIL, BLADDERWORT, MUSKGRASS, EEL GRASS, NATIVE PONDWEEDS, AND EURASIAN WATER MILFOIL
- COONTAIL, MUSKGRASS, EEL GRASS, BUSHY PONDWEED, NATIVE PONDWEEDS, AND EURASIAN WATER MILFOIL
- COONTAIL, MUSKGRASS, EEL GRASS, AND NATIVE PONDWEEDS
- MUSKGRASS, EEL GRASS, AND NATIVE PONDWEEDS
- SPARSE MUSKGRASS AND EEL GRASS
- WATER LILIES



Source: Aron & Associates and SEWRPC.

In general, Lake Keesus supports a very healthy and diverse aquatic macrophyte community, although species such as milfoil and coontail had a tendency to form dense mats that may interfere with boat traffic; harvesting has been necessary in selected areas to ameliorate the adverse effects of excessive aquatic plant growth.

Phytoplankton

Phytoplankton, or algae, are small, generally microscopic plants that are found in all lakes and streams. They occur in a wide variety of forms, in single cells or colonies, and can be either attached or free floating. Phytoplankton abundance varies seasonally with fluctuations in solar irradiance, turbulence due to prevailing winds, and nutrient availability. In lakes with high nutrient levels, heavy growths of phytoplankton, or algal blooms, may occur.

Algal blooms are known to have occurred on Lake Keesus. However, as indicated by chlorophyll-a concentrations of between an average of five to 10 micrograms per liter, as shown in Table 8, with the exception of *Gleotrichia* sp., these have not been considered a major problem. Therefore, identification and quantification of the algae present within the Lake have not been included as part of the U.S. Geological Survey or Wisconsin Department of Natural Resources studies conducted to date. *Gleotrichia* has been identified as the causal agent in outbreaks of "swimmer's itch"—a condition caused by an histaminic reaction to extra-cellular blue-green algal toxins resulting in symptoms that include noticeable pain, swelling, severe itching, and occasional fever in afflicted persons[1]—at Lake Keesus. This form of "swimmer's itch" should be distinguished from that caused by the more common reaction of persons to skin irritants produced by parasitic flatworms carried by waterfowl and snails seeking a mammalian host.[2]

Aquatic Plant Management

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Therefore, while previous interventions were likely, the first recorded efforts to manage the aquatic plants in Lake Keesus took place in 1952. Aquatic plant management activities in Lake Keesus can be categorized as macrophyte harvesting, chemical macrophyte control, and chemical algae control.

Perceived excessive macrophyte growth on Lake Keesus has historically resulted in a control program that used both harvesting and chemicals. Under the existing macrophyte control program, the Lake Keesus Management District harvests macrophytes with an Aquarius Systems H-420 harvester which was acquired under Chapter NR 7 Recreational Boating Facilities Grant Program in 1996. Since chemical herbicides are generally applied to Lake Keesus in early summer, harvesting is initiated only after the macrophytes become reestablished, usually in mid- to late July. Typically, only the macrophytes growing along the shoreline of the Lake are cut, although excessive macrophyte growths occur in other shallow portions of the Lake away from the shoreline. These are occasionally cut to improve navigation and enhance swimming opportunities. No State permits are currently required to mechanically harvest vegetation in lakes, although the harvested plant material must, under State regulations, be removed from the water.

Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Chemical herbicides are known to have been applied to Lake Keesus from at least 1952 through 1994.

In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison area, and, by the 1930s, sodium arsenite was widely used throughout the State for aquatic plant control. No other chemicals were applied in significant amounts to control macrophytes until recent years, when a number of organic chemical herbicides have come into general use. The amounts of sodium arsenite applied to Lake Keesus, and years of application during the period 1950 to 1969, are shown on Table 13. The total amount of sodium arsenite applied being about 6,584 pounds.

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

[1] *W. W. Carmichael,* The Water Environment, Algal Toxins and Health, *Plenum Press, New York, 1981.*

[2] *Wisconsin Department of Natural Resources Publication No. PUBL-WR-170 87REV,* Swimmers' Itch, *November 1987.*

Table 13

CHEMICAL CONTROL OF AQUATIC PLANTS IN LAKE KEESUS: 1952-1994

Year	Sodium Arsenite (pounds)	Macrophyte Control					Algae Control	
		Diquat (gallons)	Aquathol-K (gallons)	2,4-D (gallons)	Hydrothol (gallons)	Hydrothol (pounds)	Copper Sulfate (pounds)	Cutrine Plus (gallons)
1952-1969	6,584	0	0	0	0	0	10,410	0
1970	0	37	0	180	0	0	475	1
1971	0	0	200	0	0	0	300	0
1972	0	0	0	0	0	0	400	0
1973	0	0	0	0	0	0	1,050	0
1974	0	0	0	0	0	0	492	0
1975	0	0	0	0	5	0	411	140
1976	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	50
1980	0	0	0	0	0	0	0	1,475
1981	0	0	0	0	0	0	0	86
1982	0	0	0	0	0	0	0	107
1983	0	0	0	0	0	0	0	128
1984	0	0	0	0	0	0	0	154
1985	0	0	0	0	0	0	0	147
1986	0	0	0	0	0	0	0	143
1987	0	0	0	0	0	0	0	71
1988	0	0	0	0	0	0	0	12
1989	0	0	0	0	0	0	0	27
1990	0	0	0	0	0	0	0	44
1991	0	0	0	0	0	0	0	40
1992	0	0	0	0	0	0	0	16
1993	0	0	0	0	0	0	0	31
1994	0	0	0	0	0	0	0	37
Total	6,584	37	200	180	5	0	13,538	2,709

Source: Wisconsin Department of Natural Resources.

active form, much of the arsenic residue is deposited in the lake sediments.

When it became apparent that arsenic was accumulating in the sediments of treated lakes, the use of sodium arsenite was discontinued in the State of Wisconsin in 1969. The applications and accumulations of arsenic were found to present potential health hazards to both humans and aquatic life. In drinking water supplies, arsenic was suspected of being carcinogenic and, under certain conditions, arsenic has leached into and contaminated groundwaters, especially in sandy soils that serve as a source of drinking water in some communities. The U.S. Environmental Protection Agency-recommended drinking water standard for arsenic is a maximum level of 0.05 mg/l.

During anaerobic conditions, arsenic may be released from the bottom sediments to the water column above. In this way, some dissolved arsenic probably continues to be removed from Lake Keesus during some flushing events or periods of increased outflow. However, the arsenic-laden sediments are continually being covered by new sediments; thus, the level of arsenic in the water and in the surface sediments may be expected to decrease with passage of time.

As shown in Table 13, the aquatic herbicides Diquat, Aquathol, Hydrothol, and 2,4-D have also been applied to Lake Keesus to control aquatic macrophyte growth since 1970. Diquat, Aquathol, and Hydrothol are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is non-selective and will actually kill many other aquatic plants such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Aquathol and Hydrothol kill primarily pondweeds, but do not control such nuisance species as Eurasian water milfoil (*Myriophyllum spicatum*). The herbicide 2,4-D is a systemic herbicide which is absorbed by the leaves and translocated to other parts of the plant; it is more selective than the other herbicides listed above and is generally used to control Eurasian water milfoil. However, it will also kill more valuable species, such as water lilies (*Nymphaea* sp. and *Nuphar* sp.). The present restrictions on water uses after application of these herbicides are given in Table 14.

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to Lake Keesus. As shown in Table 13, Cutrine Plus and Copper Sulfate have been applied to Lake Keesus, on occasion, since 1952, primarily to control algae. Like arsenic, copper, the active ingredient in many algicides including Cutrine Plus, may accumulate in the bottom sediments. Excessive levels of copper have been found to be toxic to fish and benthic organisms, but have not been found to be harmful to humans. Restrictions on the water uses after application of Cutrine Plus are also given in Table 14.

At present, the Lake Keesus Management District holds the State permits for chemical treatment of aquatic plants required under Chapter NR 107, *Wisconsin Administrative Code*. Chemicals are applied annually on a contractual basis by a local licensed applicator. As previously noted, herbicide application usually takes place in late spring or early summer with, occasionally, a second treatment of a smaller area, if necessary, in late July or early August. Map 16 shows the areal extent of that portion of Lake Keesus to which chemicals were applied between 1988 and 1994. All chemicals for aquatic plant control used today must be approved by the U.S. Environmental Protection Agency and the Wisconsin Department of Natural Resources and are registered in terms of the Federal Insecticide, Fungicide, and Rodenticide Act as amended in 1972.

AQUATIC ANIMALS

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

Zooplankton

Zooplankton are minute, free-floating animals inhabiting the same environment as phytoplankton. Zooplankton are primary consumers in the aquatic food chain, feeding to a large extent on such phytoplankton as green algae and diatoms. The zooplankton, in turn, are preyed upon by fish, particularly the larvae and fry of bluegills, pumpkinseeds, sunfish, and largemouth bass. While the zooplankton population is an indicator of the trophic status of a lake and of the diversity of aquatic habitat, zooplankton were not sampled during the U.S. Geological Survey inventory; no information on the species composition or relative abundance is available for Lake Keesus. However, given the composition and condition of the fish community in Lake Keesus, it may be assumed that the zooplankton population is sufficiently robust and diverse to support a relatively healthy fishery.

Fish of Lake Keesus

Lake Keesus supports a moderately diverse, but relatively unstudied, fish community. The Wisconsin Department of Natural Resources Publication No. FM-800-95, *Wisconsin Lakes*, 1995, indicates that largemouth bass are abundant, panfish are common, and that walleyed pike and northern pike are also present. Based on a lake inventory of Lake Keesus conducted by the Wisconsin Department of Natural Resources[3], the fish community was comprised of bluegills, pumpkinseeds, yellow perch, green sunfish, largemouth bass, central mudminnow, golden shiner, Iowa darter, grass pickerel, and yellow bullheads.

Important predator fishes in Lake Keesus include northern pike, walleyed pike, and largemouth bass. These species are carnivorous, feeding primarily on other fish, crayfish, and frogs. These species are among the largest and most prized game fish sought by Lake Keesus anglers.

"Panfish" is a common term applied to a broad group of smaller fish; their relatively short and usually broad shape makes them a perfect size for the frying pan. Panfish species most likely to be present in Lake Keesus

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[3]*D. Fago, Wisconsin Department of Natural Resources Research Report No. 148,* Retrieval and Analysis Used in Statewide Fish Distribution Survey, *2nd Edition, December 1988.*

Table 14

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

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

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

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

Source: Wisconsin Department of Natural Resources.

include bluegills, pumpkinseeds, green sunfish, black crappies, white suckers, golden shiners, yellow perch, and bullheads. The habitats of panfish vary widely among the different species, but their cropping of the plentiful supply of insects and plants, coupled with prolific breeding rates, leads to large populations with a rapid turnover. Some lakes within Southeastern Wisconsin have stunted, or slow-growing, panfish populations because their numbers are not controlled by predator fishes.[4] Panfish frequently feed on the fry of predator fish and, if the panfish population is overabundant, they may quickly deplete the predator fry population. Figure 10 illustrates the importance of a balanced predator-prey relationship, using walleyed pike and perch as an example.

"Rough fish" is a broad term applied to species such as carp that do not readily bite on hook and line, but feed on game fish, destroy habitat needed by more desirable species, and which are commonly considered within Southeastern Wisconsin undesirable for human consumption. Carp are known to be present in Lake Keesus, but are not indicated as representing a significant problem.[5]

Other Wildlife

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

Given the rural nature of all but the immediate shoreland area, many animals and waterfowl commonly inhabit areas of the watershed, especially in the undeveloped southwestern areas of the Lake and upstream. Mink, muskrat, beaver, white tailed deer, red and grey fox, grey and fox squirrel, and cottontail rabbits are reported mammals. Mallards, wood duck, and blue-winged teal are the most numerous waterfowl and are known to nest in the area. Many game birds, song birds, waders, and raptors also visit the Lake and its environs. Sandhill cranes and loons are notable migratory visitors. In addition, bald eagles, osprey, black terns, great egrets, peregrine falcons, barn owls, and red-shouldered hawks—all threatened or endangered species—have been reported to have been seen in the vicinity of Lake Keesus.

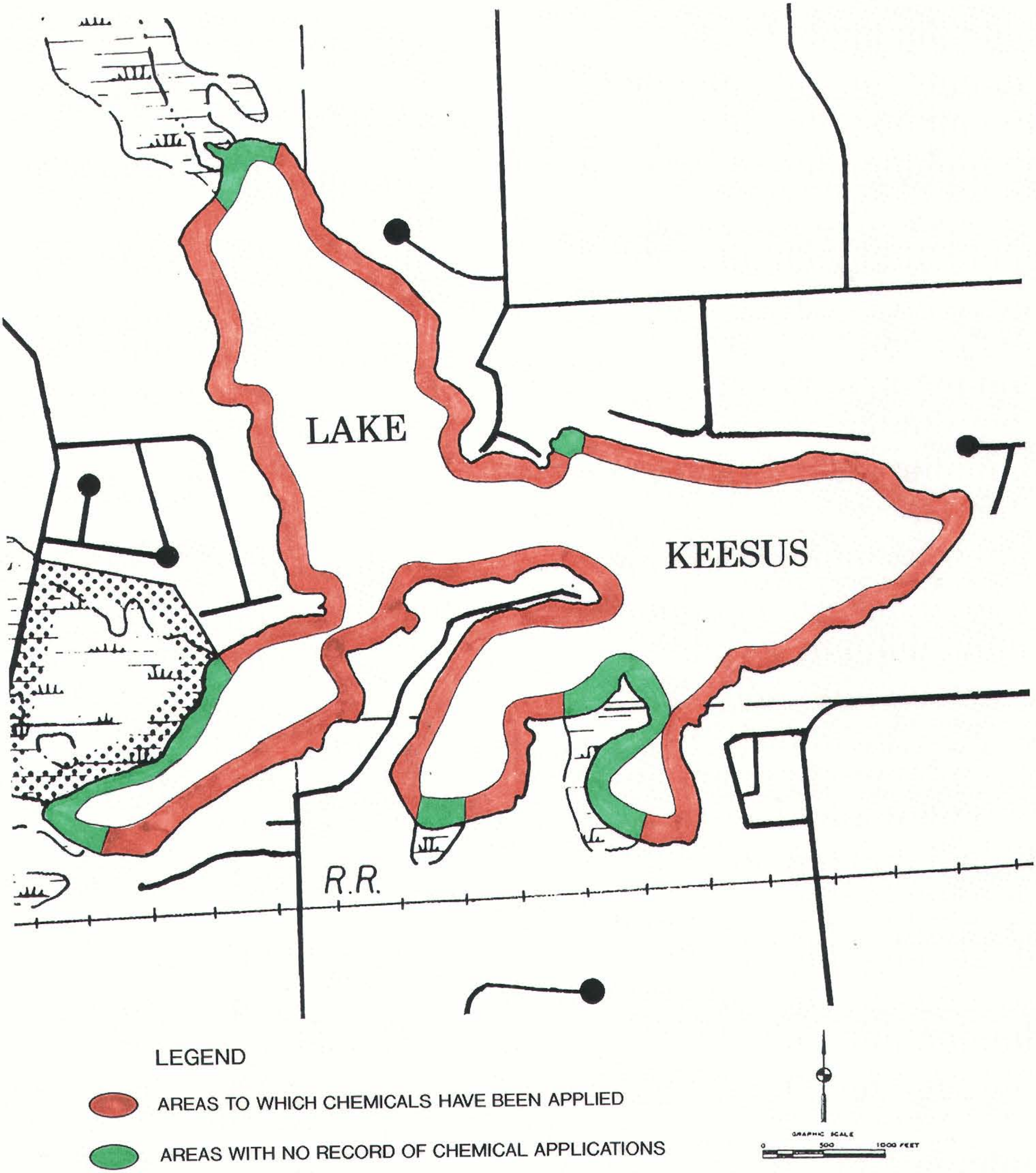
Amphibians and reptiles are vital components of the ecosystem in an environmental unit like the Lake Keesus drainage area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Lake

[4]*Personal communication, Dr. Ron Crunkilton, University of Wisconsin-Stevens Point College of Natural Resources, 1992.*

[5]*According to the Wisconsin Department of Natural Resources, carp are typically considered a significant problem if they are the most populous fish species in the lake, or if they appear stressed or cause stress among other fish populations in the lake.*

Map 16

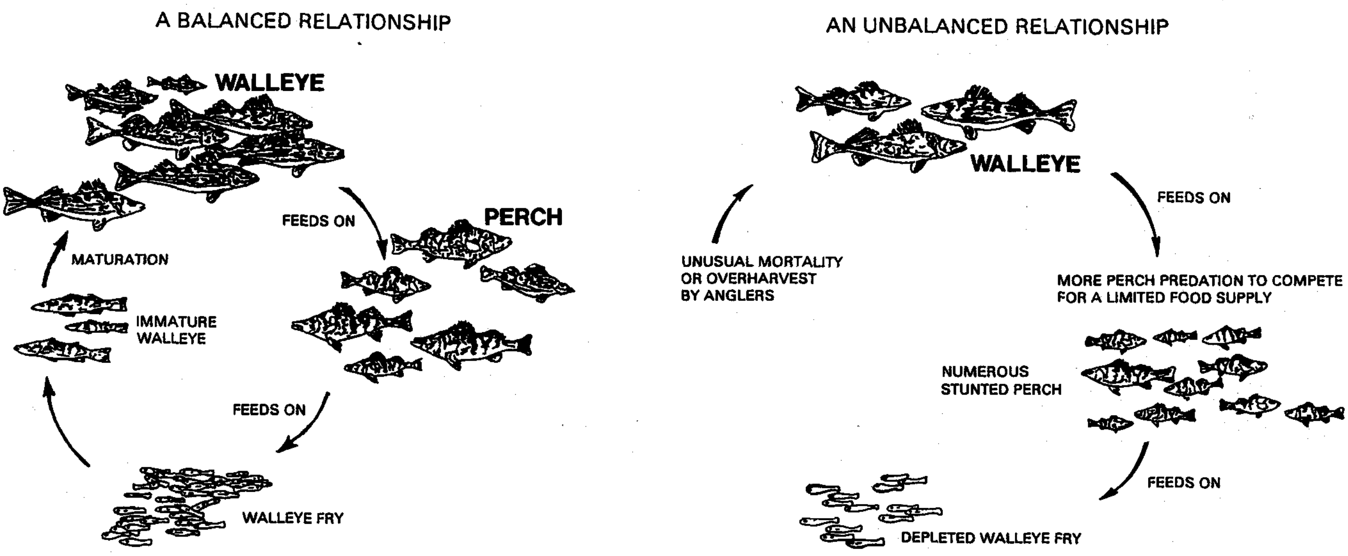
SHORELINE AREAS OF LAKE KEESUS HISTORICALLY TREATED WITH HERBICIDES



Source: SEWRPC.

Figure 10

THE PREDATOR-PREY RELATIONSHIP



Source: Wisconsin Department of Natural Resources.

Keesus area. Table 15 lists 14 amphibian and 13 reptile species normally expected to be present in the Lake Keesus area under present conditions and identifies those species most sensitive to urbanization.

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Lake Keesus area. Table 16 lists those birds that normally occur in the drainage area. Each bird is classified as to whether it may be expected to breed within the area, visit the area only during the annual migration periods, or visit the area only on rare occasions.

Because of the mixture of lowland and upland woodlots, wetlands, and agricultural lands still present in the area, along with favorable summer climate, the area supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, whippoorwills, woodpeckers, nuthatches, and flycatchers, as well as several other species, serve as major insect predators. In addition to their ecological roles, birds such as robins, red-winged blackbirds, orioles, cardinals, king fishers, and mourning doves serve as subjects for bird watchers and photographers.

A variety of mammals, ranging in size from large animals like the northern white-tailed deer to small animals like the short-tailed shrew, are found in the Lake Keesus area. Table 17 lists 38 mammals whose ranges may be expected to be included in the area.

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

Table 15

AMPHIBIANS AND REPTILES OF THE LAKE KEESUS AREA

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

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

[b] *Indentified as threatened in Wisconsin.*

Source: Wisconsin Department of Natural Resources, The Wisconsin Herpetological Atlas, and SEWRPC.

Table 16

BIRDS KNOWN OR LIKELY TO OCCUR IN THE LAKE KEESUS AREA

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Podicipedidae			
Horned Grebe	--	--	X
Pied-Billed Grebe	X	--	X
Ardeidae			
American Bittern	X?	--	X
Least Bittern	X?	--	X
Great Egret	--	--	R(T)
Great Blue Heron	--	--	X
Green Heron[a]	X?	--	X
Black-Crowned Night-Heron	--	--	R
Anatidae			
Mute Swan	--	--	X
Tundra Swan	--	--	R
Canada Goose[b]	X	X	X
Snow Goose	--	--	X
Wood Duck[b]	X	--	X
Green-Winged Teal	--	--	X
Ruddy Duck	--	--	X
American Black Duck	--	X	X
Gadwall	--	--	X
Mallard[b]	X	X	X
Northern Pintail	--	--	X
Blue-Winged Teal[a]	X	--	X
Northern Shoveler	--	--	X
American Wigeon	--	--	X
Redhead	--	--	X
Ring-Necked Duck	--	--	X
Canvasback	--	--	X
Lesser Scaup	--	--	X
Common Goldeneye	--	--	X
Bufflehead	--	--	X
Hooded Merganser	--	--	X
Red-Breasted Merganser	--	--	X
Common Merganser	--	--	X
Gaviidae			
Common Loon	--	--	X
Cathartidae			
Turkey Vulture	--	--	X
Accipitridae			
Osprey	--	--	R(E)
Bald Eagle	--	--	R(E)
Northern Harrier[a]	R?	--	R
Sharp-Shinned Hawk	--	--	X
Cooper's Hawk	X?	--	X
Northern Goshawk	--	--	R
Red-Shouldered Hawk	--	--	R(T)
Broad-Winged Hawk	--	--	X
Red-Tailed Hawk[b]	X	X	X
Rough-Legged Hawk	--	X	X

Table 16 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Falconidae			
American Kestrel[b]	X	X	X
Merlin	--	--	R
Peregrine Falcon	--	--	R(E)
Phasianidae			
Ring-Necked Pheasant[b] (introduced)	X	X	NA
Rallidae			
Virginia Rail[b]	X	--	X
Sora[b]	X	--	X
Common Moorhen[b]	R?	--	X
American Coot	R	--	X
Gruidae			
Sandhill Crane	--	--	R
Charadriidae			
Semipalmated Plover	--	--	X
Killdeer[b]	X	--	X
Scolopacidae			
Greater Yellowlegs	--	--	X
Lesser Yellowlegs	--	--	X
Least Sandpiper	--	--	X
Solitary Sandpiper	--	--	X
Spotted Sandpiper[b]	X	--	X
Semipalmated Sandpiper	--	--	X
Dowitcher spp.	--	--	X
Dunlin	--	--	X
Pectoral Sandpiper	--	--	X
Common Snipe	R	R	X
American Woodcock[b]	X	--	X
Wilson's Phalarope	--	--	R
Laridae			
Bonaparte's Gull	--	--	X
Ring-Billed Gull	--	X	X
Herring Gull	--	X	X
Common Tern	--	--	R(E)
Forster's Tern	--	--	R(E)
Black Tern	R?	--	R
Columbidae			
Rock Dove	X	X	NA
Mourning Dove	X	X	X
Cuculidae			
Black-Billed Cuckoo[b]	X	--	X
Yellow-Billed Cuckoo[b]	X	--	X
Strigidae			
Eastern Screech Owl[b]	X	X	NA
Great Horned Owl[b]	X	X	NA
Snowy Owl	--	R	R
Long-Eared Owl	--	R	R
Short-Eared Owl	--	--	R
Northern Saw-Whet Owl	--	R?	R

Table 16 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Caprimulgidae			
Common Nighthawk	X	- -	X
Whippoorwill	- -	- -	X
Apodidae			
Chimney Swift	X	- -	X
Trochilidae			
Ruby-Throated Hummingbird	X	- -	X
Alcedinidae			
Belted Kingfisher[b]	X	X	X
Picidae			
Red-Headed Woodpecker[b]	X	R	X
Red-Bellied Woodpecker[b]	X	X	NA
Yellow-Bellied Sapsucker	- -	R	X
Downy Woodpecker[b]	X	X	NA
Hairy Woodpecker[b]	X	X	NA
Northern Flicker[b]	X	R	X
Tyrannidae			
Olive-Sided Flycatcher	- -	- -	X
Eastern Wood-Pewee[b]	X	- -	X
Yellow-Bellied Flycatcher	- -	- -	X
Acadian Flycatcher	- -	- -	R(T)
Alder Flycatcher	- -	- -	X
Willow Flycatcher[b]	X	- -	X
Least Flycatcher[b]	R?	- -	X
Eastern Phoebe[b]	X	- -	X
Great Crested Flycatcher[b]	X	- -	X
Eastern Kingbird[b]	X	- -	X
Alaudidae			
Horned Lark[a]	X	X	X
Hirundinidae			
Purple Martin	X	- -	X
Tree Swallow[b]	X	- -	X
Northern Rough-Winged Swallow[b]	X?	- -	X
Bank Swallow[a]	X?	- -	X
Cliff Swallow[a]	X	- -	X
Barn Swallow[b]	X	- -	X
Corvidae			
Blue Jay	X	X	X
American Crow	X	X	X
Paridae			
Black-Capped Chickadee[b]	X	X	X
Tufted Titmouse[b]	R?	R	NA
Sittidae			
Red-Breasted Nuthatch	- -	R	X
White-Breasted Nuthatch[b]	X	X	NA
Certhiidae			
Brown Creeper	- -	X	X
Troglodytidae			
Carolina Wren	- -	- -	R
House Wren	X	- -	X

Table 16 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Troglodytidae (continued)			
Winter Wren	--	--	X
Sedge Wren[b]	X	--	X
Marsh Wren[b]	X	--	X
Muscicapidae			
Golden-Crowned Kinglet	--	X	X
Ruby-Crowned Kinglet	--	--	X
Blue-Gray Gnatcatcher[a]	X	--	X
Eastern Bluebird[a]	R	--	X
Veery[a]	R?	--	X
Gray-Cheeked Thrush	--	--	X
Swainson's Thrush	--	--	X
Hermit Thrush	--	--	X
Wood Thrush[a]	X	--	X
American Robin	X	R	X
Mimidae			
Gray Catbird[b]	X	--	X
Brown Thrasher[b]	X	--	X
Motacillidae			
Water Pipit	--	--	X
Bombycillidae			
Bohemian Waxwing	--	R	R
Cedar Waxwing	X	X	X
Laniidae			
Northern Shrike	--	X	X
Sturnidae			
European Starling	X	X	X
Vireonidae			
Solitary Vireo	--	--	X
Yellow-Throated Vireo[b]	X	--	X
Warbling Vireo	X	--	X
Philadelphia Vireo	--	--	X
Red-eyed Vireo[b]	X	--	X
Emberizidae			
Blue-Winged Warbler[a]	R	--	X
Golden-Winged Warbler	--	--	X
Tennessee Warbler	--	--	X
Orange-Crowned Warbler	--	--	X
Nashville Warbler	--	--	X
Northern Parula	--	--	X
Yellow Warbler[b]	X	--	X
Chestnut-Sided Warbler[a]	R?	--	X
Magnolia Warbler	--	--	X
Cape May Warbler	--	--	X
Black-Throated Blue Warbler	--	--	X
Yellow-Rumped Warbler	--	--	X
Black-Throated Green Warbler	--	--	X
Blackburnian Warbler	--	--	X
Pine Warbler	--	--	X
Palm Warbler	--	--	X
Bay-Breasted Warbler	--	--	X
Blackpoll Warbler	--	--	X

Table 16 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Emberizidae (continued)			
Cerulean Warbler	--	--	R(T)
Black and White Warbler[a]	R?	--	X
American Redstart[a]	R?	--	X
Ovenbird[a]	R	--	X
Northern Waterthrush	--	--	X
Connecticut Warbler	--	--	X
Mourning Warbler[a]	R	--	X
Common Yellowthroat[b]	X	--	X
Hooded Warbler	--	--	X(T)
Wilson's Warbler	--	--	X
Canada Warbler	--	--	X
Scarlet Tanager[a]	X	--	X
Northern Cardinal	X	X	NA
Rose-Breasted Grosbeak[b]	X	--	X
Indigo Bunting[b]	X	--	X
Dickcissel	--	--	R
Eastern Towhee[b]	X	--	X
American Tree Sparrow	--	X	X
Chipping Sparrow	X	--	X
Clay-Colored Sparrow	--	--	X
Field Sparrow[a]	X	--	X
Vesper Sparrow[a]	X	--	X
Savannah Sparrow[a]	X	--	X
Grasshopper Sparrow[a]	X?	--	X(T)
Henslow's Sparrow[a]	X?	--	X
Fox Sparrow	--	--	X
Song Sparrow[b]	X	R	X
Lincoln's Sparrow	--	--	X
Swamp Sparrow[b]	X	R	X
White-Throated Sparrow	--	R	X
White-Crowned Sparrow	--	--	X
Harris' Sparrow	--	--	R
Dark-Eyed Junco	--	X	X
Lapland Longspur	--	R?	X
Snow Bunting	--	R?	X
Bobolink[a]	X	--	X
Red-Winged Blackbird[b]	X	X	X
Eastern Meadowlark[a]	X	R	X
Western Meadowlark[a]	R?	--	X
Yellow-Headed Blackbird	--	--	X
Rusty Blackbird	--	R	X
Brewer's Blackbird	--	--	X
Common Grackle	X	X	X
Brown-Headed Cowbird	X	X	X
Orchard Oriole	R	--	R
Baltimore Oriole	X	--	X
Pine Grosbeak	--	R	R
Purple Finch	--	X	X
House Finch	X	X	NA
Red Crossbill	--	R	R
White-Winged Crossbill	--	R	R
Common Redpoll	--	X	X
Pine Siskin	--	X	X
American Goldfinch	X	X	X
Evening Grosbeak	--	R	X

Table 16 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Phalacrocoracidae Double-Crested Cormorant	- -	- -	R
Ploceidae House Sparrow	X	X	NA

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

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

[a] *Species lost as breeding birds with full watershed urbanization.*

[b] *Species reduced in numbers as breeding birds with full watershed urbanization.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

motor vehicle traffic that produces disruptive noise levels and air pollution; and the introduction of domestic pets.

WILDLIFE HABITAT AND RESOURCES

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

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

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

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

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

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

On the basis of these five criteria, the wildlife habitat areas in the Lake Keesus drainage area were categorized as either Class I, High-Value; Class II, Medium Value; or Class III, Good-Value, habitat areas.

Class I wildlife habitat areas contain a good diversity of wildlife, are adequate in size to meet all of the habitat requirements for the species concerned, are generally located in proximity to other wildlife habitat areas, and meet all five criteria listed above. Class II wildlife

Table 17

MAMMALS OF THE LAKE KEESUS AREA

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

Source: H. T. Jackson, Mammals of Wisconsin, 1961; and SEWRPC.

habitat areas generally fail to meet one of the five criteria in the preceding list for a high-value wildlife habitat. However, they do retain a good plant and animal diversity. Class III wildlife habitat areas are remnant in nature in that they generally fail to meet two or more of the five criteria for a high-value wildlife habitat, but may, nevertheless, be important if located in proximity to medium- or high-value habitat areas if they provide corridors linking wildlife habitat areas of higher value or if they provide the only available range in an area.

As shown on Map 17, approximately 375 acres, or 14 percent, of the drainage area to Lake Keesus, were identified as wildlife habitat. Of that area about 130 acres, or 5 percent, of the drainage area were classified as Class I habitat; 135 acres, or 5 percent, of the drainage area were classified as Class II habitat; and about 110 acres, or 4 percent, of the drainage area tributary to Lake Keesus, were classified as Class III habitat.

WETLANDS

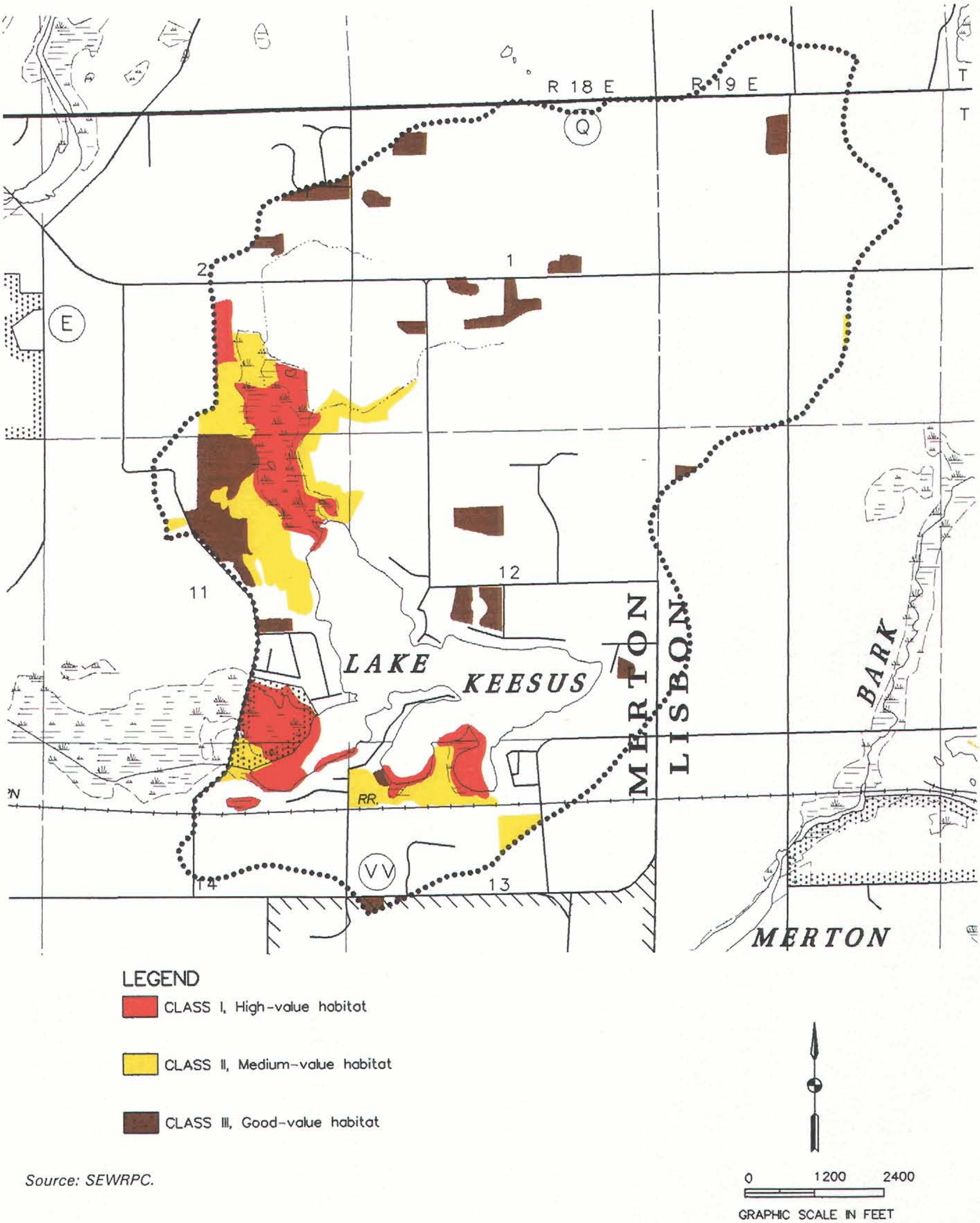
Wetlands are defined by the Regional Planning Commission as, "areas that have a predominance of hydric soils and that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions." This definition which is also used by the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency is essentially the same as the definition used by U.S. Natural Resources Conservation Service.[6]

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

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

Map 17

WILDLIFE HABITAT AREAS IN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS



Source: SEWRPC.

supporting aquatic or hydrophytic vegetation, and which has soils indicative of wet conditions." In practice, the Department definition differs from the Regional Planning Commission definition in that the Department considers very poorly drained, poorly drained, and some of the somewhat poorly drained soils as wetland soils meeting their "wet condition" criterion. The Commission definition only considers the very poorly drained and poorly drained soils as meeting the "hydric soil" criterion. Thus, the State definition as actually applied is more inclusive than the Federal and Commission definitions in that the Department may include some soils that do not show hydric field characteristics as wet soils capable of supporting wetland vegetation, a condition which may occur in some floodlands.[7]

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

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

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

The Regional Planning Commission maintains an inventory of wetlands within the region which is updated every five years. As shown on Map 18, in 1990, wetlands covered about 110 acres, or 4 percent, of the drainage area tributary to Lake Keesus. The amount and distribution of wetlands in the area should remain relatively constant if the recommendations contained in the regional land use plan and Waukesha County development plan are followed.

WOODLANDS

Woodlands are defined by the Regional Planning Commission as those areas containing a minimum of 17 trees per acre with a diameter of at least four inches at breast height (4.5 feet above the ground).[8] The woodlands are classified as dry, dry-mesic, mesic, wet-mesic, wet hardwood, or conifer swamp forests; the last three are also considered wetlands. The Regional Planning Commission also maintains an inventory of woodlands within the region which is updated every five years. In the Lake Keesus drainage area, shown on Map 18, approximately 180 acres of woodland were inventoried in 1990. These woodlands covered about 7 percent of the drainage area. The major tree species include the black willow (*Salix nigra*), cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), silver maple

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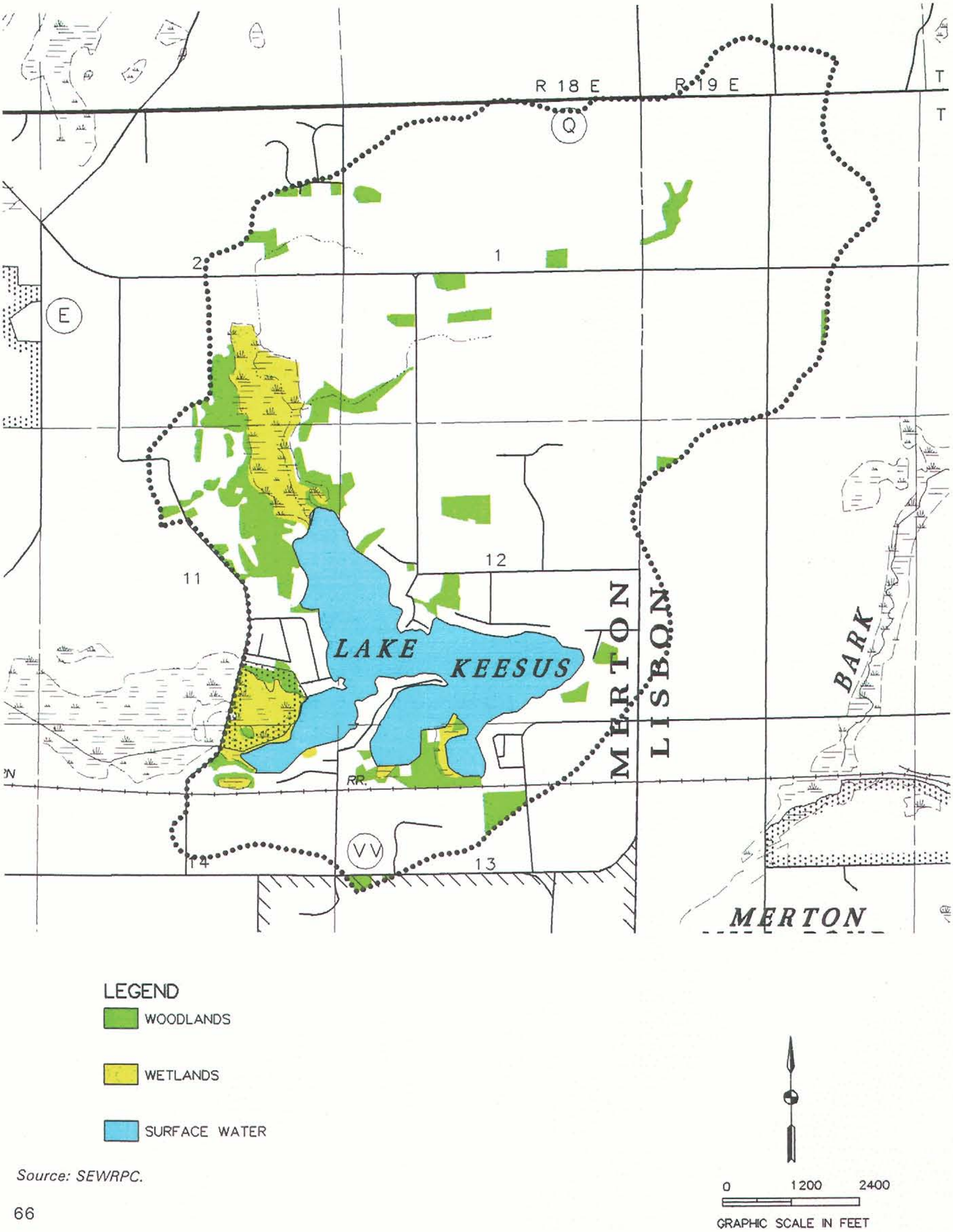
[7]*Although prior converted cropland is not subject to Federal wetland regulations unless cropping ceases for five consecutive years and the land reverts to a wetland condition, the State may consider prior converted cropland to be subject to State wetland regulations if the land meets the criteria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

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

Map 18

EXISTING WETLANDS IN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS



Source: SEWRPC.

(*Acer saccharinum*), American elm (*Ulmus americana*), basswood (*Tilia americana*), northern red oak (*Quercus rubra*), and shagbark hickory (*Carya ovata*). Some isolated stands of tamarack (*Larix laricina*) also exist in the drainage area, together with such other upland species as the white oak (*Quercus alba*), burr oak (*Quercus macrocarpa*), black cherry (*Prunus serotina*), American beech (*Fagus grandifolia*), and paper birch (*Betula papyrifera*). If, however, urban development is allowed to continue within the watershed much of the remaining woodland cover may be expected to be lost.

The amount and distribution of woodlands in the area should also remain relatively stable in the drainage area tributary to Lake Keesus if the recommendations contained in the regional land use plan and the Waukesha County development plan are followed.

ENVIRONMENTAL CORRIDORS

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

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

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

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

Primary Environmental Corridors
Primary environmental corridors in the Lake Keesus drainage area are shown on Map 19. About 270 acres, or 10 percent, of the drainage area were identified as primary environmental corridor. The corridor areas are largely, but not entirely located around the shorelands of Lake Keesus, little of these corridors are in public ownership. A further 10 acres, or less than 1 percent of the drainage area, were classified as secondary environmental corridor, while 12 acres, or 0.5 percent, were identified as isolated natural resource areas located within the drainage area.

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

In the Lake Keesus drainage area, the river banks and lakeshores located within the environmental corridors should be candidates for immediate protection through proper zoning or public ownership. Of the corridor areas not already publicly owned, the remaining areas of natural shoreline, shown on Map 3, are perhaps the most sensitive areas in need of greatest protection. Of these, the areas adjacent to the wetland complexes in the northern, western and southern bays, are all extremely valuable habitat areas are most susceptible to erosion. Further, two areas within the drainage area tributary to Lake Keesus have been identified in the recommended natural areas and critical species habitat protection and management plan[9] as especially worthy of preservation—these sites were identified as the Lake Keesus fen-meadow comprising the 141-acre wetland area riparian to the southwestern embayment of the Lake, adjacent to the Lake outlet and within the existing State Natural Area; and, the 48-acre Camp Whitcomb lowland located north of the Lake on lands occupied by Camp Whitcomb-Mason and currently situated within privately owned open space lands. The former is a habitat area of countywide or regional significance, encompassing critical bird species habitat sites, and the latter is an habitat area of local significance.

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

SUMMARY

Lake Keesus has avoided some of the more severe water quality and environmental impacts characteristic of waterbodies in Southeastern Wisconsin and still presents a relatively unblemished vista for the casual observer. However, the Lake does suffer from an excessive abundance of aquatic plants, predominantly the nuisance species *Myriophyllum spicatum* (Eurasian water milfoil), and *Ceratophyllum* sp. (coontail). These aquatic plants have historically been managed using a combination of chemical and mechanical control. Chemical controls, previously effected with sodium arsenite and more recently with Cutrine Plus and various synthetic organic herbicides—Diquat, Aquathol, and 2,4-D (see Table 13) —are applied in late spring, with a possible follow-up treatment in late summer. Mechanical controls are effected with an Aquarius H-420 harvester.

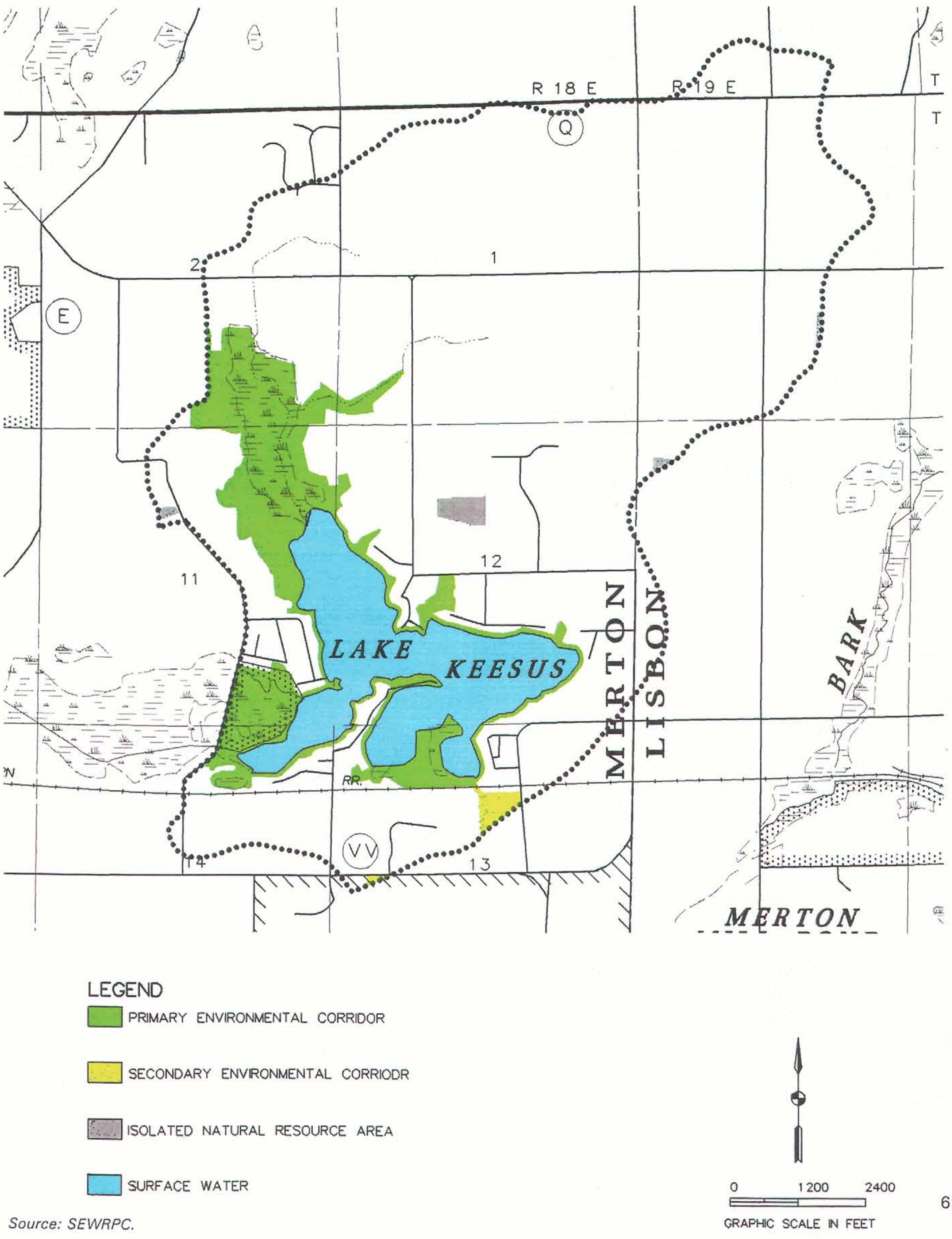
The Lake supports a vigorous, well-balanced, fish community, including sport fish, panfish, and rough fish that are heavily sought by anglers.

Other aquatic life and wildlife in the drainage area tributary to Lake Keesus include amphibians and reptiles, birds, and small and large mammals. While many of the wetland habitats frequented by many of these animals are expected to remain intact, the predominantly hardwood forest woodlands that house much of the terrestrial fauna are prime areas for further urban residential and recreational development. Nevertheless, the drainage area tributary to Lake Keesus area provides an adequate refuge for a healthy and diverse fauna.

The preservation of shoreland and major portion of the drainage area tributary to Lake Keesus which are incorporated into the primary environmental corridor lands as recommended in the regional land use plan and County development plan would be an important step toward the preservation of a relatively high-quality environment in the Lake Keesus area.

Map 19

ENVIRONMENTALLY VALUABLE AREAS IN THE DRAINAGE AREA TRIBUTARY TO LAKE KEESUS



Source: SEWRPC.

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Chapter VI

CURRENT WATER USES AND WATER USE OBJECTIVES

INTRODUCTION

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

RECREATIONAL USE

Lake Keesus, lying adjacent to an urbanizing area, provides an ideal setting for the provision of park and open space sites and facilities. Camp Whitcomb, a camping and related outdoor recreational use facility, is currently the only existing recreational facility in the vicinity of Lake Keesus, located on the northern most section of the Lake in what is considered North Bay. A wetland area located on the western shoreline of the southwestern bay is currently under public ownership by the Wisconsin Department of Natural Resources. There is currently no public or private access on Lake Keesus, although a public access and parking facilities are scheduled to be constructed during 1998 by the Lake Keesus Management District with funds provided, in part, by the Wisconsin Department of Natural Resources.

Water-based outdoor recreational activities on Lake Keesus include boating, fishing, swimming, and other active and passive recreational pursuits. Because of its size, Lake Keesus receives a significant amount of powerboat use, and many of these craft were moored along the shore. Boating surveys conducted in July and September of 1995 indicated that up to 21 watercraft of various types were in use on the Lake at one time on those days, as set forth in Table 18. Based upon the survey of moored and stored boats, it was also estimated that 350 boats of riparian property origin are available for use on the Lake.

A water use survey, conducted during 1991 by the Lake Keesus Advancement Association, in cooperation with the College of Natural Resources, University of Wisconsin-Stevens Point,[2] identified swimming and boating as the primary lake uses during the summer months. Together with angling, these activities represented over one-half of the total use made of the Lake which was described as moderate to heavy. Winter usage of the Lake was primarily related to skating and ice-fishing and were less intense than summer usage. The majority of respondents made daily use of the Lake during summer, but restricted their use in winter primarily to weekends. Weekend use exceeded weekday use, and duration of weekend use was generally greater than during the week; duration of use was also greater in summer than in winter. Although all respondents reported passive use of the Lake for aesthetic viewing, few recognized such use as a recreational use of the waterbody. Active lake uses centered along the southern lakeshore (site of the former private access site) and main Lake basin.

Prior to 1996, the Badgerland Water Ski Team made extensive use of the southern portion of Lake Keesus during the summer months. The Badgerland Water Ski

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

[2]*Jeffrey A. Thornton, "Perceptions of Public Waters: Water Quality and Water Usage in Wisconsin," in Thomas VanValey, Sue R. Krull, and Lewis Walker,* The Small City and Regional Community, Proceedings of the 1992 Conference, Western Michigan University, Volume 10, *Center for the Small City, University of Wisconsin Stevens-Point Press, 1993, pp. 469-478.*

Table 18

RECREATIONAL USE SURVEY FOR LAKE KEESUS

	Participants			
	Weekday July 25, 1995		Weekend September 9, 1995	
Activity	10:30 a.m. to 11:00 a.m.	1:00 p.m. to 1:30 p.m.	10:30 a.m. to 11:00 a.m.	3:30 p.m. to 4:30 p.m.
Fishing	2	0	0	5
Pleasure Boating	0	1	2	12
Skiing	1	0	0	1
Sailing	0	0	1	2
Jet Skiing	0	0	0	1
Swimming	0	3	0	0
Windsurfing	0	0	0	0
Total	3	4	3	21

Source: SEWRPC.

Team operated from the private launch site on the southeastern shore of Lake Keesus on a lake course that extended from the southeastern shore of the Lake into the eastern portion of the main Lake and into the middle embayment on the western shore of the Lake. The team provided weekly ski shows during the summer season that were well attended by residents and visitors to the Lake. However, the hours during which the team practiced throughout the week, and areas of the Lake which the team used and required the operation of their high-speed watercraft, also created a degree of controversy in the community, with some lake residents and users alleging significant shoreline erosion, lake bottom habitat, and other recreational and aesthetic disruption consequent to the Team's operations. These issues remained unresolved when, in 1996, the private access site on the Lake was closed to make way for a residential development and development of the proposed public access site, and the necessary permits for the Team to operate their ski show on the Lake were not obtained.[3]

Determination of the amount of access that should be accommodated at Lake Keesus is dependent on the areal extent of open water lake surface. Lake Keesus, with a surface area of 237 acres, falls into the 100- to 499-acre category for recreational use lakes established in Chapter NR1 of the *Wisconsin Administrative Code*. The criteria set forth in this Chapter establish a minimum number of car-trailer units that could be accommodated at Lake Keesus as a combination of seven car-trailer units, plus a handicapped-accessible unit, for a total of eight units; and a maximum number of car trailer units as a combination of 15 car-trailer units, plus a handicapped-accessible unit, for a total of 16 units. Standards set forth in the Regional and County land use plans indicate that the fast or high-speed boating capacity of the Lake is limited to 16 boats. Assuming that 5 percent of the approximately 350 watercraft moored or trailered at Lake Keesus are in operation as fast or high-speed boats, the high-speed boating capacity of Lake Keesus would be largely used by the riparian residents. Observations by Commission staff, conducted during July and September 1995, indicated that between one and 12 high-speed watercraft were in operation during weekdays and weekend days on Lake Keesus. These observations indicate that some additional boating can be accommodated, as would be expected with development of a public recreational boating access.

It is important to note that the provision of park and open space sites in the Lake Keesus drainage area should be guided, to a large extent, by the recommendations contained in the Waukesha County Park and Open Space

[3]*During 1996 and 1997, the Badgerland Water Ski Team relocated operations to other waterbodies, including a portion of the Fox River within the Frame Park in the City of Waukesha.*

Plan[4] as refined in the County development plan. [5]The purpose of the plan is to guide the preservation, acquisition, and development of land or park, outdoor recreation, and related open space purposes and to protect and enhance the underlying and sustaining natural resource base of the County. With respect to the Lake Keesus drainage area, the plans recommend the maintenance of existing park and open space sites in the area and provisions of a public recreational boating access site on the Lake. In addition, the plans recommend that the undeveloped lands in the primary environmental corridor around Lake Keesus be retained and maintained as natural, open space through zoning or public acquisition, especially those areas of local, regional, or countywide significance as set forth in the regional natural areas or critical species habitat plan.[6] There is one site, Camp Whitcomb lowland, of local significance in the drainage area tributary to Lake Keesus, and one site of Countywide significance, the Lake Keesus fen-meadow, located southwest of the Lake in the vicinity of the outlet wetland complex.

Wisconsin Department of Natural Resources Recreational Rating

A recreational rating technique has been developed by the Wisconsin Department of Natural Resources to characterize the recreational value of inland lakes. As shown in Table 19, under this rating technique, Lake Keesus would receive 50 out of the possible 72 points, indicating that moderately diverse recreational opportunities are provided by the Lake. Favorable features include the healthy fishery and boating opportunities provided, while unfavorable features include variable water quality and aquatic macrophyte growth. In general, Lake Keesus provides good opportunities for a variety of outdoor recreational activities, particularly boating, fishing, and aesthetic enjoyment. In order to assure that Lake Keesus will continue to provide such recreational opportunities, the resource values of the Lake must be protected.

Recreational Use Conclusions

The scope of uses engaged in on Lake Keesus is sufficiently broad to be consistent with the recommended use objectives of full recreational use and the support of a healthy warmwater sport fishery, as set forth in the regional water quality management plan.[7]

WATER USE OBJECTIVES

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

The recommended full recreational use objective provides for full-body contact recreational use. In addition, field observations at Lake Keesus by Commission staff during 1995 confirmed the desire of the community to engage boating activities. Pleasure boating was one of the most popular activities reported during the aforereferenced water use and quality survey conducted during 1991 and observed during the field reconnaissance conducted during the summer of 1995 with upwards of 12 watercraft being observed to be in operation on the Lake for this purpose—or about one-half of the total number of watercraft in operation at the time of the reconnaissance—as shown in Table 18.

The recommended warmwater sport fishery objective is supported in Lake Keesus by a sport fishery based largely on bass and panfish during the warm-weather months, with walleyed pike and some northern pike also being caught mostly during the ice-fishing season. These fishes have traditionally been sought-after in Lake Keesus.

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

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

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

[7]*SEWRPC Planning Report No. 30, Volume Two, op. cit., Map 1, p. 14; also SEWRPC Memorandum Report No. 93, op. cit., p. 199.*

Table 19

DEPARTMENT OF NATURAL RESOURCES RECREATIONAL RATING OF LAKE KEESUS

Space: Total Area—237 acres Total Shore Length—5.3 miles

Ratio of Total Area to Total Shore Length: 0.070

Quality (18 maximum points for each item)

Fish:		
__ 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
Swimming:		
__ 6 Extensive sand or gravel substrate (75 percent or more)	__ 4 Moderate sand or gravel substrate (25 to 50 percent)	X 2 Minor sand or gravel substrate (less than 25 percent)
__ 6 Clean water	X 4 Moderately clean water	__ 2 Turbid or darkly stained water
__ 6 No algae or weed problems	X 4 Moderate algae or weed problems	__ 2 Frequent or severe algae or weed problems
Boating:		
X 6 Adequate water depths (75 percent of basin more than five feet deep)	__ 4 Marginally adequate water depths (50 to 75 percent of basin more than five feet deep)	__ 2 Inadequate depths (less than 50 percent of basin more than five feet deep)
__ 6 Adequate size for extended boating (more than 1,000 acres)	X 4 Adequate size for some boating (200 to 1,000 acres)	__ 2 Limit of boating challenge and space (less than 200 acres)
__ 6 Good water quality	X 4 Some inhibiting factors such as weedy bays, algae blooms, etc.	__ 2 Overwhelming inhibiting factors such as weed beds throughout
Aesthetics:		
X 6 Existence of 25 percent or more wild shore	__ 4 Less than 25 percent wild shore	__ 2 No wild shore
__ 6 Varied landscape	X 4 Moderately varied	__ 2 Unvaried landscape
__ 6 Few nuisances, such as excessive algae, carp, etc.	X 4 Moderate nuisance conditions	__ 2 High nuisance condition

Total Quality Rating: 50 out of a possible 72

Source: Department of Natural Resources and SEWRPC.

WATER QUALITY STANDARDS

The water quality standards supporting the warmwater fishery and full recreation use objectives as established for planning purposes in the regional water quality management plan, are set forth in Table 20. These standards are similar to those set forth in Chapters NR 102 and 104 of the *Wisconsin Administrative Code*, but were refined for planning purposes in terms of their application. Standards are recommended for temperature, pH, dissolved oxygen, fecal coliform, and total phosphorus. These standards apply to the epilimnion of the lakes and to streams. The total phosphorus standard applies to spring turnover concentrations measured in the surface

Table 20

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

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

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

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

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

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

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

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

Source: SEWRPC.

waters. Such contaminants as oil, debris, and scum; or odor, taste, and color-producing substances; and toxins are not permitted in concentrations harmful to the aquatic life as set forth in Chapters NR 102 of the *Wisconsin Administrative Code*.

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

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Chapter VII

ALTERNATIVE WATER QUALITY MANAGEMENT MEASURES

INTRODUCTION

Based upon the review of the lake resident survey conducted in 1991,[1] a review of the inventory and analyses set forth in Chapters II through V, and consideration of the water use and recreational use objectives set forth in Chapter VI, the following issues were identified as requiring consideration in the formulation of alternative and recommended lake management measures: 1) water quality improvement; 2) aquatic plant management; 3) onsite sewage disposal; 4) recreational lake use and lake use management; 5) fishery management; and, 6) water level control.

Potentially effective measures for the management of Lake Keesus include watershed management and land use planning and zoning, and in-lake rehabilitation techniques. Watershed management and land use planning and zoning can serve to protect the Lake by promoting and maintaining a sound land use pattern in the area; protecting groundwater recharge areas; and reducing runoff of nonpoint source pollutants to the Lake. In-lake rehabilitation techniques would seek to treat directly the identified problems.

LAND USE PLANNING AND ZONING ALTERNATIVES

A basic element of any water quality management effort for a lake is the promotion of sound land use development and management in the tributary watershed. The type and location of future urban and rural land uses in the tributary drainage area to Lake Keesus will to a large degree determine the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, stormwater management; and, to some degree, the water quality of the Lake.

Existing 1990 and planned year 2010 land use patterns and existing zoning regulations in the tributary area to Lake Keesus have been described in Chapter III. If the recommendations set forth in the adopted regional land use plan are followed, under year 2010 conditions, no significant changes in land use conditions within the drainage area tributary to Lake Keesus would occur. However, some infilling of existing platted lots and some backlot development would be expected to occur. In addition, the redevelopment and reconstruction of existing single-family homes on lakefront properties may be expected. Recent surveillance indicates that large-lot subdivision development, at densities of three to five acres per dwelling unit, is occurring in the areas in which such development was not envisioned in the adopted regional land use plan. If this trend continues, much of the open space areas remaining in the drainage area of the Lake will be replaced over time with large-lot urban development. This may be expected to increase the pollutant loadings to the Lake associated with urbanization and increase the pressure for recreational use of the Lake. Under the full buildout condition envisioned under the Waukesha County development plan[2] completed in 1996, significantly increased levels of low-density and suburban-density residential development of lands directly tributary to Lake Keesus are envisioned. Given the foregoing, it would be desirable to carefully evaluate land use development or redevelopment proposals around the shoreline of Lake Keesus and within the drainage area tributary to the Lake for potential impacts on the Lake.

One option for minimizing the effect of future development on Lake Keesus is to carefully review the applicable zoning ordinances and propose changes addressing the concerns noted. Changes in the zoning ordinance could be considered to minimize the areal extent of the development by providing specific provisions and incentives to cluster residential development on smaller lots while preserving portions of the open space on each

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[1] *Jeffrey A. Thornton, "Perceptions of Public Water: Water Quality and Water Use in Wisconsin,"* The Small City and Regional Community, Volume 10, *University of Wisconsin-Steven Point Press, 1993, pp. 469-478.*

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

property or group of properties considered for development.[3]

Wetland and groundwater recharge area protection can be accomplished through land use regulation and public acquisition of sensitive sites, and both are measures that should be considered for inclusion in the recommended Lake Keesus management plan. Wetlands in the Lake Keesus drainage area are shown on Map 18. These wetland areas are currently protected to a degree under the U.S. Army Corps of Engineers 404 Permit Program and the Waukesha Shoreland Zoning Program, and local zoning ordinances. Nearly all wetland areas in the Lake Keesus drainage area are included in the environmental corridors delineated by the Regional Planning Commission. A significant portion of wetland areas in the vicinity are included in lands currently owned by the State of Wisconsin as part of the Wisconsin Department of Natural Resources lands located on the southwestern shore of the Lake.

WATERSHED MANAGEMENT ALTERNATIVES

Watershed management measures may be used to reduce nonpoint source pollutant loadings from such rural sources as runoff from crop and pasture lands, and from livestock wastes; from such urban sources as runoff from residential, commercial, industrial, transportation, and recreational land uses; from construction activities; and from onsite sewage disposal systems. The subsequently described watershed-based nonpoint source pollution control measures considered in this report are based upon the recommendations set forth in the adopted regional water quality management plan,[4] the Oconomowoc River priority watershed plan,[5] the Waukesha County soil erosion control plan,[6] and information presented by the U.S. Environmental Protection Agency.[7]

An estimate of nonpoint source pollutant loadings from the various pollution sources in the drainage area of the Lake has been presented in Chapter IV. The inventory identified nonpoint pollution sources within the Lake Keesus drainage area which included upland agricultural field and open land erosion. Streambank and lakeshore erosion, urban runoff, and construction site erosion were not identified as significant potential sources of water pollution in this watershed, although urban runoff and construction site erosion are potential future sources of nonpoint source pollution given the intensity of development set forth in the aforereferenced County development plan. Notwithstanding, the control of nonpoint sources of water pollution from these rural and residential lands in the tributary watershed can be achieved to some degree through relatively low-cost measures. Properly applied, such measures can reduce the pollutant loadings to the Lake by about 25 percent. The pollutant loadings which are the most controllable include runoff from the residential lands adjacent to the Lake and the onsite sewage disposal systems. The potential exists within the watershed for significant construction site erosion impacts if development continues in the tributary watershed as has been the recent trend. Such impacts are partially controllable by application of sound construction erosion control practices.

Appendix A presents a list of nonpoint source pollution management measures that could be considered for use in the Lake Keesus area to reduce loadings from non-

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

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

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

[6]*SEWRPC Community Assistance Planning Report No. 159,* Waukesha County Agricultural Soil Erosion Control Plan, *June 1988.*

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

point sources of pollution. Information on the cost and effectivity of the measures is also presented in this appendix.

Urban Nonpoint Source Controls

Established urban uses comprise about 445 acres, or about 17 percent, of the drainage area tributary to Lake Keesus. The annual phosphorus loading from the urban lands, including phosphorus loading from onsite sewage disposal systems, is estimated to be 210 pounds, with the total urban loading being approximately equally distributed between urban nonpoint sources and onsite sewage disposal systems.

The regional water quality management plan recommends that the nonpoint source pollutant loadings from urban areas tributary to Lake Keesus be reduced by about 25 percent, in addition to reductions from urban construction erosion control, onsite sewage disposal system management, and streambank and shoreline erosion control measures. As described in Chapter IV, all of these loadings together constitute about 14 percent of the total loading to Lake Keesus. Consideration should be given to reducing the pollutant loadings from the controllable sources to the extent practicable in order to minimize the negative results of nutrient loadings on the Lake.

Potentially applicable urban pollution control measures include wet detention basins, grassed swales, and good urban "housekeeping" practices. Generally, the application of low-cost urban housekeeping practices may be expected to reduce nonpoint source loadings from urban lands by about 25 percent. Public information programs can be developed to encourage good urban housekeeping practices, to promote the selection of building and construction materials which reduce runoff contributions of metals and other toxic pollutants, and to promote the acceptance and understanding of the proposed pollution abatement measures and importance of lake water quality protection. Urban housekeeping practices and nonpoint source controls include restricted use of fertilizers and pesticides, improved pet waste and litter control, the substitution of plastic for galvanized steel and copper roofing materials and gutters, proper disposal of motor-vehicle fluids, proper disposal or recycling of leaves and yard waste, and reduced use of street deicing salts.

Proper design and application of urban nonpoint source control measures, such as grassed swales and detention basins, requires preparation of a detailed stormwater management system plan that addresses stormwater drainage problems and control of nonpoint sources of pollution. Based upon a preliminary evaluation, however, it is estimated that the practices which could be effective in the tributary area are limited largely to good urban housekeeping practices and grassed swales. Review of the distribution of the pollutant loadings relative to the location of the potential sites for detention basins within existing areas of urban development surrounding Lake Keesus indicates that such basins would be relatively ineffective, as well as costly, since stormwater flow to the Lake generally occurs in the form of short overland sheet flows, making it difficult to collect and detain stormwater runoff from reasonably large areas at discrete locations. However, such measures could be considered for use should future residential development in the drainage area tributary to Lake Keesus be at such densities as to make the collection and detention of stormwater economically feasible. Stormwater management measures are recommended to be considered for use in future clustered developments.

Developing Areas

Developing areas can generate significantly higher pollutant loadings than established areas of similar size. Developing areas include a wide array of activities, including urban renewal projects, individual site development within the existing urban area, and new land subdivision development. Between 1985 and 1990, development was occurring on an average of about seven acres of land per year in the Lake Keesus drainage area. This rate of development is expected to continue or increase based upon the current zoning and the planned conditions set forth in the County development plan.

Construction sites especially may be expected to produce suspended solids and phosphorus loadings at rates several times higher than established urban land uses. Control of sediment loss from construction sites can be provided by measures set forth in the construction erosion control ordinances, based on the model ordinance developed by the Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,[8] adopted by Waukesha County. These controls are temporary measures taken to reduce pollutant loadings from

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[8]*Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook, *1989. These ordinances define the land disturbance activities subject to control, set forth standards and criteria for erosion control, describe permit application and administrative procedures, and identify enforcement and appeal procedures.*

construction sites during stormwater runoff events. Construction erosion controls may be expected to reduce pollutant loadings from construction sites by about 75 percent. Such controls are important measures to take in order to prevent localized short-term loadings of phosphorus and sediment from the tributary drainage area, and may be anticipated to have a potentially significant impact on the total pollutant loading to the Lake as the intensity of land use development increases. Control measures include such revegetation practices as temporary seeding, mulching, and sodding and such runoff control measures as filter fabric fences, straw bale barriers, storm sewer inlet protection devices, diversion swales, sediment traps, and sedimentation basins.

At the present time, Waukesha County has adopted a construction site erosion control ordinance which is administered and enforced by the County in both the shoreland and nonshoreland areas of the Towns of Merton and Lisbon in the drainage area tributary to Lake Keesus. The provisions of this ordinance apply to all development except single- and two-family residential construction. Single- and two-family construction erosion control measures are specified as part of the building permit process. Washington County also has a soil erosion control and stormwater management ordinance which is enforced by the County in unincorporated areas and in larger-scale developments, such as subdivisions and planned unit developments. Individual small-scale development sites and other construction sites are also controlled under this ordinance, unless similar or more restrictive local zoning ordinance provisions apply.

Because of the potential for development, albeit unplanned, it is important that adequate construction erosion control programs, including ordinance enforcement, be in place.

Rural Nonpoint Source Controls

Rural uses comprise about 2,200 acres, or about 83 percent, of the drainage area tributary to Lake Keesus. The annual sediment and phosphorus loadings from the rural lands are estimated to be 350 tons and 1,300 pounds, respectively. Upland erosion from agricultural and other rural lands is a major contributor of sediment to streams and lakes in the Oconomowoc River watershed, generally, and to Lake Keesus, in particular, even though the Lake is situated on a tributary stream to the Oconomowoc.

The regional water quality management plan recommends measures be taken to provide about a 25 percent reduction in nonpoint source pollution loading from rural lands in the watershed.[9] As described in Chapter IV, loadings from rural lands constitute about 90 percent of the total loadings to Lake Keesus. It is estimated that the largest portion of these pollutant loadings, about 1,265 pounds of phosphorus and 330 tons of sediment, or about 85 percent of these loadings, are contributed annually from the agricultural lands in the drainage area tributary to Lake Keesus. Such lands comprise about 1,690 acres, or about 63 percent, of the drainage area tributary to Lake Keesus. While the sediment loadings estimated from inventories compiled by the Oconomowoc River Nonpoint Source Pollution Control Priority Watershed Program did not generally exceed the target level of agricultural erosion control of three tons per acre per year identified in the Waukesha County agricultural soil erosion control plan, approximately 183 acres of the 1,502 acres inventoried by the DNR were considered to be in need of control measures to reduce soil loss to tolerable levels.[10] Potentially applicable rural pollution control measures include conservation tillage, and establishment and maintenance of stream bank buffer strips—stream bank management zones—especially around drain tiles in the watershed. Implementation of these recommendations is considered to be adequate for water quality management purposes related to Lake Keesus.

Detailed farm conservation plans will be required to adapt and refine erosion control practices for individual farms. Generally prepared with the assistance of the U.S. Natural Resources Conservation Service or County Land Conservation Department staffs, such plans identify desirable tillage practices, cropping patterns, and

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[9]*As recommended in the regional water quality management and County agricultural soil erosion control plans, detailed farm conservation plans will be required to adapt and refine these recommendations for individual farm units. Conservation plans are detailed plans, generally prepared with the assistance of the U.S. Natural Resources Conservation Service or County Land Conservation Department staffs, intended to guide agricultural activity in a manner which conserves soil and water resources. The conservation plan indicates desirable soil management practices, cropping patterns, and rotation cycles, considering the specific topography, hydrology, and soil characteristics of the farm, together with the specific resources of the farm operator and the operator's objectives as owner or manager of the land.*

[10]*Wisconsin Department of Natural Resources Publication No. PUBL-WR-194-86, op. cit.*

rotation cycles, while considering the specific topography, hydrology, and soil characteristics of the farm; identify the specific resources of the farm operator; and articulate the operator objectives of the owners and managers of the land.

Onsite Sewage Disposal System Management

As described in Chapter IV, onsite sewage disposal systems are estimated to contribute about 100 pounds, or about 7 percent, of the total phosphorus loading to Lake Keesus.[11] In addition to lake water quality considerations, sewage disposal options in the area have implications for groundwater quality and property values. Thus, onsite sewage disposal is an important consideration in the Lake Keesus area. Two basic alternatives can be considered for abatement of pollution from onsite sewage disposal systems: 1) continued reliance on, and management of, the onsite sewage disposal systems; and, alternatively, 2) the construction of a public sanitary sewer system.

In the adopted regional water quality management plan, the concentrations of urban development located along the shorelines of Lake Keesus were not included within recommended public sanitary sewer service areas. Rather, the area was identified as an urban concentration whose sewage disposal needs would continue to be provided through onsite sewage disposal systems. The regional plan, however, also recommended that sewerage needs in such areas be periodically reevaluated in light of changing conditions.

During 1997, such a reevaluation of the need for public sanitary sewerage, as recommended in the regional water quality management plan, was underway as part of a study of sewerage needs in the northwestern portions of Waukesha County.[12] Preliminary results from this planning project indicate that the sewage disposal needs of the urban development surrounding Lake Keesus should continue to be provided by onsite sewage disposal systems in the near term. Given the age of the existing onsite sewage disposal systems, the lot sizes, and the steeply sloped areas in some portions of the shoreline development, the sewerage system plan recommends that the urban development be included in the long-term planned sewer service area. However, for planning purposes, it is assumed that connection of this area to a public sanitary sewer system will be deferred until beyond the year 2010. Given that it is expected that the area will continue to rely on onsite sewage disposal systems for the next 10 or more years, it is recommended that a continuing onsite sewage disposal system management program be carried out in conjunction with the Waukesha County Department of Parks and Land Use, Environmental Health Division. The basic objective of such a program would be to ensure the proper installation, operation, and maintenance of existing systems, and of any new systems that may be required to serve existing urban development in the drainage area tributary to Lake Keesus. An onsite sewage disposal system management program could potentially be undertaken by the assumption of sanitary district powers by the existing lake protection and rehabilitation district, or through the creation of a separate sanitary district. A major component of such a program would be a regular inspection program. A secondary benefit of an inspection program would be the knowledge system owners would gain from the periodic inspection of these systems and identification of any deficiencies. A continuing informational and educational effort should also be included in an onsite sewage system management plan. Homeowners should be advised of the rules, regulations, and system limitations governing onsite sewage disposal systems, and should be encouraged to undertake preventive maintenance programs.

Conclusion: Nonpoint Source Pollution Controls

Implementation of nonpoint source pollution control measures in the drainage area directly tributary to Lake Keesus can achieve the pollutant loading reductions set forth in the regional water quality management plan, and refined in the Oconomowoc River priority watershed plan. Based upon the likely level of control of nonpoint source pollutants that can be achieved through implementation of the measures set forth above, and identified in Appendix A, these pollutant loading reduction measures should reduce nonpoint source pollutants loads from urban areas by up to 40 percent and from rural areas by up to 25 percent.

IN-LAKE MANAGEMENT ALTERNATIVES

The reduction of external nutrient loadings to Lake Keesus by the aforedescribed measures should help to prevent deterioration of lake water quality conditions. These measures are not expected to eliminate existing

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

[12] *Black & Veatch,* A Sanitary Sewerage System Plan for the Northwestern Waukesha County Area, *Draft, in preparation.*

water quality and lake-use problems. In mesotrophic and eutrophic lakes, water quality and other in-lake conditions can result in abundant macrophyte growth which restricts water use potentials. In addition, lake water level, shoreline, and recreational use problems can require direct treatment measures. Thus, the application of in-lake rehabilitation techniques should be considered.

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

Alternative lake rehabilitation measures include in-lake water quality, aquatic plant, fish, shoreline, and recreational use management measures. Each of these groups of management measures, together with the attendant costs, are set forth in Tables 21 through 24 and described briefly below.

Water Quality Management Measures

The in-lake management practices set forth in Table 21 include a variety of measures designed to directly modify the magnitude of either a water quality determinant or biological response. Specific measures aimed at managing aquatic plants and fishes are considered separately.

Phosphorus Precipitation and Inactivation

Nutrient inactivation is a restoration measure designed to limit the biological availability of phosphorus by chemically binding the element in the lake sediments using a variety of divalent or trivalent cations—highly positively charged elements. Aluminum sulphate (alum), calcium carbonate (lime), ferric chloride, and ferric sulphate are commonly used cation sources. The susceptibility of portions of Lake Keesus to wind- and boat motor-induced mixing excludes the use of nutrient inactivation in Lake Keesus.

Nutrient Load Reduction

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

Controlling in-lake nutrients generally involves removing contaminated sediments or encapsulating nutrients by chemical binding. Costs are generally high, as it involves an engineered design and usually some form of pumping or excavation. Effectiveness is variable.

External nutrient load reduction measures are recommended, while internal nutrient load reduction measures are not recommended for use in Lake Keesus.

Water Level Management Measures

The in-lake management measures set forth in Table 22 consist of actions designed to modify the depth of water in the waterbody. Generally, the objective of such manipulation is to enhance a particular class of recreational use and/or to control the types and densities of organisms within the waterbody.

Drawdown

Water level management refers to the manipulation of lake water levels, especially in man-made lakes, in order to change or create specific types of habitat and thereby manage species composition within a waterbody. Drawdown may be used to control aquatic plant growth and to manage fisheries. However, due to the unpredictability of the results, the impairment of recreational uses, and the temporary nature of the beneficial effects of a drawdown, drawdown is not recommended for Lake Keesus.

Dredging

Sediment removal is a restoration measure that is carried out using a variety of both land-based and water-based techniques, depending on the extent and nature of the sediment removal to be carried out. Both methods are expensive, especially if a suitable disposal site is not located close to the dredge site. The effectiveness of dredging varies with the effectiveness of watershed controls in reducing or minimizing the sediment source. The potential negative environmental effects of a large-scale lakewide dredging project and the high cost associated with dredge spoil disposal, indicates that this option

Table 21

MANAGEMENT ALTERNATIVES FOR LAKE KEESUS WATER QUALITY MANAGEMENT

Management Alternatives	Summary Description	Estimated Cost	Advantages	Disadvantages	Considered Viable for Inclusion in Lake Management Plan
Phosphorus Precipitation and Inactivation	Positively-charged elements, such as aluminum, iron and calcium, chemically bind phosphorus in a form that limits the availability of the nutrient for plant growth within the lake and further limits the potential for the nutrient to be released from the lake sediments during periods of anoxia	$150 per ton; 2.5 tons per acre	• Removes phosphorus from the water column • Improves water clarity	• Limited effectiveness in shallow waters • Must be reapplied • High cost to implement	No
Nutrient Load Reduction (external)	Land management measures reduce the mass of contaminants reaching the lake	- -	• Addresses contamination at source • Consistent with good housekeeping and sound land development practices	• May be difficult to implement as it requires changes in current practices • May have high cost to implement	Yes
Nutrient Load Reduction (internal)[a]	Contaminated sediments are removed or encapsulated	$3.00 to $15 per cubic yard	• Minimizes resuspension and release of contaminants	• High cost to implement • Variable results	No

[a]*See also dredging and sediment removal measures set forth in Table 23.*

Source: SEWRPC.

should be considered only on a limited basis for small-scale projects designed to improve hydraulic capacity or boating access. Given the proximity of shoreland wetlands, and the presence of DNR-designated sensitive areas, dredging in Lake Keesus is not generally recommended.

It should be noted, however, that during the 1980s Lake Keesus experienced a period of elevated water levels which created a significant level of concern within the riparian community. As a consequence, the Lake Keesus Advancement Association, in cooperation with the Southeastern Wisconsin Regional Planning Commission, commissioned Ruekert & Mielke to undertake an hydrological study of the Lake in order to identify appropriate mitigation measures. This study, based upon hydrological conditions existing within Lake Keesus during November 1987, identified four options for controlling water levels within the Lake; namely, 1) dredging the outlet channel of the Lake west of Camp Whitcomb Road, 2) excavating a channel of constant slope between CTH E and Camp Whitcomb Road, 3) constructing an outlet control structure, and 4) maintaining the outlet channel. Of these measures, Alternative 4 was recommended as the option least disruptive of the wetland system traversed by the outlet channel.[13] This recommendation was implemented by the Lake Keesus Advancement Association in 1988, when the Association undertook the clearing of debris and vegetation from the outlet channel of the Lake. This maintenance program restored the historic hydraulic capacity of the outlet and moderated lake levels within Lake Keesus during subsequent years.

Aquatic Plant Management Measures

The management measures set forth in Table 23 are aimed at both the removal of nuisance vegetation and the manipulation of aquatic plant species composition in order to enhance and provide for recreational water use.

[13]*Ruekert & Mielke,* Lake Keesus Water Level Study, *January 1988.*

Table 22

MANAGEMENT ALTERNATIVES FOR LAKE KEESUS WATER LEVEL MANAGEMENT

Management Alternatives	Summary Description	Estimated Cost	Advantages	Disadvantages	Considered Viable for Inclusion in Lake Management Plan
Drawdown	Changes in water level are used to manipulate species composition of fishes and aquatic plants and control nutrient release from lake bottom sediments	- -	• May affect species composition • Can result in sediment compaction and stabilization • Can enhance rough fish control	• Variable results • May result in an initial nutrient surge on reflooding • May limit the use of some areas of the waterbody • Must be reapplied	No
Dredging	Accumulated sediment and associated contaminants are removed from the waterbody	$3.00 to $15 per cubic yard	• Increases lake depth • Removes nutrients and toxic pollutants • Can remove oxygen demanding substances • May be applied to specific locations	• Short-term negative consequences on aquatic habitats • May encourage nuisance species colonization of the disturbed lakebed • Effectiveness varies with level of source control applied • High cost to implement • Impacts may be temporary	Yes

[a]*Dredging and drawdowns may require local, State, or Federal permits.*

Source: SEWRPC.

Generally, aquatic plant management measures are classed into four groups: physical measures which include lake bottom coverings and water level management; mechanical removal measures which include harvesting and manual removal; chemical measures which include the use of aquatic herbicides; and biological control measures which include the use of various organisms, including insects. Of these, chemical control and biological controls are stringently regulated and require a State permit. Costs range from minimal for manual removal of plants using rakes and hand-pulling to upwards of $90,000 for the purchase of a mechanical plant harvester—the operational costs for which can approach $10,000 to $20,000 per year depending on staffing and operating policies. Harvesting is probably the measure best suited to large areas of open water, while chemical controls may be best suited to use in confined areas and for initial control of invasive plants. Controlling Eurasian water milfoil by planting native plant species or by introducing the weevil, *Eurhychiopsis lecontei*, are largely experimental on a lakewide basis, but can be considered for use in a specialized shoreland management zone at the water's edge.

Aquatic Herbicides

Chemical treatment with aquatic herbicides is a short-term method of controlling heavy growths of aquatic macrophytes and algae. Chemicals are applied to the growing plants in either liquid or granular form. Because of the demonstrated need to control aquatic plants in selected areas of Lake Keesus, the relatively low cost of chemical treatment, and current management decisions which have indicated a need for some chemical treatment, chemical treatment is a viable management option and should be considered for Lake Keesus, especially for the control of the blue-green alga, *Gleotrichia* sp.

Table 23

MANAGEMENT ALTERNATIVES FOR LAKE KEESUS AQUATIC PLANT MANAGEMENT

Management Alternatives	Summary Description	Estimated Cost	Advantages	Disadvantages	Considered Viable for Inclusion in Lake Management Plan
Aquatic Herbicides	Chemical agents applied to the lake water in liquid or granular form control the growth of undesirable aquatic plants and algae	$250 to $500 per acre per year	• Easy to use • Convenient to apply • Delivers rapid control of plants • May be selective • Cost effective	• May have short-term, lethal effects and long-term, sublethal effects • May lead to algal blooms • Releases nutrients into the water and adds organic matter to the sediments • May lead to depletion of dissolved oxygen • Destroys habitat • Must be reapplied each summer • May be nonselective • Affects water uses for some period	Yes
Aquatic Plant Harvesting	Removal or harvesting of aquatic macrophytes using specialized mechanical equipment consisting of a cutting apparatus which cuts up to eight feet below the water surface and a conveyor system to cut plants and haul them to shore	Operating and maintenance costs equals $10,000 to $20,000 per year; capital costs equals $100,000 per decade	• Removes plant biomass and nutrients • Can affect the regrowth of certain plants • May remove filamentous algae • Retains habitat and stabilizes lake sediments • May reduce stunted populations of panfish by *increasing* predation in opened areas • Cut plants can be used as mulch	• Cannot be used in shallow water • Difficult to use around docks and buoys • Can increase turbidity and bottom-dwelling fauna • May lead to algal blooms • May catch young-of-the-year fish and fish-food organisms • May adversely affect habitat • May favor Eurasian water milfoil which propagate from cut fractions • High cost to implement	Yes
Manual Harvesting of Aquatic Plants	Aquatic plants are removed by hand or hand-operated devices in limited areas	$100	• Selective • Cost effective	• Effective only in very small areas • Physically demanding to employ	Yes
Biological Control of Aquatic Plants	Biological control agents such as fish, aquatic insects, and competing aquatic plant species are used to manipulate the species composition of aquatic plants in lakes	- -	• Acts in a "natural" manner • May be selective • Easy to apply	• May not be selective • May not be compatible with other aquatic plant control measures • May be prohibited in Wisconsin	No

Table 23 (continued)

Management Alternatives	Summary Description	Estimated Cost	Advantages	Disadvantages	Considered Viable for Inclusion in Lake Management Plan
Physical Control of Aquatic Plants	Placement of bottom coverings on the lakebed shade out undesirable plants in small areas of the lake	$50 to $250 per 700 square feet	• Site specific • Unobtrusive	• Difficult to install • Nonselective • May be expensive to acquire and install properly • May be subject to movement or recreational interferences • Ongoing annual removal requirement	No
Public Information	Informing lake users and riparian residents of the value of native aquatic plants in lakes, and the location of environmentally sensitive or ecologically valuable areas within the lake basin, as well as identification and control measures, minimizes the spread of nuisance plant species, such as Eurasian water milfoil, and encourages the use of alternative measures to control undesirable aquatic plant growth	- -	• Low cost • Uses materials which are readily available • Can be undertaken by lake residents and/or school groups, service organizations, or units of government	• None known	Yes

[a]*Herbicide application should be undertaken by a licensed applicator; chemical herbicide application in aquatic environments require a Wisconsin Department of Natural Resources permit.*

[b]*Use of biological organisms to control aquatic plant growth may require State permits; use of grass carp as a control organism is not permitted in Wisconsin; use of the milfoil weevil, Eurhychiopsis lecontei is presently being employed on an experimental basis in selected Wisconsin lakes by the Wisconsin Department of Natural Resources and University of Wisconsin-Stevens Point, College of Natural Resources, between 1995 through 1998.*

Source: SEWRPC.

Aquatic Plant Harvesting

Aquatic macrophytes are mechanically harvested with specialized equipment consisting of a cutting apparatus, which cuts up to five feet below the water surface, and a conveyor system which picks up the cut plants and hauls them to shore. Because of the demonstrated need for aquatic plant control in Lake Keesus and because the current lake management decisions have indicated a need for aquatic plant harvesting, harvesting is considered a viable management option to continue.

Manual Harvesting

Due to an inadequate depth of water, it is not always possible for harvesters to reach the shoreline of every property. Manual harvesting involves the purchase of specially designed rakes, designed specifically to manually remove aquatic plants from the shoreline area. The advantage of the rakes is that they are easy and quick to use, and immediately remove the plants from the lake, whereas chemical treatment involves a waiting period. Removing the plants from the lake avoids the accumulation of organic matter on the lake bottom, which adds to the nutrients that favor more plant growth. Because maneuvering the mechanical harvester between the piers takes time and skill, manual harvesting is recommended for small area use in Lake Keesus.

Biological Controls

An alternative approach to controlling nuisance weeds, particularly Eurasian water milfoil, is biological control. Classical biological control has been successfully used to control both weeds and herbivorous insects.[14] Recent

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

Table 24

MANAGEMENT ALTERNATIVES FOR LAKE KEESUS FISH MANAGEMENT

Management Alternatives	Summary Description	Estimated Cost	Advantages	Disadvantages	Considered Viable for Inclusion in Lake Management Plan
Habitat Protection	Measures designed to maintain fish breeding habitat, feeding areas and food stuffs, and shelter, through shoreline erosion control and use of natural shoreline materials	- -	• Low cost • Promotes shoreline aesthetics while protecting habitat • Encourages natural reproduction • Contributes to maintaining healthy fish populations	• May limit application of other lake management measures by restricting areas in which other measures may be applied	Yes
Habitat Creation	Placement of rock cribs, brush piles, or other structures within a lake replaces or recreates habitat lost due to prior pollution, or lacking due to low numbers of aquatic plants	- -	• Replaces lost habitat • Provides habitat in situations where natural habitat availability is limited	• High cost to implement • May require permits	No
Modification of Species Composition	Stocking or removal of fishes manipulates the fishery and encourages healthy and balanced fish populations	- -	• Can potentially restore balance and diversity	• Uncertain effects • May require chemical treatments or removal of rough fish • Can be offset by recruitment • High cost to implement • Dependent on availability of fishes to be stocked • May have undesirable consequences if stocked fishes compete with native fishes	No
Regulation of Angling	Legal and informational measures limit the harvest of fishes from waterbodies, typically including public participation campaigns such as "catch-and-release" programs and regulatory programs, such as fishing license, fish size and numbers, and fishing season requirements	- -	• Traditional approach • Low cost	• May be difficult to implement as it requires changes in current practices • May not be fully observed • Requires enforcement	Yes

Source: SEWRPC.

aquatic weevil species, has potential as a biological control agent for Eurasian water milfoil,[15] and the use of *Eurhychiopsis lecontei* as a means of aquatic plant management control is being studied in selected lakes within Wisconsin.[16] Nevertheless, because of its experimental nature, it is not recommended for use on Lake Keesus at this time. Grass carp (*Ctenopharyngodon idella*), another potential biological control, are not permitted for use in Wisconsin.

Lake Bottom Covering

Lake bottom covers and light screens provide limited control of rooted plants by creating a physical barrier which reduces or eliminates the sunlight available to the plants. They have been used to create swimming beaches on muddy shores, to improve the appearance of lakefront property, and to open channels for motorboating. Sand and gravel are usually readily available and relatively inexpensive to use as cover materials, but plants easily recolonize areas so covered in about a year. Synthetic material, such as polyethylene, polypropylene, fiberglass, and nylon, can provide relief from rooted plants for several years, but must be removed annually to avoid displacement of the material and/or deposition of sediment over the material during the winter months, both of which would negate the effectivity of lake bottom covers as an aquatic plant management measure. Both methods require permits from the DNR. Because of the limitations involved, lake bottom covers as a method to control aquatic plant growth are not recommended for Lake Keesus.

Public Information

Aquatic plant management usually centers on the eradication of nuisance aquatic plants for the improvement of recreational lake use. The majority of the public view all aquatic plants as "weeds" and residents often spend considerable time and money removing desirable plant species from a lake without considering the environmental impact. Thus, public information is an important component of an aquatic plant management program. Posters and pamphlets are available from the University of Wisconsin-Extension and Wisconsin Department of Natural Resources that provide information and illustrations of aquatic plants, that detail their importance in providing habitat and food resources aquatic environments, and explain the need to control the spread of undesirable and nuisance plant species.

Fish Management Measures

Lake Keesus provides a quality habitat for a healthy, warmwater fishery. Adequate water quality, dissolved oxygen levels, and a diverse aquatic plant community contribute to the maintenance of a fish population that is dominated by desirable sport fish. Although fisheries data are limited, suitable conditions exist for the maintenance of a sport fish population in the Lake. The management measures set forth in Table 24 are designed to protect and enhance the lake fishery.

Habitat Protection

Habitat protection refers to a range of conservation measures designed to maintain existing fish spawning habitat, including measures such as restricting recreational and other intrusions into gravel-bottomed shoreline areas during the spawning season (for bass this is spring, mid-April to mid-June), use of natural vegetation in shoreland management zones, and other "soft" shoreline protection options that aid in habitat protection. Because these alternatives are preventative in nature, no cost is associated with them and application of these practices along the Lake Keesus shoreline is recommended.

Habitat Creation

In lakes where vegetation is lacking or where plant species diversity is low, artificial habitat may need to be developed. As discussed in Chapter V, the results of the aquatic plant surveys of Lake Keesus indicate that there is sufficient habitat for a healthy fish community. Therefore, habitat creation programs are not recommended for Lake Keesus.

Modification of Species Composition

Species composition management refers to a group of conservation and restoration measures which include the selective harvesting of undesirable fish species and the stocking of desirable species and are designed to enhance the angling resource value of a lake. These measures include water level manipulation, which can aid in breeding desirable species by increasing water levels in spring to provide additional breeding habitat for pike. Lake drawdown can disadvantage undesirable species by

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[15] *Sallie P. Sheldon, "The Potential for Biological Control of Eurasian Water Milfoil (*Myriophyllum spicatum*) 1990-1995 Final Report," Department of Biology Middlebury College, February 1995; U.S. Environmental Protection Agency Report No. EPA-841/F-97-002, Number 3,* Use of Aquatic Weevils to Control a Nuisance Weed in Lake Bomoseen, Vermont, *1997.*

[16] *L.L. Jester, M.A. Bozek, and S.P. Sheldon, "Researching the Use of an Aquatic Weevil for Biological Control of Eurasian Water Milfoil in Wisconsin,"* LakeLine, *Volume 17, Number 3, pp. 18-19, 32-34.*

concentrating forage fish, thus increasing predation success. This can also strand juveniles and desiccate the eggs of undesirable species. More extreme measures include fisherees that place a bounty on undesirable species as a means of increasing angling pressure on, or selectively cropping, certain fishes, poisoning, and enhancement of predation by stocking. In lakes with an unbalanced fishery, dominated by carp and other rough fish, chemical eradication has been used to manage the fishery. Lake drawdown is often used with the chemical treatments to expose spawning areas and eggs and concentrate fish in shallow pools, thereby increasing their availability to anglers, commercial harvesters, or chemical eradication treatments. Although they are generally effective, such extreme measures are not recommended for Lake Keesus where the fisheries value of the Lake has been assessed as good to excellent.

The more common management measure is stocking game fishes. The mixture of species is determined by the stocking objectives, which are usually to: supplement an existing population; maintain a population that cannot reproduce itself; add a new species to a vacant niche in the food web; replace species lost to a natural or manmade disaster; or establish a fish population in a depopulated lake. As these conditions are not known to exist in Lake Keesus, these measures are not recommended at this time. Rather, consideration should be given to monitoring and surveying the current fishery as discussed in Chapter VIII. Based upon data collected by this fishery survey, recommendations for modification of the species composition may be found to be needed.

Regulations and Public Information

To reduce the risk of overharvest, the DNR has placed restrictions on the number and size of certain fish species caught by anglers. The open season, size limits, and bag limits for the fish species of Lake Keesus are given in Table 25. Enforcement of these regulations is important to the success of any sound fish management program.

Shoreline Maintenance

Shoreline maintenance refers to a group of measures designed to reduce and minimize shoreline loss due to erosion by waves, ice, or related action of the water. Currently, about 40 percent of the shoreline of Lake Keesus is protected by some type of structural measure. Four shoreline erosion control techniques, set forth in Figure 11, were in use in 1995: vegetative buffer strips, rock revetments, wooden bulkheads, and gabions. These alternatives were selected because they can be constructed, at least partially, by local residents; because most of the construction materials involved are readily available; because the measures would, in most cases, enable the continued use of the immediate shoreline; and because the measures are visually "natural" or "seminatural" and should not significantly affect the aesthetic qualities of the lake shoreline. Shoreline erosion was found to exist only at isolated locations on Lake Keesus, and no serious problems were identified. However, because of the system of shoreline armor already in place at Lake Keesus, armoring the additional unprotected shoreline in the main basin of the Lake, as and when necessary, would appear to be a viable option. If additional shore protection is installed, it is recommended that consideration be given to the visual aesthetics of blending various types of construction along the shore. This will not only enhance the visual appeal of the shoreline, but minimize the edge effects that can occur as the result of two dissimilar abutting styles of construction. Vegetative buffer strips are also desirable for selected areas in this Lake.

Recreational Use Zoning

Regulatory measures provide a basis for controlling lake use and use of the shorelands around a waterbody. On land, shoreland zoning, requiring set backs and shoreland buffers, can protect and preserve views both from the water and from the land, control development around a lake to minimize its environmental impacts, and manage public and private access to a waterbody. On water, recreational use zoning can provide for safe and multipurpose use of lakes by various groups of lake users and protect environmentally sensitive areas of a lake. At present, the current zoning and boating ordinances adopted by the Town of Merton are generally consistent with the types of shoreland development and recreational uses indicated in and around Lake Keesus. In addition, public recreational boating access to the Lake, consistent with the requirements set forth in Chapter NR 1 of the *Wisconsin Administrative Code*, is currently scheduled to be constructed during 1998 by the Lake Keesus Management District with funds provided, in part, by the Wisconsin Department of Natural Resources. Thus, these components of the recreational use management plan element may be considered to be in place.

Public Informational and Educational Programs

Educational and informational brochures and pamphlets, of interest to homeowners and supportive of the lake management program, are available from the University of Wisconsin-Extension, the Wisconsin Department of Natural Resources, the Waukesha County Department of Parks and Land Use, and many Federal government agencies. These brochures could be provided to home-

Table 25

1996-1997 OPEN SEASON, SIZE LIMITS, AND BAG LIMITS FOR FISH SPECIES IN KEESUS LAKE[a]

Species	Open Season	Daily Limit	Minimum Size
Northern Pike	May 4 to March 1	2	26 inches
Walleyed Pike	May 4 to March 1	5	15 inches
Largemouth and Smallmouth Bass	May 4 to March 1	5	14 inches
Bluegill, Pumpkinseed (sunfish), Crappie, and Yellow Perch	Open all year	50	None
Bullhead	Open all year	None	None
Rough Fish	Open all year	None	None

[a] *The limits and sizes set forth in this table are for Lake Keesus. Daily limits and minimum sizes vary between lakes.*

Source: Wisconsin Department of Natural Resources.

owners through local media, direct distribution, or targeted library/civic center displays. Many of the ideas contained in these publications can be integrated into ongoing, larger-scale activities, such as anti-littering campaigns, recycling drives and similar pro-environment activities.

Finally, the participation of Lake Keesus in the State-sponsored volunteer "Self-Help Monitoring" program, which involves citizens in taking Secchi-disk transparency readings in the Lake at regular intervals, should be continued. Data gathered as part of this program should be presented by the volunteer at the annual meeting of the Lake District, where the citizen monitors could be given some recognition for their work. The Lake Coordinator of the Wisconsin Department of Natural Resources-Southeast Region could assist in enlisting more volunteers in this program. The information gained at first hand by the public from participation in this program can increase the credibility of the proposed changes in the nature and intensity of use to which the Lake is subjected.

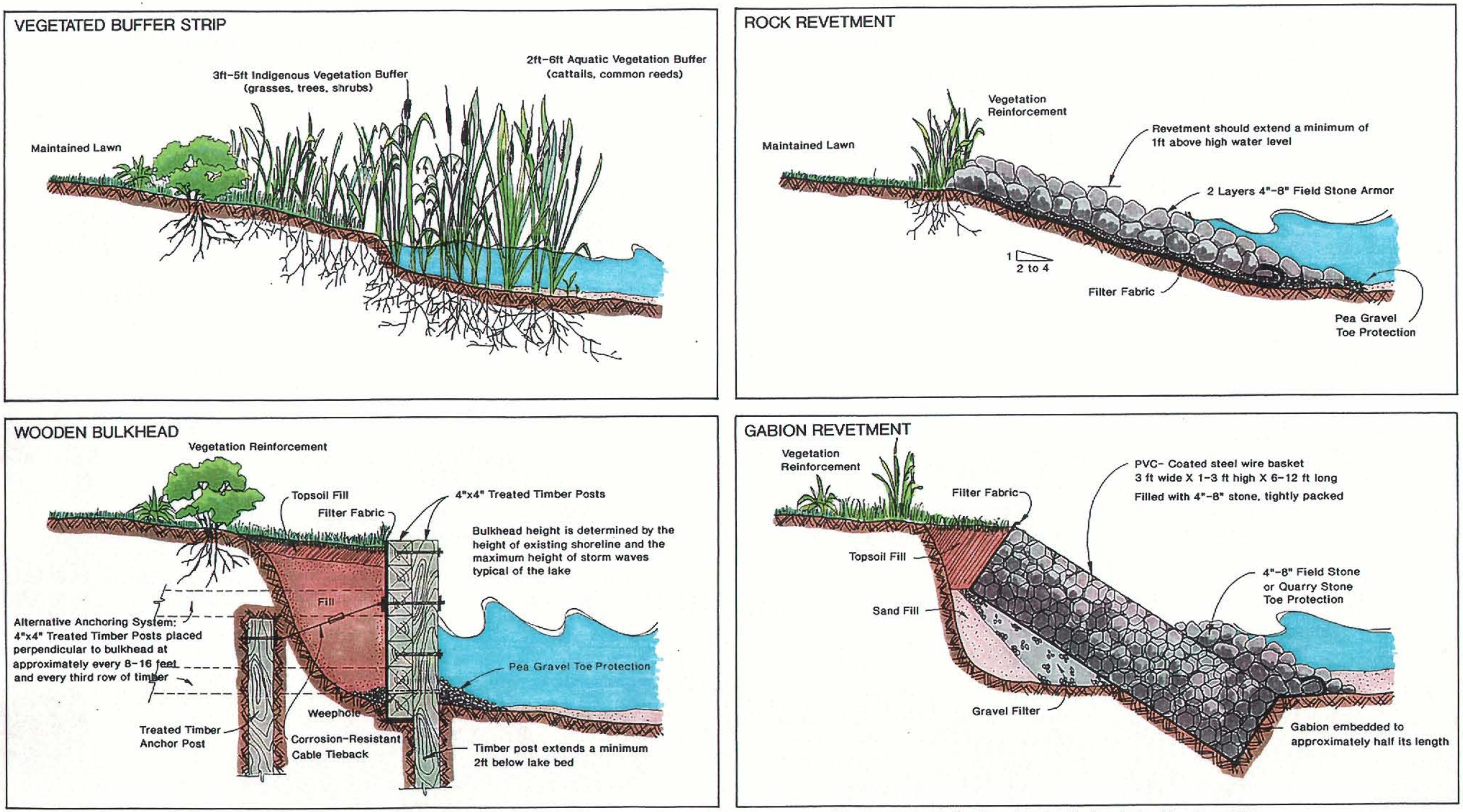
SUMMARY

This chapter has described options that could be employed in managing the types of problems recorded as occurring in Lake Keesus and which could, singly or in combination, assist in achieving and maintaining the water quality objectives set forth in Chapter VI. Selected characteristics of these measures are summarized in Table 26.

An evaluation of the potential management measures for improving the Lake Keesus water quality was carried out on the basis of the effectiveness, cost, and technical feasibility of the measures. Those alternative measures not considered further at this time are: nutrient precipitation and inactivation, internal nutrient load reduction, drawdown, large-scale dredging, biological control of aquatic plants, lake bottom covering, fish habitat creation, and fish species modification. The remaining measures were considered further for incorporation in the recommended plan described in Chapter VIII.

Figure 11

PLAN ALTERNATIVES FOR SHORELINE EROSION CONTROL



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

Source: SEWRPC.

Table 26

SELECTED CHARACTERISTICS OF ALTERNATIVE LAKE MANAGEMENT MEASURES FOR KEESUS LAKE

Alternative Measure	Description	Estimated Costs		Considered Viable for Inclusion in Recommended Lake Management Plan
		Capital	Operation and Maintenance	
Rural Nonpoint Source Pollutant Control	Conservation tillage, and streambank management	- -	- -	Yes
Urban Nonpoint Source Pollutant Control	Detention and infiltration basins	- -	Variable	Limited
	Good urban housekeeping practices	- -	Low	Yes
Construction Erosion Control	Soil stabilization, surface roughening	$250 per acre	$25 per acre	Yes
Sewage Disposal System *Management*	Septic tank management program	Variable	Up to $100 per year	Yes
	Public sanitary sewage system	High	- -	Yes *(after 2010)*
Nutrient/Toxicant Inactivation	Alum treatment	- -	$88,875	No
Nutrient Load Reduction	Nutrient load reduction (internal)	- -	Variable	No
	Nutrient load reduction (external)	- -	Variable	Yes
Water Level Management	Dredging	- -	$3.00 to $15 per cubic yard	Yes (small-scale)
	Drawdown	- -	- -	No
Aquatic Plant Management	Herbicides	- -	$250 to $500 per acre	Yes
	Harvesting	$100,000	$20,000 per year	Yes
	Sediment covering	- -	$50 to $250 per 700 square feet	No
	Biological control	- -	- -	No
Fish Management	Habitat protection	- -	- -	Yes
	Habitat creation	- -	- -	No
	Species modification	- -	- -	No
	Stocking	- -	$0.70 to $0.75 per fish	No at this time
	Fishing regulation	- -	- -	Yes
Shoreline maintenance	Maintenance of structures	$7.50 to $36 per linear foot	- -	Yes
Recreational Use Zoning	Space and time zoning to maximize public safety	- -	- -	Yes
	Shoreland zoning	- -	- -	Yes
Informational Programs	Public information programming	- -	- -	Yes

Source: SEWRPC.

Chapter VIII

RECOMMENDED MANAGEMENT PLAN FOR LAKE KEESUS

INTRODUCTION

This chapter presents a recommended management plan, including attendant costs, for Lake Keesus. The plan is based upon inventories and analyses of land use and land and water management practices; pollution sources in the drainage area tributary to Lake Keesus; the physical and biological quality of the waters of the Lake; the land use and population forecasts; and an evaluation of alternative lake management plans. The recommended plan sets forth means for: 1) providing water quality conditions suitable for full-body contact recreational use and the maintenance of healthy communities of warmwater fish and other aquatic life; 2) reducing the severity of existing nuisance problems due to excessive macrophyte growth, which constrain or preclude desired water uses; 3) protecting environmentally sensitive areas; 4) promoting sound recreational use of the Lake; and 5) minimizing shoreline erosion. The recommended plan was selected from among the alternatives described in Chapter VII, and evaluated on the basis of which of the feasible alternatives may be expected to meet the plan objectives at a reasonable cost.

Analyses of water quality and biological conditions indicate that the general condition of the water in Lake Keesus is good, although water based recreation may be somewhat limited by growths of aquatic macrophytes. The recommended plan sets forth recommendations for: land use regulation and land management in the drainage area tributary to Lake Keesus including onsite sewage disposal system management; in-lake management measures, including water quality monitoring, aquatic plant management, fishery management, habitat protection, recreational use zoning, and shoreline protection measures; and informational and educational programming. These measures complement the watershedwide land use control and management measures recommended in the regional water quality management plan and nonpoint source control plan for the Oconomowoc River priority watershed project.[1]

[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Three,* Recommended Plan, *June 1979; and Wisconsin Department of Natural Resources Publication No. PUBL-WR-194-86,* A Nonpoint Source Control Plan for the Oconomowoc River Priority Watershed Project, *March 1986.*

The recommended management measures for Lake Keesus are graphically summarized on Map 20 and are listed in Table 27. The recommended measures are more fully described in the following paragraphs.

LAND USE PLANNING AND ZONING MEASURES

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

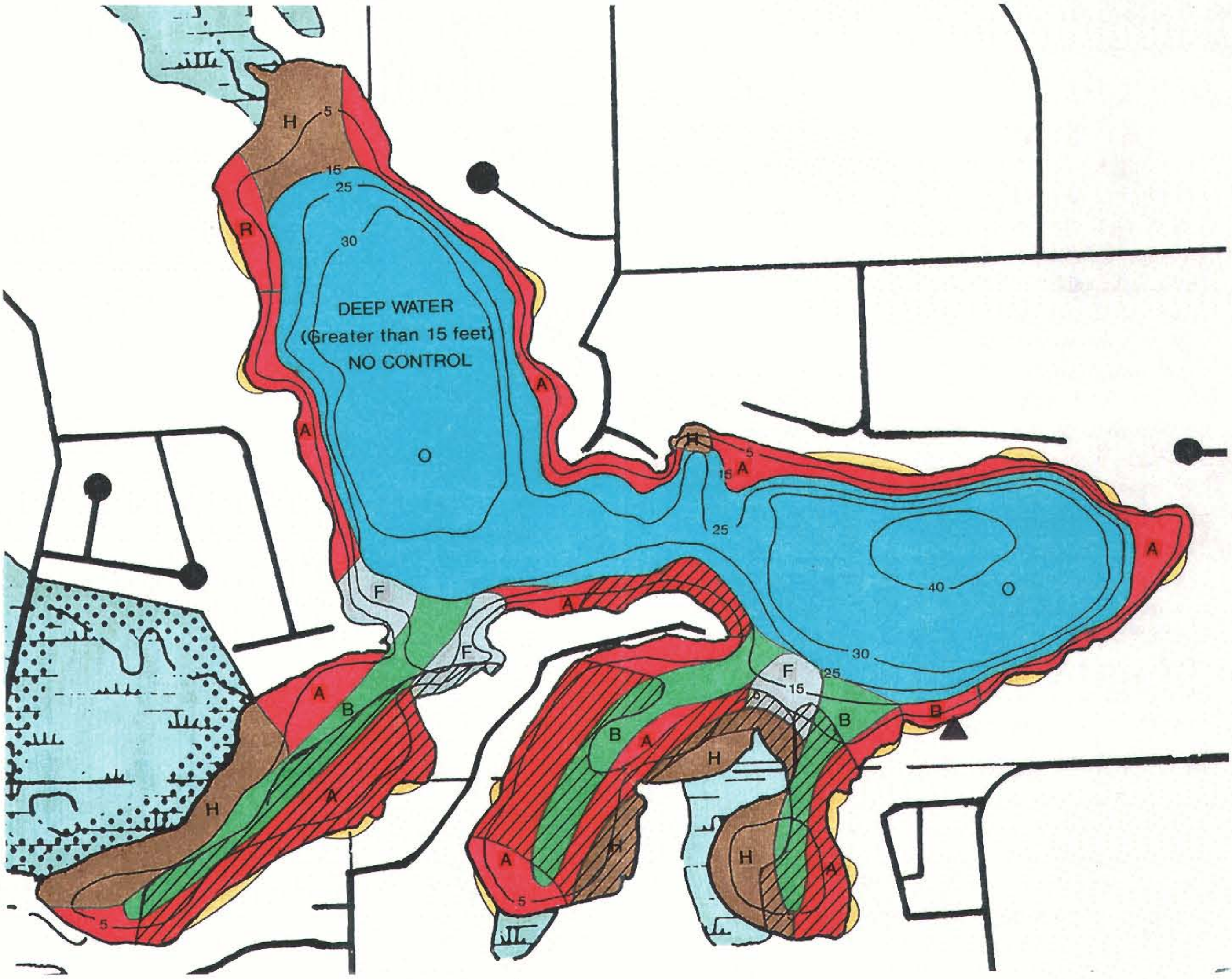
The recommended design year 2010 land use plan for the drainage area tributary to Lake Keesus is described in Chapter III. The framework for this plan is the regional land use plan as prepared and adopted by the Regional Planning Commission, as refined by the Waukesha County development plan prepared by the Commission and adopted by the County.[2] The recommended land use plan recommends that additional urban land use development should be permitted to occur at low densities in the Lake Keesus drainage area only in areas which are covered by soils suitable for the intended use, which are not subject to special hazards such as flooding, and which are not environmentally sensitive; that is, not encompassed within the Regional Planning Commission delineated environmental corridors described in Chapter V.

A major land use issue which has the potential to affect Lake Keesus is the potential development for urban uses of the agricultural and other open space lands in the Waukesha County portion of the tributary drainage area. As noted in Chapters III and VII, large-lot residential development is occurring in areas of the lake watershed in which such development was not envisioned in the adopted regional land use plan. If this trend continues,

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

Map 20

RECOMMENDED LAKE MANAGEMENT PLAN FOR LAKE KEESUS



LEGEND

WATER DEPTH CONTOUR IN FEET

POTENTIAL PUBLIC ACCESS SITE

LAKE USE ZONES

A: ACCESS H: HABITAT

B: BOATING O: OPEN WATER

F: FISHING R: RECREATION

AQUATIC PLANT MANAGEMENT

HARVESTING: HIGH PRIORITY
CHEMICALS: LIMITED

HARVESTING: MODERATE PRIORITY
CHEMICALS: LIMITED

HARVESTING: LOW PRIORITY
CHEMICALS: NONE

HARVESTING: NONE
CHEMICALS: NONE

ENVIRONMENTALLY VALUABLE AREAS
RECOMMENDED FOR PROTECTION

MILFOIL CONTROL AREA HARVESTING:
SHALLOW CUTTING TO CONTROL
EURASIAN WATER MILFOIL

MONITORING PROGRAM

CONDUCT FISH SURVEY

CONDUCT AQUATIC PLANT SURVEY

CONTINUE WATER QUALITY MONITORING

LAND USE MANAGEMENT

PROTECT ENVIRONMENTALLY
VALUABLE AREAS:

-NO BOAT ACCESS

-NO PLANT HARVESTING

-NO HERBICIDE USE

INCLUDE SHOREYARD PROVISIONS
IN ZONING ORDINANCE

SHORELINE PROTECTION

MAINTAIN AND REPAIR EXISTING
STRUCTURES, PROTECT UNSTABLE AREAS

ESTABLISH SHORELINE VEGETATION

GRAPHIC SCALE
0 500 1000 FEET

Source: SEWRPC.

Table 27

RECOMMENDED MANAGEMENT PLAN ELEMENTS FOR LAKE KEESUS

Plan Element	Subelement	Location	Management Measures
Land Use and Zoning	Land use development planning	Entire watershed	Observe guidelines set forth in regional land use plan, including protection of environmental corridors
	Zoning modifications	Entire watershed	Modify zoning ordinances to minimize open space losses
	Density management	Lakeshore areas	Maintain historic medium- and low-density residential uses
	Protection of primary environmental corridors	Entire watershed	Preserve environmental corridor areas as recommended in regional land use plan and in Waukesha County park and open space plans
Watershed Land Management	Urban nonpoint source controls	Entire watershed New clustered developments	Good urban housekeeping practices Develop a stormwater management systems where appropriate densities exist
	Construction site erosion control	Entire watershed	Continue enforcement of existing ordinances
	Rural nonpoint source controls	Entire watershed	Implement good soil conservation and nutrient management practices based upon detailed farm plans
	Onsite sewage disposal system management	District Entire watershed	Develop an onsite sewage disposal system management program Promote sound maintenance practices and periodic inspections
Water Quality Management	Water quality monitoring	Entire Lake	Continue participation in DNR Self-Help Monitoring Program Enroll in the expanded Self-Help Monitoring Program
Aquatic Plant Management	Chemical treatment	Within 50 feet of the shoreline, and areas of nuisance growth	Limit use of selective chemicals to control Eurasian water milfoil around docks, purple loosestrife in wetlands, and blue-green algae on shorelines Spring applications recommended
	Major channel harvesting	Boating, access, and recreation zones	Harvest aquatic plants as required Avoid disturbance of lake bottom
	Minor channel harvesting	Fishing zones	Harvest fishing and shared boating access lanes Avoid disturbance of ecologically valuable areas
	Eurasian water milfoil control	Entire Lake	Control dense, nuisance areas of Eurasian water milfoil as necessary, using appropriate methods and techniques pursuant to Wisconsin Department of Natural Resources guidelines
	Algal control	Entire Lake	Identify and quantify algae present in the Lake and its relationship to swimmer's itch outbreaks

Table 27 (continued)

Plan Element	Subelement	Location	Management Measures
Fisheries Management	Fish survey	Entire Lake	Implement a fishery survey
	Assess harvesting pressures	Entire Lake	Undertake an assessment of angling pressures with assistance from Department of Natural Resources
	Refine fishery management program	- -	Utilize survey findings to refine fishery management strategy
Habitat Protection and Lake Use Management	Restrict aquatic plant management activities	Habitat and Fishing zones	Restrict harvesting to areas shown on Map 20 Restrict harvesting in spring and autumn to avoid disturbances in fish breeding areas
Shoreland Protection	Maintain structures	Entire Lake	Maintain existing structures
	Install vegetative buffer strips and/or structures	Along lakeshore and tributary streams	Install and maintain erosion control measures
Informational and Educational Program	Public informational and educational programming	Entire watershed	Continue and refine public awareness and informational programming

Source: SEWRPC.

much of the open space areas remaining in the drainage area to Lake Keesus, will be replaced over time with large-lot urban development. This may significantly increase the pollutant loadings to the Lake and increase the pressures for recreational use of the Lake. Under the full buildout condition envisioned under the Waukesha County development plan,[3] most of the undeveloped lands outside the environmental corridors and other environmentally sensitive areas could potentially be developed for low-density urban uses.

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

The existing zoning, in both the Washington and Waukesha County portions of the drainage basin, permits urban development generally on large, suburban-density lots over much of the remaining open lands other than the environmental corridors. As noted in Chapter III, shoreland zoning controls governing new construction are incorporated into County zoning ordinances applicable to the Lake Keesus drainage area. Control of shoreland redevelopment, and the related intensification of use, however, is not specifically addressed in the existing zoning codes, although new construction is required to meet specific compliance and inspection requirements for onsite sewage disposal systems. It is recommended that the impact of future land use development on Lake Keesus be minimized through review and modification of the applicable zoning ordinance regulations and zoning district maps to address the concerns noted. Changes in the zoning ordinance are recommended to minimize the areal extent of development by providing specific provisions and incentives for the clustering of residential development on smaller lots, while preserving portions of the open space on

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

each property or group of properties considered for development.[4]

Wetland and groundwater recharge area protection can be accomplished through land use regulation and public land acquisition. Both measures are included in the recommended Lake Keesus management plan. A significant portion of the wetlands in the drainage area are owned by the State of Wisconsin as part of the Wisconsin Department of Natural Resources lands on the southwestern shore of the Lake. Other wetland areas within the drainage area tributary to the Lake are currently largely protected through the U.S. Army Corps of Engineers 404 Permit Program, State shoreland zoning requirements, and local zoning ordinances. Nearly all wetland areas and most of the groundwater recharge and discharge areas in the Lake Keesus drainage area are included in the environmental corridors delineated by the Regional Planning Commission and protected under one or more of the existing Federal, State, County, and local regulations. In this regard, implementation of the recommendations of the adopted park and open space plan element of the Waukesha County development plan would provide for the protection and preservation of these environmentally sensitive lands.

WATERSHED MANAGEMENT MEASURES

The recommended watershed management measures are specifically aimed at reducing the water quality impacts on Lake Keesus from nonpoint sources of pollution within the tributary drainage area. These measures are set forth in the aforereferenced regional water quality management plan and priority watershed plan.

As indicated in Chapters IV and VII, the only significant sources of phosphorus loading on the Lake that are subject to control are rural and urban nonpoint sources and onsite sewage disposal systems.

As indicated in Chapter VII, nonpoint source control measures should be considered for the areas tributary to Lake Keesus, including the upstream tributary drainage area. The regional water quality management plan recommended that a reduction of about 25 percent in both the rural and urban nonpoint sources, plus streambank erosion control, construction site erosion control, and onsite sewage disposal system management be achieved in the drainage area tributary to Lake Keesus.

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

Nonpoint source pollution abatement controls the drainage area are recommended to be achieved through a combination of rural agricultural nonpoint controls, construction erosion controls, and urban stormwater management. The implementation of the land management practices described below may be expected to result in an overall reduction of total phosphorus loadings to Lake Keesus from both rural and urban sources of about 25 percent, a reduction considered to be the maximum practicable given the findings of the inventories and analyses conducted under the planning effort.

The recommended management agency responsibilities for watershed land management are set forth in Table 28.

Urban Nonpoint Source Control

The development of urban nonpoint source pollution abatement measures for the Lake Keesus areas should be the responsibility of Washington and Waukesha Counties, the Town of Merton in Waukesha County, the Lake Keesus Management District, and private property owners. Accordingly, it is recommended that the Lake Keesus Management District continue to take an active role in promoting the urban nonpoint source pollution abatement elements as set forth in the nonpoint source pollution abatement priority watershed plan for the tributary drainage area to Lake Keesus. These projects would be undertaken by Waukesha County and would also involve the local units of government in the drainage area tributary to Lake Keesus, working cooperatively with the Wisconsin Department of Natural Resources.[5]

As discussed in Chapter VII, it is recommended that the most viable measure for controlling urban nonpoint sources of pollution will be good urban land management and urban housekeeping practices. Such practices consist of fertilizer and pesticide use management, litter and pet waste controls, and managing leaf and yard waste. The promotion of these measures will require a public informational and educational program. Additionally, the public educational program should present information on the groundwater resources of the area and on the measures, such as onsite sewage disposal sys-

[5]*The Oconomowoc River Priority Watershed Project has been closed as of December 31, 1996, and no State cost-share funds are currently available for new projects. However, priority actions not previously implemented could be supported using local revenues.*

Table 28

LOCAL GOVERNMENTAL MANAGEMENT AGENCY RESPONSIBILITIES FOR PLAN IMPLEMENTATION

Plan Element	Subelement	Agency				
		Washington County	Waukesha County	Lake Keesus Management District	Municipalities within Watershed[a]	Department of Natural Resources
Land Use and Zoning	Land use development planning	X	X	--	X	--
	Zoning modifications	X	X	--	X	--
	Density management	X	X	--	X	--
	Protection of primary environmental corridors	X	X	--	X	--
Watershed Land Management	Urban nonpoint source controls	--	X	X	X	X
	Construction site erosion controls	X	X	--	X	--
	Rural nonpoint source controls	X	X	--	--	X
	Onsite sewage disposal system management	X	X	X[b]	X[b]	--
Water Quality Management	Water quality monitoring	--	--	X	--	X
Aquatic Plant Management	Comprehensive plan refinement	--	--	X	--	X[c]
	Chemical treatment	--	--	X	--	X[d]
	Major and minor channel harvesting	--	--	X	--	--
	Eurasian water milfoil control	--	--	X	--	--
	Algal control	--	--	X	--	X
Fisheries Management	Fish survey	--	--	X	--	X
	Assess harvesting pressures	--	--	X	--	X
	Refine fishery management program	--	--	X	--	X
Habitat Protection and Lake Use Management	Restrict aquatic plant management activities	--	--	X	X	X
Shoreland Protection	Maintain structures	--	--	X[b]	--	--
	Install vegetative buffer strips and/or structures	--	--	X[b]	--	X[d]
Informational and Educational Program	Public informational and educational programming	X[e]	X[e]	X	--	--

[a] *Municipalities include the Town of Erin in Washington County and the Towns of Lisbon, Merton, and Richfield, and the Village of Merton in Waukesha County.*

[b] *Resident responsibility; the District and municipalities can provide guidance and facilitate technical support.*

[c] *The Wisconsin Department of Natural Resources reviews aquatic plant management plans, revisions thereof, and boating ordinances for compliance with State rules.*

[d] *This activity requires a Wisconsin Department of Natural Resources permit.*

[e] *County assistance is provided through the Land Conservation Division of the County Department of Parks and Land Use, and the University of Wisconsin-Extension.*

Source: SEWRPC.

tem management and waste disposal, required to protect these resources.

As indicated in Chapter VII, the inclusion of additional facilities to provide for a high level of urban nonpoint source control, including stormwater treatment facilities such as detention basins, does not appear to be a necessary or effective element of a water quality management plan for the existing urban areas surrounding Lake Keesus. This conclusion was reached because stormwater flow to the Lake is relatively diffuse, with no practical means for concentrating the flow at treatment facilities. Furthermore, the opportunities for effectively utilizing structural measures in other urbanized areas within the tributary area to Lake Keesus are minimal due to the nature of the development. Most of the development in the drainage area tributary to the Lake does have a rural drainage system which utilizes roadside swales, as opposed to curb and gutter and storm sewers. Thus, there is currently some control of nonpoint sources effected. Notwithstanding, the use of stormwater management measures within urbanizing areas of the drainage area tributary to Lake Keesus is recommended to be considered in clustered developments where residential densities are such as to make the collection and detention of stormwater economically feasible. Application of these measures should be determined on a site specific basis in accordance with individual cluster development plans.

As an initial step in carrying out the recommended urban practices, it is recommended that a fact sheet identifying specific residential land management measures beneficial to the water quality of Lake Keesus be prepared and distributed to property owners by the Lake Keesus Management District with the assistance of the University of Wisconsin-Extension Service and the Waukesha County Department of Parks and Land Use, Land Conservation Division. The recommended measures may be expected to provide up to about a 22 percent reduction in phosphorus loading to the Lake from urban sources.

Construction Site Erosion Control

It is recommended that Waukesha and Washington Counties and the Town of Lisbon continue their efforts to control soil erosion from construction activities in accordance with existing ordinances. As noted in Chapter VII, these two Counties have adopted construction erosion control ordinances. The Waukesha County ordinance is based on the model ordinance promulgated by the Wisconsin Department of Natural Resources in cooperation with the Wisconsin League of Municipalities[6]. Enforcement of the ordinance by Waukesha County is generally considered effective. The provision of this ordinance applies to all development, except single- and two-family residential construction. The single- and two-family construction erosion control is to be carried out as part of the building permit and construction process. The Washington County ordinance is set forth in Chapter 17 of the Washington County Code, "Erosion Control and Stormwater Management." The County enforces the ordinance in unincorporated areas and in the larger-scale developments, such as subdivisions and planned unit developments. Individual development sites and other construction sites are controlled by the County ordinances as part of the building permit and construction process, unless there are more restrictive provisions promulgated under local zoning ordinances with enforcement by local building inspectors. At the local government level within the drainage area, the Town of Lisbon also has adopted an construction site erosion control ordinance. The ordinance is not the model construction site erosion control ordinance and is largely carried out by the town engineer and/or building inspector. Construction site erosion controls may include the use of silt fences, sedimentation basins, and rapid revegetation of disturbed areas; the control of "tracking" from the site; and careful planning of the construction sequence to minimize areas disturbed. Construction site erosion control is particularly important in minimizing the more severe localized short-term nutrient and sediment loadings into Lake Keesus that can result from uncontrolled construction sites.

Construction site erosion control measures may be expected to reduce the phosphorus loading from that source by about 75 percent. However, because of the limited amount of new urban development envisioned within the drainage areas tributary to Lake Keesus, the total calculated change in loading to the Lake is expected to be minimal. Because of the potential for development in the Waukesha County portion of the area tributary to Lake Keesus, it is, nevertheless, important that adequate construction erosion control programs be in place.

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

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[6] *Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook, *1989.*

Rural Nonpoint Source Pollution Control

The implementation of nonpoint source pollution controls in rural areas is recommended to be a cooperative effort of the Waukesha County Land Conservation Committee, the Washington County Land Conservation Committee and the private landowners. Technical assistance can be provided by the U.S. Department of Agriculture Natural Resources Conservation Service; the Wisconsin Department of Agriculture, Trade and Consumer Protection; the Wisconsin Department of Commerce; and the Waukesha and Washington County Land Conservation offices. As discussed previously, it is recommended that the Lake Keesus Management District support ongoing efforts of the Wisconsin Department of Natural Resources, Washington and Waukesha Counties, and the local units of government involved, in addressing nonpoint source pollution. State and Federal soil erosion control and water quality management programs, individually or in combination, can be used to achieve pollutant reduction goals. Such programs include the U.S. Department of Agriculture Environmental Quality Incentive Program (EQIP), the Wisconsin Department of Natural Resources Priority Watershed Program and Lake Protection Grant Program, and various State and local land acquisition initiatives.

Highly localized, detailed, and site specific measures are required to effectively reduce soil loss and contaminant runoff in rural areas. These measures are best defined and implemented at the local level through the preparation of detailed farm conservation plans. Practices which are considered most applicable to the Lake Keesus area include conservation tillage, integrated nutrient and pesticide management, and pasture management. In addition, it is recommended that consideration be given to cropping patterns and crop rotation cycles, with attention to the specific topography, hydrology, and soil characteristics for each farm. A reduction of about 25 percent in the nonpoint source loading from rural lands is recommended, in addition to the recommendations of the County Soil Control plans to achieve "tolerant" soil loss levels, or levels which can be sustained without impairing the productivity of the soil. Application of rural conservation practices within agricultural areas of the drainage area tributary to Lake Keesus can be expected to reduce phosphorus loading from that source by up to about 50 percent, providing about a 48 percent reduction in phosphorus loading to the Lake from rural sources.

The cost of the needed measures will vary depending upon the details of the recommended farm conservation plans. To a large extent, the costs of agricultural land erosion controls may be expected to be incurred regardless, as a result of good farm management practices.

Onsite Sewage Disposal System Management

As reported in Chapter IV, onsite sewage disposal systems are estimated to contribute about 7 percent of the total phosphorus loading to Lake Keesus. However, in addition to lake water quality considerations, sewage disposal options in the area have implications for groundwater quality and property values. The areawide water quality management plan as currently adopted recommends that sewage disposal needs in the Lake Keesus community concerned be provided through onsite sewage disposal systems. The regional plan, however, also recommends that sewage disposal needs in these communities be periodically reevaluated in light of changing conditions. During 1997, such a reevaluation of the need for public sanitary sewerage, as recommended in the regional water quality management plan, was underway as part of a study of sewerage needs in the northwestern portions of Waukesha County.[7] Preliminary results from this planning project indicate that the sewage disposal needs of the urban development surrounding Lake Keesus should continue to be provided through onsite sewage disposal systems in the near term. However, given the existing onsite sewage disposal systems ages, lot sizes, and steeply sloped areas in some portions of the shoreline development, the sewerage system plan recommends that urban development be included in the long-term planned sewer service area. For planning purposes, it is assumed that connection of this area to a public sanitary sewer system will be deferred until beyond the year 2010.

The nearest existing public sanitary sewerage system to the Lake Keesus area is the Village of Hartland system located about four miles to the southwest. That system connected to the Delafield-Hartland Water Pollution Control Commission (Dela-Hart) sewerage system. Given that it is unlikely that a new public sewage treatment plant to serve the Lake Keesus area would be cost-effective, connection to the Dela-Hart sewerage system would be the alternative most likely to be viable at such time as an identified need to provide a public sewer system to serve the urban development in the drainage area tributary to Lake Keesus becomes apparent.

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[7]*Black & Veatch,* A Sanitary Sewerage System Plan for the Northwestern Waukesha County Area, *Draft, in preparation.*

Notwithstanding the potential for a future development of a public sanitary sewer service system, it is recommended that the District work with the Waukesha County Department of Parks and Land Use, Environmental Health Division, to develop an onsite sewage disposal system management program. It is recommended that the Lake Keesus Management District assume the lead in providing the public informational and educational programs to encourage property owners to have the existing onsite systems inspected and any needed remediation measures undertaken. Homeowners should be advised of the rules and regulations governing, and the limitations of, onsite sewage disposal systems, and should be encouraged to undertake preventive maintenance programs. The cost of this measure is included as part of the cost for the public informational and educational measures and is provided through the operating budget of the District.

The purpose of the recommended inspection program would be to identify any malfunctioning sewage disposal systems. Ideally, each system would be inspected once every three years and, accordingly, about one-fifth of all such systems would be inspected annually, unless more frequent inspections are required for systems installed after 1983. A secondary benefit of an inspection program would be the knowledge system owners would gain from the periodic inspection and identification of any system failures. It is recommended that the District undertake the development of a preventive maintenance program that would provide for periodic inspection of all onsite sewage disposal systems within the District, with consideration being given to possible financial assistance in the case of hardship. Under an expanded version of this option, the onsite sewage disposal system management program could potentially include the adoption of sanitary district powers by the lake management district as provided under Section 33.22(3), *Wisconsin Statutes*, to enable the district to administer funds; inspect, design, and construct upgraded systems; ensure proper operation and maintenance of the systems; and monitor the performance of said systems. The cost for onsite sewage disposal system inspection and management programs will vary, depending upon the combination of options included. Typical costs are $100 to $200 per year for a basic inspection and maintenance service, and can be higher for more extensive programs.

IN-LAKE MANAGEMENT MEASURES

The recommended in-lake management measures for Lake Keesus are summarized in Table 27 and are graphically summarized on Map 20. The major recommendations include water quality monitoring, aquatic plant management, fish management, habitat protection, shoreline protection, recreational use zoning, and public informational and educational programs.

Water Quality Monitoring

Continued water quality monitoring of Lake Keesus is recommended. Continued enrollment of one or more Lake Management District residents as Wisconsin Department of Natural Resources Self-Help Monitoring Program volunteers is recommended. Such enrollment may be accomplished through the Southeast Region office of the Department at little cost to the Lake Management District. A firm time commitment is required of the volunteers. In addition, participation in the expanded or trophic state index (TSI) Self-Help Monitoring Program, measuring nutrients, chlorophyll-a, and temperature, is recommended. Such monitoring should be conducted five times per year at the same location which is currently used by the U.S. Geological Survey at the northeast deep water area.

Aquatic Plant Monitoring and Management

An aquatic macrophyte control plan consistent with Chapters NR 103 and NR 107 of the *Wisconsin Administrative Code* has been prepared for the Lake by Aron & Associates, consultants to the Lake Keesus Management District. The plan recommends that continued aquatic macrophyte surveys be conducted at three- to five-year intervals, but with variation depending upon the observed degree of change in the Lake. In addition, information on the aquatic plant control program should be recorded and should include descriptions of: major areas of nuisance plant growth; areas harvested and/or chemically treated; species harvested and amounts of plant material removed from lake; and species and approximate numbers of fish caught in the harvest. A daily harvester log containing this information should be maintained. This information, in conjunction with recommended aquatic macrophyte surveys will allow long-term evaluation of the effectiveness of the aquatic plant control program, such that adjustments can be made in the program to maximize its benefit.

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

1. Mechanical harvesting is recommended as the primary management method. As indicated in Chapter VII, this will, in the long-term, help to

maintain good water quality conditions by removing plant materials which are currently contributing to an accumulation of decomposing vegetation and the associated nutrient recycling. The harvesting should be carried out by the Lake Management District using its existing harvester and transport equipment.

2. It is recommended that shared access lanes should be harvested, rather than clear cutting large open areas, to minimize the potential detrimental effects on the fish and invertebrate communities. Directing boat traffic through these common lanes should delay the regrowth of vegetation in these areas.

3. Surface harvesting of nonnative aquatic plants, such as the Eurasian water milfoil, cutting to a depth of approximately two feet, is recommended. This should provide a competitive advantage to the low-growing native plants present in the Lake. By not disturbing the low-growing species, which generally grow within one to two feet of the lake bottom and in relatively low densities—leaving the root stocks and stems of all cut plants in place—the resuspension of sediments in Lake Keesus will be minimized. Furthermore, cutting should be focused on boating lanes placed around the perimeter of the main lake basin.

4. It is recommended that the use of chemical herbicides be limited to controlling nuisance growth of exotic species in shallow water around docks and piers, where the harvester is unable to reach. Such use should be evaluated annually and the herbicide applied only on an as needed basis. Only herbicides that selectively control milfoil, such as 2,4-D, should be used.

5. It is recommended that chemical application, if required, should be made in early spring to maximize its effectiveness on nonnative plant species, to minimize its impact on native plant species, and to act as a preventative measure to reduce the development of nuisance conditions. Use of algicides, such as Cutrine Plus, may be used to control the blue-green alga, *Gleotrichia* sp. Because valuable macroscopic algae, such as *Chara* and *Nitella*, are killed by this chemical, applications of algicides should be site specific in response to *Gleotrichia* sp. outbreaks.

6. It is recommended that the District work with the Department of Natural Resources to obtain more information on the identification and quantification of the algae present in the Lake and its relation to outbreaks of swimmer's itch which have occurred.

7. The control of rooted vegetation between adjacent piers is recommended to be left to the riparian owners concerned, as it is time consuming and costly for the mechanical harvester to maneuver between piers and boats, and such maneuvering may entail liability for damage to boats and piers. As an alternative option it is recommended that the Lake Management District obtain informational brochures regarding shoreline maintenance, such as information on hand-held specialty rakes made specifically for manual harvesting, as part of the riparian owner informational and educational program.

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

9. The incorporation by the Lake Management District of an overall public educational program is recommended. Information to be disseminated should include information on the types of aquatic plants Lake Keesus; on the value of and the impacts of these plants on water quality, fish, and on wildlife; and on alternative methods for controlling existing nuisance plants, including the positive and negative aspects of each method. This program can be incorporated into the comprehensive informational and educational programs which also would include information on related topics such as water quality, recreational use, fisheries, and onsite sewage disposal systems.

The recommended plan partitions Lake Keesus into zones for aquatic plant management, with control measures in each zone designed to optimize desired recreational opportunities and to protect the aquatic resources. The recommended aquatic plant control zones are shown on Map 20 and the controls recommended for each zone are described in Table 29.

The recommended aquatic plant management plan represents an expansion of the ongoing aquatic plant

Table 29

RECOMMENDED AQUATIC PLANT MANAGEMENT TREATMENTS FOR LAKE KEESUS

Zone and Priority	Recommended Aquatic Plant Management Plan
Access: Zone A	Harvest narrow channels, approximately 10 to 15 feet wide, to provide boating access, via a pier lane connecting the narrow channels to common access lanes, to the main body of Lake Keesus This zone totals 64 acres in areal extent Chemical use, if required, should be restricted to pier and dock areas within 50 feet from shore in this area
Boating: Zone B	Harvest a 100 foot wide channel in the central portion of the bay to connect to channels perpendicular to shore to allow access to main body of the Lake This zone totals 22 acres in areal extent Chemical use, if required, should be restricted to nuisance milfoil control
Fishing: Zone F	This zone is intended to accommodate fishing from a boat Harvest narrow channels, approximately 10- to 15-foot-wide, perpendicular to the shore at about 100-foot intervals This zone totals seven acres in areal extent No chemicals should be used
Open Water: Zone O	This zone includes those areas of Lake Keesus having a water depth greater than 15 feet which do not have excessive macrophyte growth Harvesting is not anticipated as being necessary in this area of deeper water This zone totals 113 acres in areal extent No chemicals should be used, except to control Gleotrichia sp. blooms
Recreational: Zone R	Harvest nuisance aquatic macrophyte growth within 150 feet of shoreline to provide maximum opportunities for boating, fishing, and limited swimming. Additional 30-foot-wide shared-access channels should extend to the center of the lake. Harvesting of an access lane connecting the Camp Whitcomb boat launching site on the northwestern shore of the Lake to the main body of the Lake should be undertaken with due regard to the presence of the DNR-designated sensitive area The maximum total area harvested would be approximately three acres The entire area may not require intensive management. Harvesting should be concentrated in areas of abundant macrophyte growth. Patterns of harvesting will vary yearly, depending on macrophyte abundance Chemical use, if required, would be restricted to pier and dock areas and would not extend more than 50 feet from shore
Habitat: Zone H	This zone and adjacent lands would be managed for fish habitat. Portions of Lake Keesus should be preserved as a high-quality habitat area No harvesting or in-lake chemical application should be conducted prior to mid-June of each year. Some limited harvesting, especially the top-cutting noted above, and/or herbicide application may be required for the control of Eurasian water milfoil thereafter This zone totals about 28 acres in areal extent Debris and litter cleanup would be needed in some adjacent areas; the immediate shoreline would be preserved in natural, open use to the extent possible

Source: SEWRPC.

management program conducted by the Lake Keesus Management District. Implementation of this plan would entail a capital cost of $108,000, the majority of which would be required for the eventual replacement of equipment, and an annual operation and maintenance cost of about $17,200.

Fish Monitoring and Management

The aquatic plant management strategy set forth above recognizes the importance of fishing as a recreational use of Lake Keesus. Integral to the aquatic plant management strategy is the protection and preservation of fish breeding habitat, especially in the marsh-like areas along the northern and western shores of the Lake. Any interventions in these areas should be confined to the navigation access channels, shown as Zone A on Map 20.

Two specific actions are recommended with respect to fisheries management: the conduct of a fishery survey and the assessment of angling pressures. The fishery survey is recommended to be conducted by the Wisconsin Department of Natural Resources at the request of the Lake Management District and would have the following objectives:

1. To identify changes in fish species composition that may have taken place in the Lake since previous surveys conducted by the Wisconsin Department of Natural Resources in 1975;

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

3. To determine the survival rates and success of stocked fishes introduced into Lake Keesus through the Wisconsin Department of Natural Resources and private fish stocking programs;

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

5. To identify any disturbance of the Lake ecosystem by rough fish populations; and

6. To conduct a one-time analysis of fish tissues for metal and toxic contamination.

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

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

2. Provide data to assess harvesting pressures on various fish species on the Lake.

While the acquisition of fisheries data could be undertaken by trained volunteers, the assessment of fishing pressures is recommended to be carried out by the Wisconsin Department of Natural Resources. Given the fishing pressures on the Lake, it would be useful to conduct a one-time analysis of fish tissues for metal and toxic contamination. This task could be included in the fish survey, when it would be possible to obtain representative samples from among the fish species collected during the survey. The cost would be dependent on availability and types of fish stocked, should stocking become necessary. Further, all of the actions recommended above will provide a quantitative basis for refining fisheries management activities on Lake Keesus. Therefore, a review and updating of the current fisheries management program, based upon the foregoing surveys and assessments, is recommended.

Habitat Protection

The habitat protection measures recommended for Lake Keesus are, in part, provided by the recommended aquatic plant management program. The aquatic plant management plan is designed to provide for habitat protection by avoiding disturbances in fish breeding areas during spring and autumn, reducing the use of aquatic plant herbicides, and maintaining stands of native aquatic plants.

In addition, it is recommended that environmentally sensitive lands, including wetlands along the lakeshore, be preserved and protected. In particular, this recommendation extends to the maintenance of the wetlands located in the northern and western portions of the lake basin, within the habitat areas, Zone H, as shown on Map 20.

Shoreline Maintenance

Most of the Lake Keesus shoreline was found to be in stable condition, with areas of erosion identified at isolated locations along the shores, including some steep slopes and other shoreland areas having sparse vegetative cover. Establishment of some form of ground cover, especially on the steep slopes, is recommended, as shown on Map 20. Various possible protection options are described in Chapter VII for consideration in the repair or replacement of protection structures. Adoption of the vegetated buffer strip method is recommended for use in lakeshore areas wherever practical in order to maintain habitat value and the natural ambience of the lakeshore. However, in some cases, the steep shoreline grade and/or composition of the shoreline may require structural measures to prevent erosion. Continued maintenance of existing revetments and bulkheads is also recommended.

Recreational Use Zoning

The principle recreational use zoning actions required include the provision of public recreational boating access consistent with Chapter NR 1 of the *Wisconsin Administrative Code*, and the imposition of "Slow-No-Wake" restrictions on those portions of the Lake bordering sensitive areas, and where boating activities could be expected to come into conflict with other uses, such as angling and habitat protection. Public recreational boating access is currently being developed by the Lake Keesus Management District in cooperation with the Wisconsin Department of Natural Resources at a site on the southern shore of the Lake, as shown on Map 20. The boating regulation ordinance adopted by the Town of Merton forms the legal basis necessary to carry out this action. Delegation of lake safety patrol functions to the Lake District pursuant to Section 33.22 of the *Wisconsin Statutes* could be considered. A Lake Keesus safety patrol operation may be eligible for partial State cost-share funds under Section 30.77 of the *Wisconsin Statutes*. To better manage the costs of such an operation, a boating safety patrol could function part-time on Lake Keesus and part-time on North Lake.

PUBLIC INFORMATIONAL AND EDUCATIONAL PROGRAMS

It is recommended that the Lake Management District assume the lead in the development of a public informational and educational program dealing with various lake management related topics including: onsite sewage disposal system management, water quality management, land management, groundwater protection, aquatic plant management, fishery management, and recreational use. The District newsletter can provide a medium for the conduct of such a program.

Educational and informational brochures and pamphlets, of interest to homeowners and supportive of the recreational use and shoreland zoning regulations, are available from the Wisconsin Department of Natural Resources and the University of Wisconsin-Extension. These cover topics, such as beneficial lawn care practices and household chemical use. Such brochures should be provided to homeowners through local media, direct distribution, or targeted library and civic center displays. Such distribution can also be integrated into ongoing, larger-scale activities, such as lakeside litter collections, which can reinforce anti-littering campaigns, recycling drives, and similar environmental protection activities.

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

PLAN IMPLEMENTATION AND COSTS

The actions recommended in this plan largely represent an extension of ongoing actions being carried out by the Lake Keesus Management District.

The recommended plan introduces few new elements, although some of the plan recommendations represent refinements of current programs. This is particularly true in the case of the aquatic plant management program, where field surveys recommended in this plan will permit more efficient management of these resources.

Generally, fisheries and aquatic plant management practices, such as stocking and monitoring, harvesting, and public awareness campaigns currently implemented by the Lake Keesus Management District, are recommended to be continued with refinements proposed herein. Some aspects of these programs lend themselves to citizen involvement through volunteer-based creel surveys, participation in the Wisconsin Department of Natural Resources Self-Help Monitoring Program, and identification with environmentally sound owner-based land management activities. It is recommended that the District assume the lead in the promotion of such citizen actions, with a view toward building community commitment and involvement. Assistance is generally available from the Wisconsin Department of Natural Resources, the County University of Wisconsin-Extension office, and the Southeastern Wisconsin Regional Planning Commission.

The major costs relating to new elements herein recommended relates to the eventual replacement of harvesting equipment. Implementation of the recommended plan would entail a capital expenditure of about $109,000 and an annual operations and maintenance expenditure of about $18,900, including existing expenditures, as shown in Table 30, over the next few years. The District's current budget for annual operation and maintenance is approximately $12,000. Some of the capital costs could be met with grants from the Wisconsin Waterways Commission under Chapters NR 103 and NR 107 of the *Wisconsin Administrative Code.*

The suggested lead agency or agencies for initiating program-related activities, by plan element, are set forth in Table 28 and the estimated costs of these elements, linked to possible funding sources where such are available, are summarized in Table 29.

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

Table 30

ESTIMATED COSTS OF RECOMMENDED LAKE MANAGEMENT MEASURES FOR LAKE KEESUS

Plan Element	Subelement	Estimated Cost 1995-2010[a] Capital	Estimated Cost 1995-2010[a] Average Annual Operation and Maintenance	Potential Funding Sources[b]
Land Use and Zoning	Land use development planning	$ 1,000[c]	- -[c]	DNR
	Zoning modifications	$ 1,000[c]	- -[c]	DNR
	Density management	$ 1,000[c]	- -[c]	DNR
	Protection of primary environmental corridors	- -	- -	DNR
Watershed Land Management	Urban nonpoint source controls	- -[d]	- -[d]	- -
	Construction site erosion control	- -[e]	$ 250 to $ 500 per acre[e]	Private firms, individuals
	Rural nonpoint source controls	- -[d,f]	- -[d,f]	USDA, DNR
	Onsite sewage disposal system management	- -	$100 to $200	Private individuals
Water Quality Management	Water quality monitoring	- -	$ 1,000[g]	DNR, USGS
Aquatic Plant Management	Comprehensive plan refinement	- -	$ 1,000	DNR
	Chemical treatment	- -	$ 3,000	- -
	Major and minor channel harvesting	$ 90,000[h]	$12,000	DNR (Waterways Commission)
	Eurasian water milfoil control	- -	- -	- -
	Algal control	- -	$ 500	DNR

Table 30 (continued)

Plan Element	Subelement	Estimated Cost 1995-2010[a] Capital	Average Annual Operation and Maintenance	Potential Funding Sources[b]
Fisheries Management	Fish survey	$ 16,000[g]	- -[g]	DNR
	Assess harvesting pressures	- -[i]	- -[i]	DNR
	Refine fishery management program	- -[i]	- -[i]	DNR, District
Habitat Protection and Lake Use Management	Restrict aquatic plant management activities	- -	- -	
Shoreland Protection	Maintain structures	- -	- -	Residents
	Install vegetative buffer strips	- -	- -	Residents
Informational and Educational Program	Public informational and educational programming	- -	$ 1,200	UWEX, DNR
Total	- -	$109,000	$18,900	- -

[a]*All costs expressed in June 1996 dollars.*

[b]*Unless otherwise specified, USDA is the U.S. Department of Agriculture, USGS is the U.S. Geological Survey, DNR is the Wisconsin Department of Natural Resources, County is Washington and Waukesha Counties, District represents Lake Keesus Management District and UWEX is the University of Wisconsin-Extension.*

[c]*Cost-share assistance may be available for ordinance review, revision, and writing under the NR 191 Lake Protection Grant Program.*

[d]*Costs included under public informational and educational program. Cost-share assistance may be available under the NR 120 Wisconsin Nonpoint Source Pollution Abatement Program, the Federal Environmental Quality Incentives Program, and various local and State water quality improvement and protection initiatives.*

[e]*Cost varies with amount of land under development in any given year.*

[f]*Costs vary and will depend upon preparation of individual farm plans.*

[g]*The DNR Self-Help Monitoring Program and proposed creel survey involves no cost, but does entail a time commitment from the volunteer.*

[h]*Costs are based on the assumption that the existing harvester and ancillary equipment may eventually need replacement; cost-share assistance for harvester purchase may be available from the Wisconsin Waterways Commission Recreational Boating Facilities Grant Program.*

[i]*Involves little or no additional cost if undertaken as part of a comprehensive fishery survey.*

Source: SEWRPC.

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APPENDIX

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Appendix A

NONPOINT SOURCE POLLUTION CONTROL MEASURES

Nonpoint, or diffuse, sources of water pollution include urban sources such as runoff from residential, commercial, industrial, transportation, and recreational land uses; construction activities; and onsite sewage disposal systems and rural sources such as runoff from cropland, pasture, and woodland, atmospheric contributions, and livestock wastes. These sources of pollutants discharge to surface waters by direct overland drainage, by drainage through natural channels, by drainage through engineered stormwater drainage systems, and by deep percolation into the ground and subsequent return flow to the surface waters.

A summary of the methods and estimated effectiveness of nonpoint source water pollution control measures is set forth in Table A-1. These measures have been grouped for planning purposes into two categories: basic practices and additional. Application of the basic practices will have a variable effectiveness in terms of control level of pollution control depending upon the subwatershed area characteristics and the pollutant considered. The additional category of nonpoint source control measures has been subdivided into four subcategories based upon the relative effectiveness and costs of the measures. The first subcategory of practices can be expected to generally result in about a 25 percent reduction in pollutant runoff. The second and third subcategory of practices, when applied in combination with the minimum and additional practices, can be expected to generally result in up to a 75 percent reduction in pollutant runoff, respectively. The fourth subcategory would consist of all of the preceding practices, plus those additional practices that would be required to achieve a reduction in ultimate runoff of more than 75 percent.

Table A-1 sets forth the diffuse source control measures applicable to general land uses and diffuse source activities, along with the estimated maximum level of pollution reduction which may be expected upon implementation of the applicable measures. The table also includes information pertaining to the costs of developing the alternatives set forth in this chapter.[1] These various individual nonpoint source control practices are summarized by group in Table A-2.

Of the sets of practices recommended for various levels of diffuse source pollution control presented in Table A-2, not all practices are needed, applicable, or cost-effective for all watersheds, due to variations in pollutant loadings and land use and natural conditions among the watersheds. Therefore, it is recommended that the practices indicated as needed for nonpoint source pollutant control be refined by local level nonpoint source control practices planning, which would be analogous to sewerage facilities planning for point source pollution abatement. A locally prepared plan for nonpoint abatement measures should be better able to blend knowledge of current problems and practices with a quickly evolving technology to achieve a suitable, site specific approach to pollution abatement.

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[1] *Costs are presented in more detail in the following SEWRPC Technical Reports: No. 18,* State of the Art of Water Pollution Control in Southeastern Wisconsin, *Volume Three,* Urban Storm Water Runoff, *July 1977, and Volume Four,* Rural Storm Water Runoff, *December 1976; and No. 31,* Costs of Urban Nonpoint Source Water Pollution Control Measures, *June 1991.*

Table A-1

GENERALIZED SUMMARY OF METHODS AND EFFECTIVENESS OF DIFFUSE SOURCE WATER POLLUTION CONTROL MEASURES

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Urban	Litter and pet waste control ordinance	Prevent the accumulation of litter and pet waste 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 $5,000-$6,000 and the cost of an alternative system is $10,000. The annual maintenance cost of a disposal system is $250. An in-ground pressure system is estimated to cost $6,000-$10,000 with an annual operation and maintenance cost of $250. A holding tank would cost $5,500-$6,500 with an annual operation and maintenance cost of $1,800
	Increased street sweeping	On the average, sweep all streets in urban areas an equivalent of once or twice a week with vacuum street sweepers; require parking restrictions to permit access to curb areas; sweep all streets at least eight months per year; sweep commercial and industrial areas with greater frequency than residential areas	30-50	Estimate curb miles based on land use, estimated street acreage, and Commission transportation planning standards; assume one street sweeper can sweep 2,000 curb miles per year; assume sweeper life of 10 years; assume residential areas swept once weekly, commercial and industrial areas swept twice weekly. The cost of a vacuum street sweeper is approximately $120,000. The cost of the operation and maintenance of a sweeper is about $25 per curb/mile swept
	Increased leaf and clippings collection and disposal	Increase the frequency and efficiency of leaf collection procedures in fall; use vacuum cleaners to collect leaves; implement ordinances for leaves, clippings, and other organic debris to be mulched, composted, or bagged for pickup	2-5	Assume one equivalent mature tree per residence plus five trees per acre in recreational areas; 75 pounds of leaves per tree; 20 percent of leaves in urban areas not currently disposed of properly. The cost of the collection of leaves in a vacuum sweeper and disposal is estimated at $180-$200 per ton of leaves
	Increased catch basin cleaning	Increase frequency and efficiency of catch basin cleaning; clean at least twice per year using vacuum cleaners; catch basin installation in new urban development not recommended as a cost-effective practice for water quality improvement	2-5	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 $10
	Reduced use of deicing salt	Reduce use of deicing salt on streets; salt only intersections and problem areas; prevent excessive use of sand and other abrasives	Negligible for pollutants addressed in this plan but helpful for reducing chlorides and associated damage to vegetation	Increased costs, such as for slower transportation movement, are expected to be offset by benefits such as reduced automobile corrosion and damage to vegetation

Table A-1 (continued)

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Urban (continued)	Improved street maintenance and refuse collection and disposal	Increase street maintenance and repairs; increase provision of trash receptacles in public areas; improve trash collection schedule; increase cleanup of parks and commercial centers	2-5	Increase current expenditures by approximately 15 percent
	Parking lot stormwater temporary storage and treatment measures	Construct gravel-filled trenches, sediment basins, or similar measures to store temporarily the runoff from parking lots, rooftops, and other large impervious areas; if treatment is necessary, use a physical-chemical treatment measure such as screens, dissolved air flotation, or a swirl concentrator	5-10	Design gravel-filled trenches for 24-hour, five year recurrence interval storm; apply to off-street parking acreages. For treatment—assume four-hour detention time. The capital cost of stormwater detention and treatment facilities is estimated at $40,000-$80,000 per acre of parking lot area, with an annual operation and maintenance cost of about $200 per acre
	Onsite storage—residential	Remove connections to sewer systems; construction onsite stormwater storage measures for subdivisions	5-10	Remove roof drains and other connections from sewer system wherever needed; use lawn aeration if applicable; apply dutch drain storage facilities to 15 percent of residences. The capital cost would approximate $500 per house, with an annual maintenance cost of about $25
	Stormwater infiltration—urban	Construct gravel-filled trenches for areas of less than 10 acres or basins to collect and store temporarily stormwater runoff to reduce volume, provide groundwater recharge and augment low stream flows	45-90	Design gravel-filled trenches or basins to store the first 0.5 inch of runoff; provide at least a 25-foot grass buffer strip to reduce sediment loadings. The capital cost of a stormwater infiltration is estimated at $12,000 for a six-foot deep, 10-foot wide trench, and at $70,000 for a one-acre basin, with an annual maintenance cost of about $10-$350 for the trench, and of about $2,500 for the basin
	Stormwater storage—urban	Store stormwater runoff from urban land in surface storage basins or, where necessary, subsurface storage basins	10-35	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 stormwater storage would range from $35,000 to $110,000 per acre of basin, with an annual operation and maintenance cost of about $40-$60 per acre
	Stormwater treatment	Provide physical-chemical treatment which includes screens, microstrainers, dissolved air flotation, swirl concentrator, or high-rate filtration, and/or disinfection, which may include chlorination, high-rate disinfection, or ozonation to stormwater following storage	10-50	To be applied only in combination with stormwater 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. Stormwater 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-$100 per acre

Table A-1 (continued)

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	Assumptions for Costing Purposes
Rural	Conservation practices	Includes such practices as strip cropping, contour plowing, crop rotation, pasture management, critical area protection, grading and terracing, grassed waterways, diversions, wood for management, fertilization and pesticide management, and chisel tillage	Up to 50	Costs for Natural Resources Conservation Service (NRCS)-recommended practices are applied to agricultural and related rural land; the distribution and extent of the various practices were determined from an examination of 56 existing farm plan designs within the Region. The capital cost of conservation practices ranges from $3,000-$5,000 per acre of rural land, with an average annual operation and maintenance cost of from $5-$10 per rural acre
	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 $100 per animal unit and $25 per animal unit, respectively. The capital cost of a liquid and slurry storage facility is about $1,000 per animal unit, with an annual operation and maintenance cost of about $75 per unit. An animal unit is the weight equivalent of a 1,000-pound cow
	Base-of-slope detention storage	Store runoff from agricultural land to allow solids to settle out and reduce peak runoff rates. Berms could be constructed parallel to streams	50-75	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 $500 per tributary acre, with an annual operation and maintenance cost of $25 per acre
	Bench terraces	Construct bench terraces, thereby reducing the need for many other conservation practices on sloping agricultural land	75-90	Apply to all appropriate agricultural lands for a maximum level of pollution control. Utilization of this practice would exclude installation of many basic conservation practices and base-of-slope detention storage. The capital cost of bench terraces is estimated at $1,500 per acre, with an annual operation and maintenance cost of $100 per acre

Table A-1 (continued)

Applicable Land Use	Control Measures[a]	Summary Description	Approximate Percent Reduction of Released Pollutants[b]	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 of management programs, and the effects of implemented measures; develop local awareness programs for citizens and public works officials; develop local contact and education efforts	Intermediate	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 $55,000 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 $250-$5,500 and $250-$1,500 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 $2,500 per acre of industrial land. Material storage control costs are estimated at $75 per ton of material
	Stream protection measures	Provide vegetative buffer zones along streams to filter direct pollutant runoff to the streams; 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	Intermediate	Intermediate

[a]*Not all control measures are required for each subwatershed. The characteristics of the watershed, the estimated required level of pollution reduction needed to meet the applicable water quality standards, and other factors will influence the selection and estimation of costs of specific practices for any one subwatershed. Although the control measures costed represent the recommended practices developed at the regional level on the basis of the best available information, the local implementation process should provide more detailed data and identify more efficient and effective sets of practices to apply to local conditions.*

[b]*The approximate effectiveness refers to the estimated amount of pollution produced by the contributing category (urban or rural)that could be expected to be reduced by the implementation of the practice. The effectiveness rates would vary greatly depending on the characteristics of the watershed and individual diffuse sources. It should be further noted that practices can have only a "sequential" effect, since the percent pollution reduction of a second practice can only be applied against the residual pollutant load which is not controlled by the first practice. For example, two practices of 50 percent effectiveness would achieve a theoretical total effectiveness of only 75 percent control of the initial load. Further, the general levels of effectiveness reported in the table are not necessarily the same for all pollutants associated with each source. Some pollutants are transported by dissolving in water and others by attaching to solids in the water; the methods summarized here reflect typical pollutant removal levels.*

[c]*For highly urbanized areas which require retrofitting of facilities into developed areas, the costs can range from $400,000 to $1,000,000 per acre of storage.*

Source: SEWRPC.

Table A-2

ALTERNATIVE GROUPS OF DIFFUSE SOURCE WATER POLLUTION CONTROL MEASURES PROPOSED FOR STREAMS AND LAKE WATER QUALITY MANAGEMENT

Pollution Control Category	Level of Pollution[b] Control	Practices to Control Diffuse Source Pollution from Urban Areas[c]	Practices to Control Diffuse Source Pollution from Rural Areas[b]
Basic Practices	Variable	Construction erosion control; onsite sewage disposal system management; streambank erosion control	Streambank erosion control
	25 percent	Public education programs; litter and pet waste control; restricted use of fertilizers and pesticides; construction erosion control; critical areas protection; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; material storage facilities and runoff control	Public education programs; fertilizer and pesticide management; critical area protection; crop residue management; chisel tillage; pasture management; contour plowing; livestock waste control
Additional Diffuse Source Control Practices[a]	50 percent	Above, plus: Increased street sweeping; improved street maintenance and refuse collection and disposal; increased catch basin cleaning; stream protection; increased leaf and vegetation debris collection and disposal; stormwater storage; stormwater infiltration	Above, plus: Crop rotation; contour strip-cropping; grass waterways; diversions; wind erosion controls; terraces; stream protection
	75 percent	Above, plus: An additional increase in street sweeping, stormwater storage and infiltration; additional parking lot stormwater runoff storage and treatment	Above, plus: Base-of-slope detention storage
	More than 75 percent	Above, plus: Urban stormwater treatment with physical-chemical and/or disinfection treatment measures	Bench terraces[c]

[a]In addition to diffuse source control measures, lake rehabilitation techniques may be required to satisfy lake water quality standards.

[b]Groups of practices are presented here for general analysis purposes only. Not all practices are applicable to, or recommended for, all lake and stream tributary watersheds. For costing purposes, construction erosion control practices, public education programs, and material storage facilities and runoff controls are considered urban control measures and stream protection is considered a rural control measure.

[c]The provision of bench terraces would exclude most basic conversation practices and base-of-slope detention storage facilities.

Source: SEWRPC.