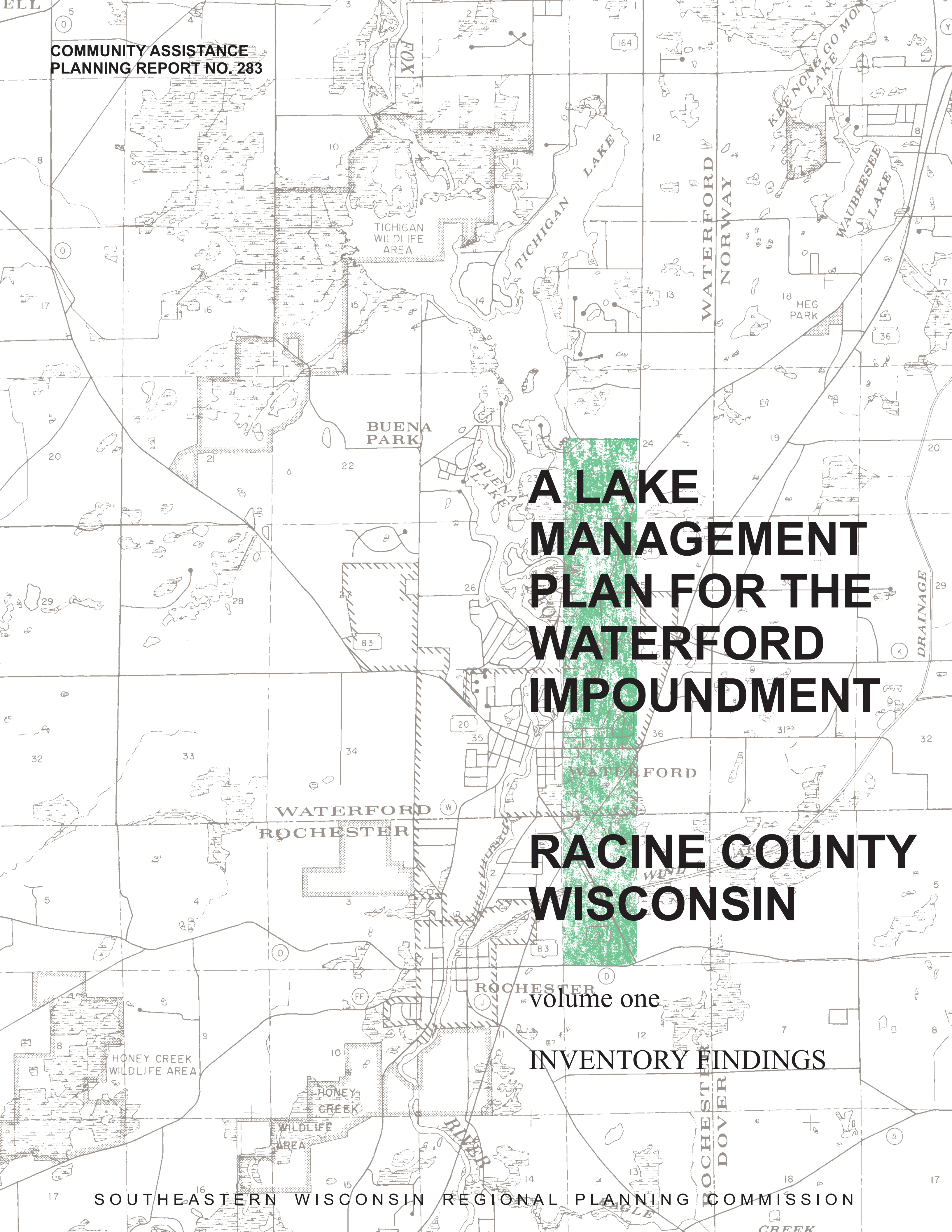
COMMUNITY ASSISTANCE
PLANNING REPORT NO. 283

A LAKE MANAGEMENT PLAN FOR THE WATERFORD IMPOUNDMENT

RACINE COUNTY WISCONSIN

volume one

INVENTORY FINDINGS



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Chapter I

INTRODUCTION

The Waterford Impoundment is a 1,132-acre[1] waterbody located within U.S. Public Land Survey Sections 10 through 15, 23, 26, and 35, Township 4 North, Range 19 East, Town and Village of Waterford, Racine County. The tributary area draining to the Impoundment is about 358 square miles in areal extent. While this tributary basin has historically encompassed large tracts of agricultural land, increasing portions of the tributary area are in urban land uses and the trend toward urban development remains ongoing.

The Impoundment is both fed and drained by the Fox River. The Fox River enters the Impoundment at its northern extreme, and continues in a southerly direction after passing over the fixed crest impoundment comprising the Waterford Dam in the Village of Waterford. The western portion of the dam was reconstructed in 1977. Two fixed spillways, flanking the radial gates installed in 1977 pursuant to recommendations set forth in the adopted Fox River watershed plan,[2] have a crest elevation of 773.4 feet above the National Geodetic Vertical Datum of 1929 (NGVD-29). The elevation of the fixed spillway was raised about 0.5-foot by the addition of an angle iron riser during 1978 to the design elevation of 773.4 feet NGVD-29. The spillway elevation of 773.4 feet NGVD-29 is equal to the elevation of the original crest of the dam, which was replaced in 1977. In addition to the Fox River, a number of small streams and springs drain to the Impoundment.

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[1]*The 1,132-acre Waterford Impoundment is comprised of the 268-acre Tichigan Lake, the 108-acre Buena Lake, and the 756-acre impounded portion of the Fox River linking and immediately upstream of these two lakes, between Bridge Drive in the Town of Waterford and the dam in the Village of Waterford. The adopted Regional Water Quality Management Plan, set forth in SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Two,* Alternative Plans*, published in February of 1979, indicates a surface area for the Impoundment of 1,374 acres. This latter surface area includes approximately 242 acres of water surface upstream of the Bridge Drive to a point in Waukesha County on the Fox River west of River Avenue, extended, and inclusive of portions of the Fox River influenced by the backwater effect of the Waterford Dam. For purposes of this plan, the surface area of 1,132 acres has been adopted based upon local conventions.*

[2]*SEWRPC Planning Report No. 12,* A Comprehensive Plan for the Fox River Watershed, *Volume One,* Inventory Findings and Forecasts*, April 1969, and Volume Two,* Alternative Plans and Recommended Plan*, February 1970; see also SEWRPC Community Assistance Planning Report No. 5,* Drainage and Water Level Control Plan for the Waterford-Rochester-Wind Lake Area of the Lower Fox River Watershed*, May 1975, as refined by SEWRPC Memorandum Report No. 102,* Water Level Control Plan for the Waterford-Vernon area of the Middle Fox River Watershed, Racine and Waukesha Counties, Wisconsin*, March 1995.*

The Fox River tributary area is located south and southeast of the tributary area draining to the Rock River, and west and southwest of the Menomonee and Root River tributary areas. Both the Rock River and Fox River form part of the Mississippi River System, while the Menomonee and Root Rivers and their tributary stream systems drain to Lake Michigan. The total land area tributary to the Waterford Impoundment (including that portion draining to the Impoundment through the Fox River tributary system) is about 231,553 acres in areal extent; within this total tributary area, the land area draining directly to the Impoundment without passing through an upstream waterbody is approximately 14,807 acres in areal extent.

The Impoundment, locally known as the Waterford Waterway, is an important asset to the residents of the County and the Region, and is a popular recreational destination for residents and visitors. The Impoundment is located in close proximity to the metropolitan Milwaukee area and adjacent to the rapidly growing urban centers of eastern and central Racine County.

With respect to the recreational usage of the Impoundment, the Waterford Impoundment provides significant opportunities for lake-oriented recreation. The Impoundment has adequate public recreational boating access, pursuant to Chapter NR 1 of the *Wisconsin Administrative Code*. Nevertheless, during recent years, the Waterford Impoundment has experienced various management problems, the symptoms of which have included excessive aquatic plant growth and perceived sedimentation problems, recreational user conflicts and limitations, and variations in water quality. In addition, concerns have been raised regarding the need to protect environmentally sensitive areas within and adjacent to the Impoundment, and to prevent the invasion of exotic species and noxious weeds.[3]

The current water use objectives for the Waterford Impoundment include:

1. Providing water quality suitable for full body contact recreational use and the maintenance of a healthy fishery and other desirable forms of aquatic life;

2. Significantly reducing the severity of the nuisance problems associated with deposition of silt sediments, and excessive aquatic plant and algal growths in Buena and Tichigan Lakes, which constrain or preclude intended water uses at sites throughout the Impoundment;

3. Restoring and rehabilitating the aquatic flora and fauna, especially within the riverine portions of the Impoundment, which lack the abundant growths observed in the Lakes;

4. Improving opportunities for both active and passive water-based recreation, navigation and human use; and

5. Maintaining and improving the hydrologic functioning of the lakes, river and impoundment to promote a healthy native flora and fauna and multiple human uses.

Seeking to improve the usability of the Waterford Impoundment, restore and protect its natural assets, and develop its recreational use potential in a manner consistent with the water use objective applied to the Impoundment and its attendant stream system, the Waterford community formed the Waterford Waterway Management District (WWMD) during early 2003. As one of its first actions, the WWMD requested that the Southeastern Wisconsin Regional Planning Commission (SEWRPC) work cooperatively with the District and Wisconsin Department of Natural Resources (WDNR) to prepare a lake management plan for the Impoundment. For this purpose, the WWMD, with the support of both the Village and Town of Waterford, applied for and received cost-share funding for plan preparation through the Chapter NR 190 Lake Management Planning Grant Program administered by the WDNR. Consequently, this lake management plan represents part of the ongoing

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[3]*Waterford Waterway Management District,* '05 Water Watch*, March 2005.*

commitment of the WWMD, as well as of the Village and Town of Waterford, to sound environmental planning and ecosystem restoration and protection with respect to the Impoundment. The goals of the District with respect to the Impoundment, as adopted at the meeting of the Board of Commissioners on November 20, 2004, include the following:

- Monitoring and proactively contributing to the preparation of the Lake Management Plan being developed by SEWRPC and aggressively implementing its recommendations.

- Building and maintaining close partnerships with the WDNR, the Town and Village of Waterford, Racine County, and the Fox River Committee Against Underwater Sedimentation and Erosion (Fox River CAUSE) to garner their commitment and support for initiatives to improve and protect the Waterway.

- Developing productive relationships with the U.S. Army Corps of Engineers, the Southeast Wisconsin Fox River Basin Partnership, the Racine County Lakes Association, and other agencies, boards, and commissions to promote the betterment of the Waterway.

- Establishing and implementing projects, programs, and measures which compliment the Lake Management Plan and improving the surrounding tributary area environment, thereby reducing or eliminating new or existing negative influences on the quality of the water within the Fox River and Tichigan Lake.

- Informing and educating the electors and property owners of the District, Waterway users, and the general community on issues, plans, and programs affecting the tributary area environment to gain their active support for, and participation in, District initiatives.

- Establishing and maintaining a fiscally responsible budget that represents the needs and desires of District electors and property owners, and that supports all programs that lead to environmental improvement and ecosystem renewal.

- Maintaining appropriate and meaningful boundaries for the District such that all property owners located within will benefit from inclusion in the District and thereby promote improvement of the waterway.

- Encouraging open discussion and public participation at all District Board of Commissioners and Committee meetings.

The lake management plan was prepared during the period 2004 through 2006 by SEWRPC in cooperation with the WWMD, and represents one of several actions undertaken by the District to manage the Waterford Impoundment and its natural resources.

This report discusses the physical, chemical, and biological characteristics of the Impoundment, as documented during previous phases of this tributary area-based study and completed by the U.S. Geological Survey, the WDNR, and SEWRPC, or which are currently underway. In addition, pertinent related characteristics of the tributary area form the basis for the determination of the current condition of the waterbody and the consequent evaluation of the feasibility of various water quality management alternatives that may enhance water quality conditions, habitat, and recreational use potential of the Impoundment. The report is presented in two volumes: Volume One includes the inventory information used to formulate and evaluate the alternative management measures that comprise the recommended lake management plan. Volume Two summarizes the alternatives and sets forth the recommended management plan for the Waterford Impoundment.

Within Volume One, Chapter II of this report provides a physical description of the Waterford Impoundment and its tributary area, including a typical water budget for the Impoundment. Chapter III sets forth inventory information on land use and population growth within the basin tributary to the Waterford Impoundment. Chapters IV and V set forth inventory information on water quality and the biological communities of the Impoundment, respectively, while Chapter VI summarizes the water quality standards and guidelines applicable to the Waterford Impoundment and inventory information on the human uses of the Impoundment.

Within Volume Two, Chapter I contains a summary of the inventory data contained in Volume One. Chapter II reviews alternative lake and tributary area management measures, while Chapter III sets forth the recommended lake and tributary area management measures. Specific information on nonpoint source pollution control measures, aquatic plant management measures, and applicable recreational use ordinances are presented as appendices. In addition, applicable point source pollution abatement considerations are addressed.

In developing this plan, the WWMD created, during early 2004, an Inland Lake Management Plan Advisory Committee, comprised of representatives of the Village and Town of Waterford, the Fox River CAUSE, the Southeastern Wisconsin Fox River Commission, WDNR, SEWRPC, and local landowners. This Committee builds upon the pioneering actions of the Town of Waterford, initiated through its Waterway Committee, and the Tichigan Lake Advancement Association, which presently are being continued by the District in partnership with the Fox River CAUSE and Southeastern Wisconsin Fox River Commission. The Advisory Committee was formulated "to monitor the development of the lake management plan," the purpose of which is to provide guidance to the riparian communities as they seek to protect and improve the water quality of the Waterford Impoundment and its tributary area. In achieving this mission, the Committee reviewed a preliminary draft of this plan, and comments received were incorporated into the final draft of the plan as appropriate.

The recommended plan elements conform to the standards set forth in Chapter 30 of the *Wisconsin Statutes* and requirements set forth in the relevant *Wisconsin Administrative Codes* governing lake and tributary area management in the basin tributary to the Waterford Impoundment.[4] Accordingly, this lake management plan should constitute a practical, as well as technically sound, guide for the management of the Waterford Impoundment and its tributary basin.

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[4]*This plan has been prepared pursuant to the statutory standards set forth in Chapter 30,* Wisconsin Statutes*, and the relevant requirements elaborated in the* Wisconsin Administrative Code *as set forth in Chapter NR 1, "Public Access Policy for Waterways;" Chapter NR 102, "Water Quality Standards for Wisconsin Surface Waters;" Chapter NR 103, "Water Quality Standards for Wetlands;" Chapter NR 107, "Aquatic Plant Management;" and Chapter NR 109, "Aquatic Plants Introduction, Manual Removal and Mechanical Control Regulations."*

Chapter II

PHYSICAL DESCRIPTION

INTRODUCTION

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

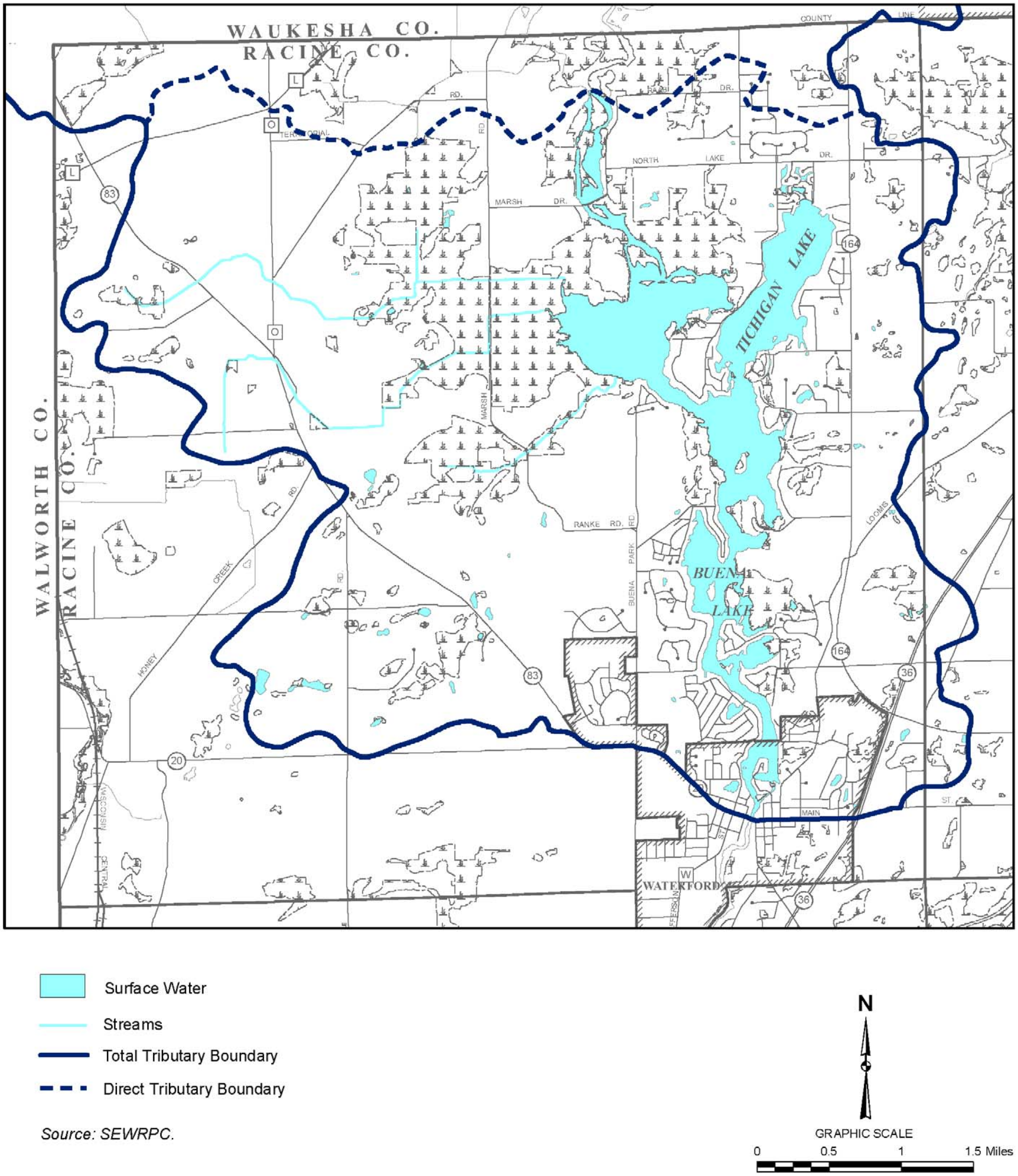
WATERBODY CHARACTERISTICS

The Waterford Impoundment is located in the Town and Village of Waterford, as shown in Map 1. The Impoundment is a drainage or through flow waterbody, having both a defined inflow and outflow, comprised of the Fox River. The Impoundment is a flowage impounding portions of the Fox River and including Buena Lake and Tichigan Lake, natural lakes preexisting at the time of closure of the dam at Waterford. The water level of the Impoundment is controlled artificially by the Waterford Dam located in the Village of Waterford. There are four islands in the southern portions of the Impoundment, downstream from Tichigan Lake, and numerous small islands in the riverway upstream from Tichigan Lake.

The Waterford Impoundment lies in a basin formed by a terminal moraine in a glacial erosion valley and is fed, in part, by numerous unnamed tributaries and adjoining wetlands. It is drained by the Fox River, which also flows into it at its northern extreme about four miles above the dam at Waterford. The Waterford Impoundment has a surface area of about 1,132 acres, with a maximum depth, in the Tichigan Lake subbasin, of about 65 feet. The maximum depth in the Buena Lake subbasin, in contrast, is about eight feet. Approximately 32 percent of the waterbody area is less than three feet deep, while about 8 percent of the Impoundment has a water depth of more than 20 feet. The Waterford Impoundment is approximately 4.2 miles long and about 1.4 miles wide at its widest point. The major axis of the Impoundment lies in a generally north-south direction. The Impoundment shoreline is approximately 24 miles long, with a shoreline development factor of 4.9, indicating that the shoreline is about five times longer than a circular lake of the same area. This is consistent with the elongate nature of the waterbody. The Impoundment has a total volume of approximately 7,113 acre-feet. These hydrographical and morphometric data are summarized in Table 1 and the bathymetry of the Impoundment is shown on Maps 2, 3, and 4.

Map 1

LOCATION OF WATERFORD IMPOUNDMENT



Source: SEWRPC.

Table 1

HYDROLOGY AND MORPHOMETRY CHARACTERISTICS OF WATERFORD IMPOUNDMENT: 2000

Parameter	Measurement
Size (total)	
Surface Area	1,132 acres[a]
Total Drainage Area	362 square miles
Volume	7,113 acre-feet
Residence Time[b]	11 days
Shape	
Maximum Length of Lake	4.2 miles
Length of Shoreline	24 miles
Maximum Width	1.4 miles
Shoreline Development Factor[c]	4.9
Depth	
Area of Lake Less than 3 Feet	32 percent
Area of Lake Greater than 20 Feet	8 percent
Maximum Depth (Tichigan)	65 feet
Maximum Depth (Buena)	8 feet

[a]*Surface area is based on the combined values for the Tichigan Lake sub-basin, the Buena Lake sub-basin, and the "widespread" portion (Conservancy Bay) of the Fox River as set forth in the Wisconsin Department of Natural Resources Lake Use Report No. FX-6, Waterford Impoundment and Tichigan Lake, Racine County, Wisconsin, 1970.*

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

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

Source: Wisconsin Department of Natural Resources and SEWRPC.

The shoreline of the Waterford Impoundment supports a variety of uses. The northernmost areas, particularly in the "Widespread" area (Conservancy Bay) downstream from the structure locally known as the "iron bridge," where Bridge Drive crosses the Fox River in the Town of Waterford, to the outlet from Tichigan Lake, have vast stretches of wetlands, while the Tichigan Lake-Buena Lake areas downstream to the Waterford Dam are developed mostly for residential uses, with some scattered commercial uses comprised primarily of businesses catering to lake users. Two additional significant wetland areas occur along the Lake's shoreline: one along the western shores of the impounded portion of the Fox River between the outlet from Tichigan Lake and Buena Lake, and the other along the eastern shoreline in the Fowler's Bay and Elm Island Bay areas.

Erosion of shorelines results in the loss of land, damage to shoreline infrastructure, and interference with recreational access and lake use. Such erosion is usually caused by wind-wave erosion, ice movement, and motorized boat traffic. A survey of the Waterford Impoundment shoreline, conducted during 2004 by Regional Planning Commission staff, identified existing shoreline protection structures around the Lake, as shown on Maps 5, 6, and 7. Significant portions of the shoreline protection structures along the lakeshore within the lower portion of the Impoundment within the Village of Waterford have been replaced and/or restored since the late-1990s, although most of the western shoreline in the Conservancy Bay portion of the impounded Fox River, as well as the eastern and western shorelines of the Fox River from conservancy Bay north to Bridge Drive, remained in a natural state. Most of the developed shorelands of Tichigan Lake, Buena Lake and that portion of the impounded Fox River downstream from Buena Lake to the Waterford Dam had some form of shoreline protection in 2004. Although most of the shoreline protection structures were in a good state of repair, improperly installed and failing shoreline protection structures, and the natural erosion of shorelines within the Waterford Impoundment due to wind action and ice movements, are a cause for concern.

Lake bottom sediment types are shown on Maps 8, 9 and 10. Silt and muck are the predominant lake bottom material throughout most of the Waterford Impoundment, although the Tichigan Lake subbasin additionally exhibits large areas of sand and gravel, primarily along the shoreline.[1]

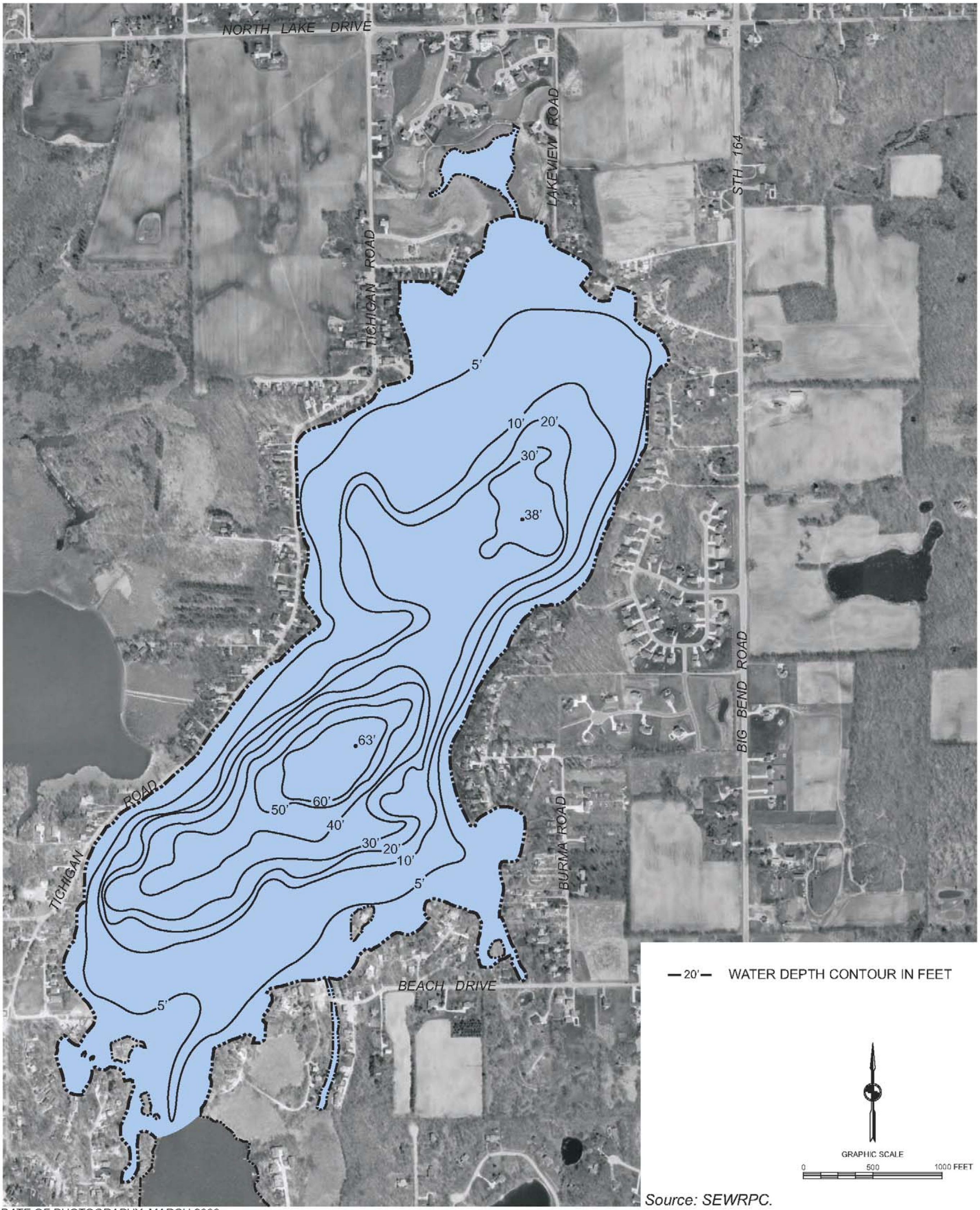
TRIBUTARY AREA CHARACTERISTICS

The total tributary area to the Waterford Impoundment is approximately 231,553 acres, or about 362 square miles, in areal extent, encompassing large portions of central Waukesha and Racine Counties and extending northward

[1]*Wisconsin Department of Natural Resources Lake Use Report No. FX-6,* The Waterford Impoundment and Tichigan Lake, Racine County, Wisconsin, *1970.*

Map 2

BATHYMETRIC MAP OF TICHIGAN LAKE

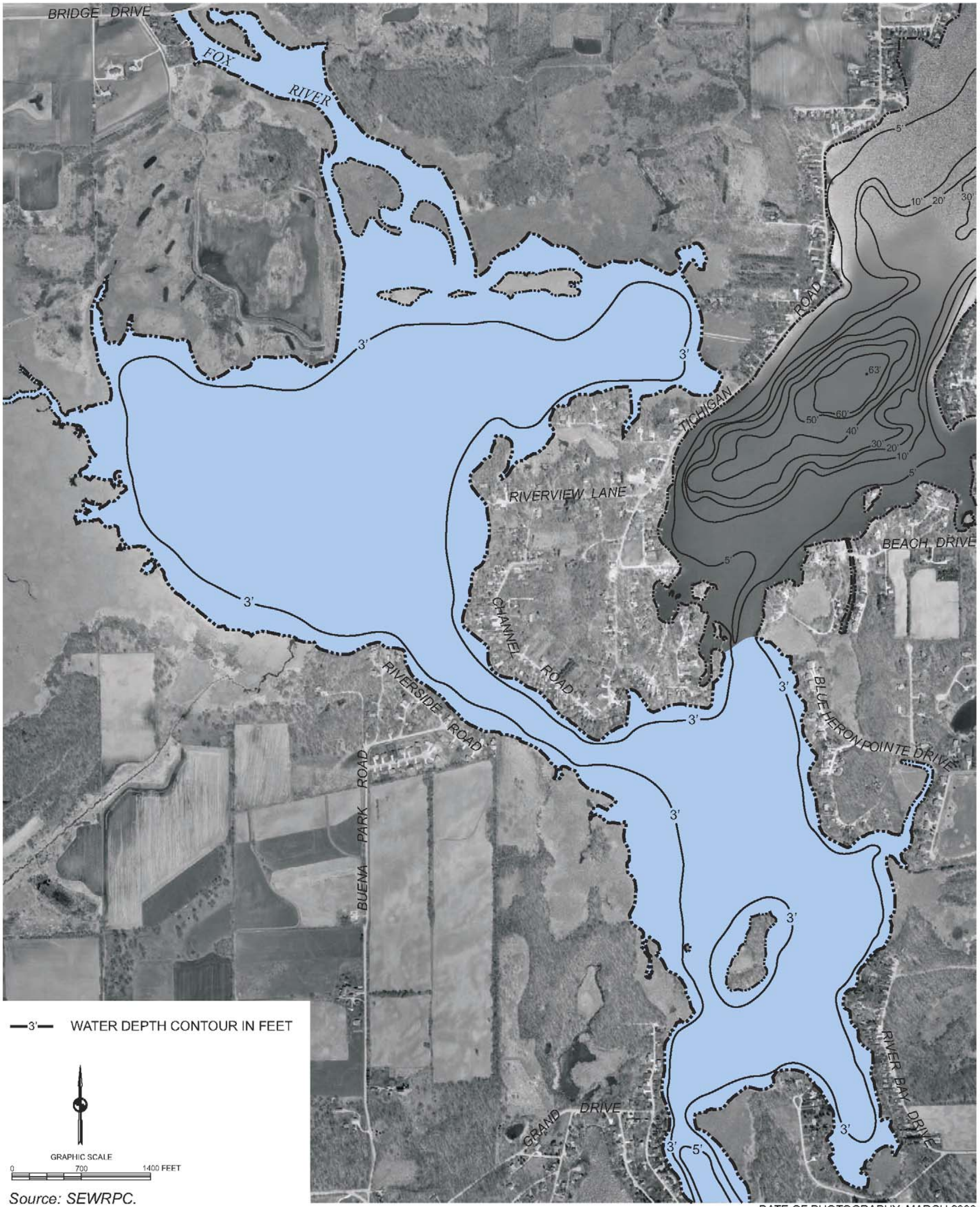


DATE OF PHOTOGRAPHY: MARCH 2000

Source: SEWRPC.

Map 3

BATHYMETRIC MAP OF WATERFORD IMPOUNDMENT

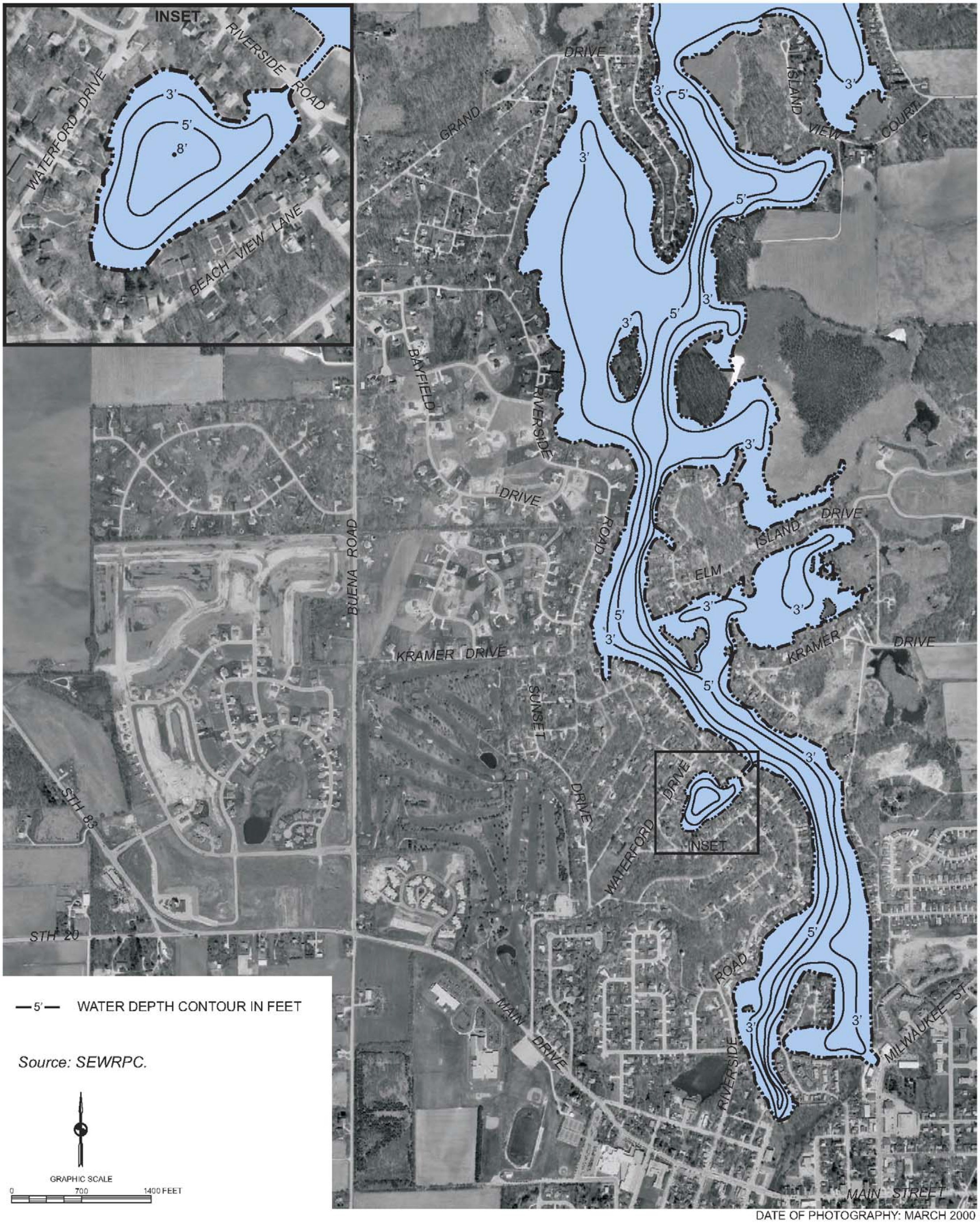


Source: SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

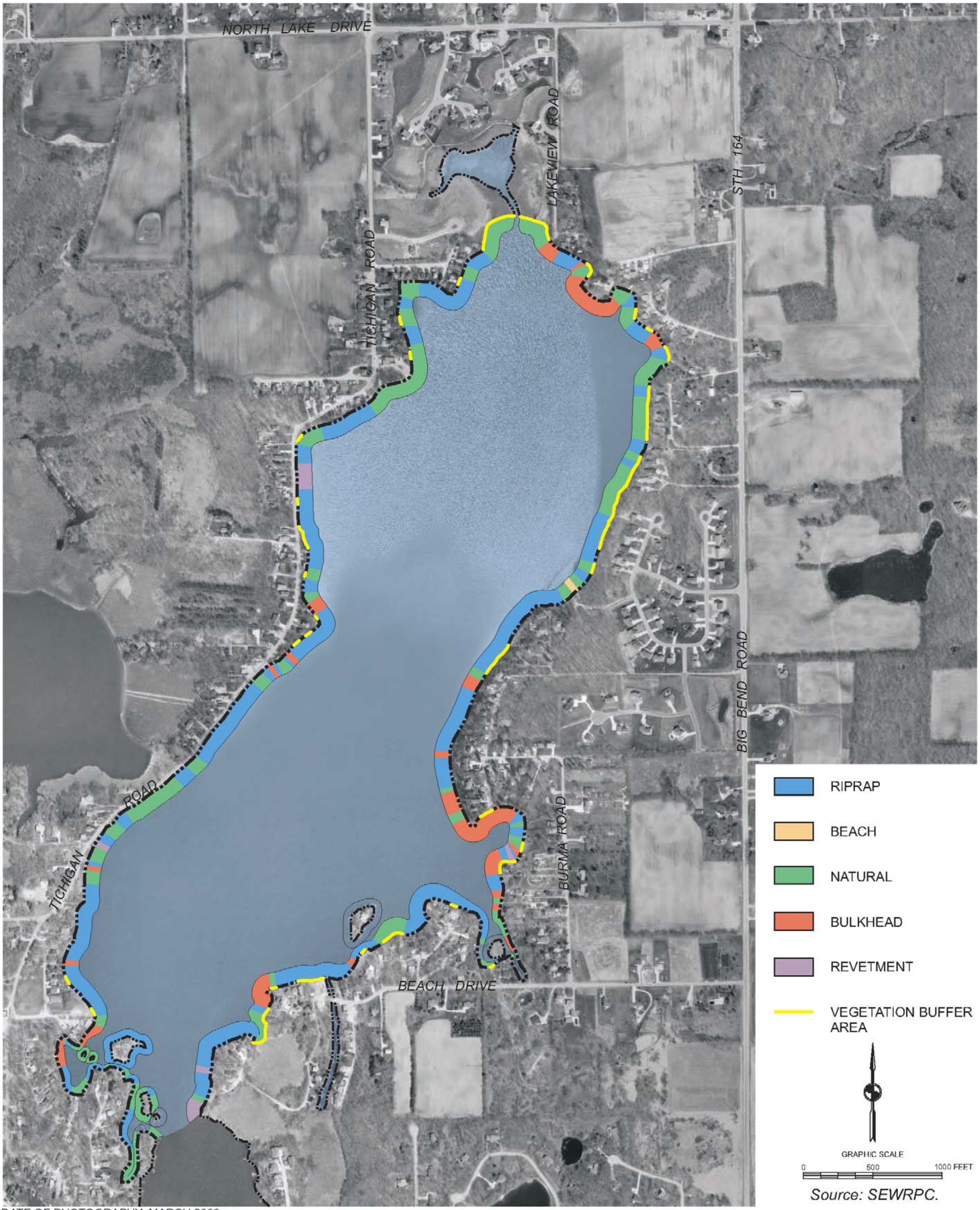
Map 4

BATHYMETRIC MAP OF WATERFORD IMPOUNDMENT AND BUENA LAKE



Map 5

SHORELINE PROTECTION STRUCTURES ON TICHIGAN LAKE: 2003

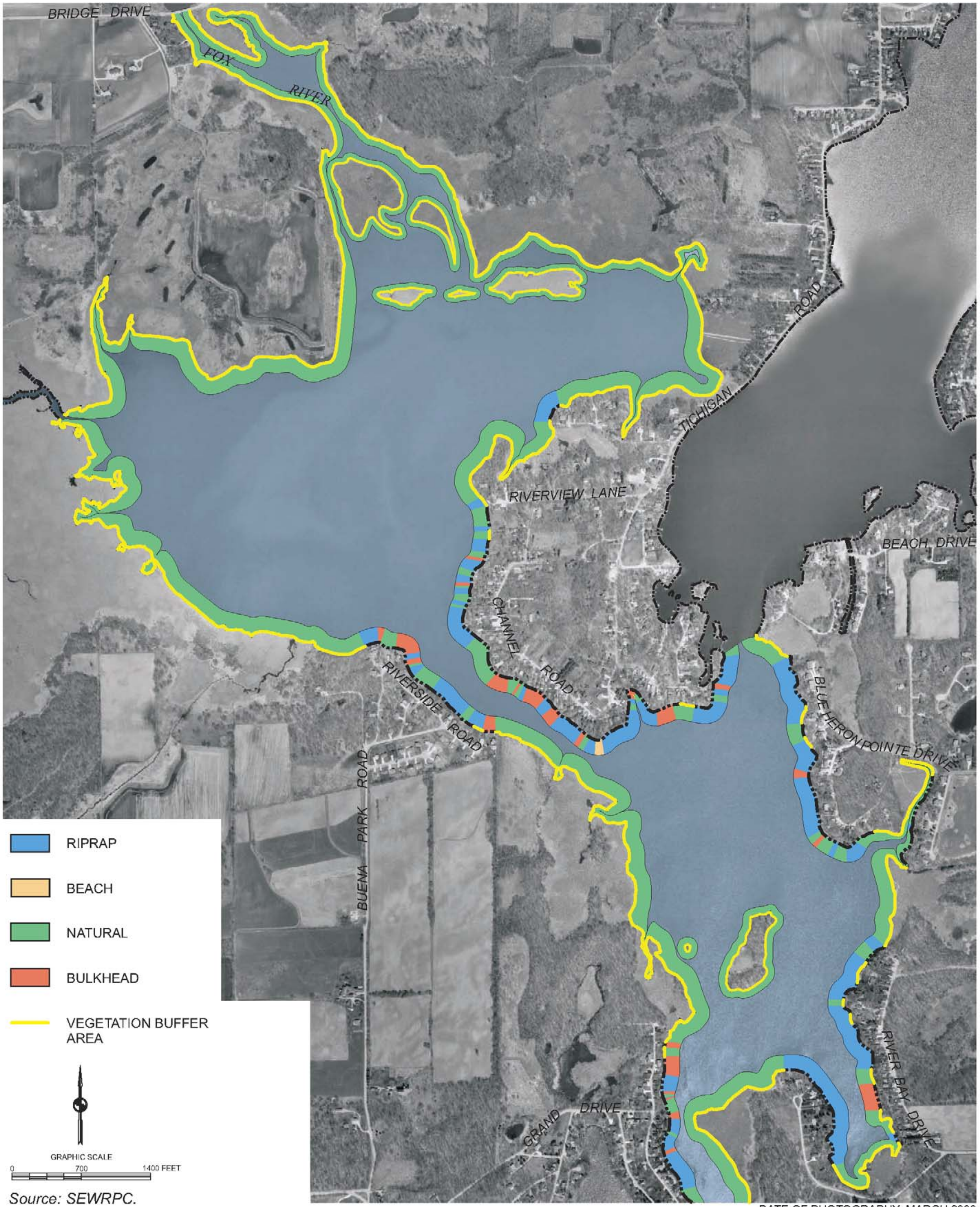


DATE OF PHOTOGRAPHY: MARCH 2000

Source: SEWRPC.

Map 6

SHORELINE PROTECTION STRUCTURES ON THE WATERFORD IMPOUNDMENT: 2003

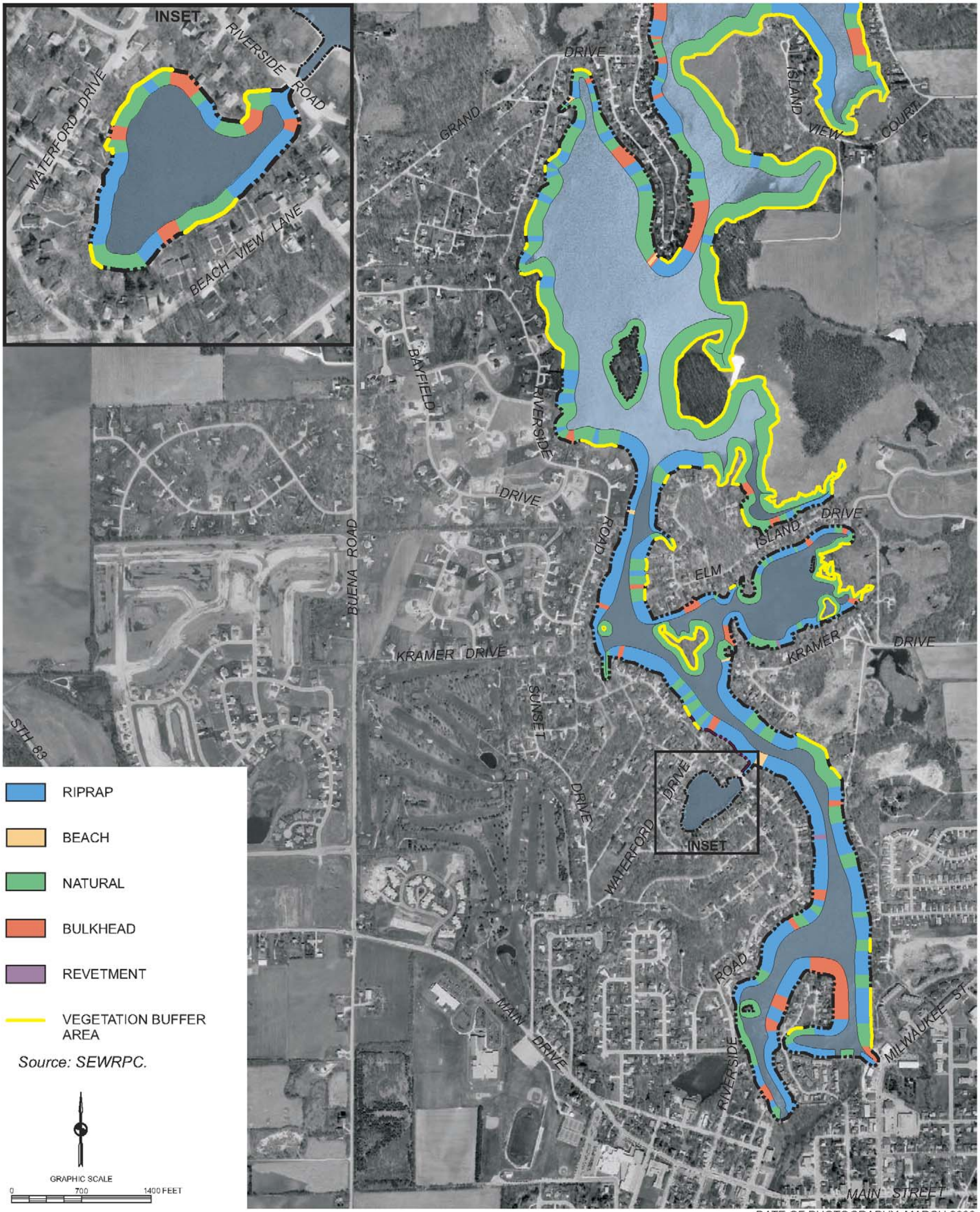


Source: SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Map 7

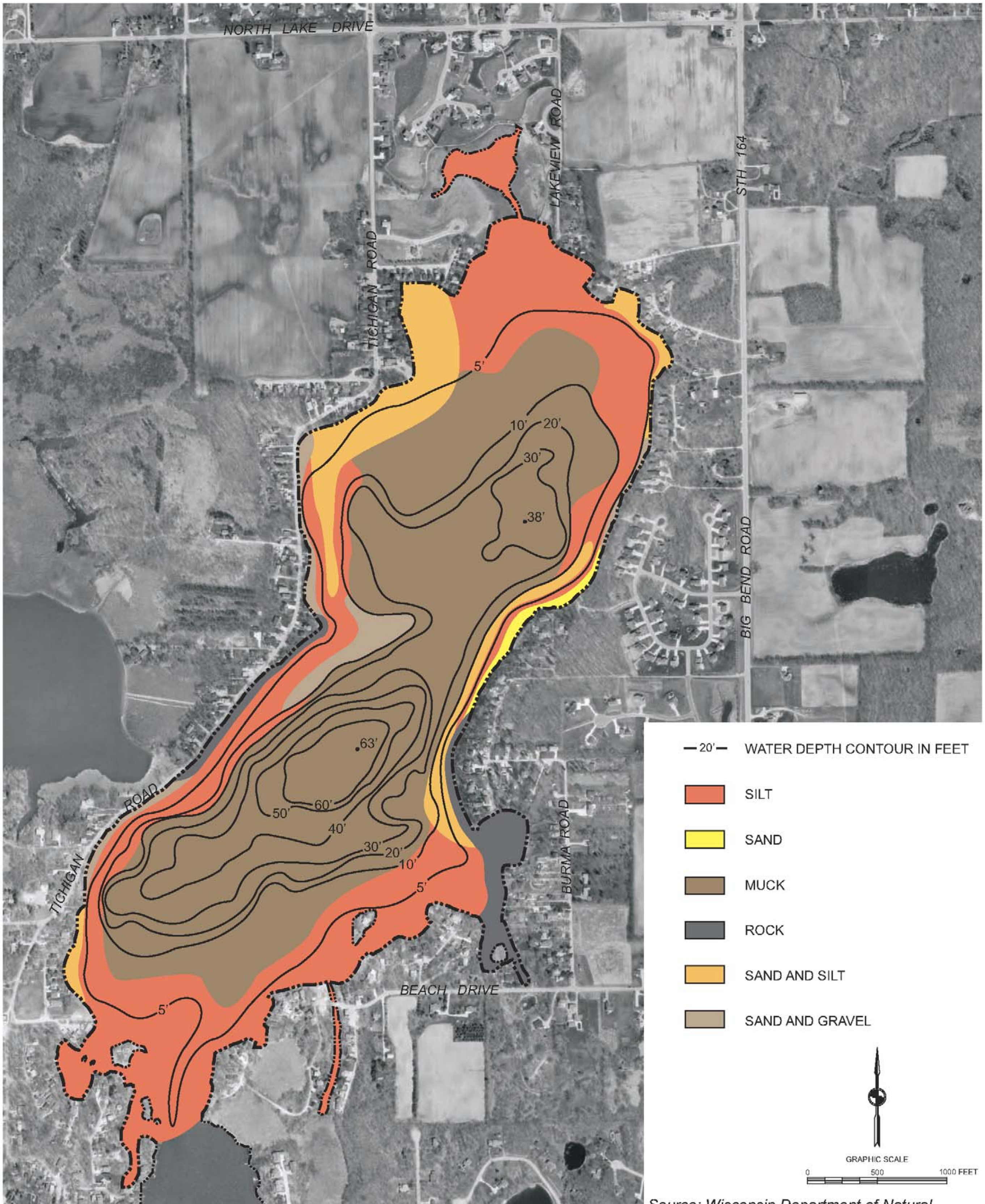
SHORELINE PROTECTION STRUCTURES ON WATERFORD IMPOUNDMENT AND BUENA LAKE: 2003



DATE OF PHOTOGRAPHY: MARCH 2000

Map 8

SEDIMENT SUBSTRATE DISTRIBUTION IN TICHIGAN LAKE

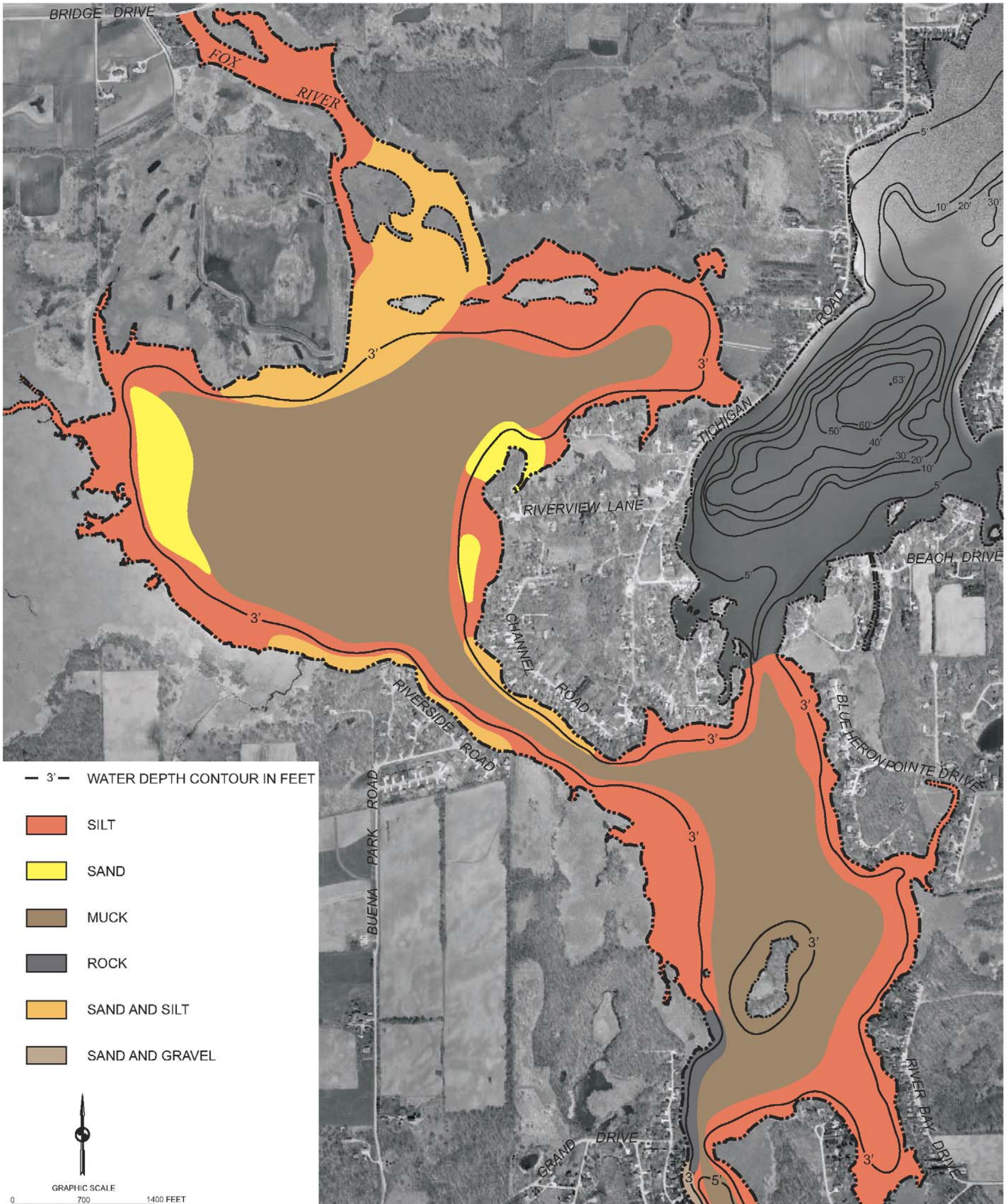


DATE OF PHOTOGRAPHY: MARCH 2000

Source: Wisconsin Department of Natural Resources and SEWRPC.

Map 9

SEDIMENT SUBSTRATE DISTRIBUTION IN WATERFORD IMPOUNDMENT

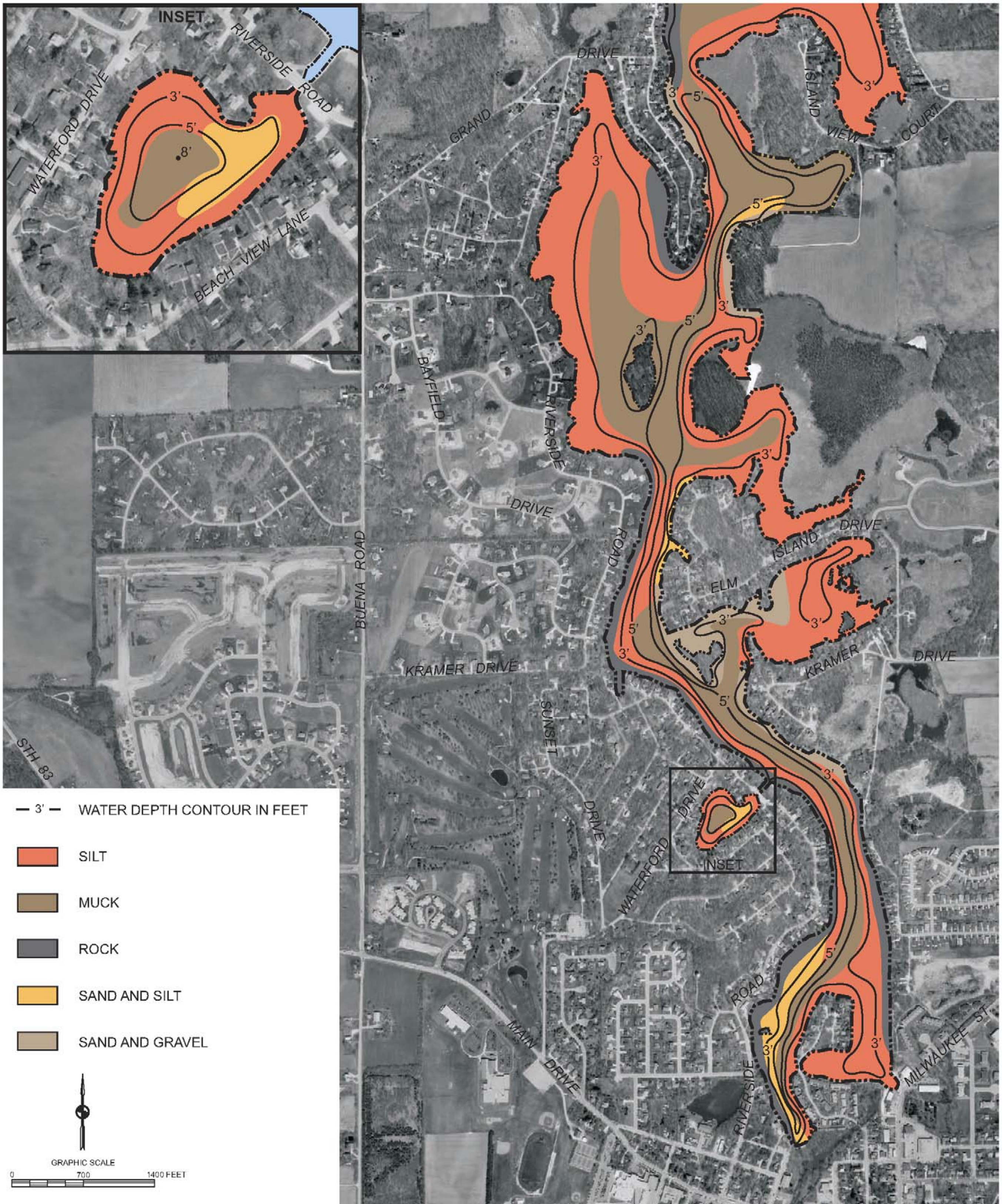


Source: Wisconsin Department of Natural Resources and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

Map 10

SEDIMENT SUBSTRATE DISTRIBUTION IN WATERFORD IMPOUNDMENT AND BUENA LAKE



Source: Wisconsin Department of Natural Resources and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 2000

into the southernmost portions of Washington County. The area directly tributary to the Waterford Impoundment, that is, the area that drains directly into the waterbody without passing through any upstream lakes or rivers, totals about 14,807 acres, or approximately 23 square miles, in areal extent, as shown on Map 1. This direct tributary area is located within the Town and Village of Waterford and Town of Norway, all in Racine County.

The Impoundment has a relatively large tributary area-to-lake surface area ratio of about 202.5 to 1, indicating that the waterbody is well-flushed with a concomitantly short water residence time, as set forth in Table 1.[2] The Waterford Impoundment is fed primarily by inflows from the Fox River entering the Impoundment from the north, inflows from several unnamed tributaries and wetland areas along the eastern shoreline, and inflows from a large wetland-stream-drainage canal network along the western shorelands just downstream of the "iron bridge." The "iron bridge" traditionally marks the transition between the River and the Impoundment. The outlet of the Waterford Impoundment to the Fox River is located in the Village of Waterford at the Waterford Dam.

Soil Types and Conditions

Soil type, land slope, and land use are among the more important factors determining lake water quality conditions. Soil type, land slope, and vegetative cover are also important factors affecting the rate, amount, and quality of stormwater runoff. Soil texture and soil particle structure influence the permeability, infiltration rate, and erodibility of soils. Land slopes are important determinants of stormwater runoff rates and of the susceptibility of soils to erosion. The erosivity of the runoff can be moderated or modified by vegetation or structural modifications of the land slopes through provision of stormwater detention structures, for example.

The U.S. Natural Resources Conservation Service, formerly the U.S. Soil Conservation Service, under contract to the Southeastern Wisconsin Regional Planning Commission (SEWRPC), completed a detailed soil survey of the Waterford Impoundment area in 1966.[3] The soil survey contained interpretations for planning and engineering applications, as well as for agricultural applications. Using the regional soil survey, an assessment was made of hydrologic characteristics of the soils in the tributary area of the Waterford Impoundment. The suitability of the soils for urban residential development was assessed using three common development scenarios. These ratings reflected the requirements of Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems as it existed through the year 2000. During 2000, the Wisconsin Legislature amended Chapter Comm 83 and adopted new rules governing onsite sewage disposal systems. These rules, which had an effective date of July 1, 2000, significantly altered the existing regulatory framework and have effectively increased the area in which onsite sewage disposal systems may be utilized. Nevertheless, the residential lands within the tributary area tributary to Waterford Impoundment currently are served by public sanitary sewerage.[4]

Nevertheless, the interpretations associated with the soil survey are such that they continue to provide insights into the potential for land-based sources of pollution to affect the Impoundment water quality either as a consequence of overland flows during storm events or through groundwater interflows in the Lake. Therefore, Map 11 presents the soil ratings for onsite sewage disposal systems as determined pursuant to the then-existing requirements of Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems as of early 2000. It is useful to note that about one-half of the lands draining to the Impoundment were identified as having a potential sensitivity to disturbance and likelihood of being permeable to pollutants.

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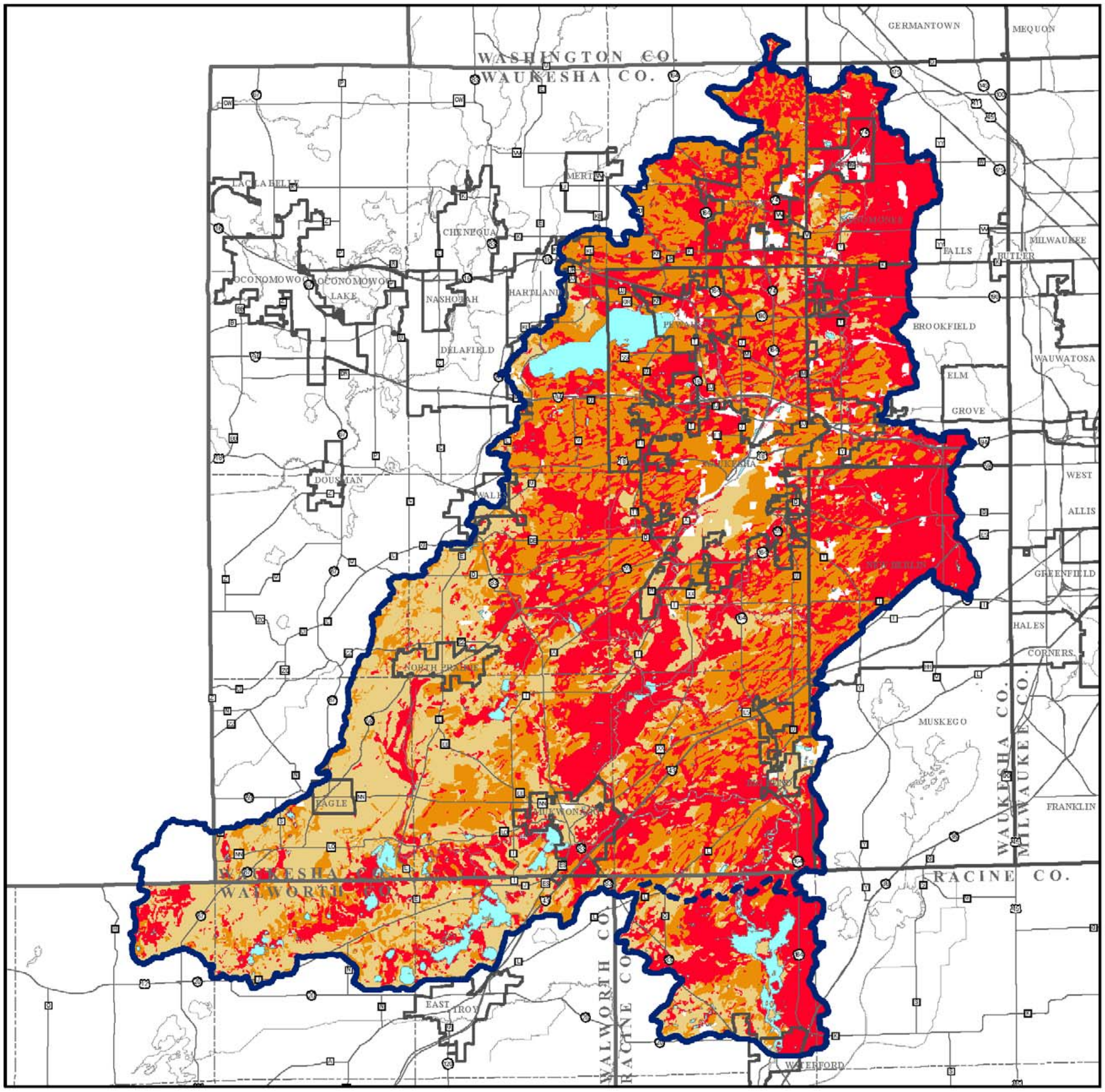
[2]*The water residence time is defined as the time required for a volume equivalent to the full volume of the lake to enter the lake from the tributary area.*

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

[4]*SEWRPC Community Assistance Planning Report No. 141, 2nd Edition,* Sanitary Sewer Service Area for the Waterford/Rochester Area, Racine County, Wisconsin, *April 1996.*

Map 11

SUITABILITY OF SOILS WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT FOR CONVENTIONAL ONSITE SEWAGE DISPOSAL SYSTEMS



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

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

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

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

SURFACE WATER

N

Miles
0 2.5 5 7.5 10

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

Soils within the area directly tributary to the Waterford Impoundment were categorized generally into four main hydrologic groups, as indicated in Table 2. Soils that could not be categorized, including disturbed areas and areas where fill has been placed, were included in an “other” group. About 42 percent of the tributary area was covered by moderately drained soils, with the balance being approximately equally covered by poorly drained and very poorly drained soils. The areal extent of these soils and their locations within the tributary area is shown on Map 12.

Major soil associations found in the area directly tributary to the Waterford Impoundment are: the Morley-Beecher-Ashkum association of well-drained to poorly drained soils that have a silty clay or silty clay loam subsoil, the Hebron-Montgomery-Aztalan association of well-drained to poorly drained soils that have a loam to silty clay subsoil, the Fox-Casco association of well-drained soils that have a clay loam and silty clay loam subsoil, the Houghton-Palms association of very poorly drained organic soils, and the Miami association of well-drained soils that have a silty clay loam and clay loam subsoil. In addition, the major soil types present within the tributary area include: Navan silt loam, Aztalan loam, Morley silt loam, Darroch fine sandy loam, Zurich silt loam and Marsh soils.

Climate and Hydrology

Long-term average monthly air temperature and precipitation values for the Waterford Impoundment area are set forth in Table 3. These averages were taken from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Waukesha, Wisconsin. The records of this station may be considered typical of the lake area. Table 3 also sets forth storm water runoff values derived from the U.S. Geological Survey (USGS) flow records for the Fox River at Waukesha. The mean annual temperature of 48.2°F at Waukesha is similar to that reported from other recording locations in southeastern Wisconsin. The mean annual precipitation at Waukesha is about 34.64 inches. More than half the normal yearly precipitation falls during the growing season, from May to September. Runoff rates are generally low during this period, since evapotranspiration rates are high, vegetative cover is good, and soils are not frozen. Normally, about 20 percent of the summer precipitation is expressed as surface runoff, but intense summer storms occasionally produce higher runoff fractions. In contrast, the approximately 45 percent of the annual precipitation occurs during the winter or early spring when the ground is frozen, and may result in high surface runoff during those seasons.

The 12-month period from January 2002 through December 2002 was a period of variable temperatures and rainfall in southeastern Wisconsin, as indicated in Table 3. Temperatures were generally above normal during the winter of 2002, about normal during the summer of 2002, and generally below normal in the spring and fall of 2002. Precipitation at Waukesha during this same period was about 33.63 inches, or about 3 percent below normal. The greatest departures from the average, of about 1.90 inches below the average and 3.73 inches above average, occurred during the months of November and August, 2002, respectively. Eight months of the 12-month study period, January, March, May, June, July, September, November, and December 2002, experienced below normal amounts of precipitation.

Lake Stage

The water level of the Waterford Impoundment is primarily determined by the twin spillways of the Waterford Dam located in the Village of Waterford. As established by the dam’s operating permit, issued by the Wisconsin Department of Natural Resources (WDNR), the level of the Lake is maintained at an elevation of 773.4 feet National Geodetic Vertical Datum of 1929 (NGVD-29).

Water Budget

A water budget for the year 2002 for the Waterford Impoundment was computed from data collected by the USGS and NOAA. During the study year, which included portions of both the 2002 hydrological year and 2003 hydrological year,[5] approximately 213,540 acre-feet of water was estimated to have entered the Impoundment.

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[5]*The hydrological or water year employed for record-keeping purposes by the U.S. Geological Survey is from October 1st to September 30th, annually. Data utilized in this analysis included the period from January 1st through December 31st, 2002.*

Table 2

GENERAL HYDROLOGIC SOIL TYPES WITHIN THE TOTAL AND DIRECT DRAINAGE AREAS TRIBUTARY TO WATERFORD IMPOUNDMENT

Group	Soil Characteristics	Direct Tributary Drainage Area (acres)	Percent of Total	Total Tributary Drainage Area (acres)	Percent of Total
A	Well drained; very rapidly to rapid permeability; low shrink-swell potential	8	<0.1	3,122	1.3
B	Moderately well drained; texture intermediate between coarse and fine; moderately rapid to moderate permeability; low to moderate shrink-swell potential	6,354	42.9	128,200	55.9
C	Poorly drained; high water table for part or most of the year; mottling, suggesting poor aeration and lack of drainage, generally present in A to C horizons	3,506	23.7	34,198	14.9
D	Very poorly drained; high water table for most of the year; organic or clay soils; clay soils having high shrink-swell potential	3,489	23.6	49,474	21.6
Other	Group not determined	102	0.7	6,328	2.8
Water	- -	1,349	9.1	7,957	3.5
- -	Total	14,808	100.0	229,278	100.0

Source: SEWRPC.

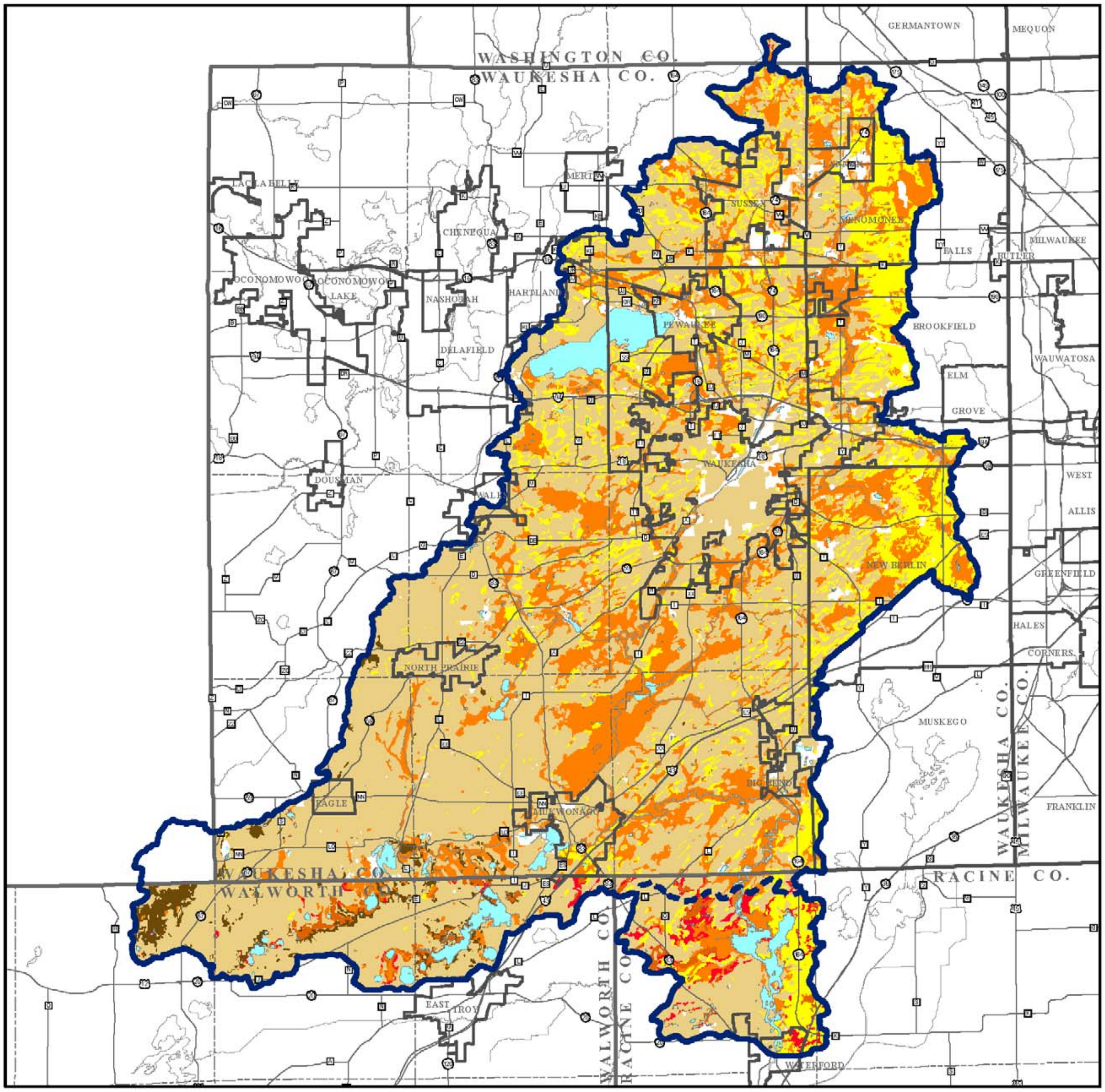
Direct precipitation onto the water surface contributed approximately 20,772 acre-feet, or 10 percent of the total water entering the Lake. The remaining 192,768 acre-feet, or 90 percent of the total water entering the Lake, were contributed by overland flow. Of the 213,540 acre-feet lost from the Waterford Impoundment during the study year, about 17,912 acre-feet evaporated from the lake surface and about 195,628 acre-feet were discharged through the Fox River. It is assumed that groundwater inflows balanced groundwater outflows during the study period.

As shown in Figure 1, a long-term water budget for the Waterford Impoundment was computed from long-term precipitation to the total waterbody surface and runoff from the total land surfaces tributary to the waterbody using data reported by NOAA, and from estimated evaporation from the waterbody surface and outflows through the Fox River at the Waterford Dam. An average of about 198,558 acre-feet, or about 90 percent, of the water entering the surface waters in the total tributary area of Waterford impoundment is contributed by surface runoff, and about 21,396 acre-feet, or about 10 percent, is contributed by precipitation directly onto surface water. Of this total long-term annual inflow, it is estimated that 17,912 acre-feet, or 8 percent of the inflow volume, is lost to evaporation from the surface of the surface waters, and 202,042 acre-feet, 92 percent, is discharged from the waterbody through the Fox River at the Waterford Dam. The long-term water balance for the Waterford Impoundment assumes no significant net change in water level and a balance between groundwater inflow and groundwater outflow.

The hydraulic residence time is important in determining the expected response time of a lake to increased or reduced nutrient and other pollutant loadings. The hydraulic residence time for the Waterford Impoundment during the study year of 2002, a year of nearly average precipitation, was estimated to be 11 days. During years of average climatological conditions, based upon the long-term water balance of the Impoundment, the hydraulic residence time is estimated also to be 11 days, as suggested by the long-term average water balance for the waterbody.

Map 12

HYDROLOGIC SOIL GROUPS WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT



GROUP A: Well-drained

GROUP A/B: Well-drained soils/Moderately drained[1]

GROUP A/D: Well-drained soil/Very poorly drained soil[2]

GROUP B: Moderately drained soil

GROUP B/D: Moderately drained soil/Very poorly drained soil[3]

GROUP C: Poorly drained soil

GROUP C/D: Poorly drained soil/Very poorly drained soil[4]

GROUP D: Very poorly drained soil

OTHER

Surface Water

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

2 Well-drained soil if water table is lowered through provision of a drainage system. Very poorly drained soil if water table is not lowered.

3 Moderately-drained soil if water table is lowered through provision of a drainage system. Very poorly drained soil if water table is not lowered.

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

N

Miles

0 2 4 6 8

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

Table 3

LONG-TERM AND 2002 STUDY YEAR TEMPERATURE, PRECIPITATION, AND RUNOFF DATA FOR THE WATERFORD IMPOUNDMENT AREA

Temperature													
Air Temperature Data (°F)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	19.5	24.7	35.3	47.3	59.3	69.1	73.8	71.7	63.2	51.4	37.6	29.4	48.2
2002 Mean Monthly	27.4	28.5	29.7	46.3	52.2	67.9	74.8	70.7	64.3	46.9	35.2	27.3	47.6
Departure from Long-Term Mean	7.9	3.8	-5.6	-1.0	-7.1	-1.2	1.0	-1.0	1.1	-4.5	-2.4	2.1	-0.6

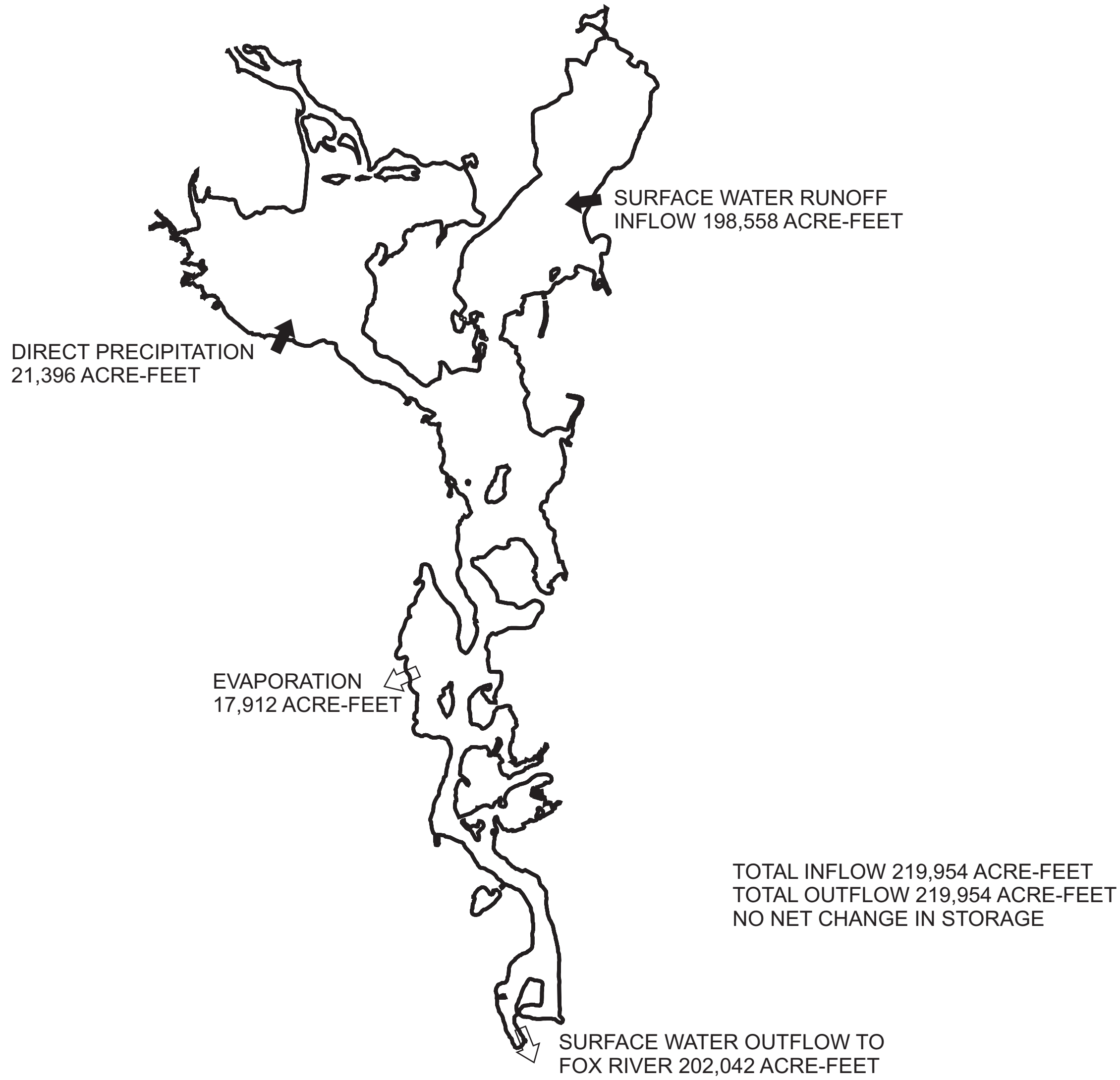
Precipitation														
Precipitation Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean	Total
Long-Term Mean Monthly	1.48	1.31	2.28	3.56	3.02	3.78	3.83	4.77	3.52	2.62	2.63	1.87	3.64	34.64
2002 Mean Monthly	0.87	1.56	1.73	3.96	2.89	3.30	3.32	8.50	3.32	2.76	0.73	0.69	2.80	33.63
Departure from Long-Term Mean	-0.61	0.25	-0.55	0.43	-0.13	-0.48	-0.51	3.73	-0.20	0.14	-1.90	-1.18	-0.84	-1.01

Runoff													
Runoff Data (inches)	January	February	March	April	May	June	July	August	September	October	November	December	Mean
Long-Term Mean Monthly	0.61	0.81	1.73	1.87	1.23	0.93	0.74	0.61	0.69	0.70	0.72	0.74	0.95
2002 Mean Monthly	0.52	0.85	1.30	1.72	1.21	1.37	0.40	1.17	0.67	0.81	0.52	0.41	0.91
Departure from Mean Monthly	-0.09	0.04	-0.43	-0.15	-0.02	0.44	-0.34	0.56	-0.02	0.11	-0.20	-0.33	-0.04

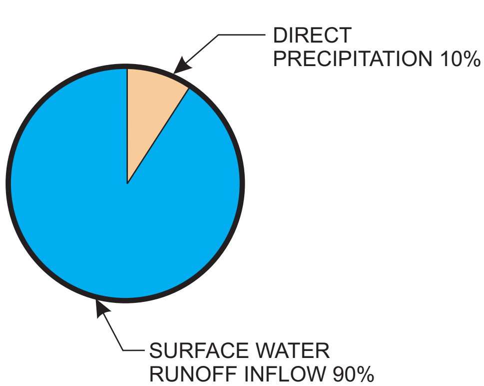
Source: National Oceanic and Atmospheric Administration and U.S. Geological Survey.

Figure 1

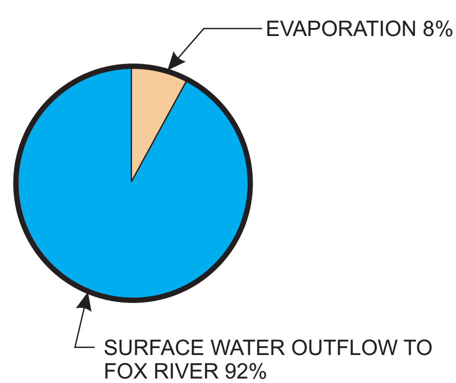
LONG-TERM HYDROLOGIC BUDGET FOR WATERFORD IMPOUNDMENT



WATERFORD IMPOUNDMENT INFLOW



WATERFORD IMPOUNDMENT OUTFLOW



Source: U.S. Geological Survey and SEWRPC.

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Chapter III

HISTORICAL, EXISTING, AND FORECAST LAND USE AND POPULATION

INTRODUCTION

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

CIVIL DIVISIONS

The geographic extent and functional responsibilities of civil divisions and special-purpose units of government are important factors related to land use and management, since these local units of government provide the basic structure of the decision-making framework within which land use development and redevelopment must be addressed. Superimposed on the total tributary area of the Waterford Impoundment are the local civil division boundaries shown on Map 13.

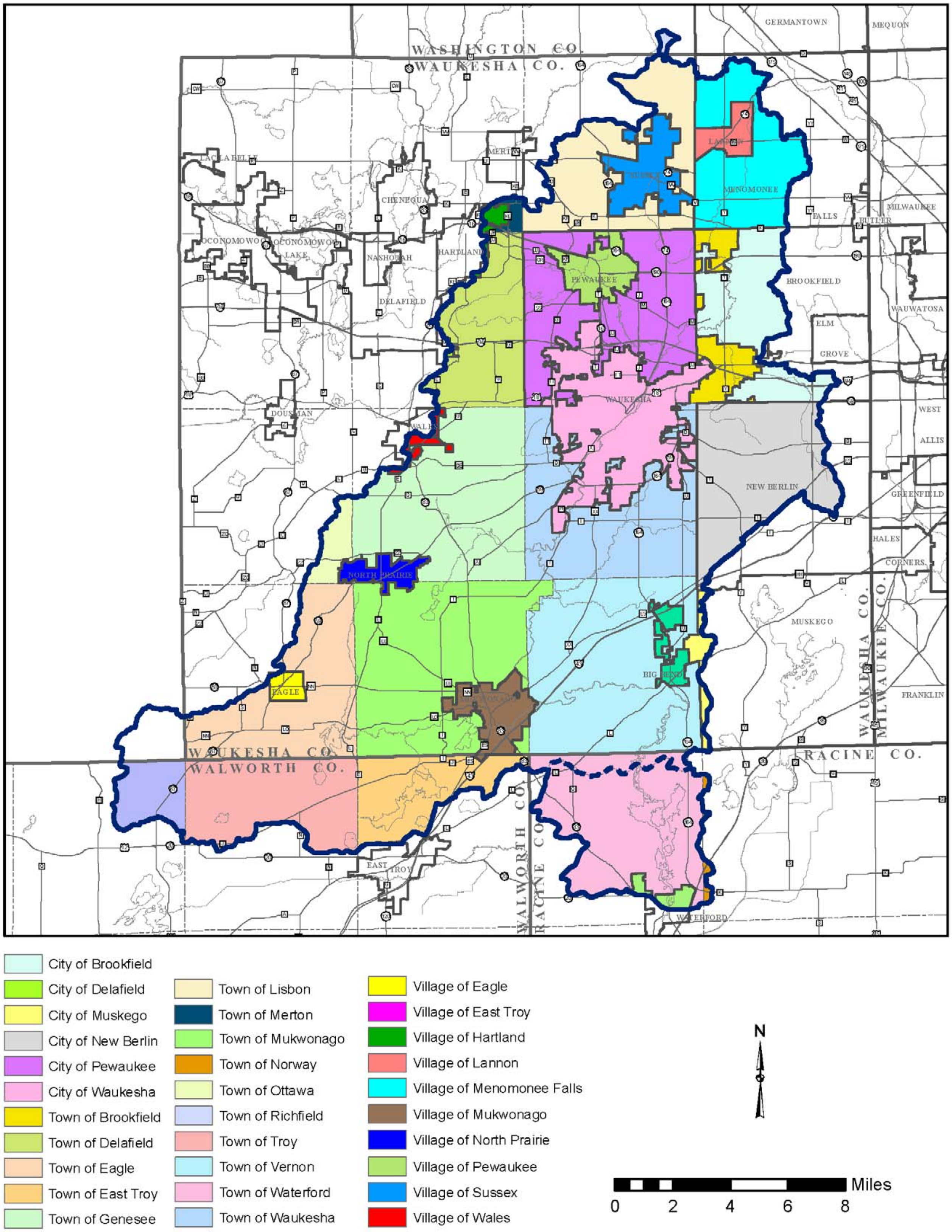
The area directly tributary to the Waterford Impoundment includes portions of the Town and Village of Waterford and the Town of Norway. The total area tributary to the lake extends northerly through much of Waukesha County into the southernmost portions of Washington County. The area and proportion of the total tributary area lying within the jurisdiction of each civil division, as of 2000, are set forth in Table 4.

POPULATION

In the area tributary to the Waterford Impoundment, as in most regions of southeastern Wisconsin, significant urban development began during the 1920s and continued to surge with major land use development occurring in

Map 13

CIVIL DIVISION BOUNDARIES IN THE WATERFORD IMPONDMENT TRIBUTARY AREA



Source: SEWRPC.

Table 4

AREAL EXTENT OF CIVIL DIVISION BOUNDARIES WITHIN THE TOTAL DRAINAGE AREA TRIBUTARY TO WATERFORD IMPOUNDMENT

Civil Division	Civil Division Area within Total Drainage Area (acres)	Percent of Total Drainage Area within Civil Division	Percent of Civil Division within Total Drainage Area
City of Brookfield	8,815	3.8	50.5
City of Delafield	53	<0.1	0.8
City of Muskego	1,107	0.5	4.8
City of New Berlin	13,129	5.7	55.6
City of Pewaukee	14,936	6.5	100.0
City of Waukesha	13,933	6.0	100.0
Village of Big Bend	1,355	0.6	100.0
Village of Eagle	755	0.3	97.4
Village of East Troy	16	<0.1	0.7
Village of Hartland	576	0.3	19.9
Village of Lannon	1,593	0.7	100.0
Village of Menomonee Falls	9,465	4.1	44.4
Village of Mukwonago	3,229	1.4	100.0
Village of North Prairie	1,519	0.7	100.0
Village of Pewaukee	2,884	1.3	100.0
Village of Sussex	3,785	1.7	100.0
Village of Wales	631	0.3	41.2
Village of Waterford	753	0.3	50.0
Town of Brookfield	3,424	1.5	96.9
Town of Delafield	9,351	4.0	70.4
Town of Eagle	12,980	5.7	57.9
Town of East Troy	7,183	3.1	34.8
Town of Genesee	17,856	7.8	87.4
Town of LaGrange	3,367	1.5	14.7
Town of Lisbon	11,391	5.0	59.0
Town of Merton	529	0.2	2.9
Town of Mukwonago	20,378	8.9	100.0
Town of Norway	337	0.1	1.5
Town of Ottawa	1,804	0.8	8.0
Town of Richfield	196	<0.1	0.8
Town of Troy	10,805	4.7	47.6
Town of Vernon	21,009	9.2	100.0
Town of Waterford	15,554	6.8	71.9
Town of Waukesha	14,584	6.4	100.0
Total	229,282	100.0	- -

Source: SEWRPC.

the years following World War II until the present time. As shown in Table 5, the number of residents in the direct tributary area was about 3,150 in 1963 and has increased relatively steadily since that time, with the largest increase occurring between 1990 and 2000. This same decade, 1990-2000, experienced great population increase in the Total tributary area, as well. An estimated 884 households were present in the direct tributary area of Waterford Impoundment in 1963, which number had increased to about 2,884 by 2000. The continued increase in population and the number of resident households in the area tributary to the Waterford Impoundment is expected to be accommodated as agricultural lands in the tributary area are converted to urban residential uses. Residential land uses are anticipated to be the dominant urban land use. This population growth, and associated demand for housing and recreational opportunities, will place a continued and increasing stress on the natural resource base of the area tributary to the Waterford Impoundment. For this reason, also, demands on the water resources, and associated use and user conflicts, may be expected to increase.

Table 5

HISTORIC AND FORECAST RESIDENT POPULATION AND HOUSEHOLD LEVELS WITHIN THE DIRECT AND TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT

	Direct Tributary Area		Total Tributary Area	
Year	Number of Residents	Number of Households	Number of Residents	Number of Households
1963	3,149	884	93,234	24,130
1970	3,786	1,143	118,939	32,330
1980	4,538	1,527	157,383	50,200
1990	4,896	1,736	174,043	60,283
2000	7,939	2,884	209,311	78,897

Source: SEWRPC.

LAND USE

The type, intensity, and spatial distribution of the various land uses within the area tributary to the Waterford Impoundment 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 the Waterford Impoundment.

The movement of European settlers into the Southeastern Wisconsin Region began about 1830. Completion, within southeastern Wisconsin, of the U.S. Public Land Survey in 1836, and the subsequent sale of public lands in Wisconsin, brought a rapid influx of settlers into the area. Map 14 shows the 1887 plat of the U.S. Public Land Survey for the Waterford Impoundment area. Note the alliterative spelling of Lake Tichigan and "Tish-shar-gan" and the unnamed widening of the Fox River that, today, is known as Buena Lake. The urban-density settlement at the southern extreme of the plat is the Village of Waterford which was incorporated in 1906.

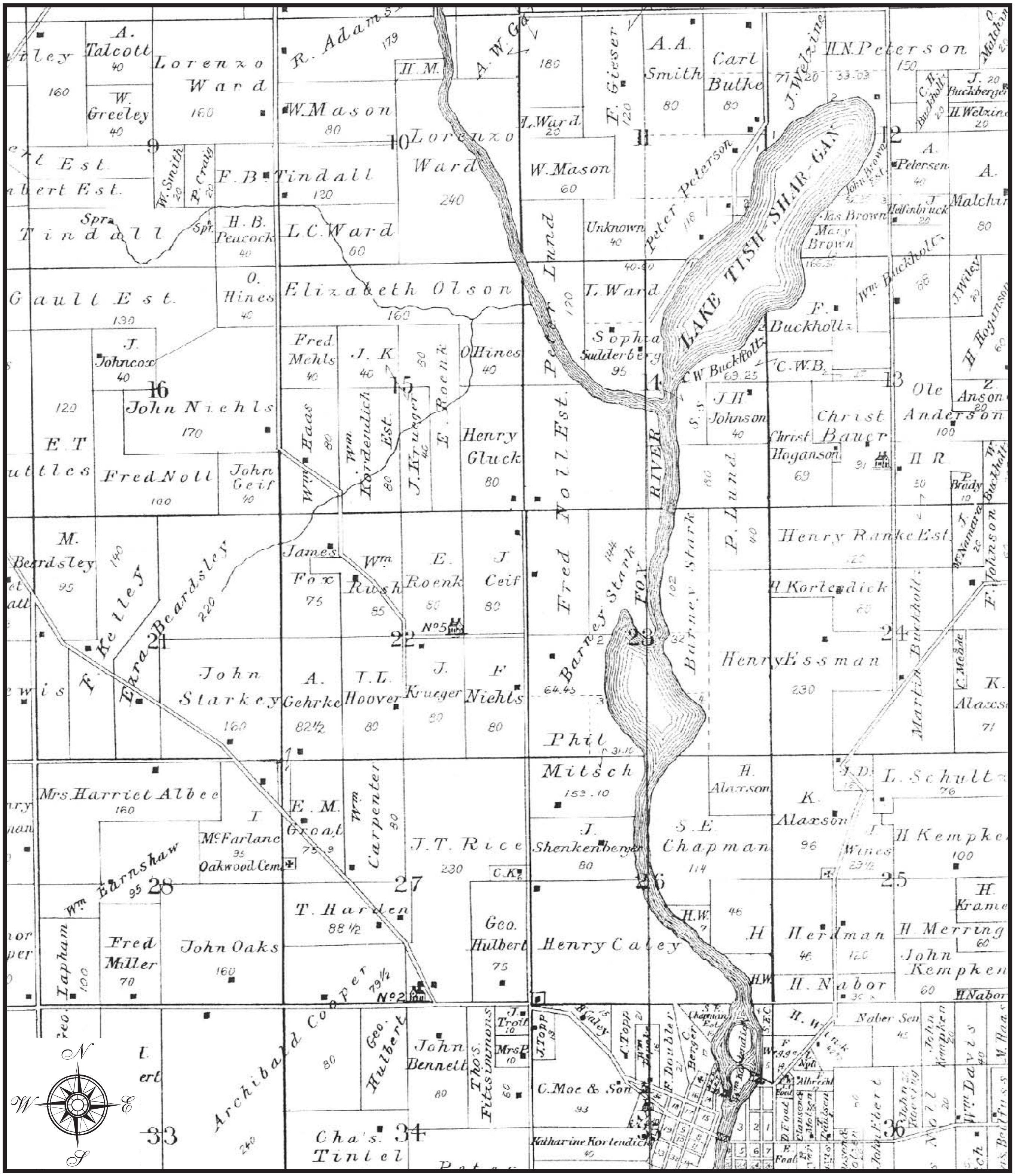
Significant urban development began to occur in the area tributary to the Waterford Impoundment in the mid-1800s in the vicinity of the current Village of Waterford. Map 15 and Table 6 indicate the historic urban growth patterns in the tributary area since 1850. The most significant urban development in the direct tributary area occurred between 1920 and 1950, and from 1995 to 2000. In the total tributary area, the most significant urban development occurred between 1950 and 1963, and from 1975 to 1980. During these periods, over 22,000 acres of the direct and total tributary areas were converted from rural to urban land uses. Although the majority of the shoreline of the waterbody is generally fully developed, the rate of urban development in the area directly tributary to the Waterford Impoundment has continued to increase significantly in the last decade. Historically, development around the site of the dams culminated in the incorporation of the Village of Waterford, which currently continues to grow in areal extent, largely to the west, away from the lake.

The existing land use pattern in the Waterford Impoundment tributary area, as of 2000, is shown on Maps 16 and 17, and is quantified in Tables 7 and 8. As indicated in Table 7, as of 2000, about 2,400 acres, or 17 percent of the area directly tributary to the Waterford Impoundment, were devoted to urban land uses. The dominant urban land use was residential, encompassing about 1,500 acres, or 63 percent of the area in urban use. As of 2000, about 12,000 acres, or 83 percent of the area tributary to the Waterford Impoundment, were still devoted to rural land uses. About 7,500 acres, or about 61 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface waters, including the surface area of the Waterford Impoundment, accounted for approximately 4,700 acres, or 38 percent, of the area in rural uses.

Within the total area tributary to the Waterford Impoundment, as of 2000, about 76,000 acres, or 33 percent of the total area tributary to the Waterford Impoundment, were devoted to urban land uses, as shown in Table 8. The dominant urban land use was residential, encompassing about 44,000 acres, or 57 percent of the area in urban use. As of 2000, about 155,000 acres, or 67 percent of the total area tributary to the Waterford Impoundment, were

Map 14

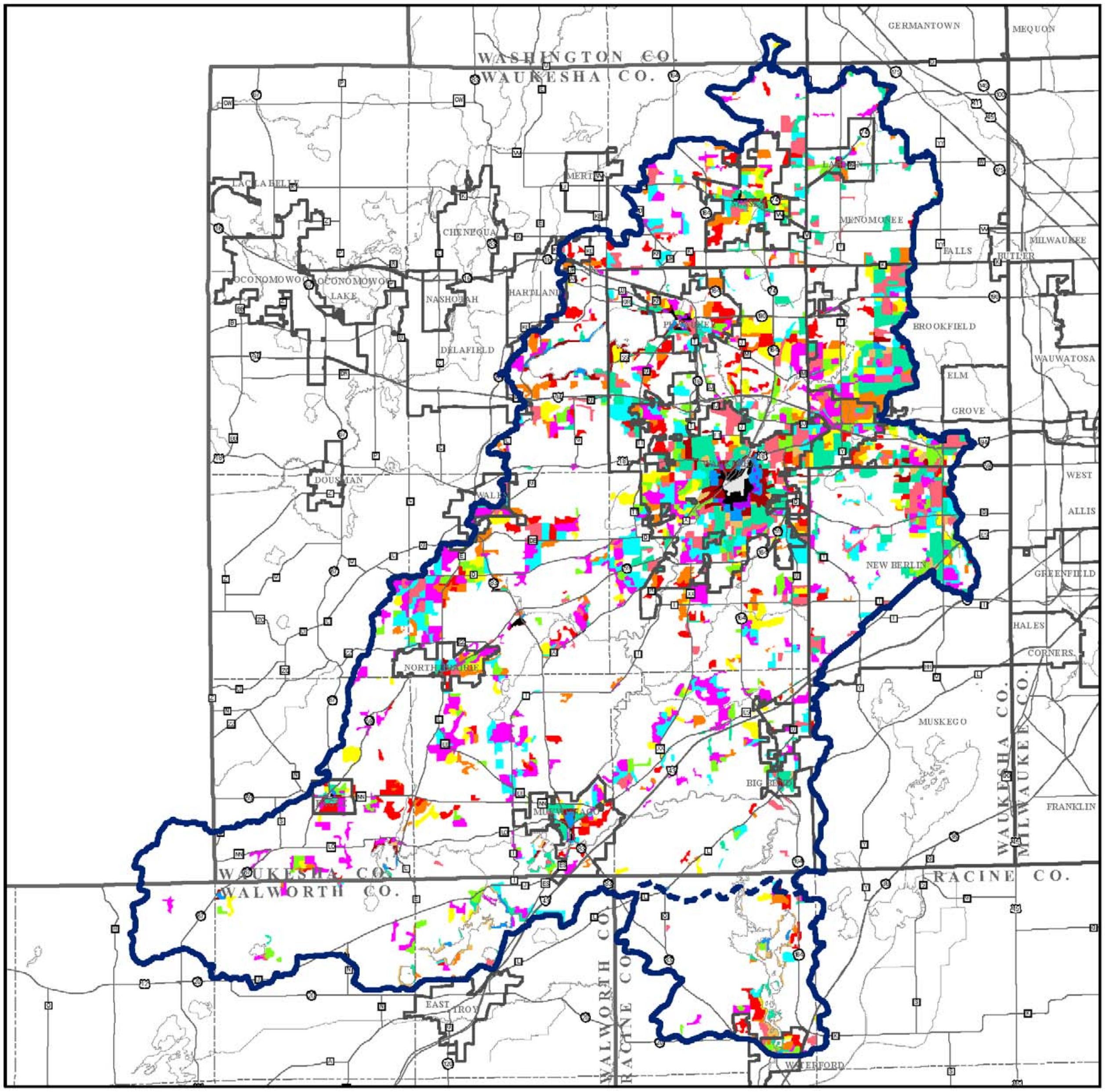
HISTORIC PLAT MAP FOR THE WATERFORD IMPOUNDMENT AREA: 1887



Source: H.O. Brown and Company, Combination Atlas Map of Racine and Kenosha Counties, Wisconsin, 1887.

Map 15

HISTORIC URBAN GROWTH WITHIN THE WATERFORD IMPOUNDMENT TRIBUTARY AREA



1850	1963
1880	1970
1900	1975
1920	1980
1940	1985
1950	1990
	1995

N

0 2 4 6 8 Miles

Source: SEWRPC.

Table 6

EXTENT OF URBAN GROWTH WITHIN THE DRAINAGE AREA TRIBUTARY TO WATERFORD IMPOUNDMENT: 1850-2000

Year	Direct Drainage Area		Total Tributary Drainage Area	
	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]	Extent of New Urban Development Occurring Since Previous Year (acres)[a]	Cumulative Extent of Urban Development (acres)[a]
1850	- -	- -	211	211
1880	2	2	630	841
1900	1	3	225	1,066
1920	77	80	991	2,057
1940	- -	- -	1,753	3,810
1950	282	362	1,187	4,997
1963	169	531	9,786	14,783
1970	165	696	7,069	21,852
1975	111	807	8,141	29,993
1980	145	952	11,672	41,665
1985	177	1,129	4,557	46,222
1990	84	1,213	5,625	51,847
1995	211	1,424	5,915	57,762
2000	399	1,823	6,010	63,772

[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.

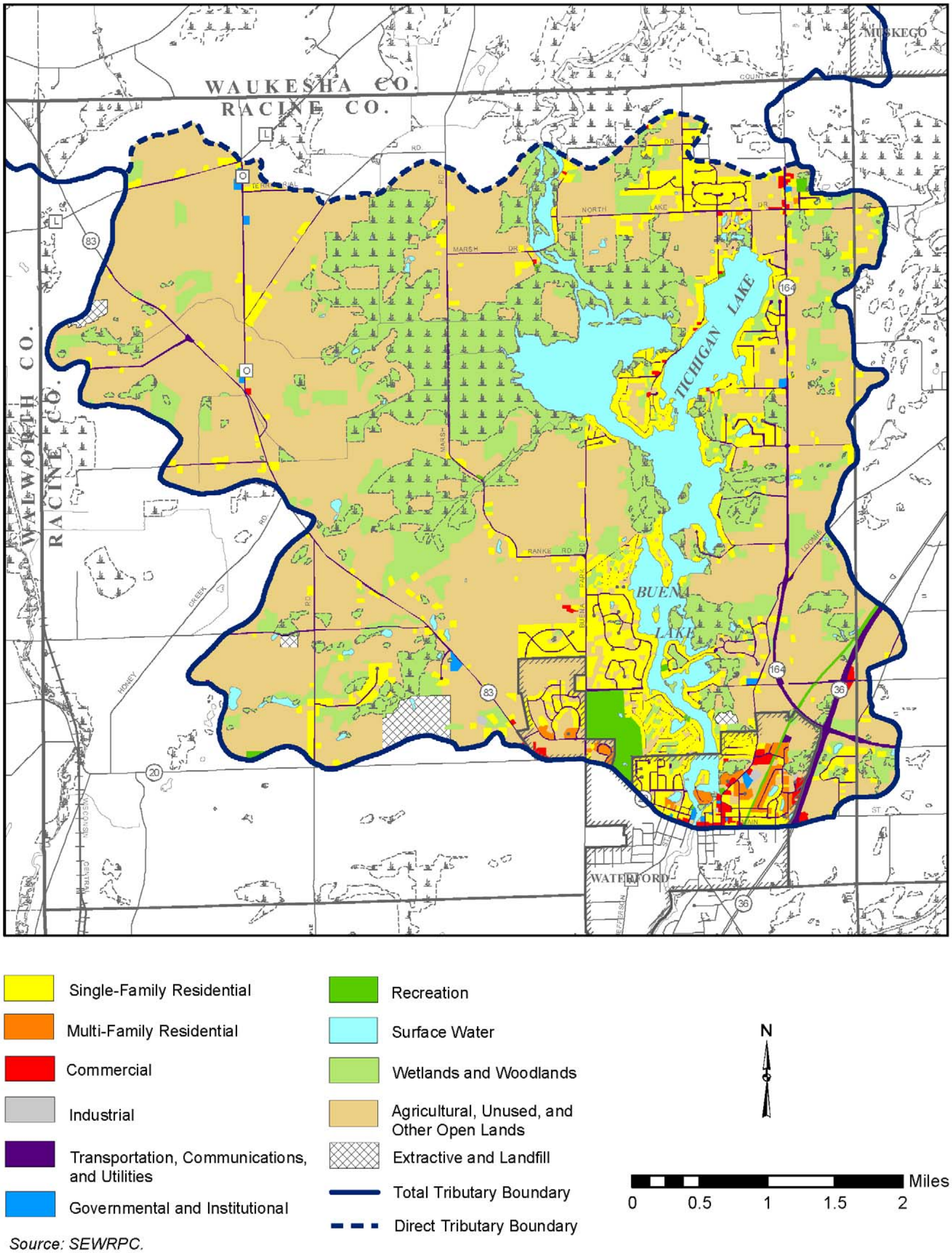
still devoted to rural land uses. About 92,600 acres, or about 60 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface waters, including the surface area of the Waterford Impoundment, accounted for approximately 60,000 acres, or 39 percent of the area in rural uses. The 1970 Wisconsin Department of Natural Resources Lake Use Report No. FX-6, *The Waterford Impoundment and Tichigan Lake, Racine County, Wisconsin,* 1970, had previously reported that, as of 1963 about 14 percent of the total area tributary to the Waterford Impoundment was devoted to urban land uses with the dominant urban land use being residential, encompassing about 48 percent of urban lands. At that time, about 86 percent of the area tributary to the Waterford Impoundment were devoted to rural uses, 72 percent of which were agricultural. Thus, the year 2000 land use data provide an indication of the magnitude of the changing land uses in this Basin. This trend is likely to be ongoing as indicated by the planned year 2020 land use conditions in the Basin.

Under planned year 2020 conditions, the trend toward more intense urban land usage is expected to be reflected in the area tributary to the Impoundment.[1] As noted above, much of this development is expected to occur as agricultural lands are converted to urban lands, primarily for residential use, as shown on Maps 18 and 19. However, some redevelopment of existing properties and the reconstruction of existing single-family homes may be expected, especially on lakeshore properties. By 2020, urban land uses within the area directly tributary to the Waterford Impoundment are expected to increase in areal extent to about 3,742 acres, or 25 percent of the area

[1]*SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997; SEWRPC Planning Report No. 48,* A Regional Land Use Plan for Southeastern Wisconsin: 2035*, June 2006; see also SEWRPC Community Assistance Planning Report No. 209,* A Development Plan for Waukesha County, Wisconsin, *August 1996.*

Map 16

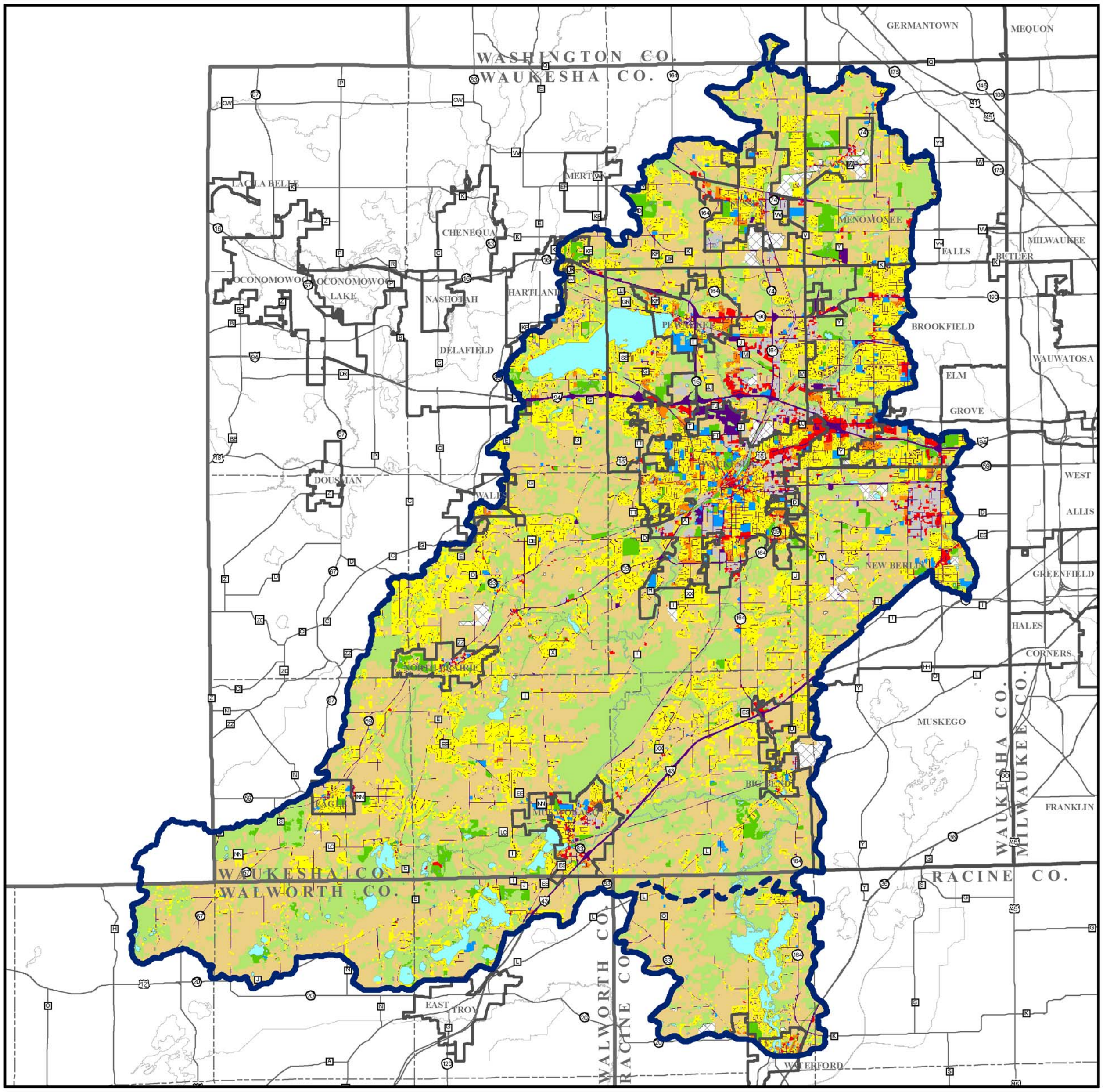
EXISTING LAND USE WITHIN THE AREA DIRECTLY TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000



Source: SEWRPC.

Map 17

EXISTING LAND USE WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000



Single-Family Residential

Multi-Family Residential

Commercial

Industrial

Transportation, Communications, and Utilities

Governmental and Institutional

Recreation

Surface Water

Wetlands and Woodlands

Agricultural, Unused, and Other Open Lands

Extractive and Landfill

Total Tributary Boundary

Direct Tributary Boundary

N

Miles

0 2.5 5 7.5 10

Source: SEWRPC.

Table 7

EXISTING AND PLANNED LAND USE WITHIN THE AREA DIRECTLY TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000 AND 2020

Land Use Categories[a]	2000 Acres	2000 Percent of Direct Tributary Drainage Area	2020 Acres	2020 Percent of Direct Tributary Drainage Area
Urban				
Residential	1,548	10.4	2,442	16.5
Commercial	53	0.3	171	1.1
Industrial	8	0.1	8	0.1
Governmental and Institutional	24	0.2	27	0.2
Transportation, Communication, and Utilities	663	4.5	916	6.2
Recreation	144	1.0	178	1.2
Subtotal	2,440	16.5	3,742	25.3
Rural				
Agricultural	7,553	50.9	6,242	42.1
Wetlands	2,156	14.6	2,156	14.6
Woodlands	1,229	8.3	1,229	8.3
Water	1,301	8.8	1,309	8.8
Extractive	128	0.9	137	0.9
Subtotal	12,367	83.5	11,065	74.7
Total	14,807	100.0	14,807	100.0

[a]*Parking included in associated use.*

Source: SEWRPC.

directly tributary to the waterbody, as shown in Table 7. Urban residential uses are expected to increase from about 1,548 acres, as of 2000, to about 2,442 acres in the year 2020. Agricultural lands in the direct tributary area, consequently, are expected to decrease in areal extent from about 7,553 acres, as of 2000, to about 6,242 acres in the year 2020.

In the total area tributary to the Waterford Impoundment, urban land uses are expected to increase in areal extent to about 76,225 acres, or about 33 percent of the total tributary area, by the year 2020, as shown in Table 8. Urban residential uses are expected to increase from about 43,596 acres, as of 2000, to about 60,868 acres in the year 2020. Agricultural lands in the tributary area, consequently, are expected to decrease in areal extent from about 92,613 acres, as of 2000, to about 61,861 acres in the year 2020. Recent surveillance indicates that such changes in land usage appear to be due to large-lot residential development. If this trend continues, some of the open space areas remaining in the tributary area are likely to be replaced with large-lot urban residential development, resulting in the potential for increased pollutant loadings to the waterbody. This development could occur in the form of residential clusters on smaller lots within conservation subdivisions, thereby preserving portions of the remaining open space and, thus, reducing the impacts on the Impoundment.[2]

LAND USE REGULATIONS

The comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. Local zoning regulations

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

Table 8

EXISTING AND PLANNED LAND USE WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000 AND 2020

Land Use Categories[a]	2000		2020	
	Acres	Percent of Total Tributary Drainage Area	Acres	Percent of Total Tributary Drainage Area
Urban				
Residential	43,596	18.8	60,868	26.3
Commercial	3,116	1.3	4,758	2.1
Industrial	3,372	1.5	5,859	2.5
Governmental and Institutional	2,632	1.1	3,455	1.5
Transportation, Communication, and Utilities	18,095	7.8	23,436	10.1
Recreation	5,414	2.3	7,366	3.2
Subtotal	76,225	32.8	105,742	45.7
Rural				
Agricultural	92,613	40.1	61,861	26.7
Wetlands	32,803	14.2	32,803	14.2
Woodlands	20,026	8.6	19,984	8.6
Water	7,412	3.2	7,414	3.2
Extractive	2,277	1.0	3,580	1.5
Landfill	197	0.1	169	0.1
Subtotal	155,328	67.2	125,811	54.3
Total	231,553	100.0	231,553	100.0

[a]*Parking included in associated use.*

Source: SEWRPC.

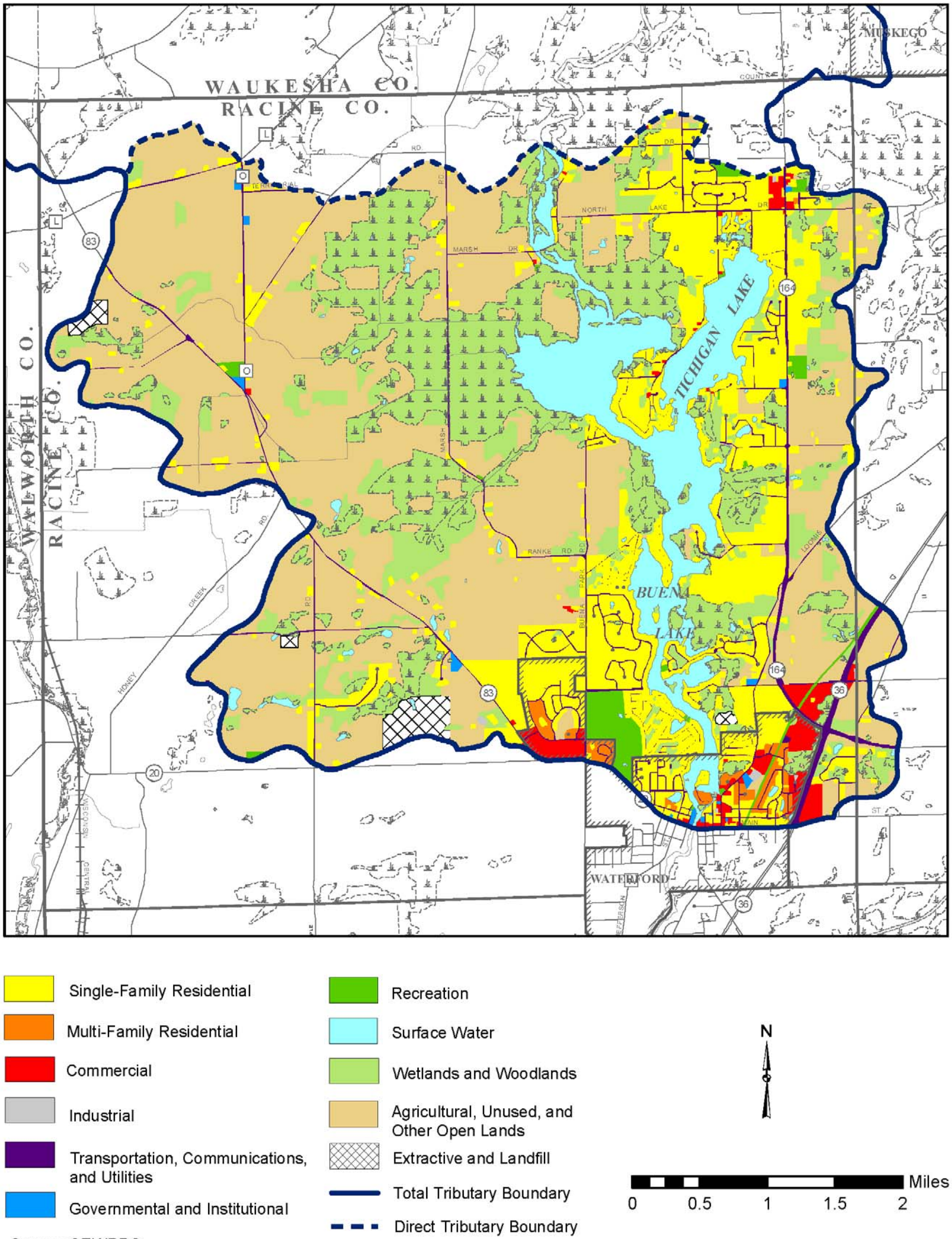
include general, or comprehensive, zoning regulations and special-purpose regulations governing floodland and shoreland areas. General zoning and special-purpose zoning regulations may be adopted as a single ordinance or as separate ordinances; they may or may not be contained in the same document. Any analysis of locally proposed land uses must take into consideration the provisions of both general and special-purpose zoning. As already noted, the area tributary to the Waterford Impoundment includes portions of the Cities of Brookfield, Delafield, Muskego, New Berlin, Pewaukee, and Waukesha, in Waukesha County; the Villages of Big Bend, Eagle, Hartland, Lannon, Menomonee Falls, Mukwonago, North Prairie, Pewaukee, Sussex, and Wales, in Waukesha County; the Village of Waterford, in Racine County; the Village of East Troy, in Walworth County; the Towns of Brookfield, Delafield, Eagle, Genesee, Lisbon, Merton, Mukwonago, Ottawa, Vernon and Waukesha, in Waukesha County; the Towns of Norway and Waterford, in Racine County; the Towns of East Troy, LaGrange and Troy, in Walworth County; and the Town of Richfield, in Washington County. The ordinances administered by these units of government are summarized in Table 9.

General Zoning

Cities in Wisconsin are granted comprehensive, or general, zoning powers under Section 62.23 of the *Wisconsin Statutes*. The same powers are granted to villages under Section 61.35, *Wisconsin Statutes*. Counties are granted general zoning powers within their unincorporated areas under Section 59.69 of the *Statutes*. However, a county zoning ordinance becomes effective only in those towns that ratify the county ordinance. Towns that have not adopted a county zoning ordinance may adopt village powers, and subsequently utilize the city and village zoning authority conferred in Section 62.23, subject, however, to county board approval where a general-purpose county zoning ordinance exists. Alternatively, a town may adopt a zoning ordinance under Section 60.61 of the *Wisconsin Statutes* where a general-purpose county zoning ordinance has not been adopted, but only after the county board fails to adopt a county ordinance at the petition of the governing body of the town concerned.

Map 18

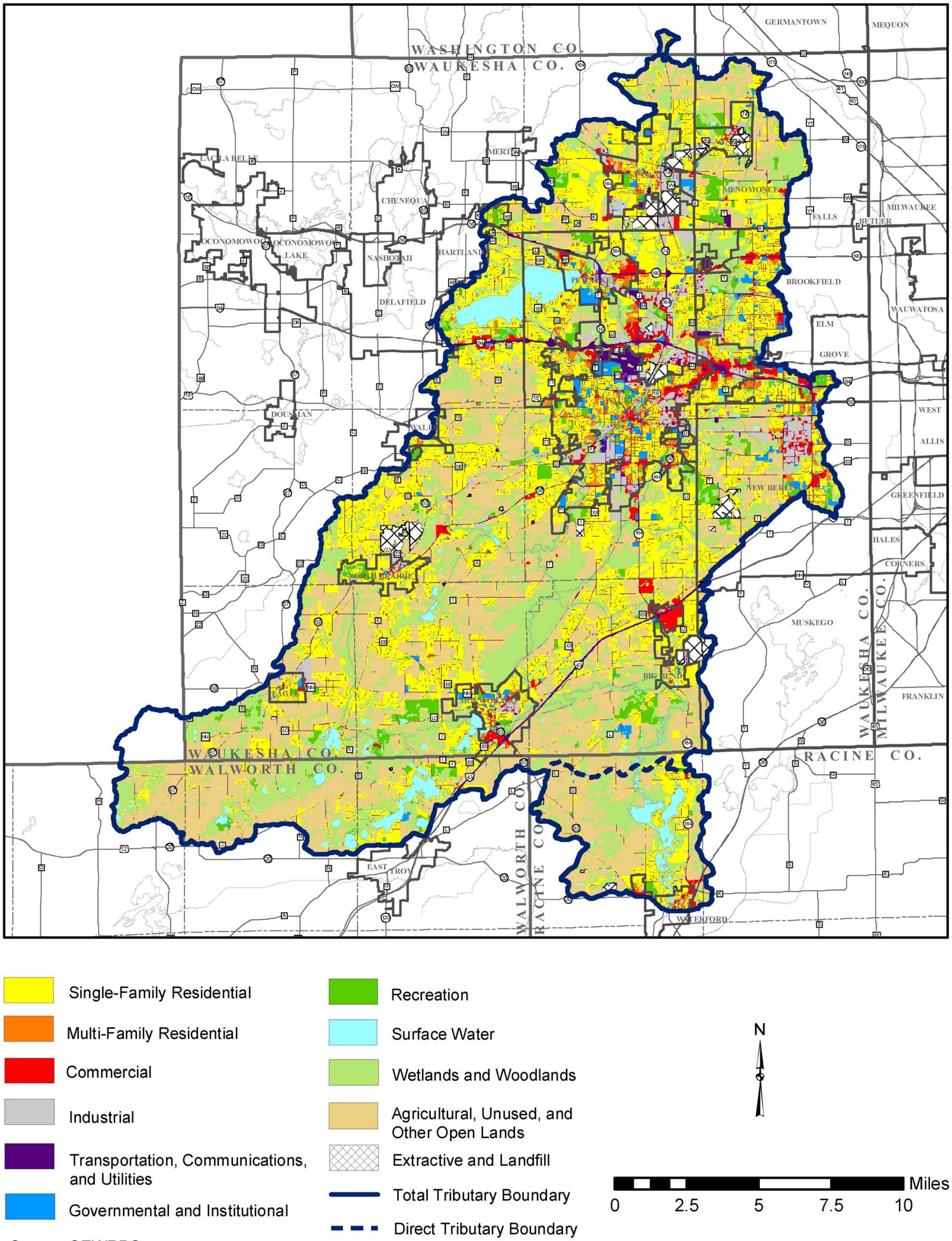
PLANNED LAND USE WITHIN THE AREA DIRECTLY TRIBUTARY TO WATERFORD IMPOUNDMENT: 2020



Source: SEWRPC.

Map 19

PLANNED LAND USE WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT: 2020



Source: SEWRPC.

Table 9

LAND USE REGULATIONS WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT BY CIVIL DIVISION: 2000

Community	Type of Ordinance				
	General Zoning	Floodland Zoning	Shoreland or Shoreland-Wetland Zoning	Subdivision Control	Erosion Control and Stormwater Management
Racine County	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Waterford	Adopted	Adopted	Adopted	Adopted	None
Town of Norway	County	County ordinance	County ordinance	Adopted	County ordinance
Town of Waterford	County	County ordinance	County ordinance	Adopted	Adopted
Walworth County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Adopted	Adopted
Village of East Troy	Adopted	Adopted	Adopted	Adopted	Adopted
Town of East Troy	County	County ordinance	County ordinance	Adopted	Adopted
Town of LaGrange	County	County ordinance	County ordinance	County	Adopted
Town of Troy	County	County ordinance	County ordinance	County	County ordinance
Washington County	- -[a]	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
Town of Richfield	Adopted	County ordinance	County ordinance	Adopted	- -[b]
Waukesha County	Adopted	Adopted	Adopted and Wisconsin Department of Natural Resources approved	Floodland and shoreland only	Adopted
City of Brookfield	Adopted	County ordinance	County ordinance	Adopted	- -[b]
City of Delafield	Adopted	Adopted	Adopted	Adopted	Adopted
City of Muskego	Adopted	Adopted	Adopted	Adopted	- -[b]
City of New Berlin	Adopted	Adopted	Adopted	Adopted	- -[b]
City of Pewaukee	Adopted	Adopted	Adopted	Adopted	- -[b]
City of Waukesha	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Big Bend	Adopted	Adopted	Adopted	Adopted	- -[b]
Village of Eagle	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Hartland	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Lannon	Adopted	Adopted	Adopted	Adopted	- -[b]
Village of Menomonee Falls	Adopted	Adopted	Adopted	Adopted	None
Village of Mukwonago	Adopted	Adopted	Adopted	Adopted	Adopted
Village of North Prairie	Adopted	Adopted	Adopted	Adopted	Adopted
Village of Pewaukee	Adopted	Adopted	Adopted	Adopted	County ordinance
Village of Sussex	Adopted	Adopted	Adopted	Adopted	- -[b]
Village of Wales	Adopted	Adopted	County ordinance	Adopted	None
Town of Brookfield	Adopted	Adopted	Adopted	Adopted	None
Town of Delafield	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Eagle	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Genesee	County	County ordinance	County ordinance	Adopted	County ordinance
Town of Lisbon	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Merton	Adopted	County ordinance	County ordinance	Adopted	County ordinance
Town of Mukwonago	Adopted	County ordinance	County ordinance	Adopted	- -[b]
Town of Ottawa	County	County ordinance	County ordinance	Adopted	County ordinance
Town of Vernon	County	County ordinance	County ordinance	Adopted	- -[b]
Town of Waukesha	Adopted	County ordinance	County ordinance	Adopted	- -[b]

[a]*In 1986, Washington County rescinded its general zoning ordinance and all of the towns which were subject to the general County zoning ordinance have since adopted town zoning ordinances. With respect to Floodland and shoreland ordinances, the Towns are subject to County overlay zoning authority, while, with respect to subdivision and stormwater management ordinances, the Towns have discretion as to whether they adopt the County ordinance or their own ordinance, which is equally or more restrictive.*

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

Source: SEWRPC.

General zoning is in effect in all communities in the area tributary to the Waterford Impoundment. General zoning in the Towns of Norway and Waterford in Racine County, the Towns of East Troy, LaGrange, and Troy in Walworth County, and the Towns of Ottawa and Vernon in Waukesha County, are pursuant to their adopted local county general zoning ordinances. In contrast, the Towns of Brookfield, Delafield, Eagle, Lisbon, Merton, Mukwonago and Waukesha, in Waukesha County, and the Town of Richfield in Washington County, have adopted their own general zoning ordinances.

Floodland Zoning

Section 87.30 of the *Wisconsin Statutes* requires that cities, villages, and counties with respect to their unincorporated areas, adopt floodland zoning to preserve the floodwater conveyance and storage capacity of floodplain areas and to prevent the location of new flood damage-prone development in flood hazard areas. The minimum standards which such ordinances must meet are set forth in Chapter NR 116 of the *Wisconsin Administrative Code*. The required regulations govern filling and development within a regulatory floodplain, which is defined as the area subject to inundation by the 100-year recurrence interval flood event, the event which has a 1 percent probability of occurring in any given year. Under Chapter NR 116, local floodland zoning regulations must prohibit nearly all forms of development within the floodway, which is that portion of the floodplain required to convey the 100-year recurrence peak flood flow. Local regulations must also restrict filling and development within the flood fringe, which is that portion of the floodplain located outside the floodway that would be covered by floodwater during the 100-year recurrence flood. Permitting the filling and development of the flood fringe area, however, reduces the floodwater storage capacity of the natural floodplain, and may thereby increase downstream flood flows and stages. It should be noted that towns may enact floodland zoning regulations which may be more restrictive than those of the County Shoreland and Floodland Protection Zoning Ordinance.

Floodland zoning ordinances are in effect in all parts of the total area tributary to the Waterford Impoundment. Racine, Walworth, Washington and Waukesha Counties have all adopted floodland zoning ordinances, as shown in Table 8. Additionally, the Towns of Norway, Waterford, East Troy, LaGrange, Troy, Richfield, Brookfield, Delafield, Eagle, Genesee, Lisbon, Merton, Mukwonago, Ottawa, Vernon, and Waukesha have all adopted the county floodland ordinance for the county in which they are located. All other cities and villages within the Waterford Impoundment tributary area have each adopted their own floodland zoning ordinances.

Shoreland Zoning

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

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

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

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

Subdivision Regulations

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

The subdivision regulatory powers of towns and counties are confined to unincorporated areas. City and village subdivision control ordinances may be applied to extraterritorial areas, as well as to the incorporated areas.[3] It is possible for both a county and a town to have concurrent jurisdiction over land divisions in unincorporated areas, or for a city or village to have concurrent jurisdiction with a town or county in the city or village extraterritorial plat approval area. In the case of overlapping jurisdiction, the most restrictive requirements apply. Each of the incorporated communities within the tributary area to the Waterford Impoundment has adopted its own subdivision ordinance.

Construction Site Erosion Control and Stormwater Management Regulations

Section 62.23 of the *Wisconsin Statutes* grants authority to cities and villages in Wisconsin to adopt ordinances for the prevention of erosion from construction sites and the management of stormwater runoff from lands within their jurisdiction. Towns may adopt village powers and subsequently utilize the authority conferred on cities and villages under Section 62.23 to adopt their own erosion control and stormwater management ordinances, subject to county board approval where a county ordinance exists. The administrative rules for the State stormwater discharge permit program are set forth in Chapter NR 216 of the *Wisconsin Administrative Code*, which initially took effect on November 1, 1994, and was most recently recreated effective August 1, 2004.

Stormwater Management

Within the total area tributary to the Waterford Impoundment, Washington and Waukesha Counties; the Cities of Brookfield, Franklin, Muskego, New Berlin, Pewaukee, and Waukesha; the Villages of Big Bend, Hartland, Lannon, Menomonee Falls, North Prairie, Pewaukee, Sussex, and Wales; and, the Towns of Brookfield, Delafield, Genesee, Lisbon, Merton, Ottawa, Richfield, Vernon, and Waukesha have been identified by the WDNR as being in urbanized areas that have been, or will be, required to obtain stormwater discharge permits unless they receive exemptions. The Cities of Brookfield, New Berlin, Pewaukee, and Waukesha; the Villages of Menomonee Falls, Pewaukee, and Sussex; and the Towns of Brookfield, Delafield, and Waukesha were designated during Phase I of the stormwater permitting program, with the other municipalities being designated

[3]*Under Section 236.02 of the* Wisconsin Statutes*, the extraterritorial plat approval jurisdiction is the area within three miles of the corporate limits of a first-, second-, or third-class city and within 1.5 miles of a fourth-class city or a village. Within the area tributary to the Waterford Impoundment, the City of Brookfield is a city of the second class, the Cities of Muskego, New Berlin, Pewaukee, and Waukesha are cities of the third class; and, the City of Delafield is a city of the fourth class. The Villages of Big Bend, Eagle, East Troy, Hartland, Lannon, Menomonee Falls, Mukwonago, North Prairie, Pewaukee, Sussex, Wales, and Waterford are within the drainage area tributary to the Waterford Impoundment.*

by the WDNR as Phase II municipalities. The Village of Mukwonago in Walworth and Waukesha Counties, also has been designated as a potential permitee under Phase II of the municipal stormwater permitting program.

Through 1997 Wisconsin Act 27, the State Legislature required the WDNR and the Wisconsin Department of Agriculture, Trade and Consumer Protection (WDATCP) to develop performance standards for controlling nonpoint source pollution from agricultural and nonagricultural land and from transportation facilities.[4] Chapter NR 216 of the *Wisconsin Administrative Code* identifies several categories of municipalities, industries, and construction sites that must obtain permits. The permit requirements are based on the performance standards set forth in Chapter NR 151 of the *Wisconsin Administrative Code*, which became effective on October 1, 2002 and were revised in July 2004.

Agricultural Performance Standards
Agricultural performance standards cover the following areas:

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

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

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

- Construction sites for new development and redevelopment,
- Post construction phase for new development and redevelopment,

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

- Developed urban areas, and

- Nonmunicipal property fertilizing.

Chapter NR 151 requires municipalities with Wisconsin Pollutant Discharge Elimination System (WPDES) stormwater discharge permits to reduce the amount of total suspended solids in stormwater runoff from areas of existing development that were in place as of October 2004 to the maximum extent practicable, according to the following standards:

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

- By October 1, 2013, the standards call for a 40 percent reduction in total suspended solids.

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

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

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

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

Construction Site Erosion Control
Construction site erosion control and stormwater management ordinances were in effect in all communities within the portion of the tributary area to the Waterford Impoundment within Waukesha County in 2006. The Cities of Delafield and Waukesha, and the Village of Hartland, have adopted both construction site erosion control regulations and stormwater management regulations. The Towns of Delafield, Lisbon, and Merton, and the Village of Pewaukee, have adopted construction site erosion control and stormwater management ordinances by reference to the County ordinances. With the exception of the City of Pewaukee which addresses construction site erosion control standards in its ordinance, stormwater management standards are built into other development policies. It should be noted that the City of Delafield and the Village of Hartland have adopted similar ordinance language in an effort to better protect the water resources shared by these neighboring communities. These ordinances differ from that of the County only in that they are applicable to sites of 4,000 square feet or more in areal extent, rather than sites of 3,000 square feet or more.

In Racine County, the incorporated municipalities have not adopted separate erosion control and stormwater management ordinances, although the Town of Waterford has an ordinance governing erosion control. As of 2004, the Town was also considering development of a stormwater management ordinance, with a draft ordinance being prepared under the auspices of the Waterford Waterway Management District for consideration by the Town.

Within the total area tributary to the Waterford Impoundment, the three upstream Counties have adopted construction erosion control and stormwater management ordinances. Racine County does not have specific erosion control or stormwater management ordinances; provisions for erosion control are referenced in shoreland control ordinances and stormwater management is generally relegated to town jurisdiction. On-site inspections and recommendations are the result of coordinated activities of several County offices, including Land Conservation Division.

The erosion control ordinances apply to the unincorporated town lands in the counties which are not subject to local zoning regiments. The Waukesha County construction site erosion control ordinance, for example, applies to all lands requiring a subdivision plat or certified survey, to sites upon which construction activities will disturb 3,000 square feet or more and/or 400 cubic yards or more of material, and to sites where pipeline placement operations disturb 300 linear feet or more of land surface. In Washington County, ordinances apply to construction sites that will disturb 4,000 square feet or more and/or 400 cubic yards or more of material, and to sites that disturb 100 or more lineal feet of land surface. The Walworth County erosion control ordinance applies to construction sites disturbing 4,000 square feet or more and/or 400 cubic yards or more of soil, and to sites where laying, repairing, replacing or enlarging underground pipe disturbs 300 linear feet or more of land. Additionally, the Walworth County ordinance applies to erection or construction of various structures such as buildings, towers, masts, poles, signs, decorations, carports, and machinery and equipment, to construction, enlargement, relocation or reconstruction of public or private streets, airstrips, driveways or bridges, to activities involving grading, removal or protective groundcover or vegetation, excavation, land filling or land disturbing activities within 1000 feet of a lake and within 300 feet of any stream, wetland, channel, ditch or other watercourse. These ordinances require persons engaging in land disturbing activities to employ soil erosion control practices on affected sites that are consistent with those set forth in the *Wisconsin Construction Site Best Management Practice Handbook*[5] or equivalent practices. In general, these practices are designed to minimize soil loss from disturbed sites through prior planning and phasing of land disturbing activities and use of appropriate onsite erosion control measures.

The Waukesha County stormwater management ordinance applies to residential lands of five acres or more in areal extent, residential lands of between three and five acres in areal extent where there is at least 1.5 acres of impervious surface, nonresidential lands of 1.5 acres in areal extent where there is at least 0.5 acre of impervious

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

surface, or other lands on which development activities may result in stormwater runoff likely to harm public property or safety. Lands within an area covered by an approved stormwater management plan are specifically exempted from the Waukesha County ordinance. The stormwater management ordinance establishes performance standards to manage both rate and volume of stormwater flows from regulated sites and water quality. The Washington County stormwater management ordinance applies, unless otherwise exempted or waived, to all land development activities that meet any of the following: divide an existing tax parcel into five separate parcels of five acres each or less in total area within a common plan of development; involve construction of any new public or private road; results in the addition of impervious surfaces of 20,000 square feet or more; or any other land development activities that are determined to significantly increase downstream runoff volumes, flooding, soil erosion, water pollution or property damage, or significantly impact an environmentally sensitive area. Performance standards adopted in these ordinances and the resultant design of appropriate management practices are based on calculation procedures and principles set forth in *Urban Hydrology for Small Watersheds*.[6]

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

Chapter IV

WATER QUALITY

INTRODUCTION

The earliest data on water quality conditions in Tichigan Lake and the Waterford Impoundment date back to the early 1900s, when E.A. Birge and C. Juday, widely recognized pioneering lake researchers from the University of Wisconsin, collected basic information on Wisconsin lakes.[1] However, most water quality information is relatively recent. During 1966, water chemistry data for the Waterford Impoundment were collected by the Wisconsin Department of Natural Resources (WDNR) at a site in the Tichigan Lake subbasin and at a site in the Buena Lake subbasin;[2] during 1972, water quality data was collected by the U.S. Environmental Protection Agency (USEPA), as part of the National Eutrophication Study, at a site in the Tichigan Lake subbasin (approximately the same as the site used earlier by the WDNR), and at a site about a quarter mile downstream of the Tichigan Lake outlet.[3]

More recently, a volunteer working under the auspices of the WDNR Self-Help Monitoring Program has monitored the water quality periodically since 1988 and currently collects water quality data from the Waterford Impoundment at a single site in the Tichigan Lake subbasin. Additionally, the U.S. Geological Survey (USGS) collected water quality data periodically between 1994 and 2004 at two sites in the Impoundment that involved the determination of various physical and chemical characteristics of the Impoundment's water, including water temperature profiles, water clarity and nutrient and chlorophyll-*a* concentrations. The USGS samplings occurred at two sites: one in the deep basin of Tichigan Lake; the other in the Fox River portion of the Impoundment, approximately 0.5 mile upstream of the Waterford Dam. Locations of the sampling sites used by the USGS and WDNR during the recent study period, and the locations of the sampling sites used by the USEPA in their earlier study, are shown on Map 20. To avoid confusion over which sampling sites are being referred to in the discussion below, the Tichigan Lake subbasin sampling site used by the USEPA (earlier report), WDNR (earlier report and recent Self-Help volunteer), and USGS (recent data collection), will be referred to as the Tichigan Lake or Tichigan Lake subbasin site; the site located just a quarter mile downstream of the Tichigan Lake outlet used by

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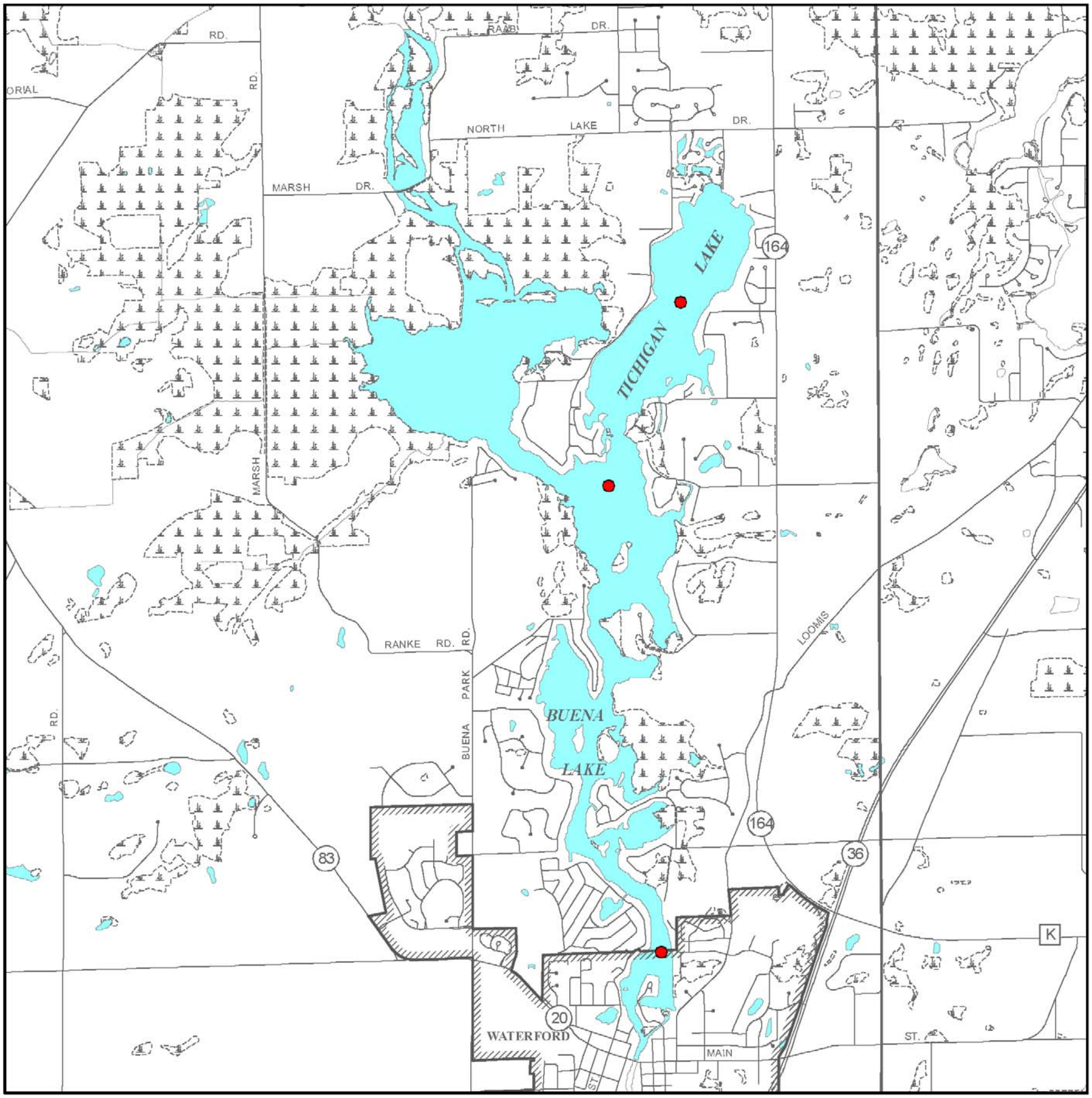
[1]*E.A. Birge and C. Juday*, The Inland Lakes of Wisconsin, 1. The Dissolved Gases and their Biological Significance, *Bulletin, Wisconsin Geological and Natural History Survey, Volume 22, 1911*.

[2]*Wisconsin Department of Natural Resources Lake Use Report No. FX-6,* The Waterford Impoundment and Tichigan Lake, Racine County, Wisconsin, *1970*.

[3]*U.S. Environmental Protection Agency National Eutrophication Survey Working Paper Series,* Report on Waterford Impoundment-Tichigan Lake Racine County Wisconsin EPA Region V Working Paper No. 52, *1974.*

Map 20

WATER QUALITY SAMPLING SITES FOR WATERFORD IMPOUNDMENT



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● Sampling Site

Surface Water

GRAPHIC SCALE

0 0.5 1 1.5 Miles

Source: Wisconsin Department of Natural Resources and SEWRPC.

the USEPA in 1972 will be referred to as the "Widespread" site; and the site located in the Fox River portion of the Impoundment, approximately 0.5 mile upstream of the Waterford Dam, used by the USGS during the recent data collection, will be referred to as the "Fox River" or "riverine" site. The Buena Lake sampling site used by the WDNR in its earlier report will be referred to simply as "Buena Lake."

EXISTING WATER QUALITY CONDITIONS

Water quality data gathered under the auspices of the recent water quality monitoring programs of the USGS and WDNR were used to assess water quality during the current study period at sites in the Tichigan Lake subbasin and the riverine portion of the Waterford Impoundment. Water quality samples generally were taken seasonally as shown in Tables 10, 11, and 12.

Thermal Stratification

Figures 2 and 3 compare water temperature profiles at the same site in the Tichigan Lake subbasin during the recent study period. Figure 2 is based on data gathered by the WDNR Self-Help volunteer; Figure 3 is based on data gathered by USGS. Between 1994 and 2004, surface water temperatures in Tichigan Lake ranged from a minimum of 32°F during the winter to 86°F during the summer. This range in water temperatures was approximately 11°F warmer than that measured during the earlier USEPA water quality study and approximately 10°F warmer than that measured by the WDNR during their earlier report. Water temperatures in the Fox River portion of the Impoundment during the current study period were similar to those in the Tichigan Lake subbasin, ranging from a minimum of 32°F during the winter to a maximum of about 81°F during the summer.

The Tichigan Lake subbasin is dimictic. This Lake mixes completely two times per year, and is subject to thermal stratification during summer and winter. This process is illustrated diagrammatically in Figure 4. Thermal stratification is a result of the differential heating of the lake water, and the resulting water temperature-density relationships at various depths within the lake water column. Water is unique among liquids because it reaches its maximum density, or mass per unit of volume, at about 39°F. The development of summer thermal stratification begins in early summer, reaches its maximum in late summer, and disappears in the fall. Stratification may also occur during winter under ice cover. The annual thermal cycle within Tichigan Lake is described below.

As summer begins, the Lake absorbs solar energy at the surface. Wind action and, to some extent, internal heat transfer mechanisms transmit this energy to the underlying portions of the waterbody. As the upper layer of water is heated by solar energy, a physical barrier, created by differing water densities between warmer and cooler waters, begins to form between the warmer surface water and the colder, heavier bottom water, as shown in Figure 4. This "barrier" is marked by a sharp temperature gradient known as the thermocline. The thermocline is characterized by a temperature gradient of a 1°C per meter (or by a drop in temperature about 2°F per three feet of depth). This zone of rapid temperature change separates the warmer, lighter, upper layer of water (called the epilimnion) from the cooler, heavier, lower layer (called the hypolimnion), as shown in Figure 5. Although this barrier is readily crossed by fish, provided sufficient oxygen exists, it essentially prohibits the exchange of water between the two layers. This condition has a major impact on both the chemical and biological activity in a lake.

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

When the water temperature drops to the point of maximum water density, 39.2°F, the waters at the lake surface become denser than the now warmer, less dense bottom waters, and "sink" to the bottom. Eventually, the water column is cooled to the point where the surface waters, cooled to about 32°F, are now lighter than the bottom waters which remain at about 39°F. The lake surface may then become ice covered, isolating the lake water from the atmosphere for a period of up to four months. On Tichigan Lake, ice cover typically exists from December

Table 10

SEASONAL WATER QUALITY CONDITIONS AT TICHIGAN LAKE DEEP BASIN IN WATERFORD IMPOUNDMENT: 1973-2004

Parameter[a]	Fall (mid-September to mid-December)		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Physical Properties								
Alkalinity, as $CaCO_3$								
Range	161-220	196-264	78-218	230-230	110-240	108-240	142-178	222-234
Mean	201.3	214.7	168.5	230	198.7	203.1	160.7	228
Standard Deviation	19.7	25.8	61.9	0	43.0	44.7	18.0	8.5
Number of Samples	7	6	4	1	7	7	3	2
Hardness, as $CaCO_3$								
Range	-	-	-	-	280-290	280-300	-	-
Mean	-	-	-	-	283.3	286.7	-	-
Standard Deviation	-	-	-	-	5.8	11.5	-	-
Number of Samples	-	-	-	-	3	3	-	-
Color (Pt-Co. scale)								
Range	-	-	-	25-25	20-30	15-25	-	-
Mean	-	-	-	25	23.3	20	-	-
Standard Deviation	-	-	-	0	5.8	5	-	-
Number of Samples	-	-	-	1	3	3	-	-
Dissolved Oxygen								
Range	6.4-11.8	0.2-11.1	-	0.0-7.0	9.1-18.5	0.0-12.5	7.8-15.7	0.0-1.2
Mean	10.0	8.5	-	3.1	12.5	6.9	10.2	0.5
Standard Deviation	2.2	4.3	-	3.2	2.1	4.9	2.1	0.4
Number of Samples	7	6	-	5	14	13	12	12
pH (units)								
Range	7.7-8.3	7.3-8.4	7.5-8.8	7.1-7.8	7.9-8.6	7.3-8.4	8.0-8.9	7.0-7.7
Mean	8.1	8.0	8.1	7.4	8.3	7.9	8.5	7.3
Standard Deviation	0.2	0.4	0.4	0.3	0.2014	0.4	0.2	0.2
Number of Samples	8	7	8	5		13	13	12
Secchi Depth (feet)[a]								
Range	2.1-5.5	-	-	-	3.0-8.9	-	2.0-8.9	-
Mean	3.5	-	-	-	5.0	-	5.3	-
Standard Deviation	1.2	-	-	-	2.2	-	2.2	-
Number of Samples	9	-	-	-	14	-	12	-
Specific Conductance (µS/cm)								
Range	420.0-964.0	503-1030	346-1140	900-1220	524-988	516-1020	402-918	548-1060
Mean	601.0	652.3	726.1	1010	775.3	809.4	724.2	856.7
Standard Deviation	175.6	183.5	237.5	125.5	134.5	162.9	149.7	162.9
Number of Samples	8	7	8	5	14	13	13	12
Temperature (°F)								
Range	41.5-65.3	41.5-46.4	32.0-38.3	36.3-39.2	39.5-74.3	39.0-49.8	71.2-86.0	45.0-52.5
Mean	49.7	44.0	34.8	37.2	55.7	44.0	78.9	47.8
Standard Deviation	10.5	2.23	2.6	1.2	11.2	2.9	4.4	2.2
Number of Samples	7	6	8	5	14	13	12	12
Turbidity (NTU)								
Range	2.9-7.0	2.8-90.0	1.4-6.5	3-3	2.2-5.0	1.8-3.0	6.1-23.0	3.7-4.9
Mean	5.2	19.6	3.3	3	3.1	2.2	13.0	4.3
Standard Deviation	1.7	34.6	2.2	0	0.9	0.4	8.8	0.8
Number of Samples	7	6	4	1	7	7	3	2
Dissolved Solids								
Range	-	-	-	-	450-478	448-486	-	-
Mean	-	-	-	-	466.7	470	-	-
Standard Deviation	-	-	-	-	14.7	19.7	-	-
Number of Samples	-	-	-	-	3	3	-	-
Metals/Salts								
Dissolved Calcium								
Range	24.0-65.8	39.0-84.5	-	64-64	52.0-75.0	44.0-76.0	32-40	49-65
Mean	48.5	58.6	-	64	58.7	58.9	36.7	57
Standard Deviation	13.8	17.2	-	0	7.8	9.3	4.2	11.3
Number of Samples	7	6	-	1	7	7	3	2
Dissolved Chloride								
Range	19-59	17-60	23-65	65-65	39.0-110.0	35.0-110.0	37-73	37-42
Mean	41.9	41.2	41.8	65	68.9	68.1	49.7	39.5
Standard Deviation	14.1	15.6	17.7	0	28.6	29.8	20.2	3.5
Number of Samples	7	6	4	1	7	7	3	2
Dissolved Iron (µg/l)								
Range	0.03-0.1	0.03-0.14	0.04-0.04	-	0.04-25.00	0.04-25.00	0.03-0.05	0.5-0.5
Mean	0.1	0.1	0.04	-	7.0	7.0	0.3	0.5
Standard Deviation	0.06	0.1	0	-	10.4	10.4	0.4	0
Number of Samples	3	3	1	-	5	5	2	1
Dissolved Magnesium								
Range	9.0-52.3	13.0-52.3	21-52	38-38	34-48	34-43	39-50	50-52
Mean	38.3	38.8	33.5	38	37.4	36.7	43	51
Standard Deviation	13.6	13.4	13.9	0	4.9	3.3	6.1	1.4
Number of Samples	7	6	4	1	7	7	3	2

Table 10 (continued)

	Fall (mid-September to mid-December)		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
Parameter[a]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Metals/Salts (continued)								
Dissolved Manganese (μg/l)								
Range	0.02-0.07	0.02-0.07	0.04-0.04	-	0.02-20.00	0.02-47.00	0.02-0.07	0.3-0.3
Mean	0.03	0.03	0.04	-	8.1	22.8	0.04	0.3
Standard Deviation	0.03	0.03	0	-	10.8	16.9	0.04	0
Number of Samples	3	3	1	-	5	5	2	1
Dissolved Potassium								
Range	1.4-3.8	2.3-5.1	1.7-4.0	4-4	2.3-4.5	2.6-4.0	3.4-4.8	2.3-3.5
Mean	2.9	3.2	3.1	4	3.0	3.1	4.0	2.9
Standard Deviation	0.8	1.0	1.0	0	0.7	0.4	0.7	0.8
Number of Samples	7	6	4	1	7	7	3	2
Dissolved Silica								
Range	-	-	-	-	0.0-0.1	0.1-0.3	-	-
Mean	-	-	-	-	0.05	0.2	-	-
Standard Deviation	-	-	-	-	0.07	0.1	-	-
Number of Samples	-	-	-	-	2	3	-	-
Dissolved Sodium								
Range	23.0-41.3	26.3-45.6	14-50	39-39	18-59	21-60	8-42	8-29
Mean	31.5	32.0	30.5	39	37.9	39.4	26	18.5
Standard Deviation	6.6	7.0	16.2	0	15.2	14.7	17.1	14.8
Number of Samples	7	6	4	1	7	7	3	2
Dissolved Sulfate SO_4								
Range	27-48	27-47	38-45	-	38-47	37-49	35-63	36-45
Mean	33.8	34.5	41.5	-	44.2	45	47.3	40.5
Standard Deviation	8.4	9.0	5.0	-	3.7	4.7	14.3	6.4
Number of Samples	5	4	2	-	5	5	3	2
Nutrients								
Dissolved Nitrogen, Ammonia								
Range	0.3-2.9	0.5-5.7	0.4-0.7	6.8-6.8	0.03-0.40	0.2-1.0	0.02-0.07	2.3-3.1
Mean	0.9	1.5	0.5	6.8	0.2	0.4	0.04	2.7
Standard Deviation	0.9	2.1	0.1	0	0.1	0.3	0.03	0.5
Number of Samples	7	6	4	1	5	7	3	2
Dissolved Nitrogen, NO_2+NO_3								
Range	0.3-0.6	0.2-0.6	0.6-1.0	0.001-0.001	0.6-0.9	0.6-1.1	0.1-0.2	0.11-0.12
Mean	0.4	0.4	0.8	0.001	0.7	0.8	0.1	0.11
Standard Deviation	0.1	0.2	0.2	0	0.1	0.2	0.1	0.01
Number of Samples	7	6	4	1	7	7	3	2
Total Nitrogen, Organic								
Range	0.8-1.3	0.8-1.4	0.5-2.1	1.4-1.4	0.6-1.3	0.6-1.1	0.9-1.9	0.9-1.3
Mean	1.0	1.0	1.1	1.4	1.0	0.9	1.5	1.1
Standard Deviation	0.2	0.2	0.7	0	0.3	0.2	0.5	0.3
Number of Samples	7	6	4	1	7	7	3	2
Total Nitrogen, Amm. + Organic								
Range	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Number of Samples	-	-	-	-	-	-	-	-
Total Nitrogen								
Range	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-
Standard Deviation	-	-	-	-	-	-	-	-
Number of Samples	-	-	-	-	-	-	-	-
Dissolved Orthophosphorus								
Range	0.02-0.6	0.03-1.37	0.02-0.18	1.1-1.1	0.001-0.198	0.004-0.121	0.03-0.04	0.6-0.6
Mean	0.2	0.3	0.1	1.1	0.05	0.053	0.03	0.6
Standard Deviation	0.2	0.5	0.1	0	0.08	0.053	0.01	0
Number of Samples	7	6	4	1	7	7	3	2
Total Phosphorus								
Range	0.04-0.8	0.1-1.3	0.02-0.2	0.1-1.3	0.03-0.17	0.04-0.46	0.02-0.13	0.5-0.9
Mean	0.2	0.5	0.1	0.7	0.01	0.2	0.05	0.7
Standard Deviation	0.2	0.5	0.1	0.8	0.01	0.2	0.03	0.2
Number of Samples	9	8	5	2	14	13	13	12
Biological								
Chlorophyll-*a* (μg/l)								
Range	14.6-16.1	-	-	-	6.7-42.4	-	0.4-25.0	-
Mean	15.4	-	-	-	23.2	-	12.4	-
Standard Deviation	1.1	-	-	-	12.8	-	7.8	-
Number of Samples	2	-	-	-	10	-	10	-

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

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

[c]*Depth of sample greater than 60 feet.*

[d]*Secchi depths are from USGS measurements and are not part of Secchi depths recorded in Table 12.*

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

Table 11

SEASONAL WATER QUALITY CONDITIONS AT FOX RIVER SITE IN WATERFORD IMPOUNDMENT: 2003-2004

Parameter[a]	Fall (mid-September to mid-December)		Winter (mid-December to mid-March)		Spring (mid-March to mid-June)		Summer (mid-June to mid-September)	
	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]	Shallow[b]	Deep[c]
Physical Properties								
Dissolved Oxygen								
Range	11.1-14.2	11	16.4	16.4	9.6-17.0	9.5-16.6	10.6-20.0	8.7-16.4
Mean	12.7	11	16.4	16.4	14.1	14.0	14.8	12.4
Standard Deviation	2.2	--	--	--	3.3	3.2	4.3	3.7
Number of Samples	2	1	1	1	4	4	4	4
pH (units)								
Range	8.8	8.8	7.6	7.6	7.8-8.6	7.8-8.6	8.3-8.5	8.2-8.5
Mean	8.8	8.8	7.6	7.6	8.35	8.33	8.43	8.35
Standard Deviation	--	--	--	--	0.4	0.4	0.1	0.1
Number of Samples	1	1	1	1	4	4	4	4
Secchi Depth (feet)[d]								
Range	0.3-0.7	--	--	--	1.0-1.6	--	0.7-2.1	--
Mean	0.5	--	--	--	1.3	--	1.2	--
Standard Deviation	0.2	--	--	--	0.3	--	0.6	--
Number of Samples	2	--	--	--	3	--	5	--
Specific Conductance (µS/cm)								
Range	994-1160	995-1160	1380	1370	814-1110	814-1110	869-1040	874-1040
Mean	1077	1078	1380	1370	975	975	952	954
Standard Deviation	117.4	116.7	--	--	124.6	124.5	79.3	77.9
Number of Samples	2	2	1	1	4	4	4	4
Temperature (°F)								
Range	61	--	32	32	47-77	47-77	72-81	72-81
Mean	61	--	32	32	59.5	59.3	76	76.5
Standard Deviation	--	--	--	--	13.8	13.7	4.1	3.9
Number of Samples	1	--	1	1	4	4	5	4
Nutrients								
Total Phosphorus								
Range	0.16	--	0.03	--	0.08-0.17	0.12-0.13	0.18-0.30	0.21-0.29
Mean	0.16	--	0.03	--	0.12	0.12	0.25	0.25
Standard Deviation	--	--	--	--	0.04	0.01	0.06	0.06
Number of Samples	1	--	1	--	6	2	3	2
Biological								
Chlorophyll-*a* (µg/l)								
Range	97.1	--	--	--	60-115	--	40-188	--
Mean	97.1	--	--	--	85	--	135	--
Standard Deviation	--	--	--	--	27.8	--	55.9	--
Number of Samples	1	--	--	--	3	--	5	--

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

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

[c] *Depth of sample greater than 3.3 feet.*

[d] *Secchi depths are from USGS measurements, not WDNR Self-Help Monitoring Program and are not, consequently, part of Secchi depths recorded in Table 12.*

Source: U.S. Geological Survey and SEWRPC.

until early April. As shown in Figure 4, winter stratification occurs as the colder, lighter water and ice remains at the surface, separated from the relatively warmer, heavier water near the bottom of the lake.

Spring brings a reversal of the process. As the ice thaws, and the temperature of the surface water warms, the entire water column eventually achieves a uniform temperature (and density) from surface to bottom. During this time of uniform density, strong winds blowing across the surface can result in a complete mixing of the entire water column. This is referred to as “spring turnover” and usually occurs within weeks after the ice goes out, as shown in Figure 4. After spring turnover, the water at the surface continues to warm, becoming less dense and causing it to float above the denser, colder, deeper water. Wind and resulting waves carry some of the energy of the warmer, lighter water to lower depths, but only to a limited extent. Thus begins the formation of the thermocline and another period of summer thermal stratification.

Table 12

SEASONAL WATER QUALITY FOR TICHIGAN LAKE SUBBASIN OF THE WATERFORD IMPOUNDMENT: 1988-2004

Measured Data			
Parameter	Spring (mid-March to mid-June)	Summer (mid-June to mid-September)	Fall (mid-September to mid-December)
Secchi Disc Depth (feet)			
Number of Samples	58	114	37
Range	2.5-15.0	2.5-11.5	3.0-9.0
Average	6.5	5.5	5.2
Standard Deviation	2.8	1.7	1.4
Chlorophyll-*a* (μg/l)[a]			
Number of Samples	12	35	11
Range	8-115	0-188	0-97
Average	41.3	29.9	36.1
Standard Deviation	30.9	48.2	31.5
Total Phosphorus (μg/l)[a]			
Number of Samples	29	43	13
Range	6-401	18-757	41-1080
Average	88.0	114.6	220.8
Standard Deviation	90.5	173.2	334.8

WTSI Calculations			
Parameter	Spring	Summer	Fall
Secchi Disc Depth			
Number of Samples	58	114	37
Range	38.1-63.9	41.9-63.9	45.4-61.3
Average	50.2	52.6	53.4
Standard Deviation	62.1	69.5	72.3
Chlorophyll-*a* (μg/l)[a]			
Number of Samples	12	35	11
Range	50.0-70.0	0-73.7	0-68.7
Average	62.1	59.6	61.1
Standard Deviation	59.9	63.3	60.0
Total Phosphorus (μg/l)[a]			
Number of Samples	29	43	13
Range	32.5-93.0	48.3-102.2	60.2-107.3
Average	71.2	75.0	84.5
Standard Deviation	71.6	81.0	90.5

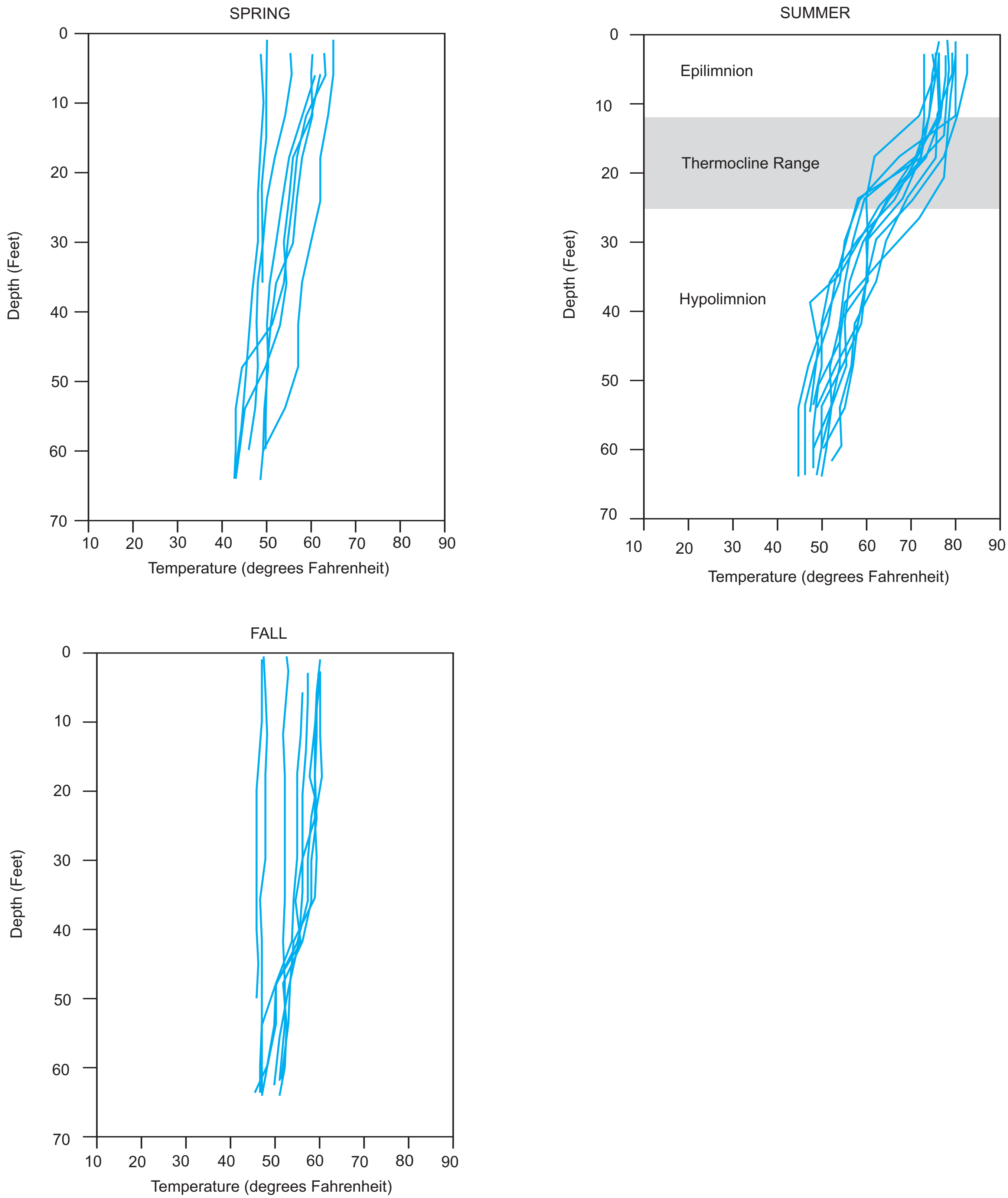
[a]*1993-2004 only.*

Source: Wisconsin Department of Natural Resources.

As aforementioned, Tichigan Lake is dimictic and stratifies twice a year – once in summer and once in winter. As shown in Figures 2 and 3, the thermocline depth during periods of stratification ranged from about 15 feet to about 20 feet during the recent studies. During the earlier WDNR studies, the level of stratification was determined to be approximately 19 feet. In contrast to the Tichigan Lake subbasin, the Fox River portion of the Impoundment does not stratify, as shown in Figure 6, due to its shallow depth and greater susceptibility to wind-induced mixing.

Figure 2

WATER TEMPERATURE AND DEPTH PROFILES FOR WATERFORD IMPOUNDMENT: 1993-2004



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 3

DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR TICHIGAN LAKE SUBBASIN OF WATERFORD IMPOUNDMENT: 1994-2003

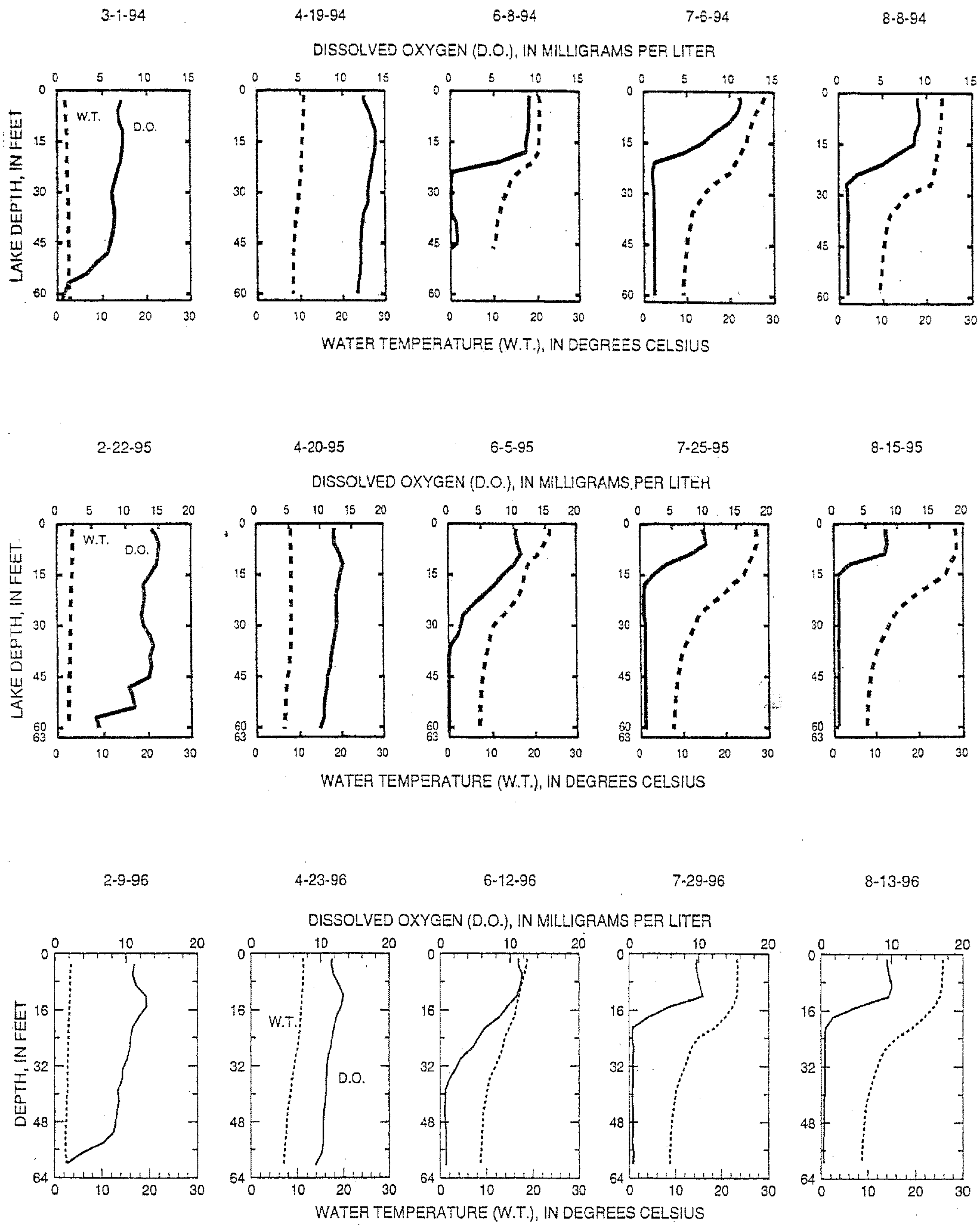
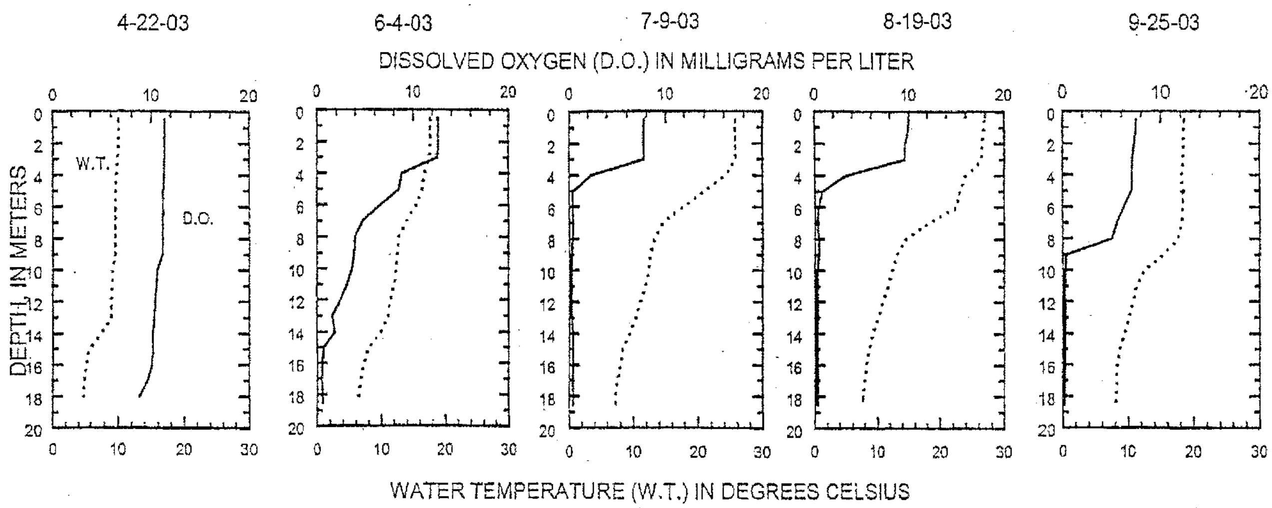


Figure 3 (continued)



Source: U.S. Geological Survey and SEWRPC.

Dissolved Oxygen

Since most aquatic organisms depend on oxygen to survive, dissolved oxygen levels are one of the most critical factors in a lake ecosystem. Generally, dissolved oxygen levels are higher at the surface of a lake, where there is an interchange between the water and atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis. Dissolved oxygen levels are generally lowest on the bottom of the Lake, where decomposer organisms and chemical oxidation processes utilize oxygen in the decay process. When a lake becomes thermally stratified, as described above, the surface supply of dissolved oxygen to the hypolimnion is cut off. Gradually, if there is not enough dissolved oxygen to meet the total demands from the bottom dwelling aquatic life and decaying organic material, the dissolved oxygen levels in the bottom waters may be reduced, even to zero, a condition known as anoxia or anaerobiasis.

The aforementioned earlier study of the Tichigan Lake subbasin conducted by the USEPA revealed an average surface water dissolved oxygen concentration of about 11 milligrams per liter (mg/l), which declined to zero at the 60-foot depth in June and at the 25-foot depth in August.[4] These data were similar to those gathered during the earlier WDNR study.[5] This earlier WDNR data indicated the occurrence of hypolimnetic anoxia at about the 22-foot depth in Tichigan Lake during August of 1966. Dissolved oxygen concentrations for the "Widespread" section of the Impoundment reported by the USEPA, averaged about 10.4 mg/l at the surface during June, and 5.6 mg/l during August, 1972. These earlier water quality studies indicated that, at a depth of approximately 15 feet in the Tichigan Lake subbasin, summer dissolved oxygen concentrations were at or below the recommended concentration of 5.0 mg/l, the minimum level necessary to support many species of fish, during most years studied. This potentially limits the volume of water available for fish habitat to the surface waters of the lake of less than 15 feet in depth. Because these are the warmer surface waters, this available habitat appears to be best suited for warmwater fishes (see Chapters V and VI of Volume One for a discussion of the biology of the Lake and its water quality objectives established pursuant to Chapters NR 102 and NR 104 of the *Wisconsin Administrative Code*, respectively).

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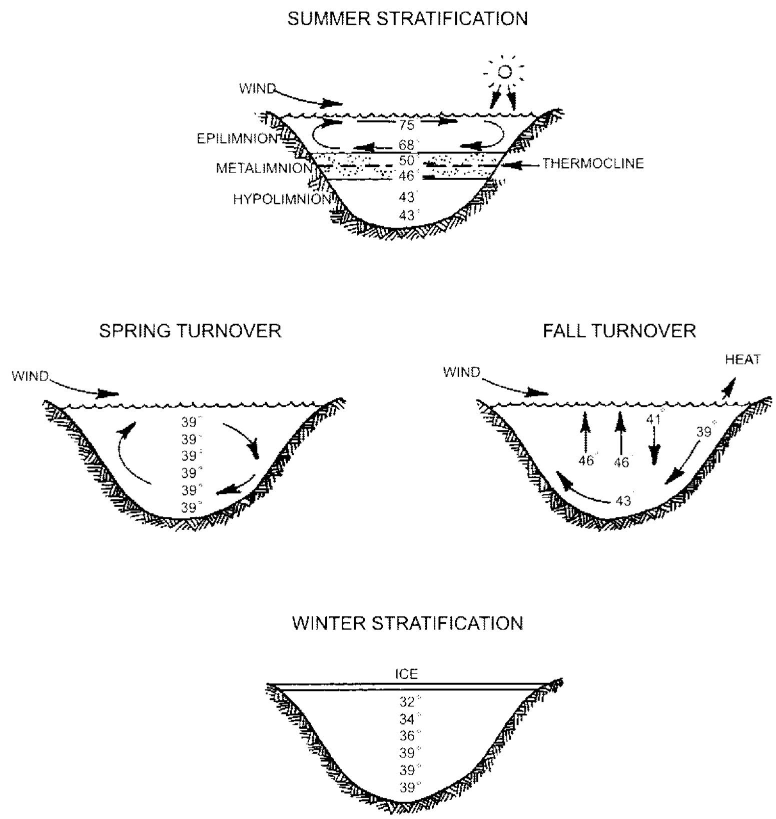
[4]*U.S. Environmental Protection Agency National Eutrophication Survey Working Paper Series No. 52,* op. cit.

[5]*Wisconsin Department of Natural Resources Lake Use Report No. FX-6,* op. cit.

Figure 4

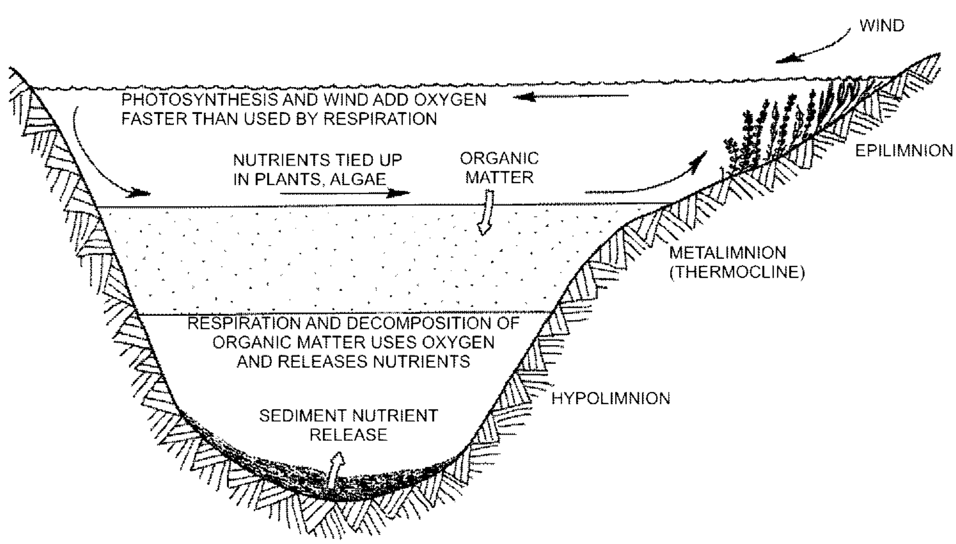
THERMAL STRATIFICATION OF LAKES



Source: University of Wisconsin-Extension and SEWRPC.

Figure 5

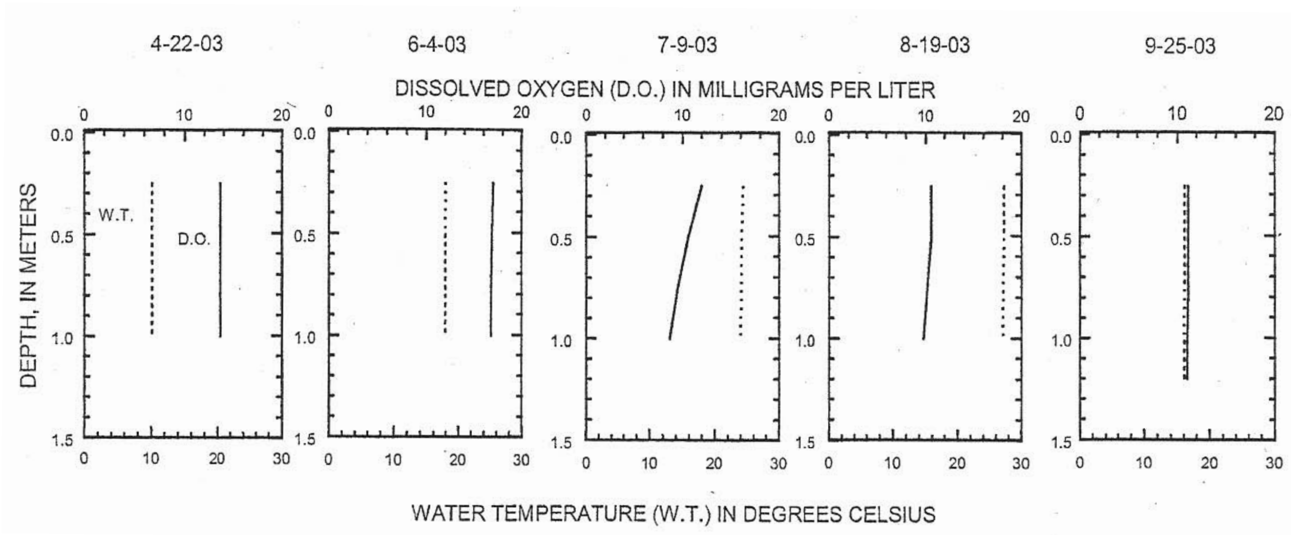
LAKE PROCESSES DURING SUMMER STRATIFICATION



Source: University of Wisconsin-Extension and SEWRPC.

Figure 6

DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR FOX RIVER PORTION OF WATERFORD IMPOUNDMENT: 2003



Source: U.S. Geological Survey and SEWRPC.

During the recent study period, as shown in Table 10, summer concentrations of dissolved oxygen in the Tichigan Lake subbasin averaged 10.2 mg/l near the surface and 0.l5 mg/l in the bottom waters. As shown in Table 11, during the recent study, summer concentrations of dissolved oxygen in the Fox River portion of the Impoundment averaged 14.8 mg/l near the surface and 12.4 mg/l in the bottom waters. Figures 3 and 6 show dissolved oxygen profiles for the Tichigan Lake subbasin and Fox River portion, respectively, during the current study period. The Tichigan Lake data indicate a condition of anaerobiasis in the bottom waters during the current study period, which is consistent with the data from the aforementioned earlier water quality studies of the USEPA and WDNR.

Fall turnover, between September and October in most years, naturally restores the supply of oxygen to the bottom waters to most lakes. This would appear to be the case in Tichigan Lake as supported by both the earlier report of the USEPA for the period during November 1972 and by the more recent USGS data, as shown in Table 10. The earlier USEPA study reported dissolved oxygen concentrations of between 10.2 mg/l and 11.1 mg/l in the Lake, and of 8.9 mg/l at a depth of four feet in the "Widespread," during the autumn. For the current period, USGS reported average fall dissolved oxygen concentrations of 8.5 mg/l in the bottom waters of Tichigan Lake and an average of 11.0 mg/l in the bottom waters at the Fox River sampling site.

Hypolimnetic anoxia can be reestablished during the period of winter thermal stratification. Winter anoxia is more common during years of heavy snowfall, when snow covers the ice, reducing the degree of light penetration and reducing algal photosynthesis that takes place under the ice. In some lakes in the Region, hypolimnetic anoxia can occur during winter stratification. Under these conditions, anoxia can contribute to the winter-kill of fish. The aforementioned earlier studies conducted by the USGS and the WDNR did not document winter dissolved oxygen levels in either Tichigan Lake or the Fox River portion of the Impoundment, although, despite the lack of data regarding dissolved oxygen concentrations in Tichigan Lake and the "Widespread" during the winter months, adequate oxygenation can be presumed from the lack of reported fish-kills. However, during the current study period, winter dissolved oxygen concentrations for the bottom waters of Tichigan Lake averaged only about 3.1 mg/l with a range from 0 mg/l to 7.0 mg/l, which would indicate a condition of anaerobiasis; winter dissolved oxygen concentrations in the Widespread portion averaged about 16.4 mg/l, indicating adequate oxygen levels throughout the winter in the riverine portion of the Impoundment.

At the end of winter, the dissolved oxygen concentrations in the bottom waters of a lake are restored during the period of spring turnover, which generally occurs between March and May. Table 10 shows this expected restoration of oxygen in the Tichigan Lake subbasin during the current study period; the earlier water quality studies did not collect dissolved oxygen data during the spring turnover periods.

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

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

Specific Conductance

Specific conductance is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. Excessively high measurements of specific conductance can be an indication that a waterbody may be receiving high concentrations of contaminants.

The earlier USEPA study reported specific conductivity measurements during late June 1972, in the Tichigan Lake subbasin, of 500 microSiemens per centimeter (μS/cm) in the surface waters and 650 μS/cm in the bottom waters and, for the Widespread, the measurement was 580 μS/cm; conductivity measurements in Tichigan Lake during August 1972 ranged from 535 μS/cm at the surface to 705 μS/cm in the bottom waters and, for the Widespread, the measurement was 600 μS/cm; specific conductivity in Tichigan Lake during November 1972 ranged from 570 μS/cm at the surface to 580 μS/cm in the bottom waters and, for the Widespread, the measurement was 750 μS/cm. The earlier WDNR study reported specific conductivity measurements during April 1966 of 514 μS/cm for Tichigan Lake at a depth of three feet and of 597 μS/cm for Buena Lake at a depth of three feet; specific conductivity measurements in August 1966 were 460 μS/cm at a depth of 10 feet in Tichigan Lake and 640 μS/cm at a depth of 10 feet in Buena Lake. These ranges are slightly above the normal range for lakes in Southeastern Wisconsin,[6] and continued to increase to the recent study period.

During the current study period, spring conductivity measurements for Tichigan Lake averaged about 775 μS/cm at the surface and about 809 μS/cm in the bottom waters; for the riverine portion of the Impoundment the average was 975 μS/cm, as summarized in Tables 10 and 11, respectively.

Specific conductance can be affected by thermal stratification. During periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion. This is a consequence of the "internal loading" phenomenon noted above. Significant surface to bottom conductivity gradients have been observed in Tichigan Lake, especially during the summer months as the

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[6] *Wisconsin Conservation Department,* Surface Water Resources of Racine County, *1961.*

aforedescribed process of stratification becomes established. During the current study period, specific conductivity measurements in Tichigan Lake during summer ranged from an average of 724 μS/cm at the surface to an average of 857 μS/cm near the bottom, as shown in Table 10.

While the intensity of the surface-to-bottom conductivity gradient diminished during the autumn, during the current study period the USGS continued to report a surface-to-bottom conductivity gradient in Tichigan Lake: average conductivity measurements ranged from 601 μS/cm at the surface to 652 μS/cm at the bottom. Winter measurements for specific conductivity in Tichigan Lake during the current study period ranged from an average of 726 μS/cm at the surface to 1,010 μS/cm in the bottom water, as shown in Table 10. Figures 7 and 8 show conductivity-pH profiles for Tichigan Lake and the Fox River portion respectively, during the current study period.

Specific conductivity for the Fox River portion of the Impoundment during the current study period does not reflect a concentration gradient due to the shallow depth of water at the sampling site. As shown in Table 11, measurements in summer averaged about 953 μS/cm, about 1,077 μS/cm during fall, and about 1,375 μS/cm during winter.

Chloride

Chloride is not common in limestone-based soils or rocks and, when occurring at natural levels in most Wisconsin lakes, is not toxic to aquatic life. Concentrations in excess of normal levels, especially when exhibiting seasonal fluctuations, could indicate possible water pollution. Common sources of chloride contamination are septic systems, fertilizer runoff, and road salt runoff.

Chloride concentrations were not measured during the earlier USEPA study. During the earlier WDNR study, chloride concentrations averaged about 26 mg/l in the Tichigan Lake subbasin and about 30 mg/l in the Buena Lake subbasin. During the current study period, chloride concentrations were not measured in the Fox River portion of the Impoundment, but, in the surface waters of Tichigan Lake, chloride averaged about 69 mg/l in the spring, 50 mg/l in summer, 42 mg/l in fall and winter; in the bottom waters of Tichigan Lake, chloride averaged about 68 mg/l in spring, 40 mg/l in summer, 41 mg/l in fall, and 65 mg/l in winter, as summarized in Table 10.[7] These current values, when compared to those of the earlier WDNR study, reflect the pattern of generally increasing chloride concentrations over time in lakes in southeastern Wisconsin, as shown in Figure 9.

Alkalinity and Hardness

Alkalinity is an index of the buffering capacity of a lake, or the capacity of a lake to absorb and neutralize acids. The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity because of the types of soils and underlying bedrock in the Region's tributary areas. It also is common for lakes with high algal activity to have high alkalinity.

In contrast, water hardness is a measure of the multivalent metallic ion concentrations, such as those of calcium and magnesium, present in a lake. Hardness is usually reported as an equivalent concentration of calcium carbonate ($CaCO_3$).

During the earlier USEPA study, alkalinity in the surface waters of Tichigan Lake averaged about 169 mg/l throughout the year; in the bottom waters, the annual average was about 231 mg/l. During the earlier WDNR study, the spring alkalinity in the Tichigan Lake subbasin averaged about 176 mg/l and in the Buena Lake subbasin averaged about 252 mg/l.

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[7] *The major sources of chlorides to lakes in the Southeastern Wisconsin Region include both road salt applications during winter months and salts discharged from water softeners and entering tributary areas through onsite sewage disposal systems.*

Figure 7

SPECIFIC CONDUCTIVITY AND pH PROFILES FOR TICHIGAN LAKE SUBBASIN OF WATERFORD IMPOUNDMENT: 1994-2003

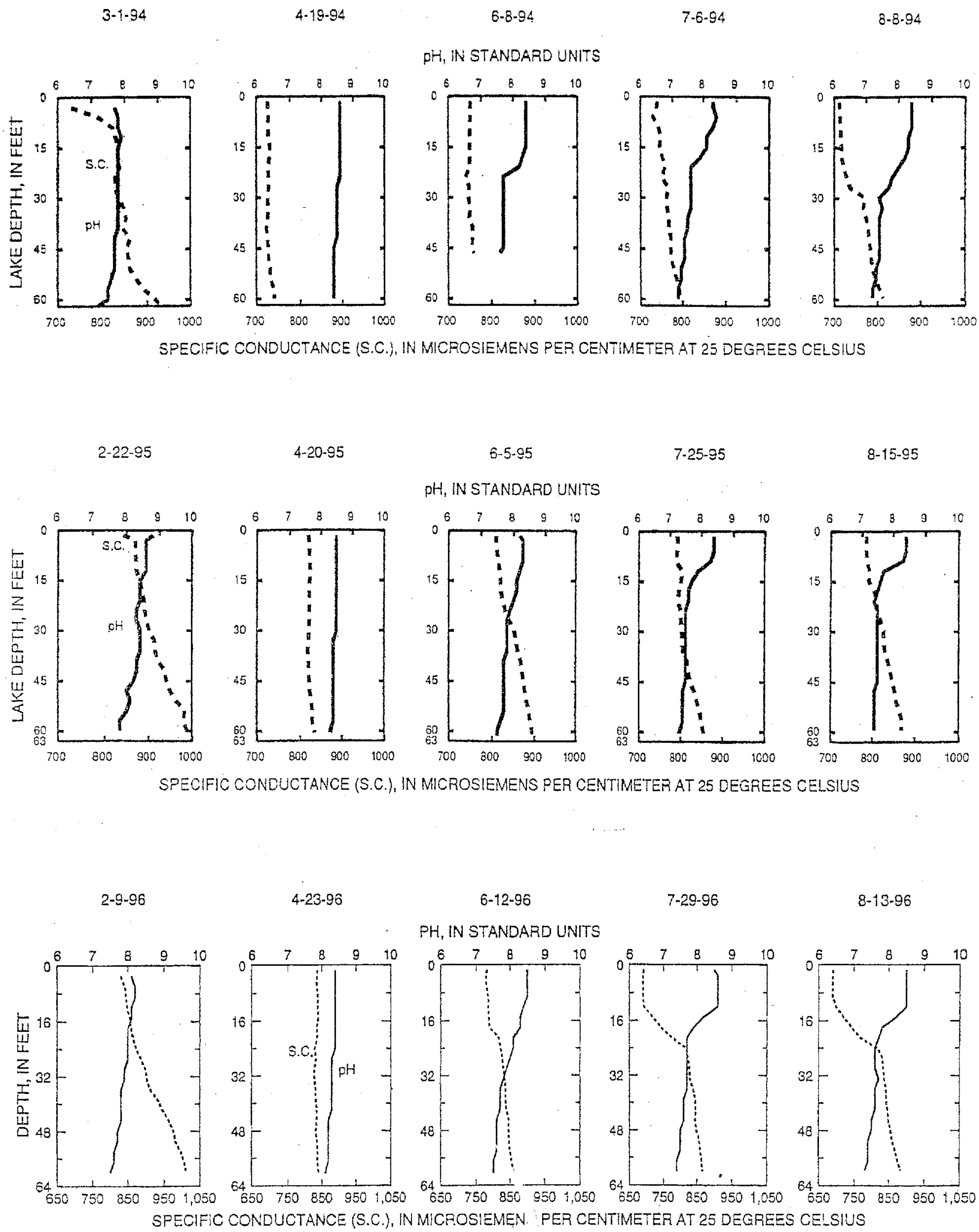
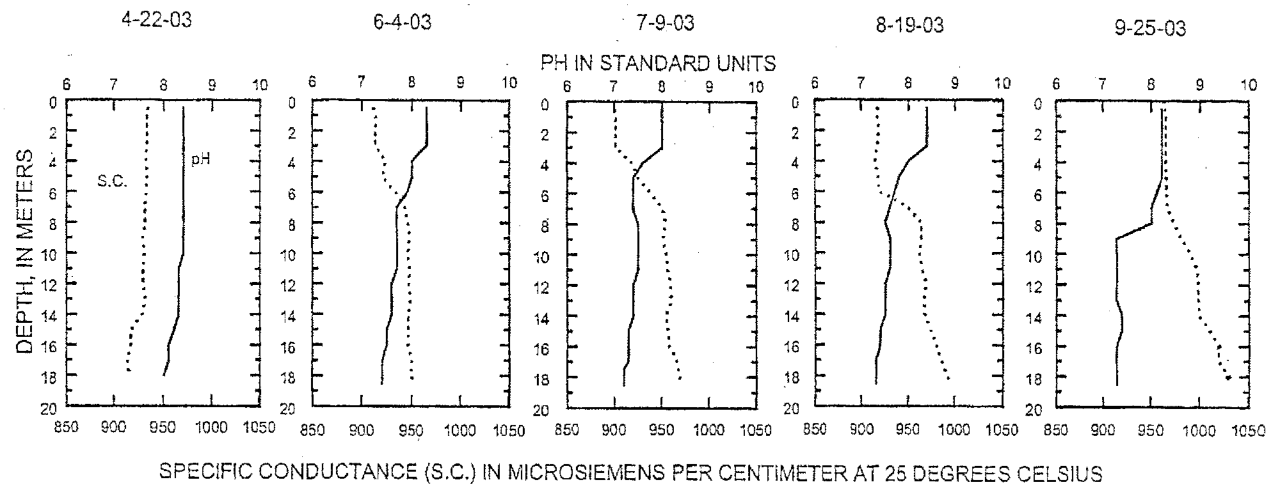


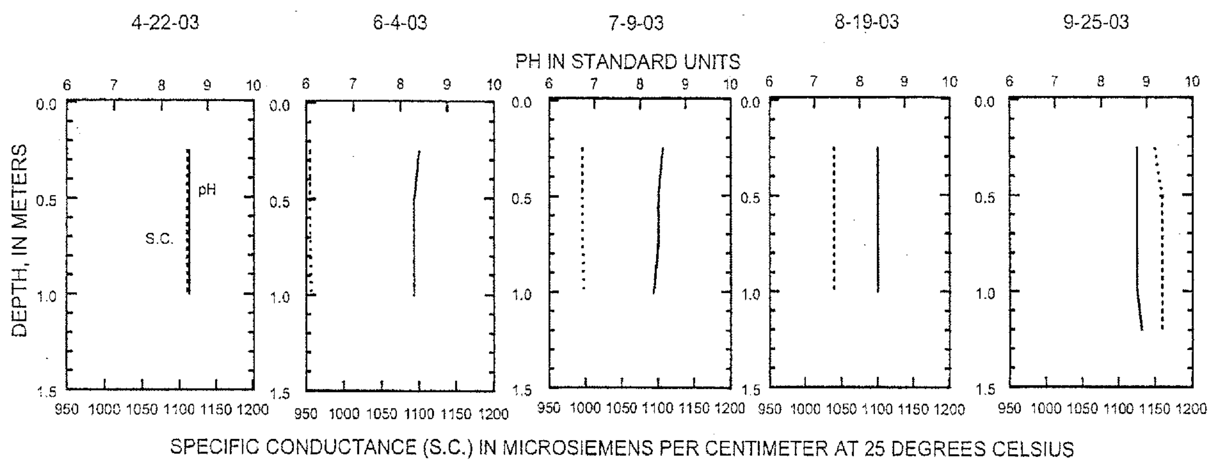
Figure 7 (continued)



Source: U.S. Geological Survey and SEWRPC.

Figure 8

SPECIFIC CONDUCTIVITY AND PH PROFILES FOR FOX RIVER PORTION OF WATERFORD IMPOUNDMENT: 2003-2004



Source: U.S. Geological Survey and SEWRPC.

During the current study period, spring alkalinity in the surface waters of Tichigan Lake averaged about 199 mg/l with an annual average of about 183 mg/l; alkalinity in the bottom waters of Tichigan Lake annually averaged about 219 mg/l. Hardness in Tichigan Lake averaged about 285 mg/l. These values, shown in Table 10, are within the normal range of lakes in Southeastern Wisconsin.[8] There were no alkalinity or hardness measurements for the Fox River portion of the Impoundment during the current study period.

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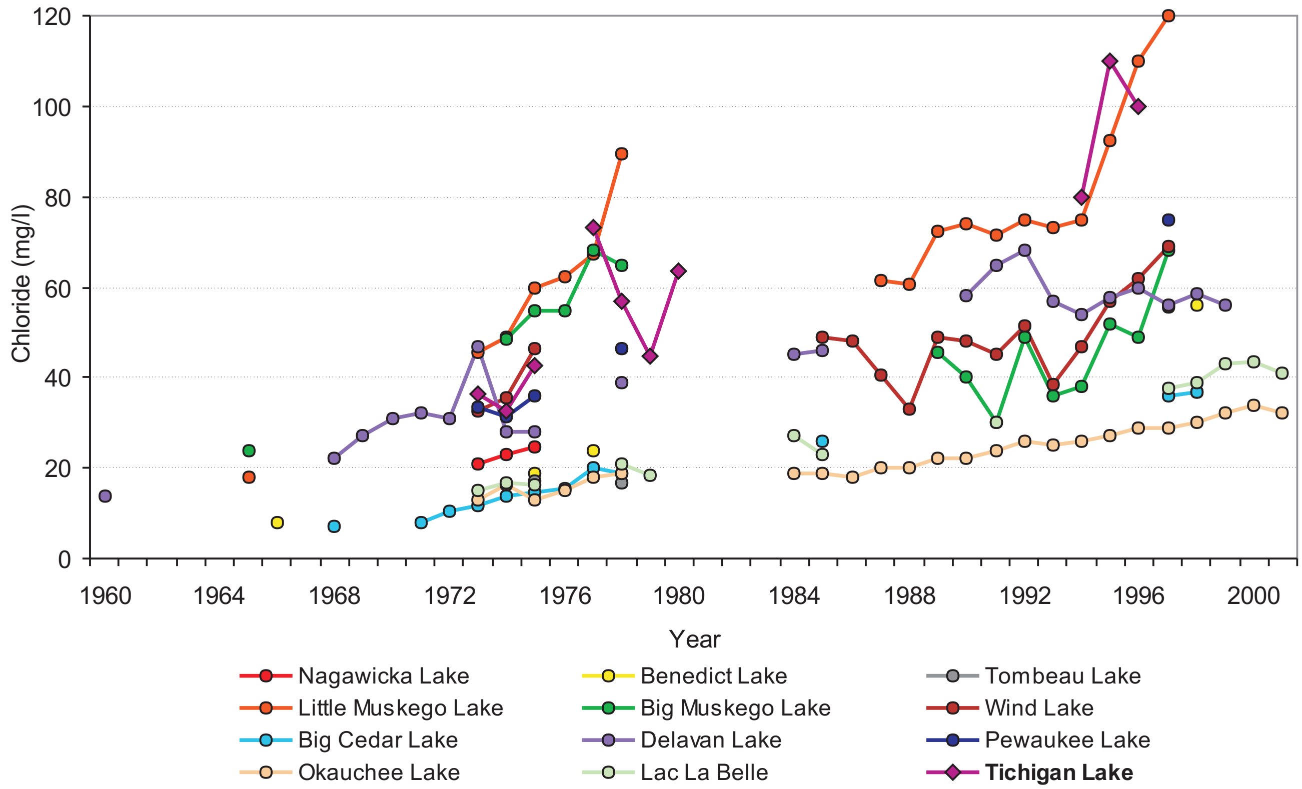
[8]*R.A. Lillie and J.W. Mason,* op. cit.

Figure 9

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



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

Applying these measures to the study lake, the Waterford Impoundment may be classified as a hard-water alkaline waterbody.

Hydrogen Ion Concentration (pH)

The pH is a measure of the hydrogen ion concentration based on a logarithmic scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, and a pH below 7 indicates acidic water. A change in pH of unit represents a tenfold change in acid level. In Wisconsin, lakes exhibit a range in pH from a low of 4.5 in some acid bog lakes, found mostly in northern Wisconsin, to 8.4 in hard water, marl lakes. While moderately low pH does not usually harm fish, under low pH certain metals, such as aluminum, zinc and mercury, if they are present in lake sediment or watershed soils, can become soluble and increase in concentrations to a level that poses a health problem for loons, eagles, osprey and humans who eat chemically tainted fish.

In the earlier WDNR study, the pH was found to range between 8.2 and 9.0 standard units for the Tichigan Lake subbasin, and between 8.5 and 8.6 standard units in the Buena Lake subbasin. During the earlier USEPA study, the pH was found to average about 8.2 standard units for Tichigan Lake and about 7.8 standard units for the "Widespread." During the current study period, as shown in Tables 10 and 11, the pH averaged about 7.9 standard units for Tichigan Lake, and about 8.5 standard units for the Fox River portion of the Impoundment.

Natural rainfall, exposed to C02 in the atmosphere, undergoes an increase of its pH level (normally about 4.4 in southeastern Wisconsin) to a level maintained at a pH of about 5.6. Since the Waterford Impoundment has a high alkalinity or buffering capacity, the result of the underlying geochemistry of the bedrock in southeastern

Wisconsin, and because the pH does not fluctuate below 7, the rainwater pH is further raised by the chemical buffering of the natural carbonate system in the Impoundment waters and the Impoundment is not, therefore, considered to be susceptible to the harmful effects of acidic deposition.

Water Clarity

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

Water clarity generally varies throughout the year as algal populations increase and decrease in response to changes in weather conditions and nutrient loadings. Secchi-disc depth measurements in Tichigan Lake during 1972 averaged about three feet; in the Widespread, Secchi-disc measurements averaged about one foot.[9] During the current study period, Secchi-disc readings collected as part of the WDNR Self-Help Monitoring Program for the period from 1988 to 2004 for Tichigan Lake averaged about 6.5 feet in spring, 5.5 feet in summer, and about 5.2 feet in fall, as shown in Table 12. Secchi-disc readings collected during the current study period by the USGS in Tichigan Lake averaged about 5.0 feet in spring, 5.3 feet in summer and 3.5 feet in winter, as shown in Table 10. Secchi-disc readings reported by the USGS for the period of 2003 to 2004 for the Fox River portion of the Impoundment averaged about 1.2 feet during the spring and summer, as shown in Table 11. As shown in Figure 10, during recent years, the Secchi-disc values for Tichigan Lake indicate poor to fair water quality. The values reported are lower than other lakes in the Southeastern Wisconsin Region, which typically have average water clarity measurements that are below that of other lakes statewide.[10]

Chlorophyll-*a*

Chlorophyll-*a* is the major photosynthetic ("green") pigment in algae. The amount of chlorophyll-*a* present in the water is an indication of the biomass or amount of algae in the water. Chlorophyll-*a* measurements taken by the USEPA during the earlier study period averaged about 13.4 μg/l at the surface of Tichigan Lake during the spring and summer; measurements for the Widespread averaged about 68.3 μg/l, although both these earlier measurements were documented as being known to be in error. During the recent study period, Chlorophyll-*a* concentrations reported for Tichigan Lake by the USGS averaged about 23 μg/l in the spring, about 12 μg/l in the summer, and about 15 μg/l in the fall, as shown in Table 10. WDNR Self-Help measurements of chlorophyll-*a* in Tichigan Lake during the current study period averaged about 41μg/l in spring, about 30 μg/l in summer, and about 36 μg/l in fall, as shown in Table 12. As shown in Table 12, chlorophyll-*a* measurements in the riverine portion of the Impoundment during the current study period were significantly higher, averaging about 85 μg/l in the spring and about 135 μg/l in the summer. Chlorophyll-*a* levels above about 10 μg/l range result in a green coloration of the water that may be severe enough to impair recreational activities such as swimming and skiing.[11] As shown in Figure 10, the Tichigan Lake measurements indicate poor to very poor water quality.

Nutrient Characteristics

Aquatic plants and algae require such nutrients as phosphorus and nitrogen for growth. In hard-water alkaline lakes, most of these nutrients are generally found in concentrations that exceed the needs of growing plants.

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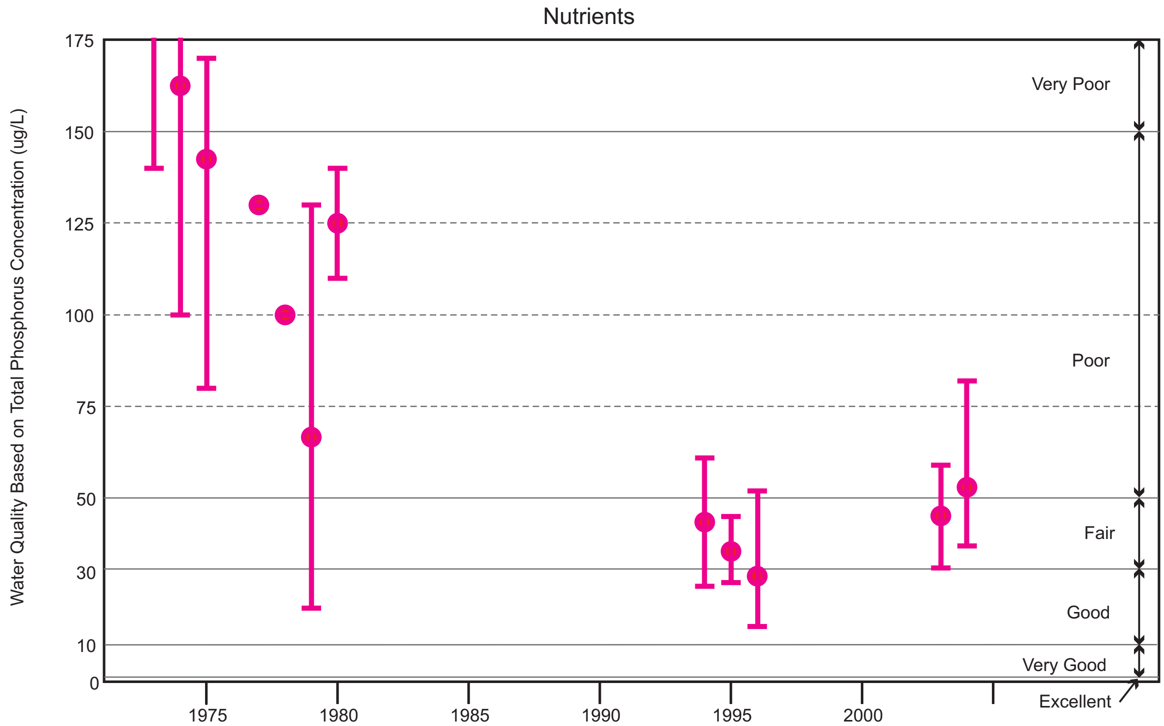
[9]*U .S. Environmental Protection Agency National Eutrophication Survey Working Paper Series,* op. cit.

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

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

Figure 10

PRIMARY WATER QUALITY INDICATORS FOR TICHIGAN LAKE SUBBASIN OF WATERFORD IMPOUNDMENT: 1988-2004



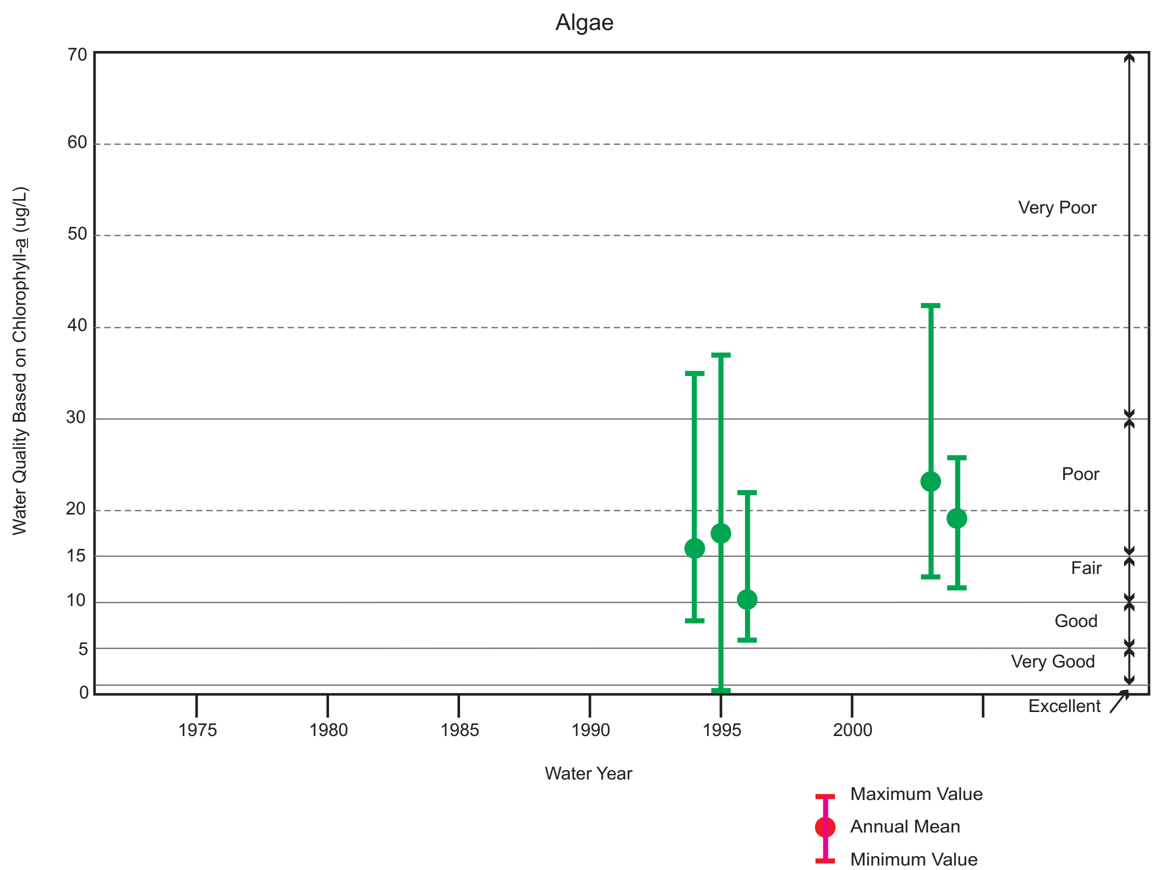
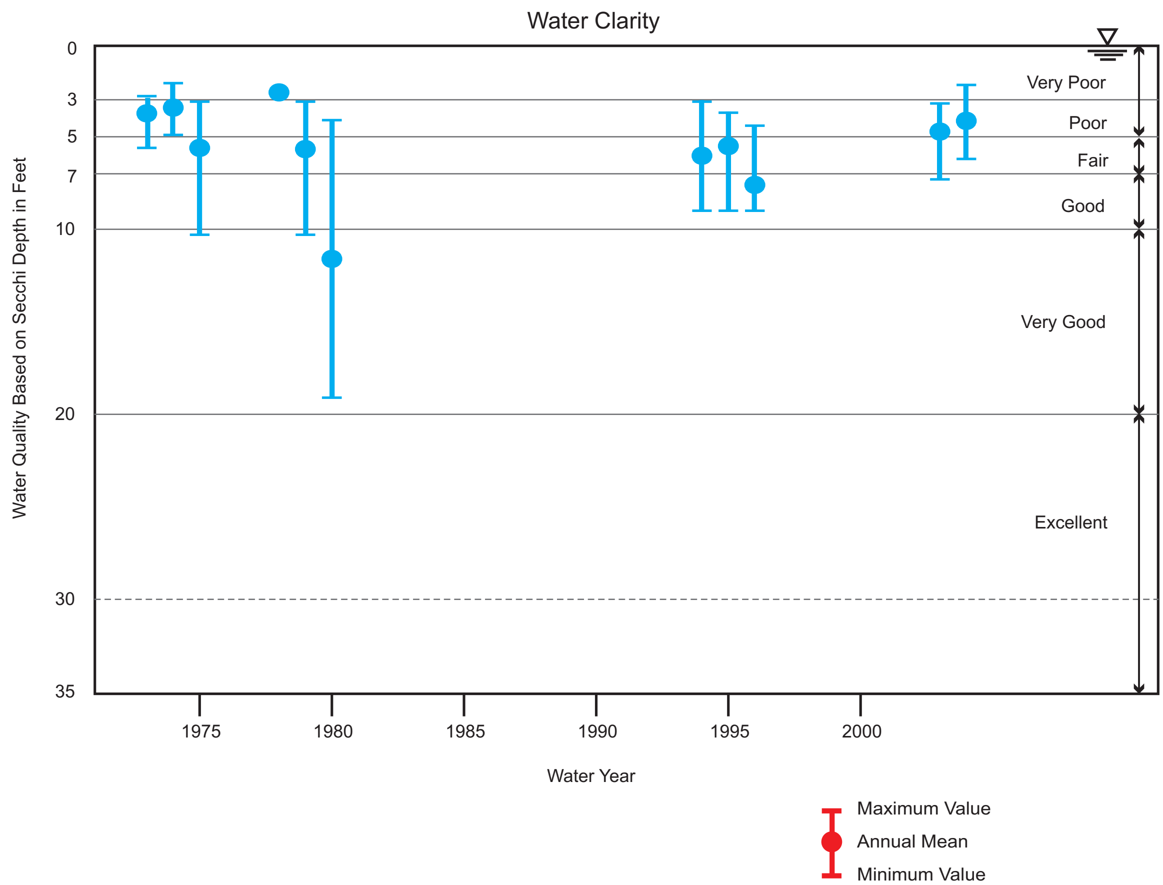


Figure 10 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

However, in lakes where the supply of one or more of these nutrients is limited, plant growth is limited by the amount of that nutrient available. The ratio of total nitrogen (N) to total phosphorus (P) in lake water indicates which nutrient is the factor most likely limiting aquatic plant growth in a lake.[12] Where the N:P ratio is greater than 14:1, phosphorus is most likely to be the limiting nutrient. If the ratio is less than 10:1, nitrogen is most likely to be the limiting nutrient. As shown in Table 13, the nitrogen-to-phosphorus ratios in samples collected from Tichigan Lake in recent years were generally greater than 10:1. This indicates that plant production was most likely consistently limited by phosphorus. In fact, the summer N:P ratio was frequently equal to or greater than 14:1. This indicates that summer aquatic plant growth in Tichigan Lake is generally limited by phosphorus. No current data were available for either the Widespread or the Fox River portion of the Impoundment..

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

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[12]*Sven-Olof Ryding and Walter Rast,* The Control of Eutrophication of Lakes and Reservoirs*, Unesco Man and the Biosphere Series, Volume 1, Parthenon Press, Carnforth, 1989; see also, Walter Rast and Jeffrey A. Thornton, "Chapter 14: The Phosphorus Loading Concept and the OECD Eutrophication Programme: Origin, Application and Capabilities."In: P.E. O'Sullivan and C.S. Reynolds,* The Lakes Handbook: *Volume 2.* Lake Restoration and Rehabilitation*, Blackwell Publishing, Oxford, 2005.*

Table 13

NITROGEN-PHOSPHORUS RATIOS FOR TICHIGAN LAKE SUBBASIN OF WATERFORD IMPOUNDMENT: 1994-1996

Date	Nutrient Levels		
	Nitrogen (mg/l)	Phosphorus (mg/l)	N:P Ratio (mg/l)
April 19, 1994 ………………	0.60	0.061	9.8
April 20, 1995………………..	0.75	0.027	27.8
April 23, 1996 ………………	0.85	0.052	16.3

Source: U.S. Geological Survey and SEWRPC.

plant and animal fragments suspended in the lake water, phosphorus bound to sediment particles, and phosphorus dissolved in the water column.

During the earlier USEPA study, the concentration of total phosphorus in Tichigan Lake was reported to be about 0.50 mg/l on an average annual basis; in the Widespread, the annual mean concentration of total phosphorus was about 0.36 mg/l. Total phosphorus concentrations in Tichigan Lake were found to be higher in the bottom waters. Surface-to-bottom gradients of phosphorus ranged from an average of about 0.22 mg/l at the surface to about 1.05 mg/l in the bottom waters. During the current study period, as shown in Table 12, total phosphorus concentrations in the Tichigan Lake subbasin, collected as part of the WDNR Self-Help Monitoring Program, averaged about 0.09 mg/l in the spring, about 0.11 mg/l in the summer, and about 0.22 mg/l in the fall. As shown in Table 10, total phosphorus concentrations in the surface waters of Tichigan Lake reported by the USGS during the current study period averaged about 0.01 mg/l in the spring, about 0.05 mg/l in the summer, about 0.20 mg/l in the fall, and about 0.10 mg/l in the winter; concentrations in the bottom waters averaged about 0.20 mg/l in the spring, 0.70 mg/l in the summer, 0.50 mg/l in the fall, and about 0.70 mg/l in the winter. As shown in Table 11, in the Fox River portion of the Impoundment, the average total phosphorus concentrations for the surface waters were reported to be about 0.12 mg/l in the spring, 0.25 mg/l in the summer, 0.16 mg/l in the fall, and 0.03 mg/l in winter; in the bottom waters, the concentrations averaged about the same as in the surface waters. As in the earlier study period, total phosphorus concentrations during the current study period were generally found to be higher in the bottom waters than in the surface waters of Tichigan Lake. Concentrations of total phosphorus in the riverine portion of the impoundment generally do not reflect a similar surface-to-bottom concentration gradient as reported in the Tichigan Lake subbasin.

These seasonal gradients of phosphorus concentration between the epilimnion and hypolimnion reflect the biogeochemistry of this growth element. When aquatic organisms die, they usually sink to the bottom of the lake, where they are decomposed. Phosphorus from these organisms is then either stored in the bottom sediments or rereleased into the water column. Because phosphorus is not highly soluble in water, it readily forms insoluble precipitates with calcium, iron, and aluminum under aerobic conditions and accumulates, predominantly, in the lake sediments. If the bottom waters become depleted of oxygen during stratification, however, certain chemical changes occur, especially the change in the oxidation state of iron from the insoluble Fe^{3+} state to the more soluble Fe^{2+} state. The effect of these chemical changes is that phosphorus becomes soluble and is more readily released from the sediments. This process also occurs under aerobic conditions, but generally at a slower rate than under anaerobic conditions. As the waters mix, this phosphorus may be widely dispersed throughout the lake waterbody and become available for algal growth, particularly if the rate of mixing is on the order of hours rather than days.[13]

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

The data indicated that there was internal loading of phosphorus from the bottom sediments of Tichigan Lake during the recent study period. As shown in Table 10, the dissolved phosphorus concentrations in the bottom waters were high, ranging from about 0.50 mg/l to 0.90 mg/l in samples collected during the summer when such releases of phosphorus are most likely to occur. While the magnitude of this release and its concomitant effects in contributing to algal growth in the surface waters of the Lake may be moderated by a number of circumstance, including the rate of mixing during the spring and fall overturn events, the contribution of phosphorus from the bottom waters of Tichigan Lake should be considered in terms of the total phosphorus load.

Total phosphorus concentrations in Tichigan Lake were found to exceed the levels necessary to support periodic nuisance algae blooms. The recommended water quality standard for phosphorus in lakes, which is set forth in the Commission's adopted regional water quality management plan, is 0.02 mg/l of total phosphorus or less during spring turnover. This is the level considered necessary to limit algal and aquatic plant growths to levels consistent with the recreational and warmwater fishery and other aquatic life water use objectives. Total phosphorus concentrations in the surface waters of Tichigan Lake during the current study period were always above 0.02 mg/l, indicating fair to poor water quality, as illustrated in Figure 10.

POLLUTION LOADINGS AND SOURCES

Pollutant loads to a lake are generated by various natural processes and human activities that take place in the area tributary to a lake.[14] These loads are transported to the lake through the atmosphere, across the land surface, and by way of inflowing streams. Pollutants transported by the atmosphere are deposited onto the surface of the lake as dry fallout and direct precipitation. Pollutants transported across the land surface enter the lake as direct runoff and, indirectly, as groundwater inflows, including drainage from onsite wastewater treatment systems. Pollutants transported by streams enter a lake as surface water inflows. In through-flow waterbodies, like the Waterford Impoundment, pollutant loadings transported across the land surface directly tributary to a lake, in the absence of identifiable or point source discharges from industries or wastewater treatment facilities, often comprise the principal route by which contaminants enter a waterbody. Such nonpoint sources of water pollution include urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities; and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems. The Waterford Impoundment, as a result of its downstream location from several large communities located along the Fox River and its major tributaries, is subject to both nonpoint sources as well as point sources of pollutants.

Point Sources

Significant point source discharges of pollutants to the Waterford Impoundment, or to the surface waters tributary to the Waterford Impoundment, include public wastewater treatment facilities in the upstream communities of the City of Brookfield (part), the City of Waukesha, the Village of Sussex, and the Village of Mukwonago. The Village of Sussex wastewater treatment facility was reported to discharge an annual average volume of treated wastewater of approximately 0.98 million gallons per day (mgd) in 1990. The discharge rates for the Brookfield West, Waukesha and Mukwonago wastewater treatment plants, as of 1990, were 6.74 mgd, 8.74 mgd and 0.51 mgd, respectively. The design capacity of the sewage treatment facility in the Village of Sussex was increased from about 1.0 mgd in 1990 to about 3.2 mgd on an average annual basis and 4.0 mgd on a maximum monthly basis following upgrading of the treatment plant in 1995. Design capacities for the sewage treatment plants at Brookfield West, Waukesha and Mukwonago, as of 1990, were 10.0 mgd, 16.0 mgd and 1.5 mgd, respectively. As of 1995, the City of Brookfield had completed facility planning for an expansion of the Brookfield West wastewater treatment facility to provide a capacity of 12.5 mgd on an average annual basis, and the City of Waukesha was in the process of a construction project to provide for an upgrading and expansion to a design capacity of 14.0 mgd on an average dry weather basis and 18.5 mgd on an average wet weather basis. This latter

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

upgrade has since been completed. Consequently, the Waterford Impoundment is currently estimated to potentially receive a maximum annual wastewater loading of about 31.2 mgd, or approximately 35,000 acre-feet per year of treated wastewater. This volume is about 15 percent of the approximately 220,000 acre-feet of water entering the Waterford Impoundment annually through surface runoff and direct precipitation onto the Lake surface, as reported in Chapter II of Volume One.

The wastewater treatment facility in the Village of Sussex employs a sewage treatment process comprised of activated sludge, clarification, filtration, phosphorus removal, and chlorination stages. The facility in Brookfield utilizes a system of phosphorus removal, activated sludge, clarification, sand filtration, chlorination, dechlorination, and post aeration stages. The City of Waukesha treatment plant employs a process utilizing a primary trickling filter, clarification, secondary trickling filters, clarification, sand filters, phosphorus removal and chlorination. The facility in the Village of Mukwonago uses a system comprised of activated sludge, clarification, phosphorus removal and a chlorination basin.

In 1990, the plant at the Village of Sussex was estimated to treat 1,092 pounds of biochemical oxygen demand (BOD) and approximately 1,025 pounds of suspended solids per day; the plant at Brookfield West treated 8,332 pounds of BOD and 7,885 pounds of suspended solids daily; the City of Waukesha facility treated 14,956 pounds of BOD and 27,727 pounds of suspended solids each day; and the Village of Mukwonago plant treated 606 pounds of BOD and 605 pounds of suspended solids daily. These loadings equate to approximately 4,560 tons of BOD and 6,800 tons of suspended solids annually entering the four treatment facilities. At these design loading rates, the four plants would discharge an estimated 190 tons each of BOD and suspended solids, and 28.5 tons of phosphorus, to the Fox River, annually.[15]

Nonpoint Sources

Nonpoint sources of water pollution include urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities; and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems from those portions of the tributary area not served by public water-borne sewerage systems. The inputs to, and outputs from, the Waterford Impoundment of representative nonpoint source contaminant loads were estimated using the Wisconsin Lake Model Spreadsheet (WILMS version 3.0) for phosphorus and unit area loading (UAL) based models for suspended solids and urban-derived metals developed for use within the Southeastern Wisconsin Region.

Phosphorus Loadings

Phosphorus has been identified as the factor generally limiting aquatic plant growth in the Waterford Impoundment. Thus, excessive levels of phosphorus in the Impoundment are likely to result in conditions that interfere with the desired use of the waterbody. Table 14 sets forth the estimated phosphorus loads to the Waterford Impoundment under existing year 2000 conditions. It was estimated, that, under the year 2000 conditions, the total phosphorus load to the Impoundment was about 98,000 pounds. Of this total, about 72,800 pounds, or 75 percent, were estimated to be contributed by runoff from rural sources, with agricultural operations accounting for about 66,100 pounds of the rural phosphorus load. The remaining land uses in the area tributary to the Waterford Impoundment—urban land uses and direct deposition onto the surface of the waterbody—were estimated to contribute the balance of the phosphorus loading, or 25,200 pounds, or 25 percent of the phosphorus load to the Impoundment.

Under forecast year 2020 conditions, the total phosphorus load to the Lake is estimated to decrease to 88,000 pounds per year. This reduction in phosphorus loading of about 10 percent over the estimated year 2000 loadings, is based primarily upon the continued urbanization of the drainage area and the conversion of agricultural lands to other land uses, as noted in Chapter III of this Volume.

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[15]*Based upon an estimated average treatment efficiency for an activated sludge wastewater treatment process, the average concentrations of BOD, suspended solids, and total phosphorus discharged from these works would be approximately 4.0 mg/l for BOD and suspended solids and 0.6 mg/l for phosphorus.*

Table 14

ESTIMATED EXTERNAL SOURCES OF PHOSPHORUS IN THE TOTAL DRAINAGE AREA TRIBUTARY TO THE WATERFORD IMPOUNDMENT: 2000 AND 2020

Source	2000		2020	
	Pounds[a]	Percentage[a]	Pounds[a]	Percentage[a]
Urban				
High-Density (commercial and industrial uses)	8,683	8.9	14,210	16.2
Medium-Density (multi-family and institutional uses)	9,246	9.4	11,995	13.7
Low-Density (single-family and suburban-density residential uses)	3,889	3.9	5,430	6.2
Recreational Lands	1,446	1.5	1,970	2.2
Subtotal	23,265	23.7	33,605	38.3
Rural				
Mixed Agriculture	66,113	67.4	44,160	50.5
Row Crop Agriculture	2,205	2.2	3,344	3.8
Wetlands	2,926	3.0	2,927	3.3
Woodlands	1,605	1.6	1,603	1.8
Water	1,983	2.1	1,982	2.3
Subtotal	74,832	76.3	54,016	61.7
Total	98,097	100.0	87,621	100.0

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

Source: SEWRPC.

Phosphorus release from the lake bottom sediments, or internal loading, may also contribute phosphorus to the Impoundment. However, this loading was assumed to be negligible given good agreement between predicted and observed phosphorus concentrations. It is likely that the shallow nature of much of the Impoundment limits the development of anoxic conditions at the sediment surface that promotes the exchange of sediment-bound phosphorus into the waterbody. Additionally, in the Tichigan Lake subbasin, where stable stratification may develop, overturn events generally occur at rates such that little of the hypolimnetic phosphorus is mixed into the epilimnion of the Lake, i.e., at rates on the order of days versus hours.

Sediment Loadings

The estimated sediment load to the Waterford Impoundment under existing 2000 land use conditions is shown in Table 15. A total annual sediment loading of about 51,750,000 pounds of sediment was estimated to be contributed to the Impoundment. Of the likely annual sediment load, it was estimated that 42,850,000 pounds per year, or about 83 percent of the total load, were contributed by runoff from rural lands, 7,500,000 pounds from urban lands, and 1,400,000 pounds by direct precipitation onto the water surface. Of the sediment load generated from rural land uses, almost all the load, or about 95 percent, was indicated as being of agricultural origin.

Under forecast year 2020 conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual sediment load to the Impoundment is anticipated to decrease slightly to about 42,500,000 pounds. About 29,600,000 pounds of this sediment are estimated to be contributed from rural, primarily, agricultural sources. A further load of 11,500,000 pounds of sediment per year is estimated to be contributed from urban sources, with the balance, 1,400,000 pounds of sediment per year, being contributed by direct precipitation onto the lake surface.

Urban Heavy Metals Loadings

Urbanization brings with it increased use of metals and other materials that contribute pollutants to aquatic systems. Table 15 sets forth the estimated loadings of copper, zinc, and cadmium likely to be contributed to the Waterford Impoundment from urban development draining to and surrounding the waterbody. The majority of these contaminants become associated with sediment particles and are likely to be encapsulated into the bottom

Table 15

ESTIMATED CONTAMINANT LOADS FROM THE TOTAL DRAINAGE AREA TRIBUTARY TO THE WATERFORD IMPOUNDMENT: 2000 AND 2020

Land Use	2000					2020				
	Area (acres)	Sediment[a] (pounds)	Copper[a] (pounds)	Zinc[a] (pounds)	Cadmium[a] (pounds)	Area (acres)	Sediment[a] (pounds)	Copper[a] (pounds)	Zinc[a] (pounds)	Cadmium[a] (pounds)
Residential	43,596	850,122	0.0	436.0	0.0	60,868	1,186,926	0.0	608.7	0.0
Commercial	3,116	2,442,944	685.5	4,642.8	31.2	4,758	3,730,272	1,046.7	7,089.4	47.6
Industrial	3,372	2,535,744	741.8	5,024.3	33.7	5,859	4,405,968	1,289.0	8,729.9	58.6
Communications, Transportation, and Utilities	18,095	171,902	0.0	0.0	0.0	23,436	222,642	0.0	0.0	0.0
Governmental	2,632	1,344,952	184.3	2,105.6	0.0	3,455	1,765,505	241.9	2,764.0	0.0
Recreational	5,414	129,936	0.0	0.0	0.0	7,366	176,784	0.0	0.0	0.0
Water	7,412[b]	1,393,456	0.0	0.0	0.0	7,414[b]	1,393,832	0.0	0.0	0.0
Extractive	2,277	1,024,650	0.0	0.0	0.0	3,580	1,611,000	0.0	0.0	0.0
Wetlands	32,803	121,371	0.0	0.0	0.0	32,803	121,371	0.0	0.0	0.0
Woodlands	20,026	74,096	0.0	0.0	0.0	19,984	73,941	0.0	0.0	0.0
Agricultural	92,613	41,675,850	0.0	0.0	0.0	61,861	27,837,450	0.0	0.0	0.0
Open Lands	197	1,872	0.0	0.0	0.0	169	1,606	0.0	0.0	0.0
Total	231,553[b]	51,766,895	1,611.6	12,208.7	64.9	231,553[b]	42,527,296	2,577.6	19,192.0	106.2

[a]*Values corrected for retention in upstream lakes.*

[b]*Excludes the surface area of the Waterford Impoundment.*

Source: SEWRPC.

sediments of the Impoundment. Under existing 2000 land use conditions, as shown in Table 15, 1,600 pounds of copper, 12,200 pounds of zinc, and 65 pounds of cadmium were estimated to be contributed annually to the Impoundment from urban lands.

Under forecast year 2020 conditions, as set forth in the Waukesha County development plan and adopted regional land use plan, the annual heavy metal loads from the total area tributary to the Lake are anticipated to increase by about 60 percent as a result of the increased urban land cover. The most likely annual loads to the Waterford Impoundment under year 2020 conditions are estimated to be 2,600 pounds of copper, 19,200 pounds of zinc, and 106 pounds of cadmium.

RATING OF TROPHIC CONDITION

Lakes are commonly classified according to their degree of nutrient enrichment, or trophic status. The ability of lakes to support a variety of recreational activities and healthy fish and other aquatic life communities is often correlated to the degree of nutrient enrichment which has occurred. There are three terms generally used to describe the trophic status of a lake: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes. These lakes characteristically support relatively few aquatic plants and often do not contain very productive fisheries. Oligotrophic lakes may provide excellent opportunities for swimming, boating, and waterskiing. Because of the naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

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

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

Several numeric "scales," based on one or more water quality indicators, have been developed to define the trophic condition of a lake. Because trophic state is actually a continuum from very nutrient poor to very nutrient rich, a numeric scale is useful for comparing lakes and for evaluating trends in water quality conditions. Care must be taken, however, that the particular scale used is appropriate for the lake to which it is applies. In this case, two indices, appropriate for Wisconsin lakes, have been used; namely, the Vollenweider-OECD open-boundary trophic classification system,[16] and the Carlson Trophic State Index (TSI).[17] In addition, the Wisconsin Trophic State Index value (WTSI) is presented.[18] The WTSI is a refinement of the Carlson TSI designed to account for the greater humic acid content—brown water color—present in Wisconsin lakes, and has been adopted by the WDNR for use in lake management investigations.

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

[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.*

Vollenweider Trophic State Classification
Using the Vollenweider trophic system and applying the data in Table 10, the Tichigan Lake subbasin of Waterford Impoundment would be classified as having about a 58 percent probability of being mesotrophic based upon phosphorus levels, as shown in Figure 11. The Lake would have about a 32 percent probability of being eutrophic, an 8 percent probability of being oligotrophic, and about a 2 percent probability of being hypertrophic, based upon mean annual phosphorus concentrations. Based upon chlorophyll-*a* levels, the Lake would be classified as having a 59 percent probability of being eutrophic, with about a 34 percent probability of being hypertrophic and about a 7 percent probability of being mesotrophic, as shown in Figure 11. Based upon Secchi-disc readings, the Lake would be classified as having a 60 percent probability of being hypertrophic, with a 35 percent probability of being eutrophic and a 5 percent probability of being mesotrophic, as shown in Figure 11. While these indicators result in slightly differing lake trophic state classifications, it may be concluded that Tichigan Lake should be classified as a eutrophic lake.

Trophic State Index
The Trophic State Index (TSI) assigns a numerical trophic condition rating based on Secchi-disc transparency, and total phosphorus and chlorophyll-*a* concentrations. The original Trophic State Index developed by Carlson has been modified for Wisconsin lakes by the WDNR using data on 184 lakes throughout the State.[19] The Wisconsin Trophic State Index (WTSI) ratings for Tichigan Lake are shown in Figure 12 as a function of sampling date. As shown in Table 12, WTSI values ranged from about 50 to 60 units in recent years in regards to Secchi-disk and chlorophyll-*a* values, and in the 70 to 80 range for total phosphorus, indicating that the Impoundment remains eutrophic, although the data show that this is an improvement in water quality from the situation prevailing in the 1970s and 1980s at the time of the USEPA and WDNR surveys. At that time, the Impoundment was approaching hypertrophy, with a WTSI value, based upon total phosphorus concentrations, exceeding 100 units at times. Based upon the WTSI values, the Waterford Impoundment can be classified as eutrophic.

SUMMARY

Tichigan Lake and the Waterford Impoundment represent a typical hard-water, alkaline lake that is considered to have relatively poor water quality. Physical and chemical parameters measured during the study period indicated that the water quality was within the “poor” to “very poor” range, depending upon the parameters considered. Total phosphorus levels were found to be generally at the level considered to cause nuisance algal and macrophytic growths. Summer stratification was commonly observed in Tichigan Lake, but was intermittently observed in the Impoundment due to the relatively shallow depth of the waterway. Nevertheless, the surface waters of the Impoundment remained well oxygenated and supported a healthy fish population. Winterkill, and internal releases of phosphorus from the bottom sediments of the Impoundment, were not considered to be problems.

The City of Brookfield (west), City of Waukesha, Village of Mukwonago, and Village of Sussex wastewater treatment facilities were point sources of pollutants to the Waterford Impoundment, discharging to the Fox River and its tributary streams upstream of the Impoundment. Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. Agricultural land uses were the largest source of nonpoint pollutants, but are diminishing in importance as urban land uses increase in areal extent. Runoff from the rural lands contributed the largest amount of phosphorus, with the runoff from urban lands contributing about one-quarter of the total phosphorus load. Direct precipitation onto the Impoundment surface and the wastewater treatment plant contributed to the urban total phosphorus load. Agricultural lands constituted the primary source of phosphorus to the waterbody under current land use conditions within the area tributary to the Impoundment. Under forecast 2020 conditions, urban lands are anticipated to contribute a greater percentage of phosphorus to the Waterford Impoundment, although rural lands will continue to contribute the greater proportion of the annual load.

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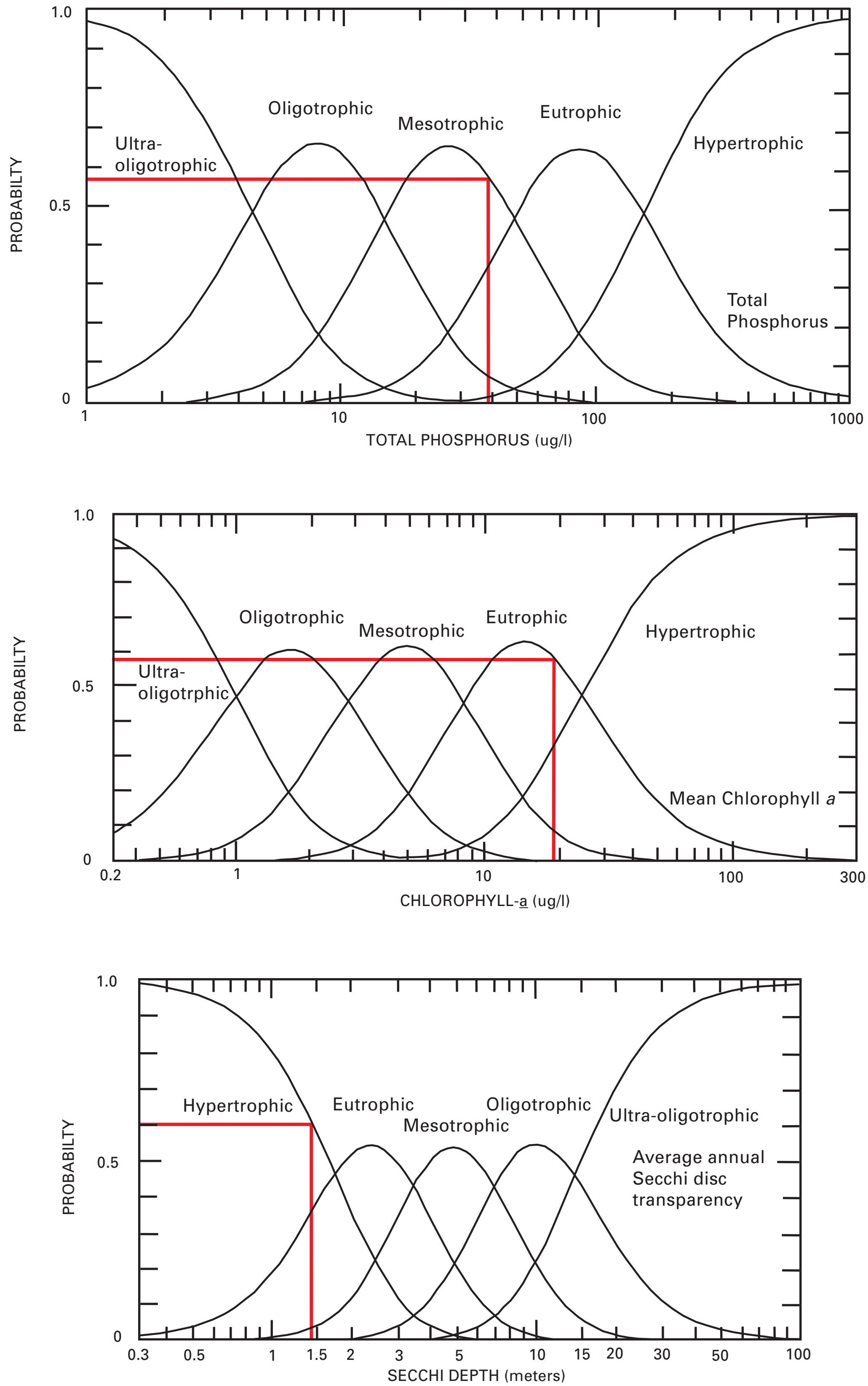
[19] *R.A. Lillie, S. Graham, and P. Rasmussen*, op. cit.

Figure 11

TROPHIC STATE CLASSIFICATION OF TICHIGAN LAKE SUBBASIN BASED UPON THE VOLLENWEIDER MODEL: 2004



Source: U.S. Geological Survey and SEWRPC.

Figure 12

WISCONSIN TROPHIC STATE INDICES FOR TICHIGAN LAKE

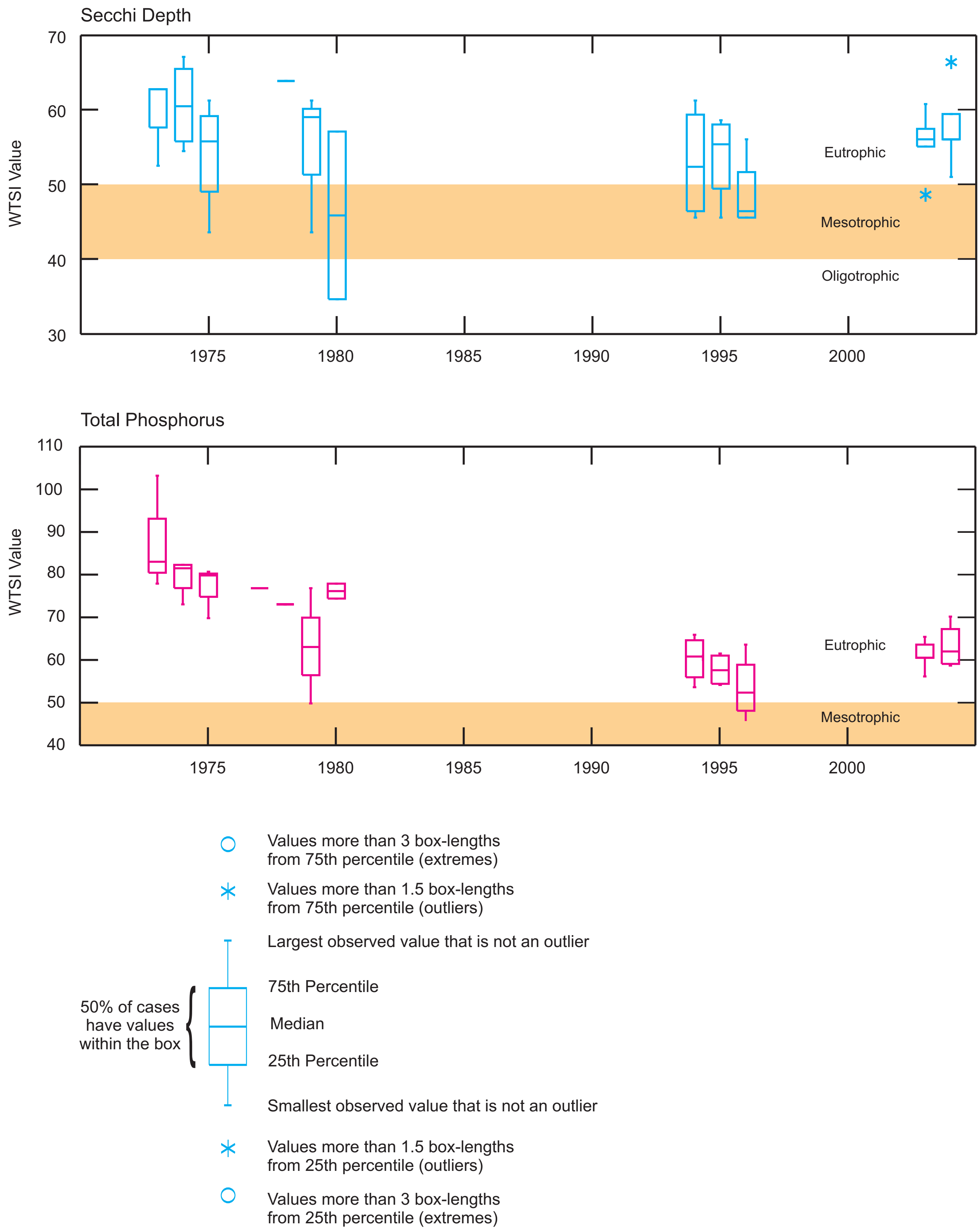
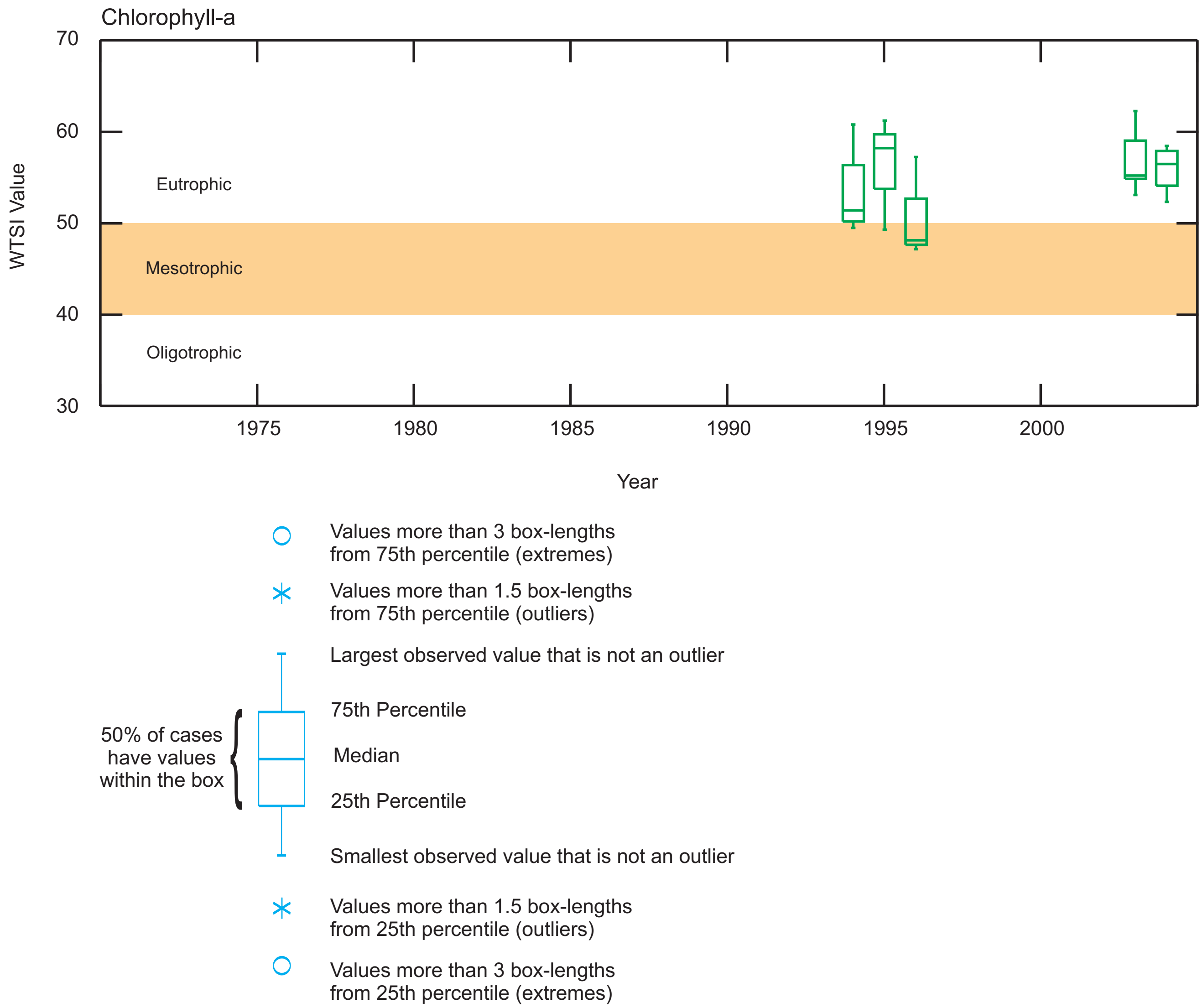


Figure 12 (continued)



Source: Wisconsin Department of Natural Resources and SEWRPC.

Approximately two-thirds of the total phosphorus loading is estimated to remain in the Impoundment by conversion to biomass or through sedimentation.

Based on the Vollenweider phosphorus loading model and the Wisconsin Trophic State Index ratings calculated from year 2003 data for Tichigan Lake and the Waterford Impoundment, the Waterway may be classified as a eutrophic lake.

Chapter V

AQUATIC BIOTA AND ECOLOGICALLY VALUABLE AREAS

INTRODUCTION

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

AQUATIC PLANTS

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

To document the types, distribution, and relative abundance of aquatic macrophytes and phytoplankton in the Waterford Impoundment, an aquatic plant survey was conducted by the Southeastern Wisconsin Regional Planning Commission (SEWRPC) staff during the summer of 2003 as part of the current planning effort. These data are summarized below.

Phytoplankton

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

Green algae (Chlorophyta) are the most important source of food for zooplankton, or microscopic animals, in the lakes of southeastern Wisconsin. Blue-green algae (Cyanophyta) are not ordinarily utilized by zooplankton or fish populations, and may become over-abundant and out of balance with the organisms that feed on them. Dramatic population increases or blooms of blue-green algae may occur when excessive nutrient supplies are available, optimum sunlight and temperature conditions exist, and there is a lack of competition from other aquatic plant species and of grazing by zooplankton.

Concentrations greater than 10 million cells per liter are generally considered to result in "bloom" conditions in a lake. Algal blooms may reach nuisance proportions in fertile, or eutrophic, lakes, resulting in the accumulation of surface scums or slimes. In some cases, heavy concentrations of wind-blown algae accumulate along shorelines, where they die and decompose, causing noxious odors and unsightly conditions. The decay process consumes oxygen, sometimes depleting available supplies and resulting in fish kills. Also, certain species of blue-green algae may release toxic materials into the water.

The seasonal increase or pulse in diatom growth is common to lakes in the Region, and is known as the spring diatom bloom. Diatoms are adapted to grow well under low light and cool temperature conditions and can, in some instances, form a brownish, slippery covering over submerged objects. After the subsidence of the spring diatom bloom, warmer water temperatures and greater light intensities can result in renewed growth and dominance of blue-green algae.

Data on the algal community of the Waterford Impoundment have not been acquired as part of the current study. However, the U.S. Environmental Protection Agency (USEPA) reported that the algal community was dominated by diatoms in 1972. Based upon three samples analyzed from the summer (June and August) and winter (November) of 1972, *Cyclotella* and *Stichococcus* were the dominant genera during summer, with *Cyclotella* and *Stephanodiscus* being dominant in winter. Other genera observed during the summer months included the diatoms *Navicula* and *Nitzschia*, as well as *Synedra*, *Oocystis*, and *Scenedesmus*. During the winter months, other genera present included the diatoms, *Fragilaria* and *Navicula*, and *Phacus*.

Aquatic Macrophytes

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

An aquatic plant survey of the Waterford Impoundment was conducted by SEWRPC staff during July 2003. During this survey, 12 species of submergent aquatic plants were identified in the Waterford Impoundment, as shown in Table 16. This table also sets forth the frequency of occurrence and the relative abundance of each species noted for the areas surveyed. In general, the aquatic plant community of the Waterford Impoundment can be described as sparse, with the most commonly occurring aquatic plant, coontail (*Ceratophyllum demersum*), being found at only approximately one-half of the sites sampled. Eurasian water milfoil was the next most commonly occurring aquatic plant, being present at less than one-third of the sites sampled. These frequencies of occurrence and the relative densities at which the aquatic plants were found during the aquatic plant survey were lower than those generally found in lakes in southeastern Wisconsin. For example, elsewhere in the Fox River

Table 16

FREQUENCY OF OCCURRENCE AND DENSITY RATINGS OF SUBMERGENT PLANT SPECIES IN WATERFORD IMPOUNDMENT: JULY 2003

Aquatic Plant Species Present	Sites Found	Frequency of Occurrence (percent)	Relative Density	Importance Value
Bushy Pondweed	21	14.40	2.3	0.3300
Coontail	78	53.40	3.4	1.8000
Curly-Leaf Pondweed	10	6.80	1.1	0.0800
Eurasian Water Milfoil	41	28.10	2.0	0.5800
Flatstem Pondweed	1	0.68	1.0	0.0068
Muskgrass	9	6.20	2.0	0.1200
Native Water Milfoil	18	12.30	2.1	0.2500
Sago Pondweed	19	19.90	2.1	0.4200
Water Stargrass	21	14.40	1.7	0.2400
Waterweed	28	19.20	2.4	0.4700

NOTE: There were 146 sites sampled during the July 2003 survey.

Source: SEWRPC.

system, aquatic plant surveys completed for Little Muskego Lake, Big Muskego Lake and Wind Lake, and on Eagle Spring Lake and the Phantom Lakes, located on tributary streams to the Fox River, have suggested that about 15 to 20 species of aquatic plants could be expected to occur at frequencies of up to 90 percent or more of sites observed.[1]

Table 17 outlines the positive ecological significance of aquatic plant species found in the Waterford Impoundment. The dominant submerged macrophytes identified during that survey were coontail (*Ceratophyllum demersum*) and Eurasian water milfoil (*Myriophyllum spicatum*), a nonnative, invasive species introduced from Europe,[2] which exhibited moderate growth in portions of the Lake, as shown on Maps 21, 22, and 23. Other common macrophytes included Sago pondweed (*Potamogeton pectinatus*), curly-leaf pondweed (*Potamogeton crispus*), bushy pondweed (*Najas flexilis*), waterweed (*Elodea canadensis*), and water stargrass (*Zosterella dubia*). Both Eurasian water milfoil and curly-leaf pondweed are designated as invasive, nonnative plants pursuant to Chapter NR 109 of the *Wisconsin Administrative Code*. Both of these species can outcompete important native aquatic plant communities which can lead to the loss of plant diversity, degradation of water quality, and reduction in habitat value for fish, invertebrates and wildlife.

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[1]*See SEWRPC Community Assistance Planning Report No. 198,* A Management Plan for Wind Lake, Racine County, Wisconsin*, December 1991; SEWRPC Community Assistance Planning Report No. 222,* A Lake Management Plan for Little Muskego Lake, Waukesha County, Wisconsin*, June 1996, as refined in SEWRPC Memorandum Report No. 155 ,* An Aquatic Plant Management Plan for Little Muskego Lake, Waukesha County, Wisconsin*, January 2004; SEWRPC Community Assistance Planning Report No. 226,* A Lake Management Plan for Eagle Spring Lake, Waukesha County, Wisconsin*, June 1998; SEWRPC Memorandum Report No. 81, An Aquatic Plant Management Plan for the Phantom Lakes, Waukesha County, Wisconsin, July 1993; and, SEWRPC Memorandum Report No. 94,* A Recommended Public Boating Access and Waterway Protection Plan for Big Muskego Lake, Waukesha County, Wisconsin*, July 1994.*

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

Table 17

POSITIVE ECOLOGICAL SIGNIFICANCE OF AQUATIC PLANT SPECIES PRESENT IN WATERFORD IMPOUNDMENT

Aquatic Plant Species Present	Ecological Significance
Ceratophyllum demersum (coontail)	Provides good shelter for young fish and supports insects valuable as food for fish and ducklings
Chara vulgaris (muskgrass)	Excellent producer of fish food, especially for young trout, bluegills, small and largemouth bass; stabilizes bottom sediments, and has softening effect on the water by removing lime and carbon dioxide
Elodea canadensis (waterweed, elodea)	Provides shelter and support for insects which are valuable as fish food
Lemna minor (lesser duckweed)	A nutritious food source for ducks and geese, also provides food for muskrat, beaver, and fish, while rafts of duckweed provide shade and cover for insects, in addition extensive mats of duckweed can inhibit mosquito breeding
Myriophyllum spicatum (Eurasian water milfoil)	None known
Myriophyllum sp. (native water milfoil)	Provides valuable food and shelter for fish; fruits eaten by many wildfowl
Najas flexilis (bushy pondweed)	Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish
Nymphaea tuberose (white water lily)	Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrat; roots eaten by beaver, deer, moose, and porcupine
Potamogeton crispus (curly-leaf pondweed)	Provides food, shelter and shade for some fish and food for wildfowl
Potamogeton pectinatus (sago pondweed)	This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish
Potamogeton zosteriformis (flat-stem pondweed)	Provides some food for ducks
Zosterella dubia (water stargrass)	Provides food and shelter for fish, locally important food for waterfowl

Source: SEWRPC.

Species that interfere with the recreational and aesthetic use of the Impoundment, such as *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Potamogeton crispus*, were all found to be present in the Impoundment. Plant growths occurred in portions of the Impoundment where the water depth was less than 15 feet, and suitable substrate was available. Eurasian water milfoil (*Myriophyllum spicatum)* and coontail (*Ceratophyllum demersum*) appeared to be the dominant species, while healthy populations of pondweeds (*Potamogeton* spp.) appeared to be scattered in specific areas of the Lake. Pondweeds were most commonly found at depths of between five and 10 feet, as shown on Maps 21, 22, and 23. Eurasian water milfoil was present throughout the Impoundment, but largely confined to areas of the Impoundment with depths of between five and 15 feet.

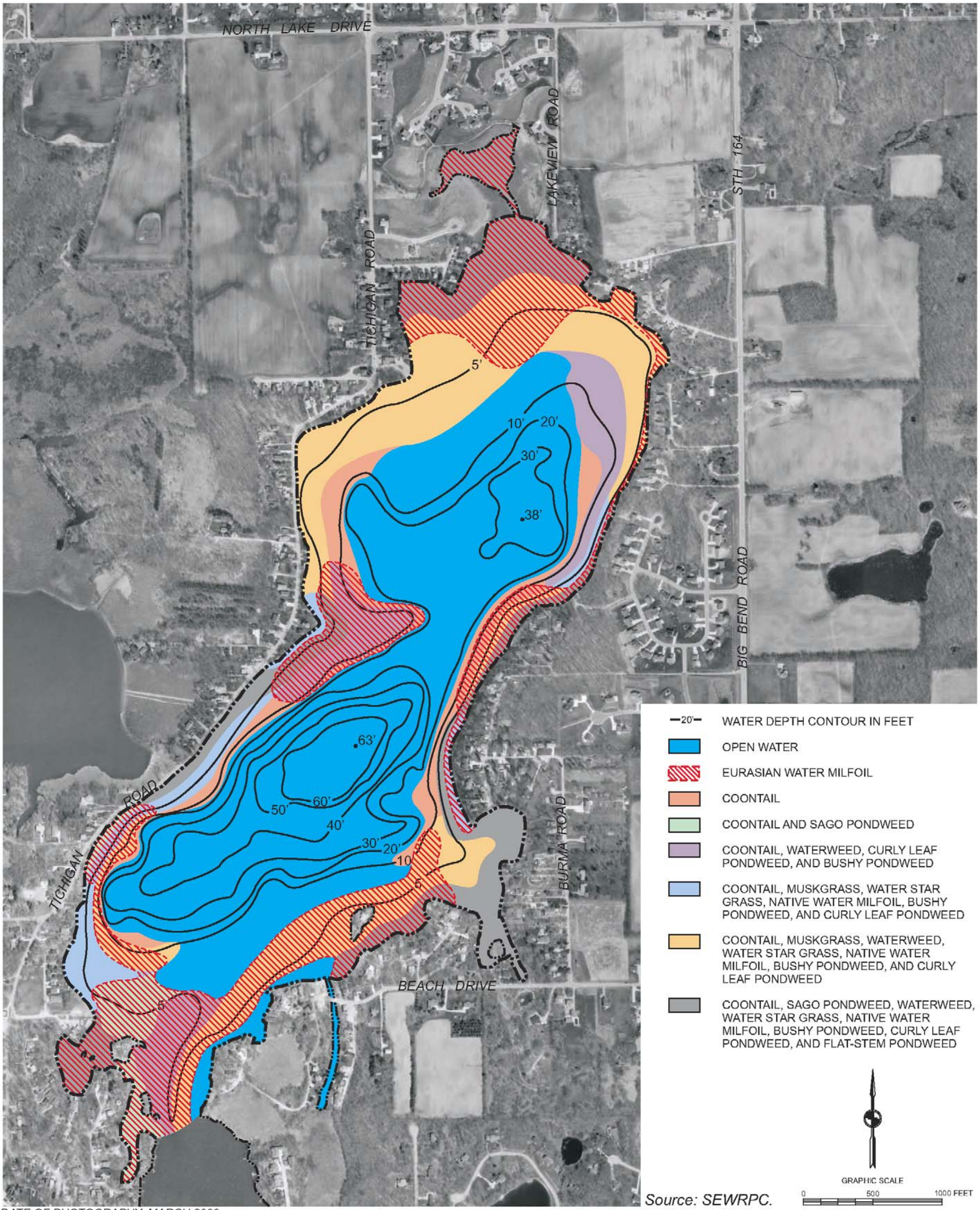
In general, the aquatic macrophyte community of the Waterford Impoundment appears to be limited and relatively sparse compared with other waterbodies within the Southeastern Wisconsin Region.

Aquatic Plant Management

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

Map 21

AQUATIC PLANT COMMUNITY DISTRIBUTION IN TICHIGAN LAKE: 2003

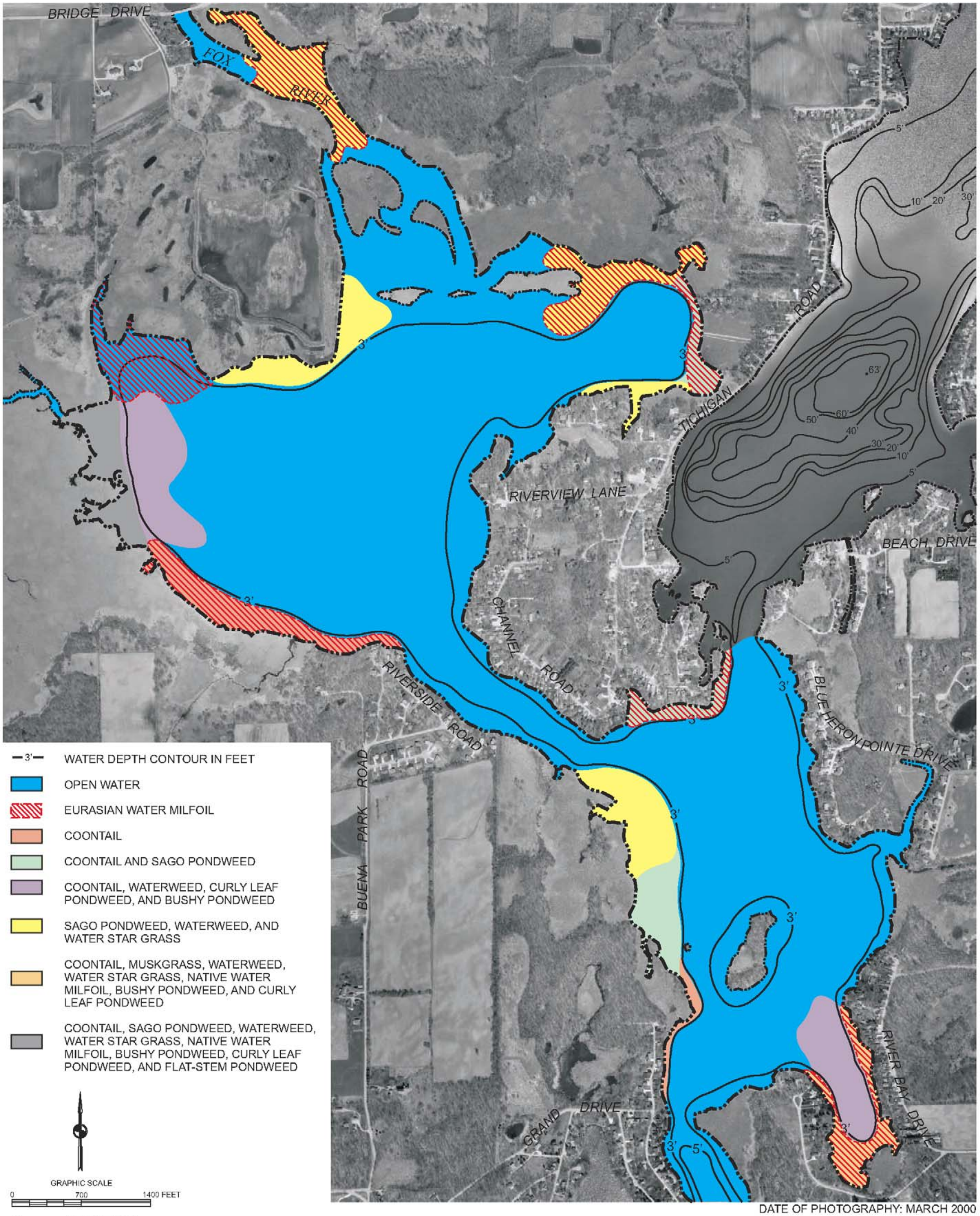


DATE OF PHOTOGRAPHY: MARCH 2000

Source: SEWRPC.

Map 22

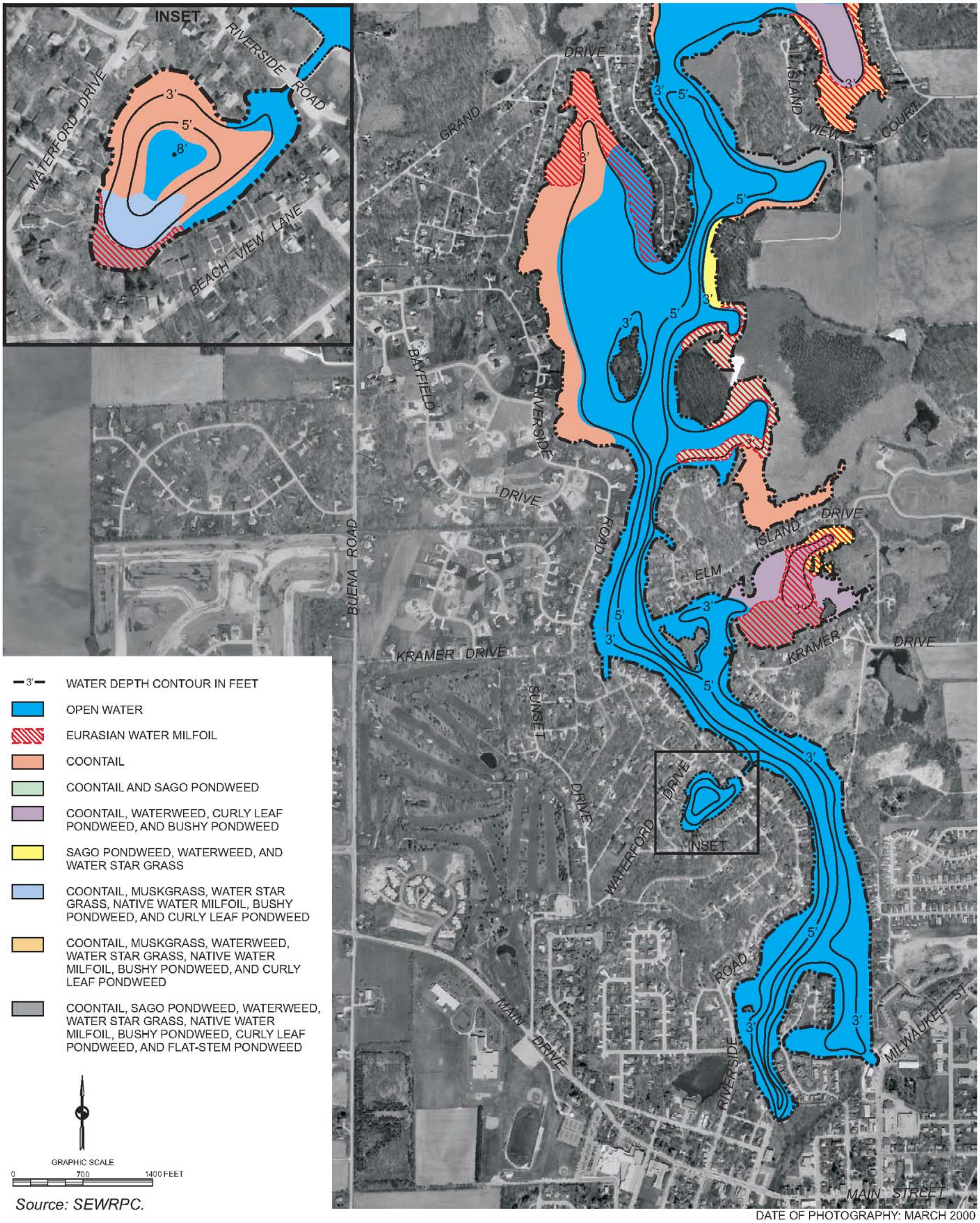
AQUATIC PLANT COMMUNITY DISTRIBUTION IN WATERFORD IMPOUNDMENT: 2003



Source: SEWRPC.

Map 23

AQUATIC PLANT COMMUNITY DISTRIBUTION IN WATERFORD IMPOUNDMENT AND BUENA LAKE: 2003



Source: SEWRPC.

Chemical Controls

Perceived excessive macrophyte growths in the Waterford Impoundment have historically resulted in the application of a chemical control program. Although the use of chemicals to control aquatic plants has been regulated in Wisconsin since 1941, records of aquatic herbicide applications have only been maintained by the WDNR beginning in 1950. Recorded chemical herbicide treatments that have been applied to areas of the Waterford Impoundment from 1950 through 2003 are set forth in Table 18.

In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison area, and, by the 1930s, sodium arsenite was widely used throughout the State for aquatic plant control. No other chemicals were applied in significant amounts to control macrophytes until recent years, when a number of organic chemical herbicides came into general use. The amounts of sodium arsenite applied to the Waterford Impoundment, and years of application during the period 1950 through 1967, are listed in Table 18. The total amount of sodium arsenite applied over this 17-year period was about 57,914 pounds.

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

When it became apparent that arsenic was accumulating in the sediments of treated lakes and that the accumulations of arsenic were found to present potential health hazards both to humans and aquatic life, the use of sodium arsenite was discontinued in the State in 1969. Draft sediment quality criteria limits set forth by the WDNR are shown in Table 19. There are no data on dissolved arsenic concentrations in the Waterford Impoundment sediments.

As shown in Table 18, the aquatic herbicides diquat, endothall, and 2,4-D have also been applied to the Waterford Impoundment to control aquatic macrophyte growth. Diquat and endothall (Aquathol) are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Endothall primarily kills pondweeds, but does not control such nuisance species as Eurasian water milfoil (*Myriophyllum spicatum*). The herbicide 2,4-D is a systemic herbicide that is absorbed by the leaves and translocated to other parts of the plant; it is more selective than the other herbicides listed above and is generally used to control Eurasian water milfoil. However, it will also kill species such as water lilies (*Nymphaea* sp. and *Nuphar* sp.). The present restrictions on water use after application of these herbicides are given in Table 20.

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to the Waterford Impoundment. As shown in Table 18, copper sulfate (Cutrine Plus) has been applied to the Waterford Impoundment, on occasion. Like arsenic, copper, the active ingredient in many algicides including Cutrine Plus, may accumulate in the bottom sediments. Excessive levels of copper may be toxic to fish and benthic organisms, but, generally, have not been found to be harmful to humans.[3] Restrictions on water uses after application of Cutrine Plus are also given in Table 20.

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

Table 18

CHEMICAL CONTROL OF AQUATIC PLANTS IN WATERFORD IMPOUNDMENT: 1950-2004

Year	Total Acres Treated	Algae Control			Macrophyte Control				
		Copper Sulfate (pounds)	Blue Vitriol	Cutrine or Cutrine-+	Sodium Arsenite (pounds)	2, 4-D (gallons)	Diquat	Endothall	Silvex (pounds)
1950	- -	- -	- -	- -	940	- -	- -	- -	- -
1951	- -	- -	- -	- -	1,120	- -	- -	- -	- -
1952	- -	- -	- -	- -	876	- -	- -	- -	- -
1953	- -	- -	- -	- -	- -	- -	- -	- -	- -
1954	- -	- -	- -	- -	1,480	- -	- -	- -	- -
					2,160[a]				
1955	- -	- -	- -	- -	2,840	- -	- -	- -	- -
1956	- -	- -	- -	- -	2,400	- -	- -	- -	- -
1957	- -	- -	- -	- -	1,900	- -	- -	- -	- -
1958	- -	- -	- -	- -	2,800	- -	- -	- -	- -
					1,908[a]				
1959	- -	- -	- -	- -	3,240	- -	- -	- -	- -
					1,980[a]				
1960	- -	- -	- -	- -	4,920	- -	- -	- -	- -
					2,540[a]				
1961	- -	- -	- -	- -	4,980	- -	- -	- -	- -
					2,540[a]				
1962	- -	- -	- -	- -	5,340[b]	- -	- -	- -	- -
					2,520[a]				
1963	- -	- -	- -	- -	3,240[a]	- -	- -	- -	- -
1964	- -	- -	- -	- -	- -	- -	- -	- -	- -
1965	- -	- -	- -	- -	360	- -	- -	- -	- -
1966	- -	- -	- -	- -	3,600[b]	- -	- -	- -	- -
1967	- -	- -	- -	- -	4,230[b]	- -	- -	- -	- -
1968	- -	- -	- -	- -	- -	- -	- -	- -	- -
1969	- -	- -	- -	- -	- -	- -	8 pounds	22.1 pounds	35.2
1970	12.33	50	- -	- -	- -	- -	- -	8.5 gallons	- -
1971-1973	- -	- -	- -	- -	- -	- -	- -	- -	- -
1974	1	- -	- -	- -	- -	- -	2 gallons	- -	- -
1975-1976	- -	- -	- -	- -	- -	- -	- -	- -	- -
1977	- -	- -	- -	- -	- -	- -	- -	271 pounds	
1978-1991	- -	- -	- -	- -	- -	- -	- -	- -	- -
1992	0.02	- -	- -	- -	- -	2	- -	- -	- -
1993	- -	- -	- -	- -	- -	- -	- -	- -	- -
1994-2004	- -	- -	- -	- -	- -	- -	- -	- -	- -
Total	13.35	50	- -	- -	57,914	2	2 gallons 8 pounds	8.5 gallons 293.1 pounds	35.2

[a]*Buena subbasin.*

[b]*Tichigan subbasin.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

AQUATIC ANIMALS

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

Zooplankton

Zooplankton are microscopic animals which inhabit the same environment as phytoplankton, the microscopic plants. An important link in the food chain, zooplankton feed mostly on algae and, in turn, are a good food source for fish. There have been no documented zooplankton surveys conducted on the Impoundment.

Table 19

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

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

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

Source: Wisconsin Department of Natural Resources.

Table 20

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

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

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

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

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

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

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

Source: Wisconsin Department of Natural Resources.

Benthic Invertebrates

The benthic, or bottom dwelling, faunal communities of lakes include such organisms as sludge worms, midges, and caddisfly larvae. These organisms are an important part of the food chain, acting as processors of organic material that accumulates on the lake bottom. Some benthic fauna are opportunistic in their feeding habits, while others are predaceous. The diversity of benthic faunal communities can be used as an indicator of lake trophic status. In general, a reduced or limited diversity of organisms present is indicative of a eutrophic lake; however, there is no single “indicator organism.” Rather, the entire community must be assessed to determine trophic status as populations can fluctuate widely through the year and between years as a consequence of season, climatic variability, and localized water quality changes. The benthic fauna of the Waterford Impoundment were not sampled during the current study period.

Fishes of Waterford Impoundment

The Waterford Impoundment supports a relatively large and diverse fish community. The WDNR conducted fish surveys on the Tichigan Lake sub-basin in April and August 2000.[4] The survey included electrofishing along four miles of shoreline and deployment of mini-fyke nets.

Sixteen species of fish were captured during these surveys, as shown in Table 21. Game fish observed during the survey included, northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), and walleye (*Stizostedion vitreum vitreum*). Numbers of panfish were also caught, including bluegill (*Lepomis macrochirus*), yellow perch (*Perca flavescens*) and pumpkinseed (*Lepomis gibbosus*). Some rough fish, including carp (*Cyprinus carpio*) were also collected.

Important predator fish in Tichigan Lake include largemouth bass, walleye and northern pike. Walleye were the most abundant gamefish. Walleye ranged in length from 13.9 to 21.3 inches; northern pike were from 5.4 to 30.1 inches; and largemouth bass ranged from 10.1 to 18.5 inches. All of these species are carnivorous, feeding primarily on other fish, crayfish, and frogs. These species also are among the largest and most prized game fish sought by Tichigan Lake anglers. Historically, northern pike and walleye have been stocked in alternate years.

A wide range of panfish was also present in the Lake, as shown in Table 21. The most abundant panfish were bluegill, followed by warmouth, pumpkinseed, yellow bullhead and green sunfish. “Panfish” is a common term applied to a broad group of smaller fish with a relatively short and usually broad shape that makes them a perfect size for the frying pan. Panfish species known to exist in Tichigan Lake include bluegills, pumpkinseeds, yellow perch, and black crappies. The habitats of panfish vary widely among the different species, but their cropping of the plentiful supply of insects and plants, coupled with prolific breeding rates, leads to large populations with a rapid turnover. Some lakes within southeastern Wisconsin have stunted, or slow-growing, panfish populations. These occur because the numbers of panfish are not controlled by predator fishes. Panfish frequently feed on the fry of predator fish and, if the panfish population is overabundant, they may quickly deplete the predator fry population. Figure 13 illustrates the importance of a balanced predator-prey relationship, using walleye and perch as an example.

“Rough fish” is a broad term applied to species, such as carp, that do not readily bite on hook and line, but feed on game fish, destroy habitat needed by more desirable species, and are commonly considered in southeastern Wisconsin as undesirable for human consumption. Rough fish species which have been found in Tichigan Lake include carp, white sucker and bowfin.

The fish community in the Waterford Impoundment is currently passively managed through utilization and enforcement of current State fishing regulations summarized in Table 22.

Other Wildlife

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

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[4] *Douglas E. Welch, Wisconsin Department of Natural Resources, e-mail letter to SEWRPC staff, May 16, 2005.*

Table 21

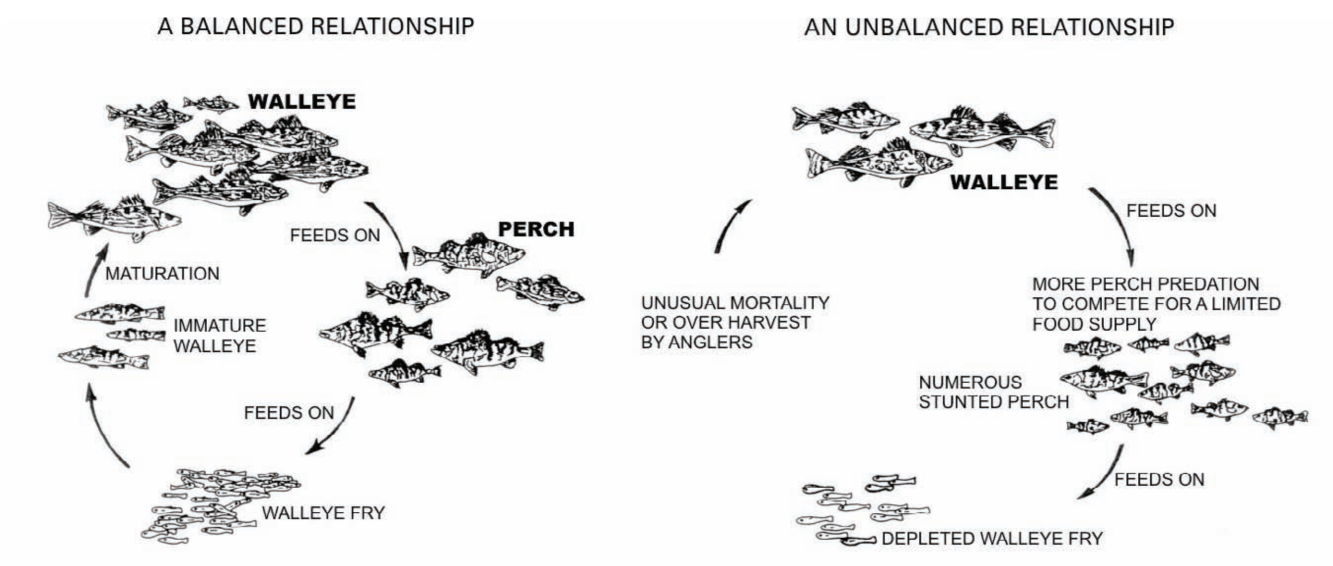
FISH SPECIES OCCURRING IN TICHIGAN LAKE SUBBASIN
WATERFORD IMPOUNDMENT: 2000

Species	Family	Scientific Name
Bowfin	Amiidae	*Amia calva*
Quillback Carpsucker	Catostomidae	*Carpiodes cyprinus*
White Sucker	Catostomidae	*Catostomus commersoni*
Rock Bass	Centrarchidae	*Ambloplites ruperstris*
Green Sunfish	Centrarchidae	*Lepomis cyanellus*
Pumpkinseed	Centrarchidae	*Lepomis gibbosus*
Warmouth	Centrarchidae	*Lepomis gulosus*
Bluegill	Centrarchidae	*Lepomis macrochirus*
Largemouth Bass	Centrarchidae	*Micropterus salmoides*
Common Carp	Cyprinidae	*Cyprinus carpio*
Spottail Shiner	Cyprinidae	*Notropis hudsonius*
Northern Pike	Esocidae	*Esox lucius*
Channel Catfish	Ictaluridae	*Ictalurus punctatus*
Yellow Bullhead	Ictaluridae	*Ictalurus natalis*
Yellow Perch	Percidae	*Perca flavescens*
Walleye	Percidae	*Stizotedion vitreum vitreum*

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

Figure 13

THE PREDATOR-PREY RELATIONSHIP



Source: Wisconsin Department of Natural Resources and SEWRPC.

the tributary area; those species which may be expected to still be present under currently prevailing conditions; and those species which may be expected to be lost or gained as a result of urbanization within the area.

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

Table 22

FISHING REGULATIONS APPLICABLE TO WATERFORD IMPOUNDMENT: 2004-2005

Species	Open Season	Daily Limit	Minimum Size
Northern Pike	May 7 to March 5	2	26 inches
Walleye	May 7 to March 5	5	15 inches
Largemouth and Smallmouth Bass	May 7 to March 5	5 in total	14 inches
Rock, Yellow and White Bass	Open all year	None	None
Bluegill, Pumpkinseed (sunfish), Crappie, and Yellow Perch	Open all year	25 in total	None
Bullhead and Rough Fish	Open all year	None	None

Source: Wisconsin Department of Natural Resources Publication No. PUBL-FH-301 2005, Guide to Wisconsin Hook and Line Fishing Regulations 2005-2006*, January 2005; and SEWRPC.*

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

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

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

Amphibians and reptiles are vital components of the ecosystem in an environmental unit like the Waterford Impoundment tributary area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Waterford Impoundment area. Table 25 lists the 14 amphibian and 15 reptile species normally expected to be present in the Waterford Impoundment area under present conditions and identifies those species most sensitive to urbanization.

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

The complete spectrum of wildlife species originally native to Racine 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

Table 23

MAMMALS OF THE WATERFORD IMPOUNDMENT AREA

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

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

habitat. In agricultural areas, these cultural management practices include draining land by ditching and tiling and the expanding use of fertilizers, herbicides, and pesticides. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; the use of road salt for snow and ice control; the presence of heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

Invasive Species

The presence of Eurasian water milfoil in the Waterford Impoundment is cause for concern. Eurasian water milfoil is an exotic, or nonnative, species that can exhibit “explosive” growth under suitable conditions, such as in the presence of organic-rich sediments or where the lake bottom has been disturbed. It reproduces by the rooting of plant fragments, and has been known to cause severe recreational use problems in lakes in southeastern Wisconsin, reducing the biodiversity of the lakes and degrading the quality of fish and wildlife habitats.[5]

Purple loosestrife, *Lythrium salicaria,* another nonnative nuisance plant, was also present in the wetlands and riparian areas surrounding the Impoundment. Like Eurasian water milfoil, purple loosestrife is known to spread profusely, outcompeting native plant growth and reducing the quality of fish and wildlife habitat while adding little ecological benefit. Purple loosestrife is a declared weed in the State of Wisconsin and is subject to an ongoing eradication program. Also present in the tributary area of the Waterford Impoundment is the first documented colony in Wisconsin of golden or yellow loosestrife, *Lysimachia punctata*, a more aggressive nonnative relative of purple loosestrife.

The zebra mussel, *Dreissena polymorpha*, an invasive species with known negative impacts on native benthic populations, has been observed in areas of the Waterford Impoundment. Zebra mussels disrupt the food chain by removing significant amounts of phytoplankton from the water, which are food for larval and juvenile fish, which are in turn food for game fish. The overall effect is that as zebra mussels and other invasive species spread to inland lakes and rivers, so do the environmental, aesthetic, and economic costs to water users.

[5]*Wisconsin Department of Natural Resources,* Eurasian Water Milfoil in Wisconsin: A Report to the Legislature, *1993.*

Table 24

BIRDS KNOWN OR LIKELY TO OCCUR IN THE WATERFORD IMPOUNDMENT AREA

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

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Phasianidae			
Grey Partridge[c]	R	R	- -
Ring-Necked Pheasant[c]	X	X	- -
Wild Turkey	X	X	- -
Rallidae			
Virginia Rail	X	- -	X
Sora	X	- -	X
Common Moorhen	X	- -	X
American Coot	X	R	X
Gruidae			
Sandhill Crane	X	- -	X
Charadriidae			
Black-Bellied Plover	- -	- -	X
Semi-Palmated Plover	- -	- -	X
Killdeer	X	- -	X
Scolopacidae			
Greater Yellowlegs	- -	- -	X
Lesser Yellowlegs	- -	- -	X
Solitary Sandpiper	- -	- -	X
Spotted Sandpiper	X	- -	X
Upland Sandpiper[a]	R	- -	X
Semi-Palmated Sandpiper	- -	- -	X
Pectoral Sandpiper	- -	- -	X
Dunlin	- -	- -	X
Common Snipe	R	- -	X
American Woodcock	X	- -	X
Wilson's Phalarope	- -	- -	X
Laridae			
Ring-Billed Gull	- -	- -	X
Herring Gull	- -	X	X
Common Tern[e]	- -	- -	R
Caspian Tern[e]	- -	- -	R
Forster's Tern[e]	- -	- -	R
Black Tern[a]	X	- -	X
Columbidae			
Rock Dove[c]	X	X	- -
Mourning Dove	X	X	X
Cuculidae			
Black-Billed Cuckoo	X	- -	X
Yellow-Billed Cuckoo[a]	X	- -	X
Strigidae			
Eastern Screech Owl	X	X	- -
Great Horned Owl	X	X	- -
Snowy Owl	- -	R	- -
Barred Owl	X	X	- -
Long-Eared Owl[a]	- -	X	X
Short-Eared Owl[a]	- -	R	X
Northern Saw-Whet Owl	- -	- -	X
Caprimulgidae			
Common Nighthawk	X	- -	X
Whippoorwill	- -	- -	X
Apodidae			
Chimney Swift	X	- -	X

Table 24 (continued)

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

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Regulidae (continued)			
Gray-Cheeked Thrush	- -	- -	X
Swainson's Thrush	- -	- -	X
Hermit Thrush	- -	- -	X
Wood Thrush[a]	X	- -	X
American Robin	X	X	X
Mimidae			
Gray Catbird	X	- -	X
Brown Thrasher	X	- -	X
Bombycillidae			
Bohemian Waxwing	- -	R	- -
Cedar Waxwing	X	X	X
Laniidae			
Northern Shrike	- -	- -	X
Loggerhead Shrike[e]	- -	- -	R
Sturnidae			
European Starling[c]	X	X	X
Vireonidae			
Bell's Vireo	- -	- -	R
Solitary Vireo	- -	- -	X
Yellow-Throated Vireo	X	- -	X
Warbling Vireo	X	- -	X
Philadelphia Vireo	- -	- -	X
Red-Eyed Vireo	X	- -	X
Parulidae			
Blue-Winged Warbler	X	- -	X
Golden-Winged Warbler[a]	R	- -	X
Tennessee Warbler[a]	- -	- -	X
Orange-Crowned Warbler	- -	- -	X
Nashville Warbler[a]	- -	- -	X
Northern Parula	- -	- -	X
Yellow Warbler	X	- -	X
Chestnut-Sided Warbler	- -	- -	X
Magnolia Warbler	- -	- -	X
Cape May Warbler[a]	- -	- -	X
Black-Throated Blue Warbler	- -	- -	X
Yellow-Rumped Warbler	- -	R	X
Black-Throated Green Warbler	- -	- -	X
Cerulean Warbler[b]	R	- -	R
Blackburnian Warbler	- -	- -	X
Palm Warbler	- -	- -	X
Bay-Breasted Warbler	- -	- -	X
Blackpoll Warbler	- -	- -	X
Black-and-White Warbler	- -	- -	X
Prothonotary Warbler[a]	- -	- -	R
American Redstart	X	- -	X
Ovenbird	X	- -	X
Northern Waterthrush	- -	- -	X
Connecticut Warbler[a]	- -	- -	X
Mourning Warbler	R	- -	X
Common Yellowthroat	X	- -	X
Wilson's Warbler	- -	- -	X
Kentucky Warbler[b]	- -	- -	R
Canada Warbler	R	- -	X
Hooded Warbler[b]	R	- -	R
Thraupidae			
Scarlet Tanager	X	- -	X

Table 24 (continued)

Scientific (family) and Common Name	Breeding	Wintering	Migrant
Cardinalidae			
Northern Cardinal	X	X	- -
Rose-Breasted Grosbeak	X	- -	X
Indigo Bunting	X	- -	X
Emberizidae			
Dickcissel[a]	R	- -	X
Eastern Towhee	X	- -	X
American Tree Sparrow	- -	X	X
Chipping Sparrow	X	- -	X
Clay-Colored Sparrow	R	- -	X
Field Sparrow	X	- -	X
Vesper Sparrow[a]	X	- -	X
Savannah Sparrow	X	- -	X
Grasshopper Sparrow[a]	X	- -	X
Henslow's Sparrow[b]	R	- -	X
Fox Sparrow	- -	R	X
Song Sparrow	X	X	X
Lincoln's Sparrow	- -	- -	X
Swamp Sparrow	X	X	X
White-Throated Sparrow	- -	R	X
White-Crowned Sparrow	- -	- -	X
Dark-Eyed Junco	- -	X	X
Lapland Longspur	- -	R	X
Snow Bunting	- -	R	X
Icteridae			
Bobolink[a]	X	- -	X
Red-Winged Blackbird	X	X	X
Eastern Meadowlark[a]	X	R	X
Western Meadowlark[a]	R	- -	X
Yellow-Headed Blackbird	X	- -	X
Rusty Blackbird	- -	R	X
Common Grackle	X	X	X
Brown-Headed Cowbird	X	R	X
Orchard Oriole[a]	R	- -	R
Baltimore Oriole	X	- -	X
Fringillidae			
Purple Finch	- -	X	X
Common Redpoll	- -	X	X
Pine Siskin[a]	- -	X	X
American Goldfinch	X	X	X
House Finch	X	X	X
Evening Grosbeak	- -	X	X
Passeridae			
House Sparrow[c]	X	X	- -

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

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

X - Present, not rare
R - Rare

Table 24 Footnotes

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

[b]*State-designated threatened species.*

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

[d]*Federally designated threatened species.*

[e]*State-designated endangered species.*

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

WILDLIFE HABITAT AND RESOURCES

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

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

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

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

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

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

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

Table 25

AMPHIBIANS AND REPTILES OF THE WATERFORD IMPOUNDMENT AREA

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

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

[b]*State-designated endangered species.*

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

[d]*State-designated threatened species.*

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

The total area tributary to the Waterford Impoundment in the 1985 inventory was about 229,279 acres in areal extent. As shown in Map 24, wildlife habitat accounted for about 75,326 acres, or about 33 percent of this total area, with 34,258 acres, or about 15 percent, classified as Class I habitat; 26,547 acres, or 12 percent, classified as Class II habitat; and 14,521 acres, or about 6 percent, classified as Class III habitat. Of the area directly tributary to the Waterford Impoundment, about 4,269 acres, or about 29 percent of the area were classified in the 1985 inventory as wildlife habitat. Of that area, about 2,088 acres, or about 14 percent of the area, were classified as Class I habitat; 1,761 acres, or 12 percent, were classified as Class II habitat; and 420 acres, or 3 percent, were classified as Class III habitat.

WETLANDS

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

Another definition, which is applied by the State of Wisconsin and which is set forth in Chapter 23 of the *Wisconsin Statutes*, defines a wetland as "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which has soils indicative of wet conditions." In practice, the WDNR definition differs from the SEWRPC definition in that the WDNR considers very poorly drained, poorly drained, and some of the somewhat poorly drained soils as wetland soils meeting the WDNR "wet condition" criterion. The SEWRPC definition only considers the very poorly drained and poorly drained soils as meeting the "hydric soil" criterion. Thus, the State definition as actually applied is more inclusive than the Federal and SEWRPC definitions in that the WDNR may include some soils that do not show hydric field characteristics as wet soils capable of supporting wetland vegetation, a condition that may occur in some floodlands.[7]

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

Wetlands in southeastern Wisconsin are classified predominantly as deep marsh, shallow marsh, southern sedge meadow, fresh (wet) meadow, shrub carr, alder thickets, low prairie, fens, bogs, southern wet- and wet-mesic hardwood forest, and coniferous swamp. Wetlands form an important part of the landscape in and adjacent to the Waterford Impoundment in that they perform an important set of natural functions that make them ecologically and environmentally invaluable resources. Wetlands affect the quality of water by acting as a filter or a buffer zone allowing silt and sediments, and their associated pollutants, to settle out and by absorbing potential

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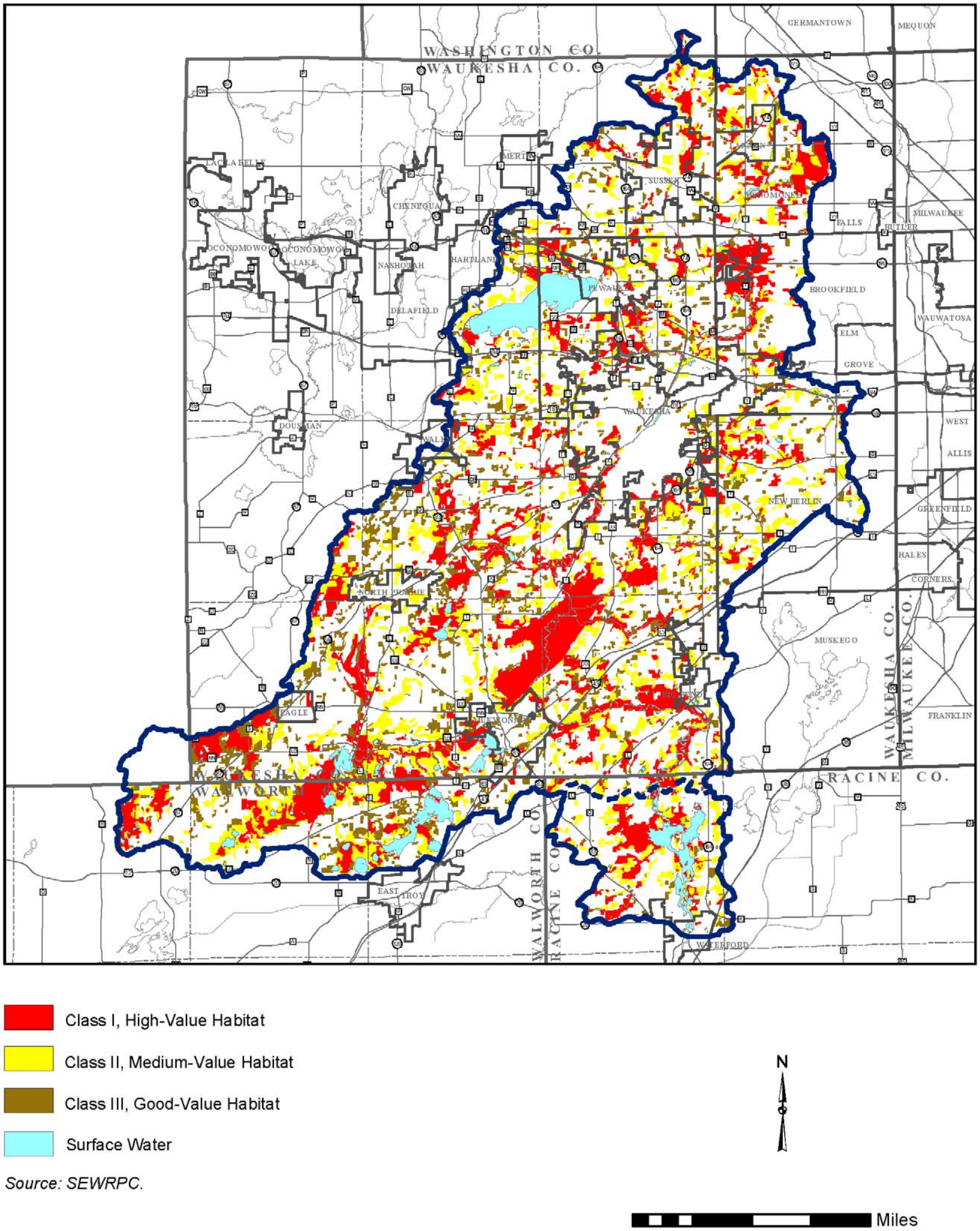
[6]*Lands designated as prior converted cropland, that is, lands that were cleared, drained, filled, or otherwise manipulated to make them capable of supporting a commodity crop prior to December 23, 1985, may meet the criteria of the U.S. Natural Resource Conservation Service wetland definition, but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

[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.*

Map 24

WILDLIFE HABITAT AREAS WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT: 1985



Source: SEWRPC.

contaminants within the plant biomass. They also influence the quantity of water by providing water during periods of drought and holding it back during periods of flood. When located along shorelines of lakes and streams, wetlands help protect those shorelines from erosion. Wetlands also may serve as groundwater discharge and recharge areas in addition to being important resources for overall ecological health and diversity by providing essential breeding and feeding grounds, shelter, and cover or refuge for many forms of fish and wildlife.

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

Table 26 characterizes the wetland plant species typically found in the tributary basin. As shown on Map 25, in 2000, wetlands covered about 2,156 acres, or 15 percent, of the area directly tributary to the Waterford Impoundment. Within this area, a significant area of marshland is contained within the Vernon Marsh, a State natural area located on the mainstem of the Fox River within the Towns of Mukwonago, Vernon, and Waukesha. The major wetland communities located in the area tributary to the Waterford Impoundment included deep and shallow marsh, sedge meadow, fresh (wet) meadow, shrub carr, southern wet to wet-mesic hardwoods, and a fen. The amount and distribution of wetlands in the area should remain relatively constant if the recommendations contained in the adopted regional land use plan are followed. As shown on Map 26, in 2000, wetlands covered about 32,802 acres, or 14 percent, of the total area tributary to the Waterford Impoundment.

Lowland forests in the Waterford Impoundment tributary basin include southern wet to wet-mesic hardwood forests, and are scattered throughout the total tributary basin. These wetlands are characterized by black willow, cottonwood, green ash, and American elm. Sedge meadows are considered to be stable wetland plant communities that tend to perpetuate themselves if dredging activities and water level changes are prevented from occurring. Sedge meadows in southeastern Wisconsin are characterized by the tussock sedge (*Carex stricta*) and, to a lesser extent, by Canada blue-joint grass (*Calamagrostis canadensis*). Sedge meadows that are drained or disturbed to some extent typically succeed to shrub carrs.

Shrub carrs, in addition to the sedges and grasses found in the sedge meadows, contain an abundance of shrubs such as willows (*Salix* spp.) and red osier dogwood (*Cornus stolonifera*). In extremely disturbed shrub carrs, the willows, red osier dogwood, and sedges are replaced by such exotic plants as honeysuckle (*Lonicera* sp.), buckthorn (*Rhamnus* sp.), and the very aggressive reed canary grass (*Phalaris arundinacea*).

Fresh (wet) meadows are essentially lowland meadows which are dominated by forbes such as the marsh (*Aster simplex*), swamp (*Aster lucidulus*), and New England (*Aster novae-angliae*) asters, and giant goldenrod (*Solidago gigantea*).

Deep and shallow marsh areas are dominated by cattails (*Typha* spp.). Other emergent plant species commonly occurring in the deep and shallow marshes within the Waterford Impoundment tributary basin include bur-reed (*Sparganium eurycarpum*), Arrow-head (*Sagittaria latifolia*), reed grass (*Phragmites communis*), bulrushes (*Scirpus* spp.), lake sedge (*Carex lacustris*), and water-willow (*Decodon verticillatus*).

Table 26

EMERGENT WETLAND PLANT SPECIES IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO WATERFORD IMPOUNDMENT

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

NOTE: This table is presented in taxonomic order.

Table 26 Footnotes

[a]*Alien or nonnative plant species.*

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

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

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

Source: Waukesha County Park and Planning Commission and SEWRPC.

WOODLANDS

Woodlands are defined by SEWRPC 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, and conifer swamp forests; the last three are also considered wetlands. SEWRPC also maintains an inventory of woodlands within the Region which is updated every five years. In the area directly tributary to the Waterford Impoundment, as shown on Map 25, approximately 1,229 acres, or 8 percent, of woodland were inventoried in 2000. As shown in Map 26, woodlands covered about 18,665 acres, or about 8 percent, of the total area tributary to the Waterford Impoundment.

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

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

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

NATURAL AREAS AND CRITICAL SPECIES HABITAT

Within the area tributary to the Waterford Impoundment, as shown on Maps 25 and 26, SEWRPC has identified natural areas and areas of local, countywide, regional, State or greater significance as determined by critical species habitat. Natural areas are defined as those areas of land or water so little modified by human activity, or which have sufficiently recovered from the effects of such activity, that they contain intact native plant and animal communities believed to be representative of the pre-European-settlement landscape. Natural areas within the area directly tributary to the Waterford Impoundment are delineated on Map 25.

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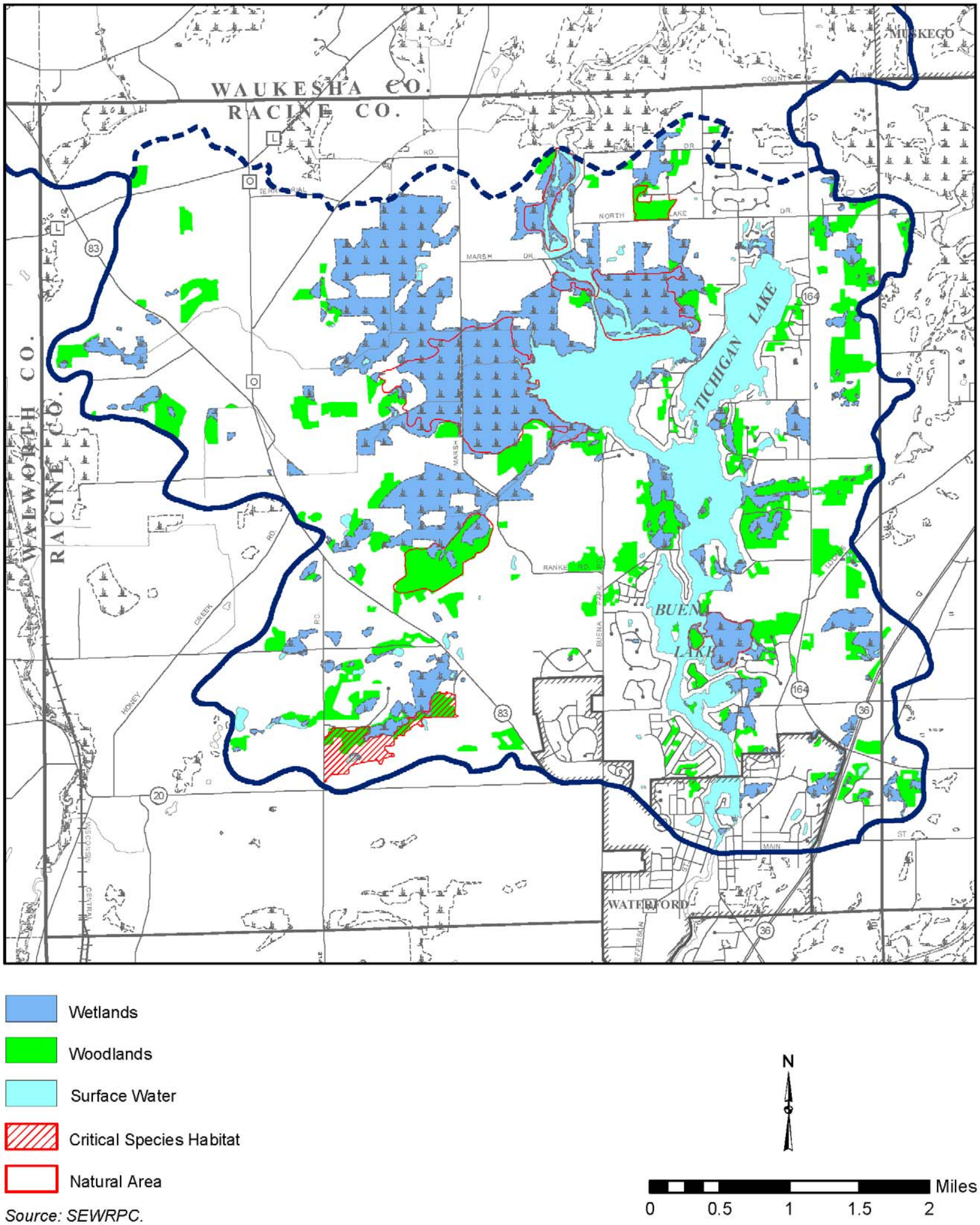
[8]*Bruce P. Rubin and Gerald H. Emmerich, Jr., "Refining the Delineation of Environmental Corridors in Southeastern Wisconsin,"* SEWRPC Technical Record*, Vol. 4, No. 2, March 1981.*

Map 25

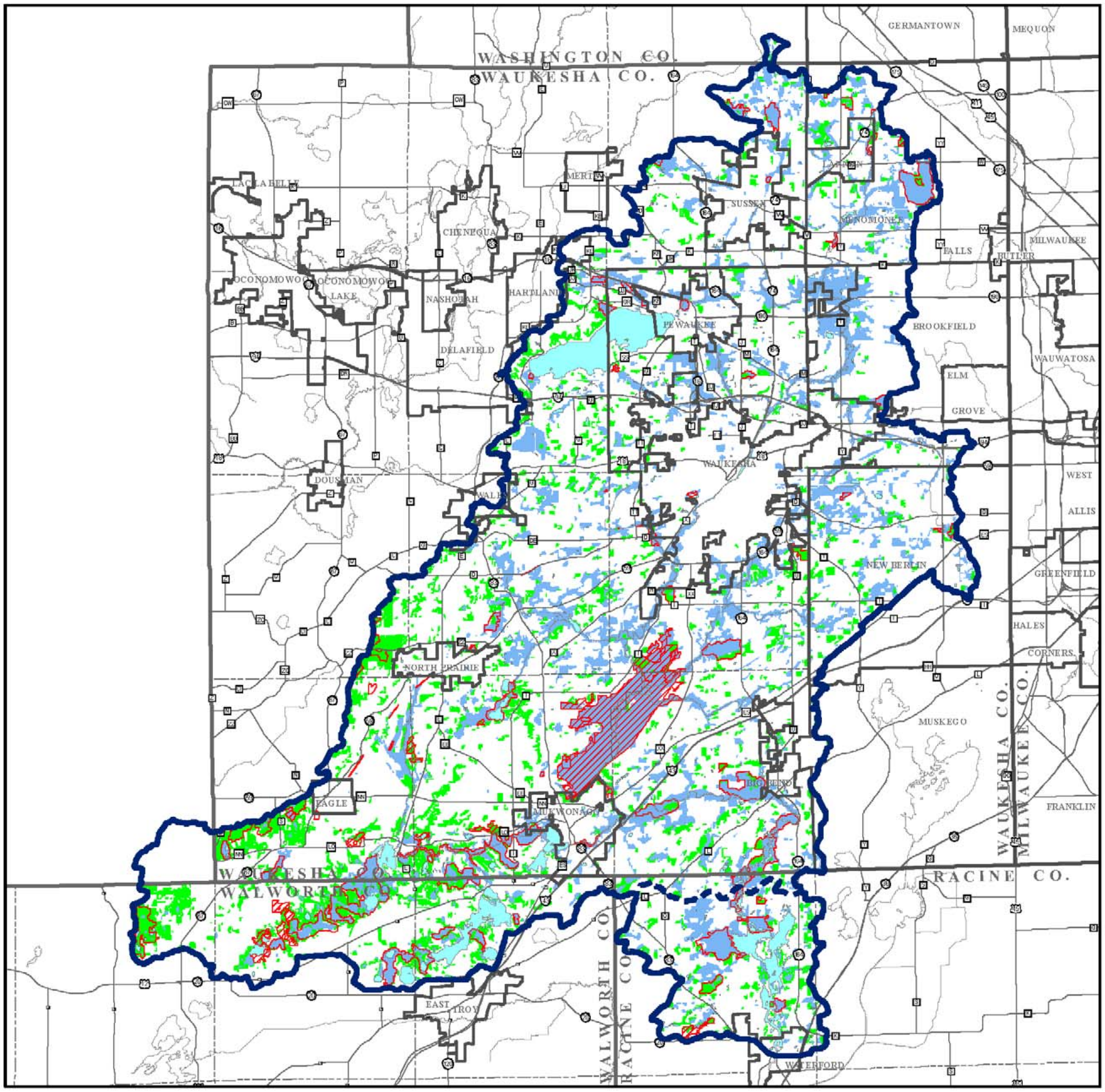
WETLANDS, WOODLANDS, NATURAL AREAS, AND CRITICAL SPECIES HABITAT WITHIN THE AREA DIRECTLY TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000



Source: SEWRPC.

Map 26

WETLANDS, WOODLANDS, NATURAL AREAS, AND CRITICAL SPECIES HABITAT WITHIN THE TOTAL AREA TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000



Wetlands

Woodlands

Natural Areas

Critical Species Habitats

Surface Water

Source: SEWRPC.

N

Miles

0 2 4 6 8

Critical species habitat is defined as those tracts of land or water which support federally or State-listed rare, threatened, and/or endangered plant or animal species as defined by State or Federal agencies. Areas of critical species habitat within the area directly tributary to the Waterford Impoundment are indicated on Map 25 and include: Elm Island-Bog Island Oak Woods, Tichigan Fen, Norris Marsh and Slough, Tichigan Marsh, Tichigan Wetlands and Low Woods, VanValin Woods and Tichigan Wet Prairie.

Areas of Statewide or Greater Significance

Elm Island-Bog Island Oak Woods is comprised of 68 acres, all under private ownership, located on the eastern shore of the Fox River opposite Buena Lake. The area includes two distinct plant communities of good quality, an upland wooded island dominated by red and white oaks without signs of past grazing or logging, bordered on the east by a sphagnum-tamarack bog with a number of characteristic bog species present.

Tichigan Fen, 118 acres under private and WDNR ownership, is located in the southwestern corner of the area directly tributary to the Waterford Impoundment, about two miles west of the Waterford Dam. The area is a fine example of springs and calcareous fen, with a number of uncommon species present. The site includes the lesser-quality upland woods to the south that protects the water sources of the springs.

Areas of Countywide or Regional Significance

Norris Marsh and Slough contain 180 acres (plus a further 32 acres located within Waukesha County), all under private ownership. It is a good-quality deep and shallow marsh located along the western shoreline of the Fox River immediately north of the area locally known as the “iron bridge,” the Bridge Drive crossing within the Town of Waterford, upstream of the Waterford Impoundment.

Tichigan Marsh, a 447 acre area owned by the WDNR, is located along the western shoreline of the Fox River adjacent to the area known as the “Widespread.” It is a large, good-quality deep and shallow marsh with small patches of sedge meadow and contains a series of ponds excavated for wildlife by the WDNR.

Tichigan Wetlands and Low Woods are comprised of 170 acres owned by the WDNR located along the eastern side of the Fox River opposite the WDNR-owned and operated boat launch, adjacent to the northeastern end of the “Widespread.”

Areas of Local Significance

VanValin Woods consists of 30 privately owned acres located along the north side of Tichigan Road about 0.5 mile east of the Fox River. It is an area of moderate-quality dry-mesic woods dominated by white oak, shagbark hickory, white ash, and sugar maple.

Tichigan Wet Prairie, a 15-acre area owned by the WDNR, is located just south of the “iron bridge” at the north end of the area directly tributary to the Waterford Impoundment. It is considered a moderate- to good-quality combination of wet prairie, sedge meadow, and shallow marsh, with some calciphiles, such as Ohio goldenrod, (*Solidago ohioensis*) present. The site is burned periodically to control shrubs.

ENVIRONMENTAL CORRIDORS

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

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

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

In the area tributary to the Waterford Impoundment, the riverbanks and lakeshores located within the environmental corridors should be candidates for immediate protection through proper zoning or through public ownership. Of the areas not already publicly owned, the remaining areas of natural shoreline, and riparian wetland areas, are perhaps the most sensitive areas in need of greatest protection. In this regard, the regional natural areas and critical species habitat protection and management plan recommends public acquisition of specific lands.[9] Within the area tributary to the Waterford Impoundment, the privately owned Elm Island-Bog Island Oak Woods, totaling 68 acres, is recommended for acquisition by Racine County. The Tichigan Fen, containing 95 acres already under protective ownership by the WDNR, also contains 23 acres recommended to be acquired by the WDNR. Norris Marsh and Slough, consisting of 180 acres in Racine County and 32 acres in Waukesha County, all under private ownership, are recommended to be acquired by each County involved to the extent of that portion located within their respective boundaries. Tichigan Marsh, Tichigan Wetlands and Low Woods, and Tichigan Wet Prairie are already owned by the WDNR. VanValin Woods, composed of 30 acres all under private ownership, is recommended to be acquired by Racine County.

Primary Environmental Corridors

The primary environmental corridors in southeastern Wisconsin generally lie along major stream valleys and around major lakes, and contain almost all of the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all of the major bodies of surface water and related undeveloped floodlands and shorelands. During the initial planning period, the primary environmental corridors in the area directly tributary to the Waterford Impoundment in 2000 encompassed about 2,803 acres, or 19 percent of the tributary area, as shown in Map 27. These corridors are subject to urban encroachment because of their desirable natural resource amenities.

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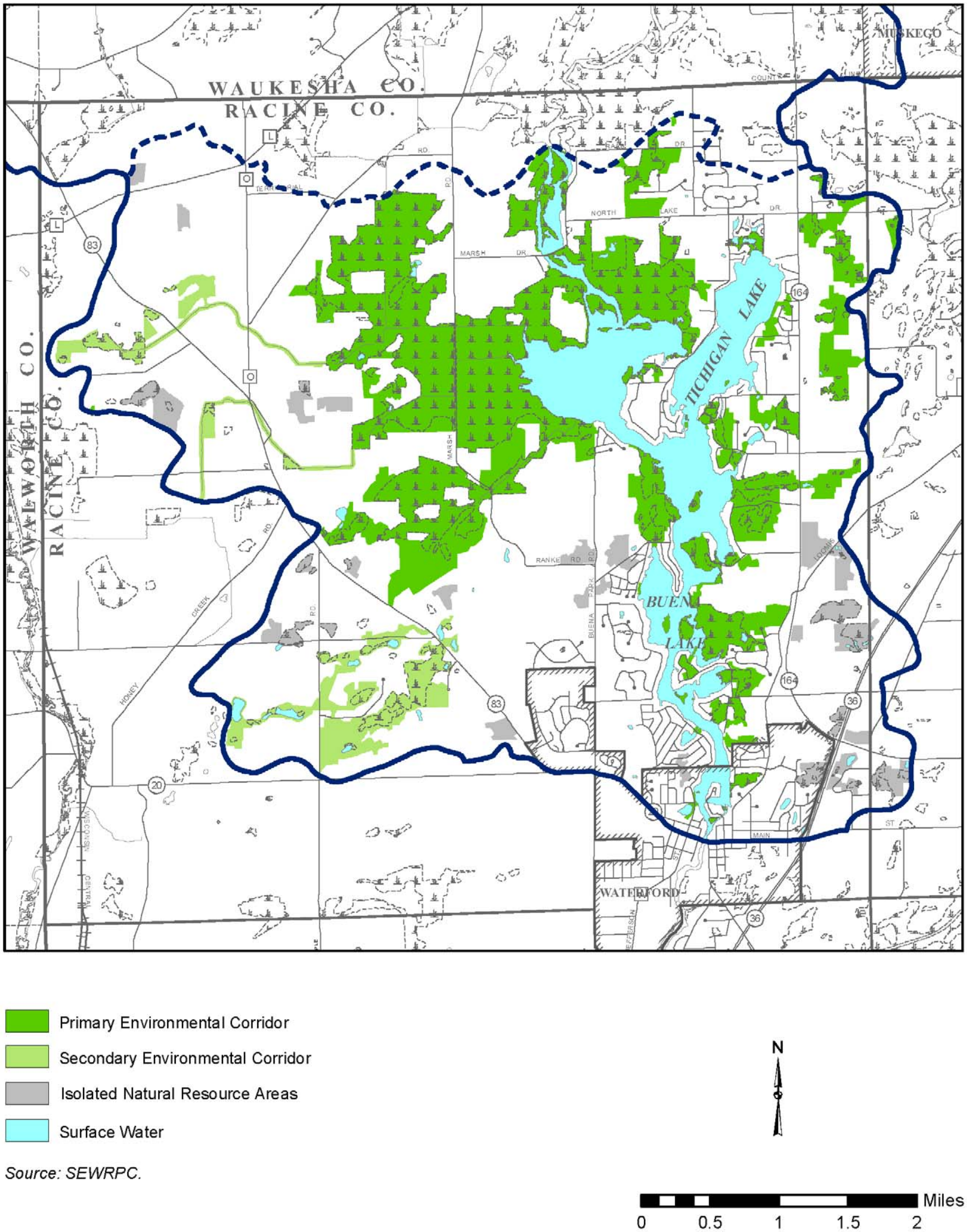
[9]*SEWRPC Planning Report No. 42,* A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin*, September 1997.*

Map 27

ENVIRONMENTAL CORRIDORS AND NATURAL RESOURCE AREAS WITHIN THE AREA DIRECTLY TRIBUTARY TO WATERFORD IMPOUNDMENT: 2000



Source: SEWRPC.

Unplanned or poorly planned intrusion of urban development into these corridors, however, not only tends to destroy the very resources and related amenities sought by the development, but tends to create severe environmental and development problems as well. The preservation of these corridors, thus, is one of the major ways in which the water quality of the Waterford Impoundment can be maintained and perhaps improved.

Secondary Environmental Corridors
The secondary environmental corridors in the Waterford Impoundment direct tributary area are located generally along intermittent streams or serve as links between segments of primary environmental corridors. These secondary environmental corridors contain a variety of resource elements, often remnant resources from primary environmental corridors which have been developed for intensive agricultural purposes or urban land uses. Secondary environmental corridors facilitate surface water drainage, maintain "pockets" of natural resource features, and provide for the movement of wildlife, as well as for the movement and dispersal of seeds for a variety of plant species. Such corridors, while not as important as the primary environmental corridors, should be preserved in essentially open, natural uses as urban development proceeds within the direct tributary area, particularly when the opportunity is presented to incorporate the corridors into urban stormwater detention areas, associated drainageways, and neighborhood parks. Secondary environmental corridors encompassed 469 acres, or about 3 percent of the area directly tributary to the Waterford Impoundment, in 2000.

Isolated Natural Resource Areas
In addition to the environmental corridors, other, small concentrations of natural resource base elements exist within the area directly tributary to the Waterford Impoundment. These resource base elements are isolated from the environmental corridors by urban development or agricultural uses and, although separated from the environmental corridor network, have important natural values. Isolated natural resource areas may provide the only available wildlife habitat in an area, provide good locations for local parks and nature study areas, and lend an aesthetic character or natural diversity to an area. Important isolated natural resource features within southeastern Wisconsin include a geographically well-distributed variety of isolated wetlands, woodlands, and wildlife habitat. These isolated natural resource features should also be protected and preserved in a natural state whenever possible. Such isolated areas, five or more acres in areal extent within the area directly tributary to the Waterford Impoundment, as of 2000, totaled about 439 acres, or 3 percent of the direct tributary area.

Chapter VI

CURRENT WATER USES AND WATER USE OBJECTIVES

INTRODUCTION

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

RECREATIONAL USES AND FACILITIES

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

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

Angling
The Waterford Impoundment fishery has been supported by Wisconsin Department of Natural Resources (WDNR) stocking programs, with northern pike and walleye being stocked in alternate years, as discussed in Chapter V of this volume. WDNR fisheries surveys indicate that the Impoundment supports an excellent panfish stock, as well as populations of largemouth bass, walleyed pike and northern pike. Evidence of the good fishing is provided by the relatively large numbers of fishing boats and shoreline anglers using the Impoundment during the summer.

Recreational Boating
Boat traffic on the Waterford Impoundment is highly variable throughout the season, and from weekday to weekend. During July 2003, boat counts by SEWRPC staff resulted in a total of about 1,442 watercraft of all descriptions, fishing, pontoon, skiing, sailing, and rowing vessels and personal watercraft, being recorded, as shown in Table 27. In June 2005, additional surveys, the results of which are shown in Tables 28 and 29, were conducted by SEWRPC staff at two different sites to determine recreational use of watercraft on the Waterford Impoundment. At the Fox River survey site, a total of 15 watercraft were observed in use on a typical weekday compared with 69 watercraft of various types during a typical weekend. At the Tichigan Lake survey site, a total of 31 watercraft were observed in use during a typical weekday compared with 94 watercraft of various types in use on a typical weekend. Other nonboating recreational uses were observed at the Tichigan Lake survey site including sunbathing, picnicking and enjoying the aesthetics provided by a waterbody. Comparison of data from the two survey sites supports the public perception that the Impoundment is heavily used, especially on weekends. Additionally, the data support the view that the majority of boating-related recreational activities are more concentrated on Tichigan Lake than on the Impoundment as a whole. The densities of high-speed watercraft, comprised of pleasure boating, water skiing, and jet skiing, on the 268-acre Tichigan Lake during a one-hour count ranged from about one boat per 22 acres on a typical weekday, to about one boat per 3.5 acres on a typical weekend. Such densities exceed those considered appropriate for the conduct of safe high speed boating activities pursuant to the adopted Regional guidelines.

Boating activities on the Impoundment are regulated by the state boating and water safety laws, and by a uniform local ordinance, adopted by the Town of Waterford, providing specific regulations for the Waterford Impoundment and enforced by the Town of Waterford Police Department. These ordinances are summarized in Appendix B.

Park and Open Space Sites
The Waterford Impoundment provides an ideal setting for the provision of parks and open space sites and facilities. There is a lake access site that is owned and operated by the Village of Waterford on the western shore of the Fox River in the Village of Waterford immediately upstream of the Dam. This park site includes a public recreational boating access site, spaces for diagonal parking of car with trailer combinations, car-only diagonal parking spaces,[2] picnic tables and rest facilities. In addition, the WDNR owns and operates a public boating access site on Conservation Road at the north extreme of the Impoundment. These public boating access sites are shown on Map 28. There are no public swimming beaches on the Impoundment.

Changes to Chapter NR 1 of the *Wisconsin Administrative Code* established quantitative criteria for determining the adequacy of public recreation boating access, the maximum and minimum standards continuing to be based upon car-trailer units. As of 2002, pursuant to these standards, the Waterford Impoundment continues to be assessed as having adequate public recreational boating access opportunities.

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[2]*At the time of the printing of this report, the car-only parking spaces carried a provision for allowing detached boat trailers to be parked in car-only spaces on weekends only.*

Table 27

WATERCRAFT ON WATERFORD IMPOUNDMENT: JULY 2003

Type of Watercraft								
Powerboat	Pontoon Boat	Fishing Boat	Personal Water Craft	Sailboat	Canoe/ Kayak	Paddle Boat	Other	Total
211	498	272	170	8	146	100	17	1,422

Source: SEWRPC.

Table 28

RECREATIONAL USE SURVEY ON WATERFORD IMPOUNDMENT—FOX RIVER SITE: JUNE 2005

	Weekend Participants							
Date and Time	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
June 11, 2005								
9:10 a.m. to 10:10 a.m.	5	8	2	0	2	0	0	17
12:30 p.m. to 1:30 p.m.	2	30	1	0	19	2	1	55
Total for the Day	7	38	3	0	21	2	1	72
Percent	10	53	4	0	29	3	1	100

	Weekday Participants							
Date and Time	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
June 9, 2005								
10:30 a.m. to 11:30 a.m.	2	3	0	0	0	0	0	5
1:00 p.m. to 2:00 p.m.	2	8	0	0	0	0	0	10
Total for the Day	4	11	0	0	0	0	0	15
Percent	27	73	0	0	0	0	0	100

Source: SEWRPC.

Table 29

RECREATIONAL USE SURVEY ON WATERFORD IMPOUNDMENT—TICHIGAN LAKE SITE: JUNE 2005

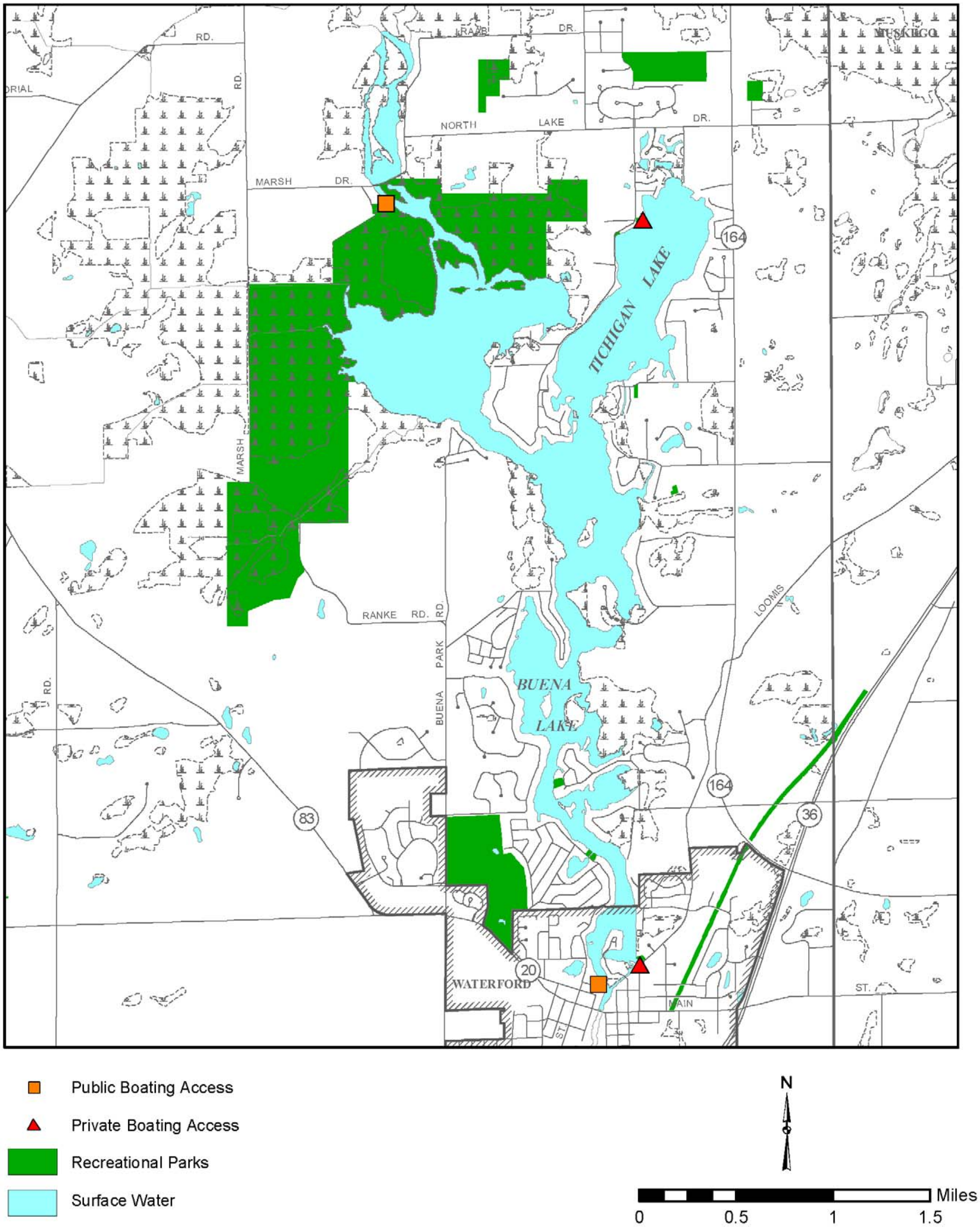
	Weekend Participants							
Date and Time	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
June 11, 2005								
10:20 a.m. to 11:20 a.m.	14	9	4	0	3	11	17	58
2:15 p.m. to 3:15 p.m.	2	42	8	0	12	30	23	117
Total for the Day	16	51	12	0	15	41	40	175
Percent	9	29	7	0	9	23	23	100

	Weekday Participants							
Date and Time	Fishing	Pleasure Boating	Skiing	Sailing	Jetskiing	Swimming	Other	Total
June 9, 2005								
9:15 a.m. to 10:15 a.m.	14	1	1	0	2	0	0	18
2:15 p.m. to 3:15 p.m.	5	7	0	0	1	15	10	38
Total for the Day	19	8	1	0	3	15	10	56
Percent	34	14	2	0	5	27	18	100

Source: SEWRPC.

Map 28

PARKS AND BOAT ACCESS SITES ON WATERFORD IMPOUNDMENT: 2005



Source: Wisconsin Departrment of Natural Resources and SEWRPC.

Privately owned sites with boat access and mooring facilities include the River City Marina located at the southeastern end of the Impoundment on Milwaukee Street in the Village of Waterford, and Dooley's Knot Inn at the northwestern end of Tichigan Lake on North Tichigan Road in the Town of Waterford. These sites are shown on Map 28.

Existing recreational facilities in the vicinity of the Waterford Impoundment, including the Town of Waterford Town Park (also known as Jenson Park) and the WDNR-owned and operated Tichigan Conservation Area, are also shown on Map 28.

It is important to note that the provision of park and open space sites within the area tributary to the Waterford Impoundment should continue to be guided by the recommendations contained in the Racine County Park and Open Space plan.[3] The purpose of that plan, in part, is to guide the preservation, acquisition, and development of land for park, outdoor recreation, and related open space purposes and to protect and enhance the underlying and sustaining natural resource base of the Town and Village. With respect to the Waterford Impoundment tributary area, the plan recommends the maintenance of existing park and open space sites in the area, and the development of the "Seven Waters Bicycle Trail" linking the Impoundment area with other regional trail systems. In addition, the plan recommends that the undeveloped lands in the primary environmental corridor area tributary to the Waterford Impoundment be retained and maintained as natural open space. These lands include the Elm Island-Bog Island Oak Woods, the Norris Marsh and Slough, the Tichigan Marsh, the Tichigan Wetlands and Low Woods, the VanValin Woods, and the Tichigan Wet Prairie, as discussed in Chapter V of this Volume.

Wisconsin Department of Natural Resources Recreational Rating

In general, the Waterford Impoundment provides a variety of outdoor recreational opportunities. Based upon the outdoor recreation rating developed by the WDNR, Waterford Impoundment received 50 of a possible 72 points, as shown in Table 30. This rating indicates that the Impoundment provides a range of recreational opportunities, including a productive fishery, some areas of moderately good swimming substrate, boat launch sites, water quality and depth conditions adequate for boating, and a varied landscape including several marsh areas suitable for wildlife observation. Features that were considered to detract from the recreational rating included a rough fish problem, occasional algal blooms, and excessive macrophyte growths in portions of the waterway.

WATER USE OBJECTIVES

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

The recommended warmwater sport fishery objective is supported in the Waterford Impoundment by a sport fishery based largely on largemouth bass, northern pike, walleye and panfish. These fishes have traditionally been sought after in the Waterford Impoundment.

WATER QUALITY STANDARDS

The water quality standards supporting the warmwater fishery and full recreational use objectives as established for planning purposes in the regional water quality management plan, are set forth in Table 31. 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

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[3]*SEWRPC Community Assistance Planning Report No. 134,* A Park and Open Space Plan for Racine County*, September 1988.*

Table 30

WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECREATIONAL RATING OF WATERFORD IMPOUNDMENT

Space: Total Area = 1,132 acres			Total Shore Length = 28 miles		
Quality (18 maximum points for each item)					
Fish:					
X 9	High production	__ 6	Medium production	__ 3	Low production
__ 9	No problems	__ 6	Modest problems, such as infrequent winterkill, small rough fish problems	X 3	Frequent and overbearing problems, such as winterkill, carp, excessive fertility
Swimming:					
__ 6	Extensive sand or gravel substrate (75 percent or more)	X 4	Moderate sand or gravel substrate (25 to 50 percent)	__ 2	Minor sand or gravel substrate (less than 25 percent)
__ 6	Clean water	X 4	Moderately clean water	__ 2	Turbid or darkly stained water
__ 6	No algal or weed problems	__ 4	Moderate algal or weed problems	X 2	Frequent or severe algal or weed problems
Boating:					
X 6	Adequate water depths (75 percent of basin more than five feet deep)	__ 4	Marginally adequate water depths (50 to 75 percent of basin more than five feet deep)	__ 2	Inadequate depths (less than 50 percent of basin more than five feet deep)
__ 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, algal blooms, etc.	__ 2	Overwhelming inhibiting factors, such as weed beds throughout
Aesthetics:					
__ 6	Existence of 25 percent or more wild shore	X 4	Less than 25 percent wild shore	__ 2	No wild shore
X 6	Varied landscape	__ 4	Moderately varied	__ 2	Unvaried landscape
__ 6	Few nuisances, such as excessive algae, carp, etc.	X 4	Moderate nuisance conditions	__ 2	High nuisance condition
Total Quality Rating: 50 out of a possible 72					

Source: Wisconsin Department of Natural Resources and SEWRPC.

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

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

Table 31

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

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

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

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

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

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

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

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

Source: SEWRPC.

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APPENDICES

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Appendix A

ILLUSTRATIONS OF COMMON AQUATIC PLANTS FOUND IN THE WATERFORD IMPOUNDMENT

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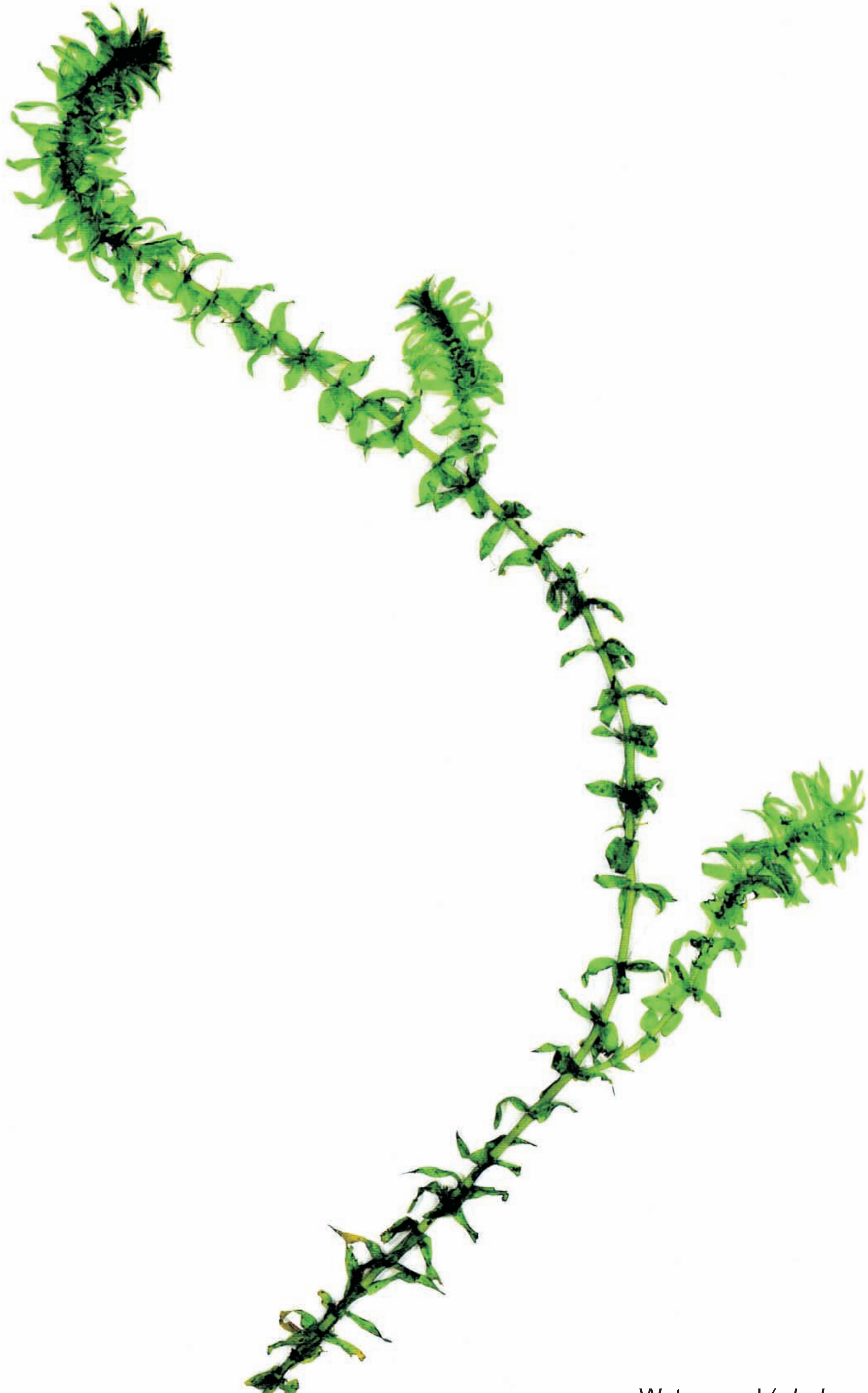
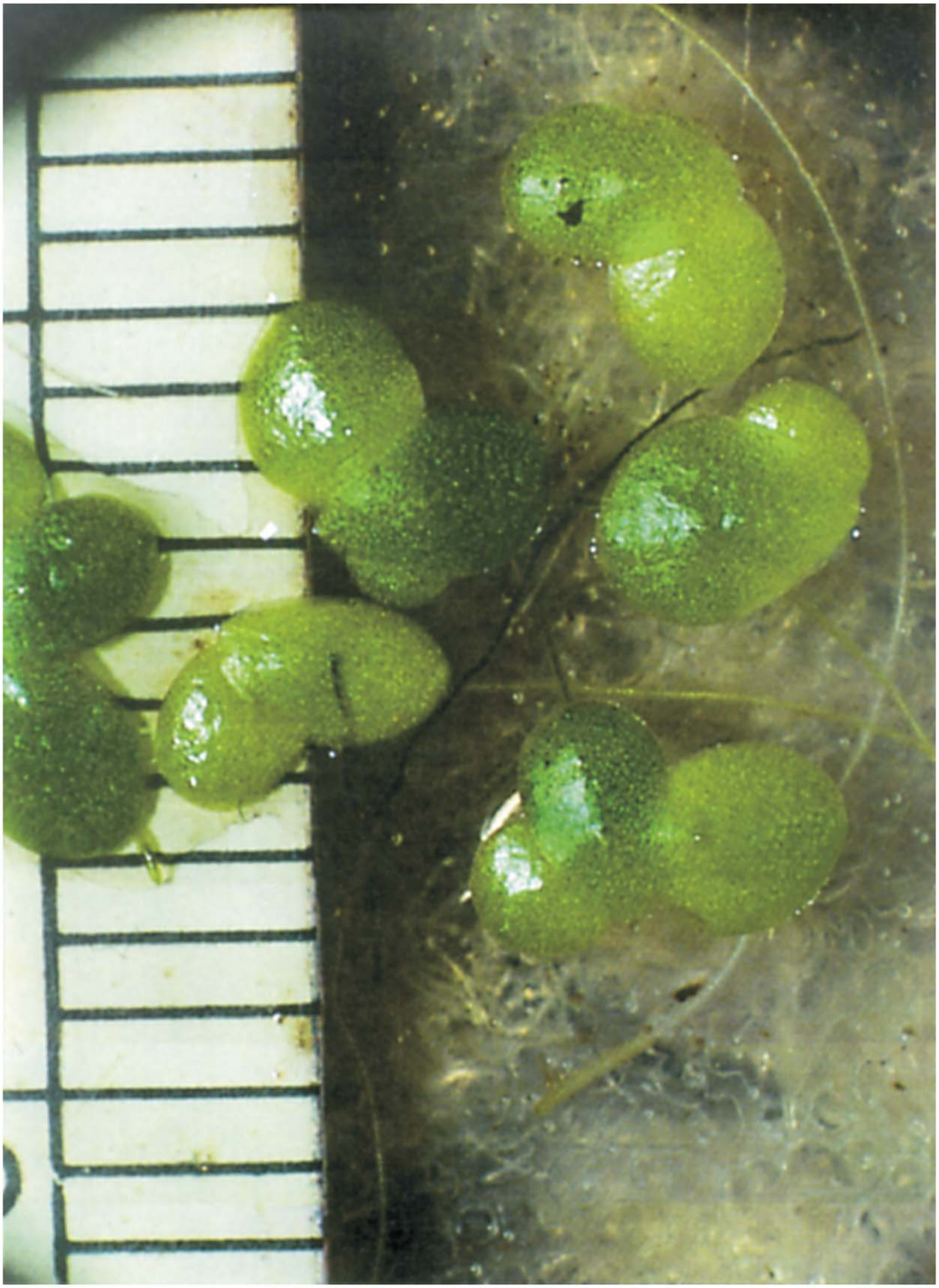
Coontail (*ceratophyllum demersum*)

Muskgrass (*chara vulgaris*)



Waterweed (*elodea canadensis*)



Lesser Duckweed (*lemna minor*)

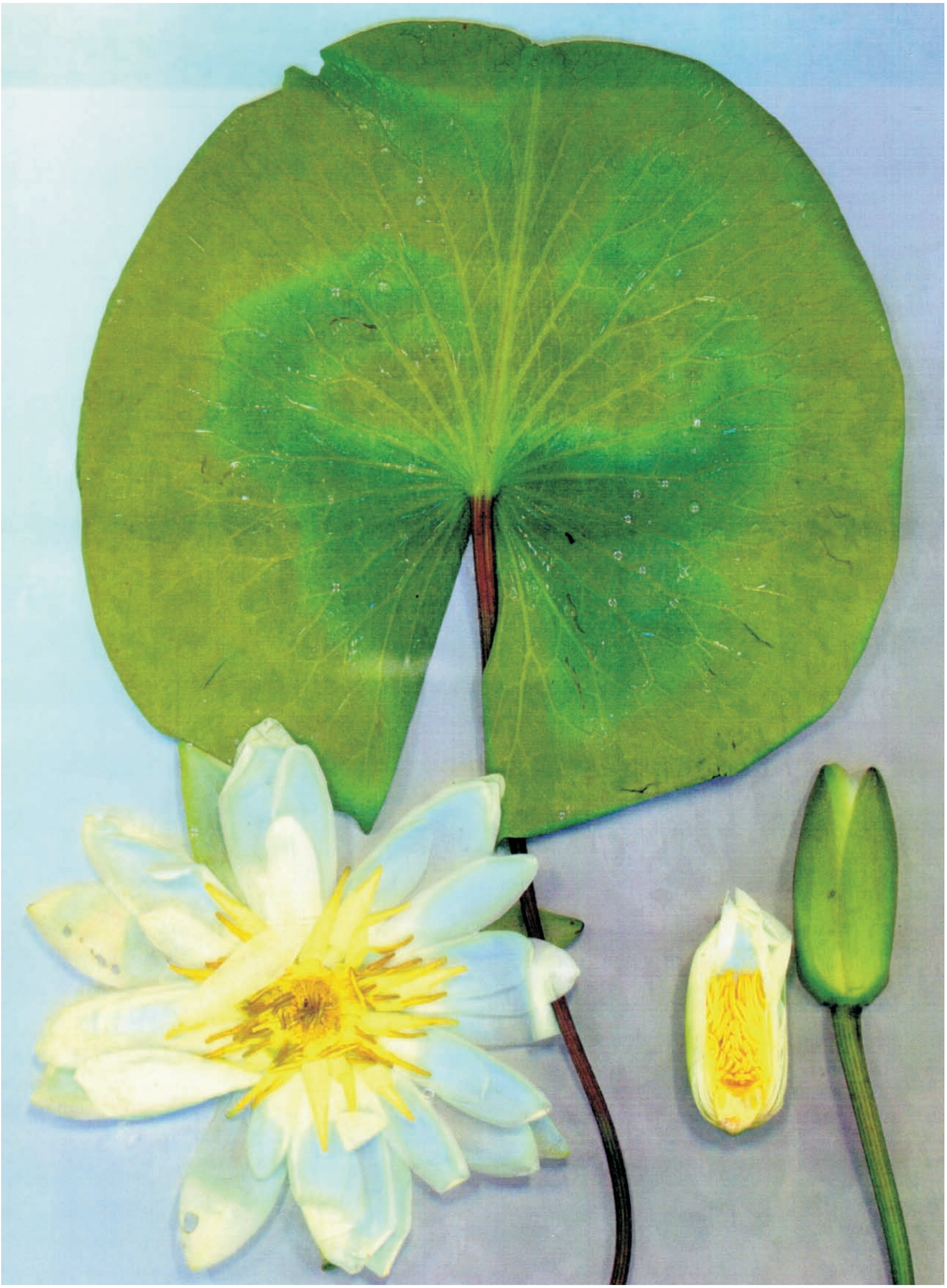
NOTE: Plant species in photograph are not shown proportionate to actual size

Source: Steve D. Eggers and Donald M. Reed, Wetland Plants and Plant Communities of Minnesota & Wisconsin, *2nd Edition, 1997*

Eurasian Water Milfoil (*myriophyllum spicatum*)

Native Water Milfoil (*myriophyllum* sp.)

Bushy Pondweed (*najas flexilis*)

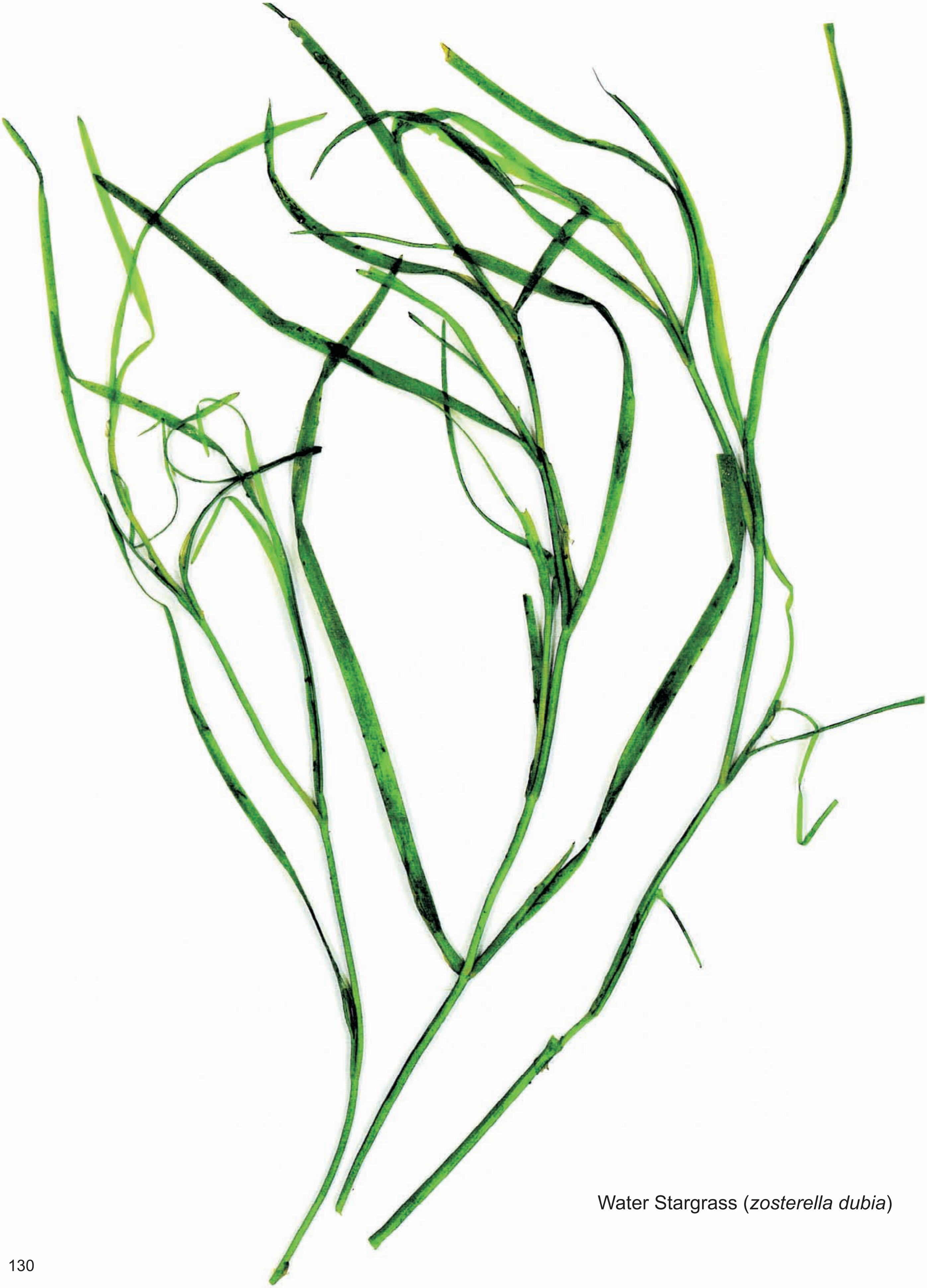


White Water Lily (*nymphaea odorata*)

Curly-Leaf Pondweed (*potamogeton crispus*)

Sago Pondweed (*potamogeton pectinatus*)

Flat-Stem Pondweed (*potamogeton zosteriformis*)



Water Stargrass (*zosterella dubia*)

Appendix B

BOATING ORDINANCE FOR THE WATERFORD IMPOUNDMENT

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CHAPTER 93: BOATING

[HISTORY: Adopted by the Village Board of the Village of Waterford as §§ 9.11 and 9.20 of the 1998 Code. Amendments noted where applicable.]

§ 93-1. Slow no wake speed established; boundary. [Amended 7-11-1994 by Ord. No. 304]

A slow, no wake speed, as defined in Wis. Stat. § 30.50(12), shall be in effect for that part of the Fox River legally defined as a portion of the Fox River, located in the NE 1/4 of Section 35, T4N, R19E, Village of Waterford, Racine County, Wisconsin, described as follows: that area of the Fox River from the northerly line of the westerly dam having control gates; thence northerly 1,600 feet, more or less, to an east-west line 100 feet north of the northern tip of Fox Isle. Said east-west line is located 500 feet, more or less, south of the north line of said NE 1/4. The area described includes the waters east and west of Fox Isle, and contains 26 acres, more or less.

§ 93-2. Violations and penalties.

Any person who shall violate any provision of this chapter, or any regulation, rule or order made hereunder, shall be subject to a penalty as provided in Chapter 1, Article II, of this Municipal Code.

CHAPTER 260: PIERS

[HISTORY: Adopted by the Village Board of the Village of Waterford as Chapter 20 of the 1998 Code. Amendments noted where applicable.]

§ 260-1. Definitions.

The definitions contained in Wis. Stat. § 30.01, as the same may be amended from time to time, shall apply to all terms contained in this chapter, unless otherwise specifically set forth in this section. For purposes of this chapter, the following terms are defined as follows: LINE OF NAVIGATION — The three-foot depth or a greater depth contour, if required, for boats in use or appropriate for the use on the waterway, based on the normal summertime low levels on the waterway or summer minimum levels where established by the DNR.

ORDINARY HIGH WATERMARK — The point on the bank or shore up to which the presence and action of the water is so continuous as to leave a distinct mark, either by erosion, destruction or prevention of terrestrial vegetation or predomination of aquatic vegetation or other easily recognized characteristics.

PIER — Any structure extending into navigable waters from the shore of such navigable waters, built or maintained for the purpose of providing a berth for watercraft or for loading or unloading cargo or passengers onto or from the watercraft and may include a temporary boat hoist without roof or walls.

RIPARIAN — An owner of land abutting a stream or lake.

SIMILAR OR RELATED STRUCTURES AND FACILITIES — Includes seasonal or permanent boat shelters or boat hoists.

WETLAND — An area where water is at, near or above the land surfaces long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions.

WHARF — Any structure in navigable waters, extending along the shore and generally connected with uplands throughout its length, built or maintained for the purpose of providing a berth for watercraft or for loading or unloading cargo or passengers onto or from the watercraft.

§ 260-2. Establishment of pierhead line.

A. Until such time that the Village establishes and the DNR approves a pierhead line on the Fox River within the Village which meets the requirements of Wis. Stat. §§ 30.11 and 30.13, and this chapter can be amended accordingly, no pier, wharf or similar or related structure or facility may exist beyond the greater of:

(1) Boat length;
(2) A three-foot water depth contour; or
(3) A greater depth contour if required for the watercraft berthed.

B. Piers, wharves and similar or related structures or facilities may not in any case interfere with public rights on the waterways and the rights of other riparian owners.

§ 260-3. Construction procedure.

Any person desiring to construct any pier, wharf or similar or related structures or facilities on the Fox River within the Village shall follow the procedures as follows.

§ 260-4. Permit required; cancellation or revocation.

A. No person may hereinafter construct, place or extend, enlarge or replace a pier, wharf or similar or related structure or facility or multi-pier development on the Fox River within the Village without first applying for and obtaining a permit from the Village for that portion of the river within the Village. Piers, wharves and similar or related structures or facilities which are legally placed as of October 14, 1991 (the date of the adoption of this chapter), which are removed and replaced seasonally, are not subject to permits or permit fees so long as any nonconformity with the requirements of this chapter are not expanded pursuant to § 260-5R.

B. Any person, developer, firm or corporation desiring to erect, construct, place, extend, replace or repair any pier, wharf or similar or related structure or facility or multi-pier development below the ordinary high watermark of the Fox River within the Village shall make and file in the office of the Village Clerk a written application for permit. Developments with conceptual approval shall not be exempt from this requirement. The application shall describe the real estate, pier, wharf or similar or related structure or facility or multi-pier development or extension thereof in detail, together with its location in regard to the shoreline, pierhead line and bulkhead line if established, ordinary high watermark location, water depth contours, extent of wetland vegetation and with the distance to all property lines of the abutting neighboring riparian lands, giving the details of the dimensions and kinds of materials, details of fueling and any sewage disposal facilities or other accessory construction, if applicable, together with drawings and any additional details and specifications that the Village Plan Commission may require. The application shall contain the name, residence, post office address, telephone number and the signature of the riparian owner of the shoreline on whose behalf the application is made and shall also state the name, residence, post office address and telephone number of the applicant, if different. The riparian owner and/or applicant shall also provide the Village Clerk with the names and addresses of the abutting neighboring riparian owners with this application for permit.

C. Upon filing of such application for permit, the Village Clerk shall refer it immediately to the Village Plan Commission for investigation and report at its next regular meeting, which Commission, after considering the application and all evidence presented and hearing all parties desiring to be heard, may recommend approval of or deny such application. The Village Clerk shall notify abutting neighboring riparian owners by mail no less than seven days prior to the Plan Commission meeting during which this permit application will be presented.

D. No permit shall be granted by the Village Board unless it determines that such construction will comply with the requirements of this chapter and will be consistent with the following Village interests. The fee for such permit shall be as described in the Village permit fee schedule. Editor's Note: The current fee schedule is on file in the Village offices.

(1) To preserve and protect the property and property values within the Village.
(2) To preserve and protect the Fox River.
(3) To protect and clarify public interests and riparian rights on the Fox River within the Village by:
(a) Prohibiting piers and similar structures in environmentally sensitive aquatic habitats.
(b) Limiting the number and location of piers and similar structures so as to avoid conflicting uses of adjacent properties.
(c) Preventing safety hazards and controlling pier construction so as to promote uniformity and preserve natural shoreline aesthetics.

E. In the event the pier, wharf or similar or related structure or facility or multi-pier development for which a permit has been granted shall not be erected, constructed, placed, extended or maintained in accordance with the plans, specifications, details and drawings submitted or in accordance with any conditions imposed on the permit or in the event such pier, wharf or similar or related structure or facility or multi-pier development shall not be used, it is used in a manner detrimental to the general public or interferes with the rights of the neighboring riparian owners, or adversely affects a critical or significant fish or wildlife habitat area, the Village Board may cancel and revoke the permit, provided it shall first hold a hearing after fixing a time and place of hearing and shall cause a written notice thereof to be issued and delivered or mailed to the holder of such permit and also to the abutting neighboring riparian owners not less than seven days before the time fixed for such hearing.

§ 260-5. Construction and use requirements; existing piers and wharfs.

A. Riparian owners may construct, place, extend, enlarge or replace piers, wharves or similar or related structures or facilities or multi-pier developments in the waters of the Fox River within the Village in aid of navigation, provided that such piers, wharves, similar or related structures and facilities or multi-pier developments do not interfere with public rights and safety in the waters or with the rights of neighboring riparian owners or occupants and do not adversely affect a critical or significant fish or wildlife habitat area, are subject to any established pierhead line and other requirements of this chapter and must be consistent with the permit and objectives as specified above.

B. Piers and wharves shall not exceed six feet in width.

C. Extensions or appurtenances to piers must comply with all of the requirements of this chapter, including all permit requirements.

D. Construction shall be of materials of white, natural or earthtone colors, aluminum or shall be visually inconspicuous as viewed against the shoreline. Aluminum piers are permissible.

E. Lighting on a pier, wharf or similar or related structure or facility or multi-pier development shall be down-focused white or yellow lights for safety and to facilitate docking. Intermittent lighting, strobe or similar lighting is prohibited.

F. New and existing piers, wharves or similar or related structures or facilities or multi-pier developments shall include reflective white or amber safety markers no more than five inches square placed on the farthest corners of the structures.

G. Any pier, wharf or similar or related structure or facility or multi-pier development extending beyond the natural shore or established bulkhead line shall be so constructed as to allow the free movement of water underneath and in such manner as will not cause the formation of land on the bed of the Fox River within the Village.

H. Mooring structures and watercraft moored shall be set back a minimum of 10 feet from common riparian rights lines and any additional distance required to confine approach and docking of watercraft to the owner's riparian zone.

I. There shall be a maximum of four permanently moored, registered watercraft per pier, including lifts. For purposes of this subsection, "permanently moored" is defined as being moored longer than seven consecutive days.

J. Subdivisions, multi-unit developments and planned unit developments which share a common waterfront lot, parcel or common area may not place more than one pier or wharf per 100 feet of shoreline. All multi-pier developments and similar or related structures and facilities serving subdivisions, multi-unit developments, planned unit developments, condominiums and homeowners' associations shall be constructed no less than 100 feet from any abutting neighboring lot line.

K. No easements of access shall be granted over existing lots, and no such easement shall be shown on a subdivision plat, multi-unit development plat, planned unit development plat, condominium plat or in a condominium agreement or homeowners' association agreement, which provides greater access than provided above.

L. Pursuant to Wis. Stat. § 236.16, subdivisions with water frontage are required to dedicate a public access to waterways which, under this chapter, shall meet with Village, county and DNR approval or be waived by the same.

M. Piers, wharves and similar or related structures and facilities may be placed and maintained only by riparian owners.

N. Electrical, fueling and waste disposal facilities for business or commercial facilities shall comply with all applicable state laws, Wisconsin Administrative Codes, DNR and Village codes and any other applicable safety and environmental protection laws. In addition, fuel and waste holding tanks shall be set back from the ordinary high watermark per applicable DNR regulations.

O. Such pier, wharf and similar or related structure or facility or multi-pier development shall be subject to the pierhead line which may be established pursuant to the provisions of Wis. Stat. § 30.13(3).

P. All piers, wharves and similar or related structures and facilities or multi-pier developments extending beyond the natural shore or established bulkhead line shall be so maintained as to prevent any part or parts thereof from floating free into the waters of the Fox River and as to prevent the structures from becoming unsafe, unserviceable or unsightly.

Q. The respective rights of neighboring riparian owners shall be determined so as to give each riparian owner his due proportion of the line of navigation by the extension of lot lines from the shoreline to the line of navigation, by drawing a chord between each pair of property lines at the point where each line meets the shoreline and bisecting the resulting angle (coterminous riparian rights line extension) or by other DNR-approved methods of determining riparian zones. All structures shall be confined within each riparian owner's respective zone.

R. Every pier, wharf and similar or related structure, facility or multi-pier development constructed, placed, extended or replaced on the Fox River within the Village in violation of this chapter is declared to be a public nuisance, and the construction thereof may be enjoined and the maintenance may be abated by action initiated by the Village.

S. Any pier, wharf, similar or related structure, facility or multi-pier development existing in place as of October 14, 1991 (the date of adoption of this chapter), and registered with the Village Clerk on or before June 30, 1992, shall be considered to meet the requirements of this chapter. Such structure may be repaired or replaced as long as any nonconformity with the requirements of this chapter is not expanded.

T. Any person or developer who owns real estate abutting the shoreline of the Fox River within the Village shall register the length, width, construction and side yard setbacks of any of his or her or its piers, wharves or similar or related structures or facilities or multi-pier developments with the Village Clerk on or before June 30, 1992, along with a color photograph of the structure. Any such structure in place as of October 14, 1991, and registered before June 30, 1992, shall be considered to meet the requirements of this chapter. Any pier, wharf or similar or related structure or facility or multi-pier development not registered by June 30, 1992, shall be required to comply with the terms of this chapter.

U. Any pier, wharf or similar or related structure or facility or multi-pier development which is legally placed as of October 14, 1991, and which does not conform to this chapter shall be considered permissible and preexisting and shall not constitute an unlawful obstruction of navigable waters so long as the structures are registered as provided herein before June 30, 1992, and are otherwise consistent with applicable Village and DNR regulations and laws.

§ 260-6. Prohibitions and exceptions.

Any pier, wharf and similar or related structure or facility or multi-pier development extending into navigable waters beyond the limits set forth herein constitutes an unlawful obstruction of navigable waters. Beyond the requirements within this chapter, riparian owners shall further comply with any requirements of Wis. Stat. ch. 30 and Wis. Admin. Code ch. NR 326, administered by the DNR.

§ 260-7. Violations and penalties.

Except as otherwise provided herein, any person found in violation of any provision of this chapter or any order, rule or regulation made hereunder shall be subject to a penalty as provided in Chapter 1, Article II, of this Municipal Code.